ODOT Digital Ball-banking Manual

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OREGON DEPARTMENT OF TRANSPORTATION
Highway Division
Technical Services
Traffic-Roadway Section
http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/

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Special thanks to:

Special thanks to these contributors in the preparation of this manual and the companion spreadsheet.

Eric Leaming, PE
Interim Traffic Devices Engineer
ODOT Traffic Standards Unit

Mike Kimlinger, PE
Traffic Standards Engineer
ODOT Traffic Standards Unit

Weldon Ryan
Speed Zone Investigator
ODOT Region 2 Traffic Unit

Amanda Salyer, PE
Senior Investigator
ODOT Region 2 Traffic Unit

Heidi Shoblom, PE
State Sign Engineer
ODOT Traffic Standards Unit

Jason Motley
Sign Management Specialist
ODOT Traffic Standards Unit

Overview and Purpose

The purpose of this document is to help users of the ODOT Digital Ball-banker become familiar with the tool and range of results that should be expected. The ODOT Traffic Standards Unit has developed a procedure aimed at consistent, repeatable results for gathering ball-bank readings on curves. These readings assist with advisory speed signing on highways.

The ODOT Digital Ball-banker (ODBB) consists of multiple pieces of technology used to implement the standards in the 2009 MUTCD part 2C.06 thru 2C.13. The ODBB consists of three parts:

1. ODOT Excel Spreadsheet to gather and analyze ball bank data

2. Rieker Digital Inclinometer (or similar digital ball-banker)*
3. QSTARZ GPS unit (or similar GPS unit)

The only necessary tools are the ODOT Excel Spreadsheet and the Rieker Instrument. Use of the Rieker Digital Inclinometer (or other) and GPS is integrated into the ODOT spreadsheet.

The final decision to sign, change signage or remove signage remains with the Region Traffic Engineer (See ODOT Traffic Manual). The ODBB is an added tool for the analysis and calculation of curve advisory speeds.

The spreadsheet should only be used under the direct supervision of a Registered Professional Engineer. Users of the spreadsheet are responsible for verifying its accuracy – use at your own risk. Calculations and data from the spreadsheet should always be scrutinized and weighed with sound engineering judgment.

Setup

Computer Setup

Before using the ODBB, make sure the proper equipment and software are available to complete the investigation. The ODOT Spreadsheet is available online, and the Rieker Instrument was purchased for each Region. The GPS is not a necessary piece of equipment, but is helpful and also requires pre-installation. Below are the steps needed to ensure that the equipment is installed and working on the investigation computer.

1. Go online to the Traffic Standards Website to download and save the ODOT Spreadsheet http://www.oregon.gov/ODOT/HWY/TS/Pages/signing.aspx#Tools_for_Signing_Curves.
2. Install the drivers for the Rieker Ball-banker Serial-USB adapter, and GPS (if using). They are available on the same website. ODOT staff need to contact IS to have these installed (Note: The Rieker Serial-USB Adapter Driver is Profile dependent).
3. Open the spreadsheet to make sure the Rieker Serial-USB adapter is installed correctly.

Use a computer that has been ruggedized (similar to a Panasonic Toughbook) or has a solid state hard drive. Using a computer with standard hard drive will result in computer crashes over time because of rough roads.

In-Office "Bench Testing"

It is important to ensure that all equipment and drivers are correctly installed and working properly before going into the field. To do this, open the ODOT Spreadsheet and connect and

* See the specifications for the digital ball-banker on the Instructions tab of the ODOT Excel Spreadsheet

turn on the Rieker Instrument. A 12V converter is needed to bench test the Rieker Instrument in the office as the supplied power source for the instrument is a cigarette lighter. A converter can be purchased on sites such as Amazon or other shopping sites. With the spreadsheet on "Local Curve" click the red "Test Com" button, select a com port and click "Test Com." If the test returns a red "Com BAD" message, communications between the ball-banker and the spreadsheet are not correctly set up.

Most commonly the Port needs to be changed in the "Comm Settings" box in the spreadsheet. It may not be set to the correct port that the Rieker is installed in. To find the Communication Port number that the Rieker is currently plugged in on, check the Device Manager for the list of connected ports. In Windows 7, go to Start>Devices and Printers. Look for the port named ATEN USB to Serial Bridge (COMX). The 'X' represents the port number the instrument is attached to. Make sure this number matches the port number you choose in the spreadsheet.

(Windows XP: START>Control Panel>System. Click the Hardware tab, and then choose the Device Manager. ODOT Employees will get a warning, click okay to proceed to the manager. Find the plus next to "Ports (COM & LPT)" and open them.)

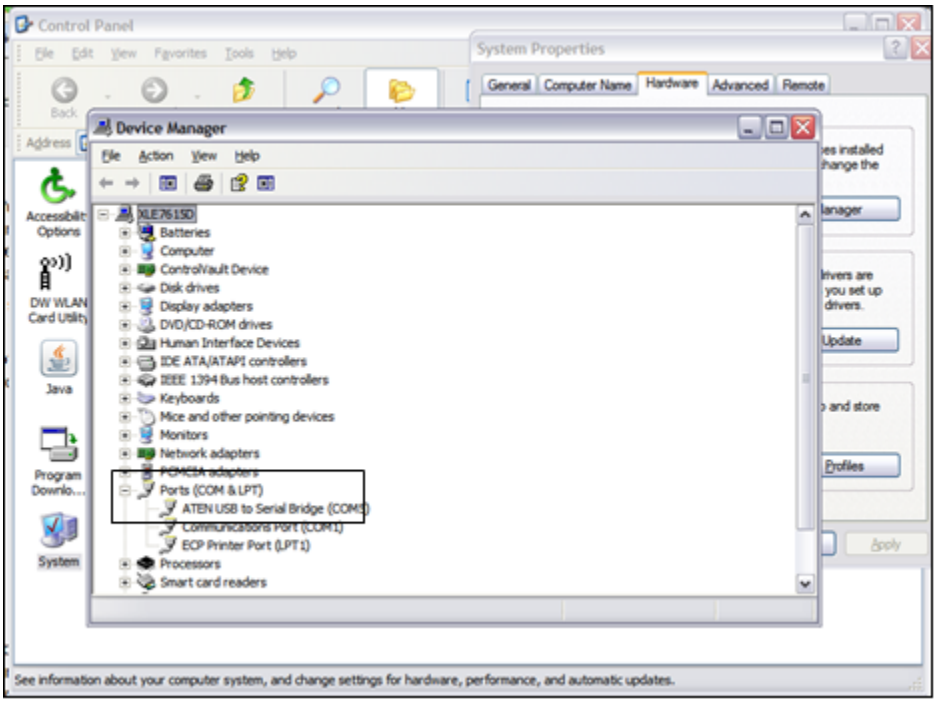


Figure 1: Windows XP Device Manager

Another possibility is that the instrument is physically plugged into a different port than the driver was installed on. Each time the instrument is plugged into the computer, it requires that

it be plugged into the same USB port as the one it was installed on. If the Rieker is plugged in to the correct port, and you still get the warning message, consider reinstalling the driver.

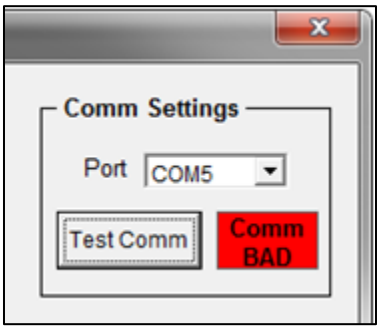


Figure 2: Communication Testing

Test GPS connectivity the same way as testing with the Rieker unit.

Ball Banker Setup

First-time vehicle installation of the ball-banking instrument will require a few extra steps. The instrument purchased for ODOT Region staff is the Rieker Digital Inclinometer. The instrument must be mounted on a surface that is less than 10° out of level. To check this, turn on the ball-banker and place it in the desired mounting location (i.e.: dashboard). If the screen reads between -10° and +10° then the selected location will work, if not, move the instrument to a different location until it reads between -10° and +10°. Once an appropriate location is determined, clean the surface with some sort of cleaner (i.e.: Windex). Next, place one of the supplied pieces of Velcro to the dashboard (or determined mounting location), and the other supplied piece of Velcro to the bottom of the instrument.

Investigations using the ODBB Spreadsheet

This section is an overview of instructions on utilizing the ODBB for investigating curve warning speed riders. An in-depth description of how the spreadsheet works and its further uses can be found on the Instructions tab of the spreadsheet. The ODOT spreadsheet calculates and reports values based on the adopted 2009 MUTCD. Below are directions, along with tips and tricks when using the ODBB Spreadsheet and Electronic Ball-banker.

Step 1: In the Office

After deciding the location of the curve (curves) you would like to investigate. Go to the "Horizontal Curve Information" website and enter in highway and mile points you would like to investigate. If you know the location but do not know the MP of the curves you are investigating, it is helpful to use TransGIS with the mile point Hundredths Layer turned on. Once you have a PDF of the Horizontal Curve Information it is important to "drive" along the highway using the ODOT Digital Video Log (DVL) and make notes of signage associated with each curve. Below is an example of the curves within the test track. The mile points on the Horizontal Curve Report are the beginning and ending of the curve in increasing mile points. The information gathered from the Horizontal Curve Report and the DVL will be used to pre-fill the spreadsheet before going into the field.

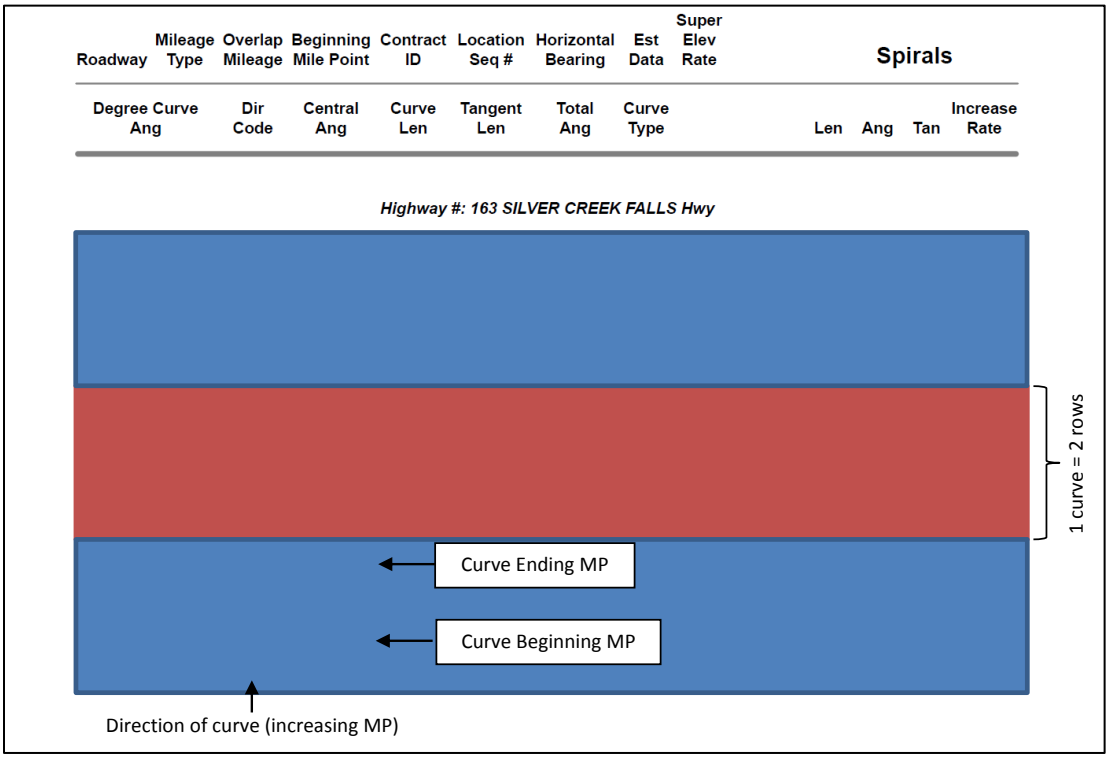


Figure 7: Horizontal Curve Report Sample

Step 2: In the Office

After labeling each curve on the Horizontal Curve Report, open a copy of the ODBB spreadsheet and save it as a new file name to preserve the original spreadsheet. Choose the "Local Curve" tab and enter the investigation information using the Yellow "Edit Investigation Info" button. Next, create a new curve in the spreadsheet for each curve from the Horizontal Curve Report. Using the gray "Edit Curve Data" button, enter the curve data into each curve in MP order. Use the beginning and ending MPs of the curve from the Horizontal Curve Report. Use this pre-filled spreadsheet for your investigation.

Step 3: Field Work

Before driving to the investigation site, make sure to "level off" the ball-banker using a known level pad of concrete, such as a truck scale. At the investigation site you will need to drive EACH individual curve 3 times in each direction at the advisory speed. If there is not a speed rider present the speed of the curve is the posted speed of the roadway. Before starting the investigation, drive the planned investigation site to become familiar with the roadway. Drive the curves as smoothly as possible, within 1 mph of the test speed, and within the wheel path and parallel to the centerline. DO NOT cross the centerline, even if the wheel path does.

Each curve will have to be driven 3 times in each direction at the advisory speed. To start recording click in the cell that belongs to the run number, curve and speed the curve will be driven. Below is a figure with an example of associated cells.

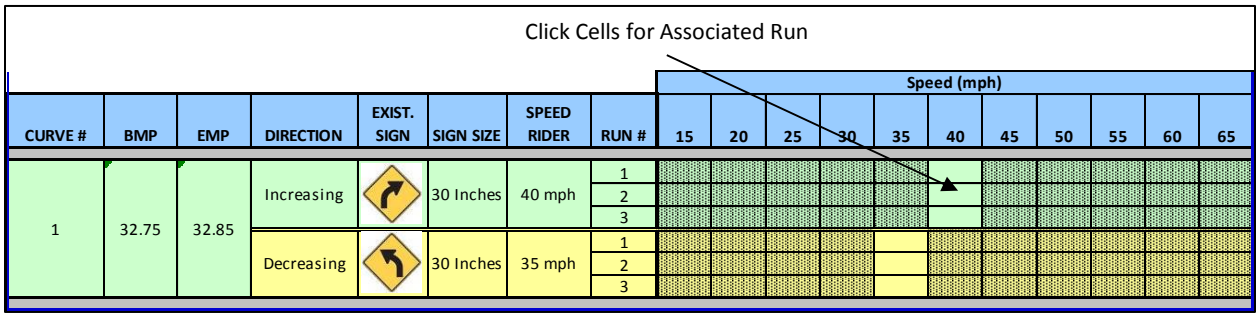
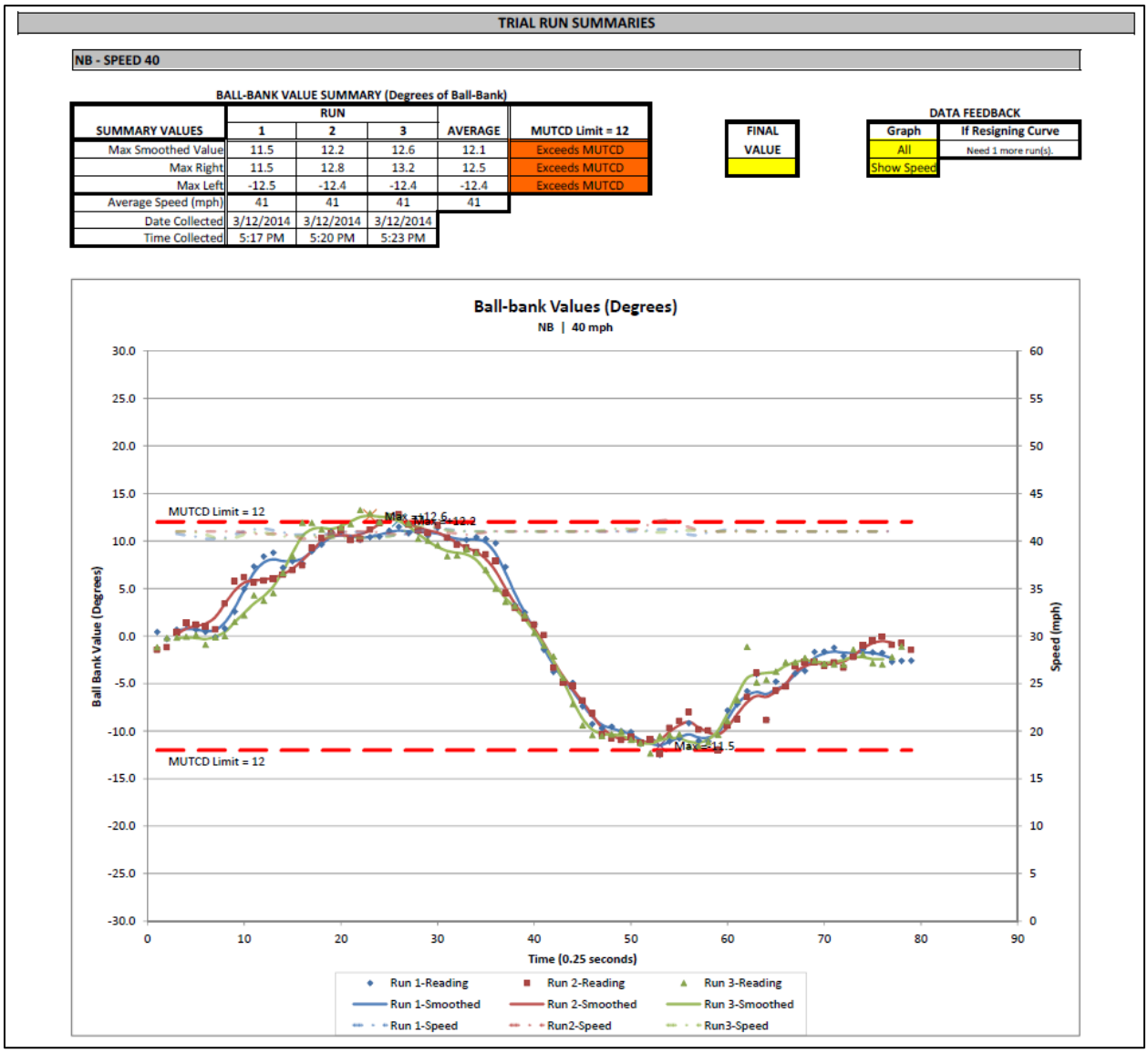


Figure 8: Example of Local Curve Sheet

When selecting a cell to begin recording, a new pop-up will appear asking if you want to start recording, click "yes." Click no on the second pop-up **unless** one or more curves are signed together, **AND** at the same speed. If this is the case, clicking yes on the second popup will enable you to drive them with one less button click. Before entering the curve, usually at the existing curve warning sign, click the green "Begin Recording" button. After exiting the curve, usually at the existing curve warning sign for the opposite direction, click the red "Exit Recording" button. Do this for each of the curves, 3 times in each direction at the speed the curve is being changed to. It is possible to go from curve to curve and jump between curves, as

long as careful consideration is taken to input data into the correct cells. Below is an example of an output graph from “Local Curve Mode” that is generated on the associated curve tab.



TRIAL RUN SUMMARIES

NB - SPEED 40

BALL-BANK VALUE SUMMARY (Degrees of Ball-Bank)

SUMMARY VALUES	RUN 1	RUN 2	RUN 3	AVERAGE	MUTCD Limit = 12
Max Smoothed Value	11.5	12.2	12.6	12.1	Exceeds MUTCD
Max Right	11.5	12.8	13.2	12.5	Exceeds MUTCD
Max Left	-12.5	-12.4	-12.4	-12.4	Exceeds MUTCD
Average Speed (mph)	41	41	41	41	
Date Collected	3/12/2014	3/12/2014	3/12/2014		
Time Collected	5:17 PM	5:20 PM	5:23 PM		

FINAL VALUE

DATA FEEDBACK

Graph	If Resigning Curve
All	Need 1 more run(s).
Show Speed	

Figure 9: Example Local Curve Data Report

Local Curve Analysis

Results can be analyzed in the field or in the office. Using engineering judgment and the graphs created using the Spreadsheet, curves can also be run at speeds different than the current posted speeds. If the output from the spreadsheet greatly differs from the speeds posted in the field, the investigator may choose to re-drive the curve at a different speed. If in driving the curve at 5 mph above or below the posted speed it is found that the curve sign should be changed, follow current ODOT standard practice for resigning curves.

Helpful Resources

Suggested Equipment

1. Computer with ODOT Spreadsheet
2. Rieker Digital Ball-banker
3. Stopwatch
4. Notebook
5. Power converter/source for computer
6. Printed Horizontal Curve Inventory
7. Printed Highway Inventory Summary (for MP information)
8. Mounting equipment for laptop

Helpful Websites

- ODOT Spreadsheet
  http://www.oregon.gov/ODOT/HWY/TS/Pages/signing.aspx#Tools_for_Signing_Curves
- Drivers for Rieker Serial-USB Adapter
  http://www.iogear.com/support/dm/driver/GUC232A
- Horizontal Curve Data (ODOT)
  http://highway.intranet.odot.state.or.us/cf/highwayReports/horizontal_curves_parms.cfm
- Map of Available Truck Scales to "Level Off"
  http://www.odot.state.or.us/forms/motcarr/mce_dist_bounds_truck_scales.pdf
- TransGIS (ODOT)
  http://wpdotappl21.odot.state.or.us/transgis/
- Digital Video Log (ODOT)
  http://rssa.odot.state.or.us/cf/dvl/index.cfm?&fuseaction=entry
- Highway Inventory Summary (ODOT)
  http://highway.intranet.odot.state.or.us/cf/highwayReports/aml_summary_parms_by_route_no.cfm
- TTI Kinematics of Curve Driving
  http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/0-5439-1.pdf#page=121
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Appendix

ODOT Digital Ballbanker Spreadsheet User Manual

Oregon Department of Transportation

Digital Ballbanker User Manual

Digital Ballbanker Version 2.0

May 2013

OREGON DEPARTMENT OF TRANSPORTATION
HIGHWAY DIVISION
TECHNICAL SERVICES
TRAFFIC-ROADWAY SECTION
http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/

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1.0 BACKGROUND

This spreadsheet is developed for use in engineering studies to determine the recommended advisory speed for horizontal curves, per the 2009 Manual on Uniform Traffic Control Devices (MUTCD) Section 2C.08 with the Rieker® Electronics, Inc. Digital Inclinometer RDS7-BB.

1.1 2009 Manual on Uniform Traffic Control Devices (MUTCD) 2009 MUTCD Website

Section 2C.08 Advisory Speed Plaque (W13-1P)

Option:

01 The Advisory Speed (W13-1P) plaque (see Figure 2C-1) may be used to supplement any warning sign to indicate the advisory speed for a condition.

Standard:

02 **The use of the Advisory Speed plaque for horizontal curves shall be in accordance with the information shown in Table 2C-5. The Advisory Speed plaque shall also be used where an engineering study indicates a need to advise road users of the advisory speed for other roadway conditions.**

03 **If used, the Advisory Speed plaque shall carry the message XX MPH. The speed displayed shall be a multiple of 5 mph.**

04 **Except in emergencies or when the condition is temporary, an Advisory Speed plaque shall not be installed until the advisory speed has been determined by an engineering study.**

05 **The Advisory Speed plaque shall only be used to supplement a warning sign and shall not be installed as a separate sign installation.**

06 **The advisory speed shall be determined by an engineering study that follows established engineering practices.**

Support:

07 Among the established engineering practices that are appropriate for the determination of the recommended advisory speed for a horizontal curve are the following:

A. An accelerometer that provides a direct determination of side friction factors
B. A design speed equation
C. A traditional ball-bank indicator using the following criteria:
   1. 16 degrees of ball-bank for speeds of 20 mph or less
   2. 14 degrees of ball-bank for speeds of 25 to 30 mph
   3. 12 degrees of ball-bank for speeds of 35 mph and higher

08 The 16, 14, and 12 degrees of ball-bank criteria are comparable to the current AASHTO horizontal curve design guidance. Research has shown that drivers often exceed existing posted advisory curve speeds by 7 to 10 mph.

Guidance:

09 *The advisory speed should be determined based on free-flowing traffic conditions.*

10 *Because changes in conditions, such as roadway geometrics, surface characteristics, or sight distance, might affect the advisory speed, each location should be evaluated periodically or when conditions change.*

1.2 ODOT Traffic Manual, 2009 Edition ODOT Traffic Manual Website

Safe speed on curves is determined by Region Traffic using the ball-bank indicator method as described in the Sign Policy and Guidelines for the State Highway System. The safe speed is determined in each direction.

Oregon Department of Transportation (ODOT) standard practice is to post horizontal alignment signs for a curve when a recommended safe speed is less than the posted speeds. An advisory speed plaque on the sign assembly is required if the recommended safe speed is 10 mph or more below the posted speed.

Warning signs for curves with a recommended safe speed equal to the posted speed may be posted depending on an engineering investigation including road geometry, crash history, and other factors, and is not required to include the speed rider (see also Part 2 of the MUTCD).

Curve signs are used for recommended safe speeds above 30 mph. Turn signs are used for recommended safe speeds of 30 mph or less.

For a full discussion of horizontal alignment signs and their use, see Part 2 of the MUTCD. The standard signs including freeway signing can be found in the warning sign and construction sign sections of the Sign Policy and Guidelines for the State Highway System.

1.3 Ball-Bank Fundamentals

For a discussion on horizontal alignment considerations and diagram of the geometry and forces acting on a ball-bank indicator, see AASHTO's *"A Policy on Geometric Design of Highways and Streets"* (The *Green Book*).

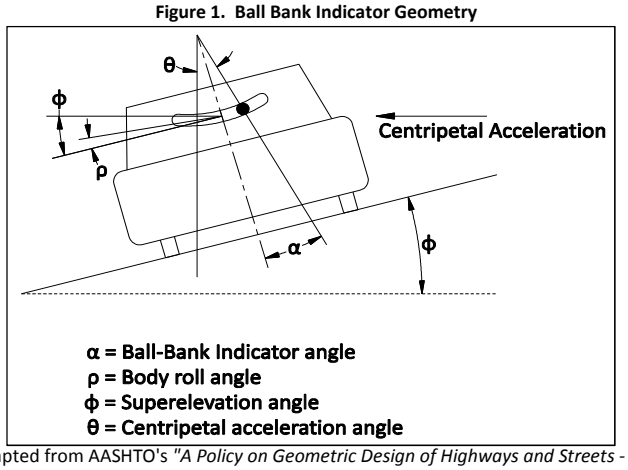
Effects of Body Roll

The following is an excerpt from Carlson and Mason (2007):

> *The ball bank indicator is the most commonly used device to select a posted advisory speed on existing horizontal curves. In a recent survey, 88 percent of the states, cities, and counties that responded indicated that they use the ball bank indicator to set safe speeds (1). However, the ball bank indicator reading is not a direct measure of lateral [centripetal] acceleration.*
>
> *Although a vehicle negotiates a curve with a constant radius at a uniform speed, the vehicle and the ball bank indicator are accelerated inward toward the center of the curve. The acceleration generated is the demanded lateral [centripetal] acceleration. The ball of the ball bank indicator attempts to maintain its tangential vector direction, which causes it to appear as if it were rolling out to a fixed position.*
>
> *With a ball bank indicator mounted in a moving vehicle, the ball bank reading (α) at any time equals the combined effect of the lateral [centripetal] acceleration angle (ϑ), the superelevation angle (φ), and the body-roll angle (ρ).*

$$Ball\ Bank\ Reading, \alpha = \theta - \phi + \rho$$

Figure 1. Ball Bank Indicator Geometry



Adapted from AASHTO's *"A Policy on Geometric Design of Highways and Streets - 2004"*

> *Therefore, if it were not for the body-roll angle, the ball bank indicator would be a direct measure of lateral [centripetal] acceleration. A criticism of the ball bank indicator's usage for setting safe speeds on existing curves is the influence of the test vehicle's body-roll. A comprehensive study of the ball bank indicator (2) concluded that "the extreme effect of the body-roll of various models and makes of cars is only about 1 degree in the ball bank angle and provides a difference of about 2 km/h (3 mph) in speed." The report recommended neglecting the body-roll influence as long as "the observers understand the effect of body-roll and make due allowance for it in case cars with extreme values are used for the driving tests."*

Carlson et. al. concluded body-roll of a vehicle does not appear to significantly change the determined safe speed.

References:

Carlson, Paul J., and John M. Mason. "Relationships Between Ball Bank Indicator Readings, Lateral Acceleration Rates, and Vehicular Body-Roll Rates." Transportation Research Record: Journal of the Transportation Research Board Online 1658, no. 1999 (2007): 34-42. http://trb.metapress.com/content/b3002j7403057037/fulltext.pdf (accessed January 3, 2012).

(1) Fitzpatrick, K., J. D. Blaschke, C.B. Shamburger, R.A. Krammes, and D.B. Fambro. *Compatibility of Design Speed, Operating Speed, and Posted Speed.* Report FHWA/TX-95/1564-2F, Texas Transportation Institute, College Station, Oct. 1995.

(2) Moyer, R.A., and D.S. Berry. Marking Highway Curves with Safe Speed Indicators. *Proc., HRB* , Vol. 20, 1940.

Ball-and-Vial vs. Electronic Inclinometer

In 2008, Dixon and Rohani investigated methodologies for estimating advisory curve speeds on Oregon highways. One part of their investigation compared the difference between "manual" ball-and-vial inclinometers and digital inclinometers. Dixon and Rohani compared a Rieker Electronics RDS7-BB and a Rieker Electronics 1023W1 manual ball-bank indicator. Below are exceprts of their findings:

> *As a general rule, the ball-bank readings obtained by the manual [ball-and-vial] versus the digital ball-bank devices resulted in recommended advisory speeds that were the same or similar (usually within 5 mph)…In general, the digital ball-bank device seemed to be slightly more sensitive than the dampened manual ball-bank device. Upon inspection of recommended advisory speeds at individual sites, it is difficut to observe a systematic trend regarding the performance of the two ball-bank devices...There is considerable scatter among the observed data; however, when a polynomial trend line is plotted it is clear that the digital ball-bank device systematically appears to recommend a slightly lower advisory speed for the same curve raidus than that indicated by the manual ball-bank device.*

It is because of this variability that the spreadsheet calculates a weighted average smoothing curve. See Section 5.0 for more information.

1.4 This Spreadsheet

This spreadsheet was originally developed to standardize the ball-bank data collection process in an effort to make the investigation process more consistent throughout Oregon. ODOT purchased Rieker® Electronics, Inc. Digital Inclinometers model RDS7-BB, in 2011 to meet this effort and needed a user interface to standardize collection and analysis of the data.

This spreadsheet is developed to be used with the Rieker® Electronics, Inc. Digital Inclinometer RDS7-BB for use in engineering studies to determine the recommended advisory speed for horizontal curves, per the 2009 Manual on Uniform Traffic Control Devices (MUTCD) Section 2C.08. Considerations of sight distance, intersections, crash records, and other conditions may result in a recommended speed other than that derived by the method used in this tool.

This spreadsheet should only be used under the direct supervision of a Registered Professional Engineer. Users of this spreadsheet are responsible for verifying its accuracy - use at your own risk. Calculations and data from this spreadsheet should always be scrutinized and weighed with sound engineering judgment. Follow all traffic laws and drive in a manner safe for the conditions.

Ideas, comments, and concerns from the engineering and highway safety community are greatly appreciated. Please submit your concerns and ideas to ODOT Traffic-Roadway Section via email at:

ODOTCurveSigning@odot.state.or.us

While it may not be feasible to add them immediately, all suggestions and concerns will be collected and potentially incorporated into future versions.

1.5 References

Below is a list of related references and websites:

2009 MUTCD
ODOT Traffic Manual
ODOT Sign Policy & Guidelines
ODOT Digital Video Log (Internal ODOT)
ODOT Digital Video Log (External ODOT)
Rieker, Inc. Website
TTI Kinematics of Curve Driving

A Policy on Geometric Design of Highways and Streets . Washington, D.C.: American Association of State Highway and Transportation Officials, 2004.

Carlson, Paul J., and John M. Mason. "Relationships Between Ball Bank Indicator Readings, Lateral Acceleration Rates, and Vehicular Body-Roll Rates." Transportation Research Record: Journal of the Transportation Research Board Online 1658, no. 1999 (2007): 34-42. http://trb.metapress.com/content/b3002j7403057037/fulltext.pdf (accessed January 3, 2012).

Dixon, Karen K., and Joshan Rohani. Methodologies for Estimating Advisory Speeds on Oregon Highways. Salem, Oregon: Oregon Department of Transportation Research Section, 2008. http://www.oregon.gov/ODOT/TD/TP_RES/docs/reports/2007/spr_641.pdf (accessed May 5, 2014).

Dixon, Karen K., and Raul Eduardo Avelar. *Safety Evaluation of Curve Warning Speed Signs* . Salem, Oregon: Oregon Department of Transportation Research Section, 2011. http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/2011/WarningSpeedSignsSPR685.pdf (accessed January 23, 2012).

Fitzpatrick, K., J. D. Blaschke, C.B. Shamburger, R.A. Krammes, and D.B. Fambro. *Compatibility of Design Speed, Operating Speed, and Posted Speed* . Report FHWA/TX-95/1564-2F, Texas Transportation Institute, College Station, Oct. 1995.

Manual on Uniform Traffic Control Devices . 2009 ed. Washington, D.C.: Federal Highway Administration, USDOT, 2009. http://mutcd.fhwa.dot.gov/pdfs/2009/pdf_index.htm (accessed January 23, 2012).

Moyer, R.A., and D.S. Berry. Marking Highway Curves with Safe Speed Indicators. *Proc., HRB* , Vol. 20, 1940.

ODOT Sign Policy and Guidelines . Salem, Oregon: Oregon Department of Transportation, 2011. http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/sign_policy.shtml (accessed January 23, 2012).

ODOT Traffic Manual with Revisions 1 and 2. Salem, Oregon: Oregon Department of Transportation, 2009. http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/Traffic_Manual_09.pdf?ga=t (accessed January 23, 2012).

2.0 SET-UP

2.1 Mount Ball-Bank Indicator

The following is from the Rieker RDS7-BB User Guide:

> *The RDS7-BB unit can be mounted on any surface that is within 10 degrees of level. To determine if the surface is within the appropriate level, power up the unit and place it on the desired location* [dash board, for example]. *If the unit displays less than 10 degrees then the chosen location is fine. Once the mounting location has been determined, wipe the surface clean with a cleanser such as Windex and apply one of the supplied strips of Velcro. Apply the remaining strip of Velcro to the bottom of the unit. The RDS7-BB unit is ready to attach to the vehicle's surface.*

2.2 Level Ball-Bank Indicator

The following is from the Rieker RDS7-BB User Guide:

> *If the indicator is not level, but within ±10 degrees of level, press and release the REL button. The display will read "REL ON" for one second then revert to normal with the indicator reading zero. If after pressing the REL button and the indicator display reads "OVER RANGE" the indicator is not within ±10 degrees of level. Re-position the unit, then repeat. When the indicator is in REL mode you will see the (*) symbol displayed indicating the relative zero (REL) function is active.*
>
> *The indicator should be auto leveled using the REL button while the vehicle is on a flat surface. Auto leveling with the REL button must be performed whenever the unit has been powered off.*

2.3 Disable Buzzer

To disable the buzzer on the RDS7-BB:

1. Turn off power to the Digital Inclinometer.
2. Hold the MIN/MAX button and turn on power.
3. When the display reads "CAL ON" release the MIN/MAX button.
4. Press and hold MIN/MAX for 2 seconds to advance to the alarm angle.
5. Press MIN/MAX to advance to the buzzer setting.
6. To change the buzzer setting, press REL. The display should read "BUZR (current Buzzer setting)"
7. Press MIN/MAX to save the settings and resume normal operation.

2.4 Spreadsheet Communications

The RDS7-BB unit is set up to communicate with a computer through a standard RS232 output (serial port). The unit's standard communications platform with a computer is through Windows Hyperterminal. If you don't want to use this spreadsheet to gather data, ball-bank data can be collected through Hyperterminal when Hyperterminal is configured to communicate at 9600 baud, 8 data bits, no parity, and 1 stop bit. To access Hyperterminal, go to Start>Programs>Accessories>Communications>Hyperterminal. For Windows 7 OS, HyperTerminal needs to be downloaded.

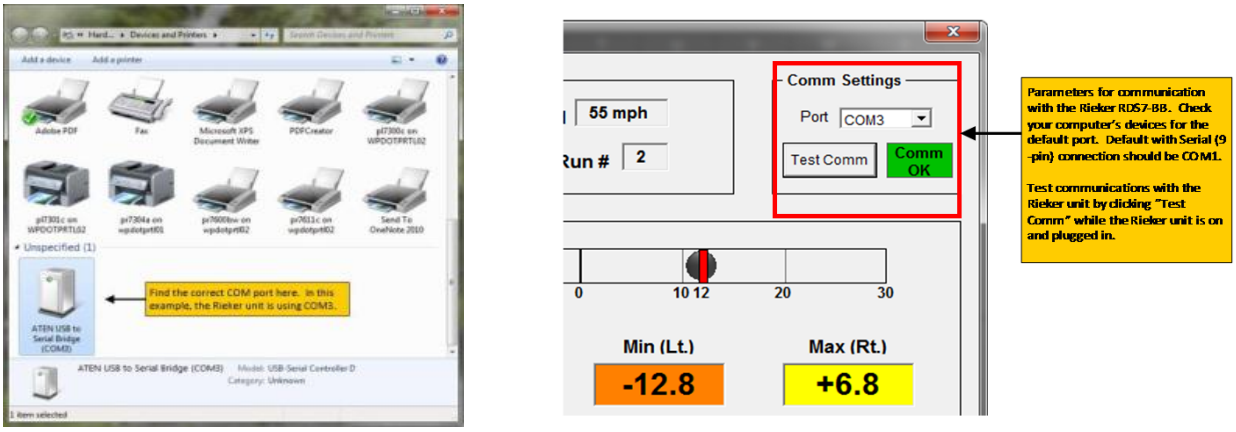
To use the Serial-USB adapter supplied by Rieker (model GUC232A), ODOT computers need to have a special driver installed by computer support staff (503-986-3800). The driver can be downloaded at:

http://www.iogear.com/support/dm/driver/GUC232A

This spreadsheet is set up to communicate directly with the RDS7-BB unit through Visual Basic macros - no third party program (like Hyperterminal) is needed to establish communications with the RDS7-BB unit. When you are ready to collect data, the data collection window shown below will appear. Communications settings can be changed in the upper right-hand box called "Comm Settings" in the data collection window. When a communications test is successful, the spreadsheet will remember which com port is set up for the Rieker unit.

To find the correct communications port, plug in the USB serial adapter and go to Start>Devices and Printers and scroll down to "USB to Serial Bridge." The Com Port should be in the device name in parentheses (e.g.: ATEN USB to Serial Bridge (COM3)). You may need to move the USB adapter to different ports on the computer to find the right port. Connections not using a USB serial adapter (direct serial connection) should be set to COM1.

Figure 1. Communications Settings.



Like the RDS7-BB, a GPS unit can communicate with the computer through a USB port. This spreadsheet is set up to communicate directly with a GPS unit through Visual Basic macros - no third party program is needed. When you are ready to collect data, the data collection window will appear. Communication settings for GPS can be changed in the upper right-hand box. When a communications test is successful, the spreadsheet will remember which com port is set up for GPS.

This spreadsheet is set up to communicate with a GPS unit at 115,200 baud, 8 data bits, no parity, and no stop bits using the GPGGS and GPRMC standard NEMA data strings. GPRMC is the primary text string used by the spreadsheet to gather location and speed information.

One GPS unit that has been tested successfully with the spreadsheet is the Qstarz BT-Q818XT GPS receiver. When using this unit with the spreadsheet, set the collection rate to 10Hz. This ensures GPS information is collected frequently enough to keep up with the ball-bank data being collected every 0.25 seconds.

3.0 DATA COLLECTION

The basic process for collecting ball-bank data is:

1. Level Ball-Bank Indicator

Level the ball bank indicator following the directions for the digital ball-bank tool. For Rieker RDS7-BB models, go to Section 2.2 of this manual.

2. Recon

Drive the planned collection area (for the day) before recording any information to become familiar with the roadway. Look for potential hazards that may affect testing. Note any inappropriately marked (or unmarked) curves that are not included in the spreadsheet that

3. Test

Test each curve individually, unless testing a series of curves or there is no safe turn-around location before the next curve. Curves should be driven as smoothly as possible, within 1 mph of the test speed, and parallel to the centerline of the curve. Begin collecting data by clicking the cell corresponding to the direction, speed, and run number for the test in the green LOCAL CURVE tab. For more information on the LOCAL see the Spreadsheet User Guide section below.

Turn around after the tested curve(s) at the nearest safe turnaround location. Repeat until the curve(s) have been tested 3 times in each direction at the speed the advisory speed will be posted at.

4. Refine and Repeat

Follow the trial summary data gathering instructions. When it says stop, the data collection for that curve is complete. Proceed to the next curve. For more information on how the spreadsheet determines when to stop, see the Data Processing section below.

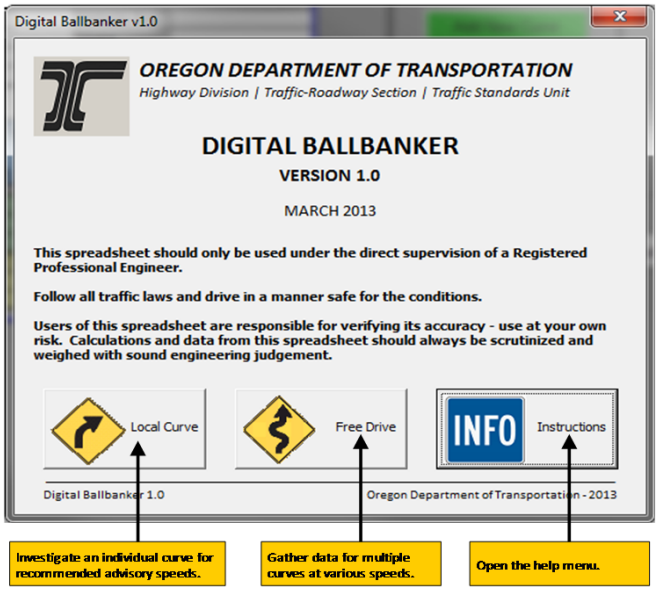
4.0 SPREADSHEET USER GUIDE

The following is a step-by-step guide to using ODOT's Digital Ballbanker spreadsheet. Changes to the spreadsheet are documented at the link below:
View spreadsheet change list.

4.1 Opening the Spreadsheet

The Ballbanker spreadsheet is opened and saved like any other macro-enabled MS Excel spreadsheet. It makes use of macro buttons, tabs along the bottom of the window, and user forms to gather data from the user, the Rieker RDS7-BB unit, and the GPS unit.

1. Open the LOCAL CURVE tab to investigate individual curves for recommendations on advisory speeds.
2. Open the FREE DRIVE tab to gather ball-bank data for multiple curves at various speeds.
3. Open the help menu and view the INSTRUCTIONS tab.



4.2 Local Curve Mode

Use Local Curve Mode to investigate individual curves for recommended advisory speeds. Local Curve Mode is controlled in the green LOCAL CURVE tab at the bottom of the spreadsheet. This tab contains the summary information for the investigation and each ball-bank run.

Run data is summarized in the curve report table and is organized by curve number, direction, run number, and investigation speed. The suggested speed to investigate the curve at is highlighted in the table.

Information in the LOCAL CURVE tab can be edited and viewed using the buttons to the right of the sheet. These buttons include:

1. **Edit Investigation Info** - The investigation information, including highway, location, date, and vehicle can be edited by clicking the yellow "Edit Investigation Info" button to the right of the sheet.

2. **Add New Curve** - If you will be investigating multiple curves, you can add new curves by clicking the green "Add New Curve" button. This will add another curve report table to the LOCAL CURVE tab and create a blue curve investigation report tab corresponding to the curve number automatically assigned by the spreadsheet.

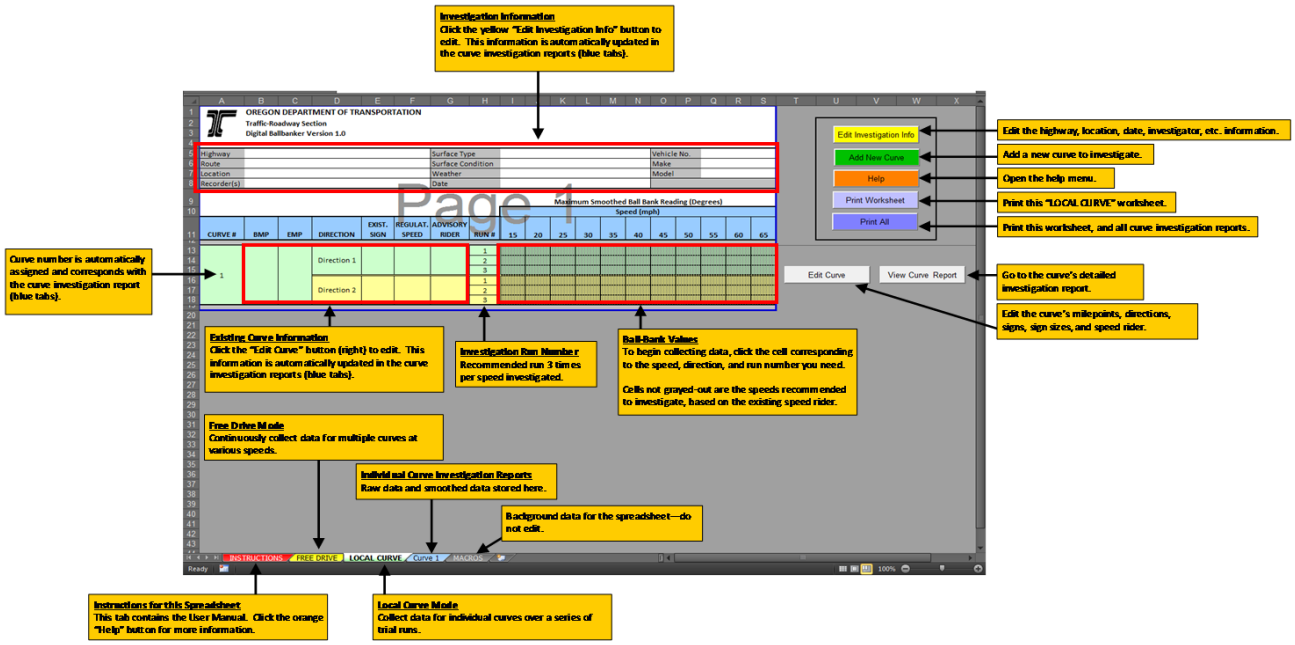
3. **Help** - The help menu can be opened by clicking the orange "Help" button.

4. **Print Worksheet** - The LOCAL CURVE tab can be printed by clicking the light blue "Print Worksheet" button.

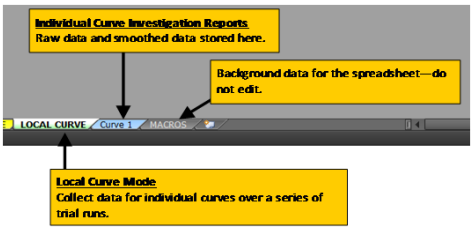
5. **Print All** - The LOCAL CURVE report and each of the curve investigation reports can be printed by clicking the blue "Print All" button.

6. **Edit Curve** - The curve's milepoints, directions, signs, sign sizes, and speed riders can be edited by clicking the curve's Edit Curve button (to the right of the curve report table).

7. **View Curve Report** - The curve's detailed investigation report can be viewed by clicking the View Curve Report button (to the right of the curve report table).



When using Local Curve Mode, each curve gets a blue curve investigation report tab. These tabs correspond to the curve numbers shown in the LOCAL CURVE tab. The blue curve investigation report tabs contain the raw ball-bank data, smoothed ball-bank data, run graphs, and summary reports.

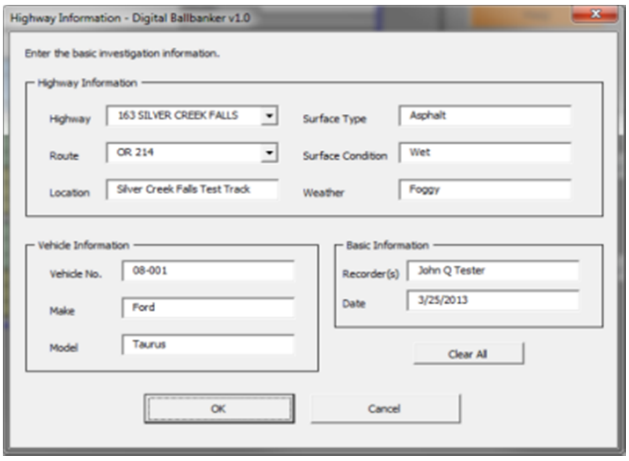


Set Up Investigation Information

The investigation information is the basic location, date, vehicle, and investigator information for the investigation. This information is repeated as a header for each curve in the investigation.

To edit this information, click the yellow "Edit Investigation Info" button to the right of the LOCAL CURVE tab. Edit the information using the Information window that appears.

Information entered in the Information window populates cells throughout the spreadsheet for documentation of the investigation. Any of this information can be edited or omitted at any time. ODOT highways and routes are already loaded in the drop-down menus for their respective category. For non-ODOT agencies, local road names can still be entered manually in either the Highway or Route category by selecting the text in the Highway or Route box and typing the desired information.



Edit Curve Information

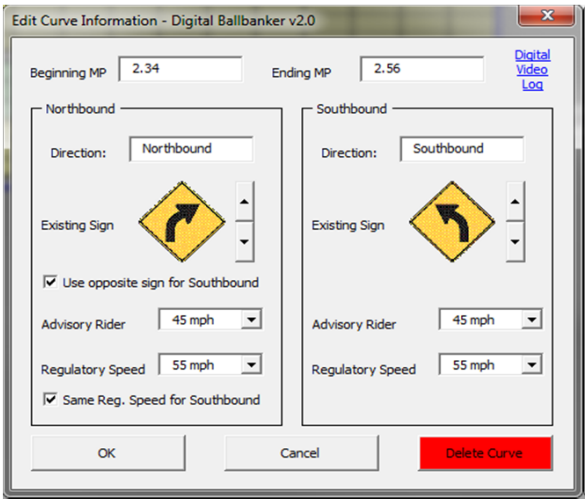
Individual curve information, such as milepoints, directions, and existing signs can be edited by clicking the "Edit Curve" button located to the right of the curve's report table in the LOCAL CURVE tab. When clicked, the window shown below appears.

Edit the information using the text boxes in the window. Direction fields are the directions driven during the investigation. The existing sign can be edited by scrolling through the available MUTCD signs using the up/down scroll bar. If the second direction's sign is the opposite of the first direction's, select the check box that says "Use opposite sign for Direction 2." If the speed rider and sign size are known, enter those values using the drop-down menus.

DOT NOT change the curve number - the spreadsheet uses this information to internally organize investigation data.

Internal ODOT employees can access the ODOT Digital Video Log by clicking the link in the upper right-hand corner.

If the curve needs to be deleted from the investigation, click the red "Delete Curve" button. This will clear the curve's information from the LOCAL CURVE tab and delete the blue curve investigation report tab corresponding to the curve number.



Add Curves to the Investigation

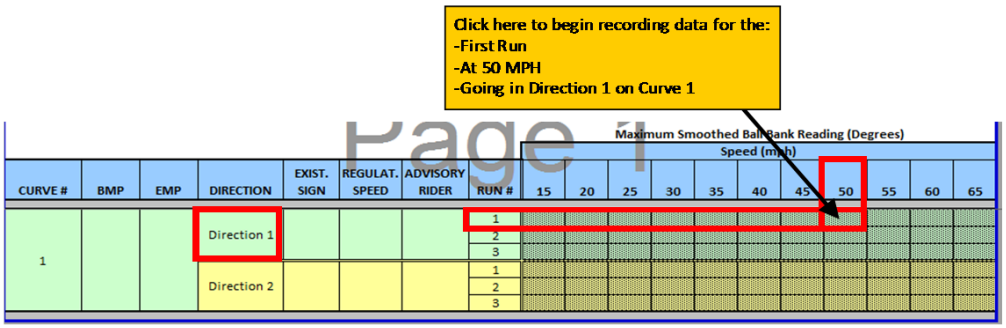
If the investigation will be testing multiple curves, these extra curves can be added to the LOCAL CURVE tab by clicking the green "Add New Curve" button. This function adds another row to the LOCAL CURVE tab and automatically numbers the curve. The function also adds a new blue curve investigation report tab that corresponds to the curve number in the LOCAL CURVE tab.

If you need to insert a new curve between existing curves in the list, select the grey row between the curves you want the new curve to be between (row number to the far left of the Excel screen). Once the row is selected, press F11 to insert the new curve. This renumbers and shifts the subsequent curves down.

Collect Ball-Bank Data

After the investigation and curve information have been entered, data collection can begin. This spreadsheet is designed to collect data using ball-bank limiting values in the 2009 MUTCD. Ball-bank data should be collected on a curve at least three times per direction at the new advisory speed in order to change the curve's advisory speed.

To collect data, click on the cell in the table that corresponds to the curve number, direction, run number, and speed for that particular trial run. For example, if the first trial run on curve 1 will be in the northbound direction at 50 mph, click the cell in the table that corresponds to these variables (see figure below). A message box will ask you if you want to begin collecting data. Click Yes to start recording data.



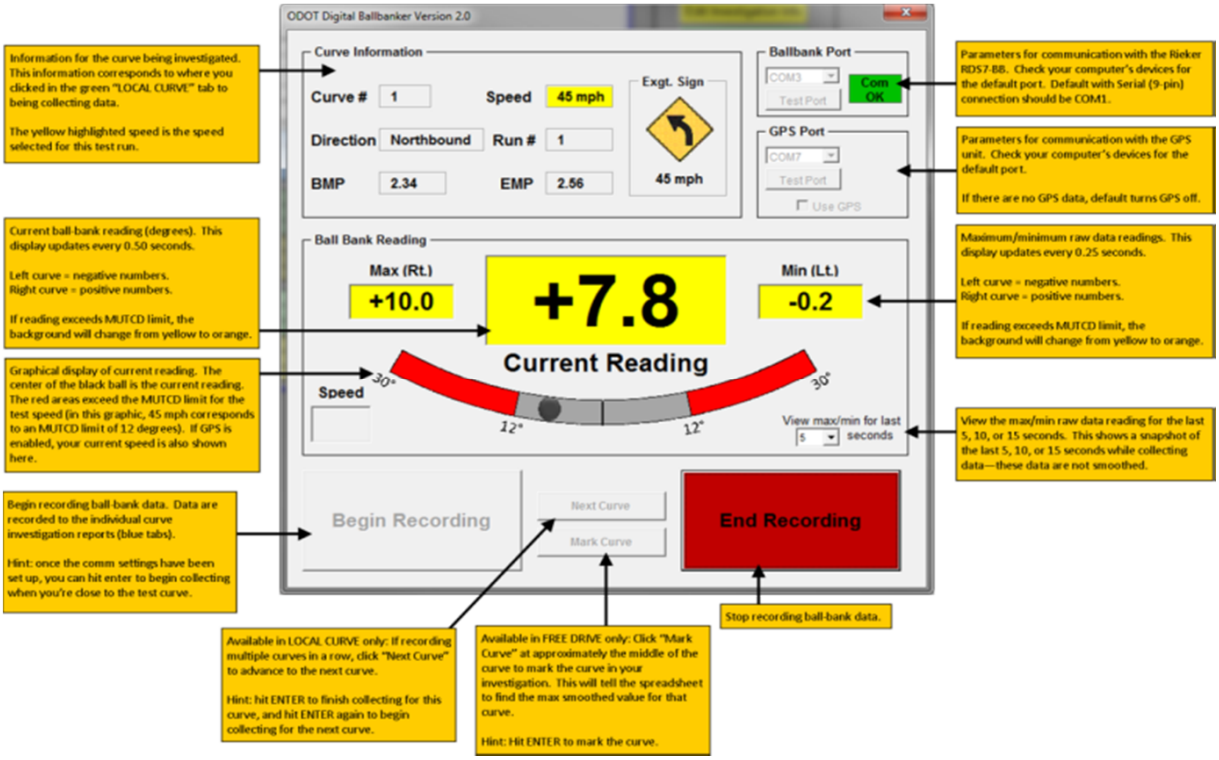
Next, the data collection window will appear. This window contains the controls and data feedback used during data collection. The upper left-hand corner contains the curve, speed, direction, and run information for this run. The upper right-hand corner contains the communications settings used
to communicate with the Rieker RDS7-BB unit and GPS (see the communications section of this manual for more information).

The bottom section contains real-time data feedback from the digital ball-banker. The middle section contains the current, live reading from the digital Rieker unit. The two smaller sections to the left and right contain the maximum readings for curves to the left (negative values) and right (positive values). These maximum values are displayed for the last 5, 10, or 15 seconds of data collection, based on the value selected in the drop-down menu .

Click the green "Begin Recording" button to begin collecting data. Data collection will continue until you click the red "Stop Recording" button. (Note: if you are driving, you can hit the Enter button on the keyboard to stop recording. If testing multiple curves, hit Enter to proceed to the next curve.)

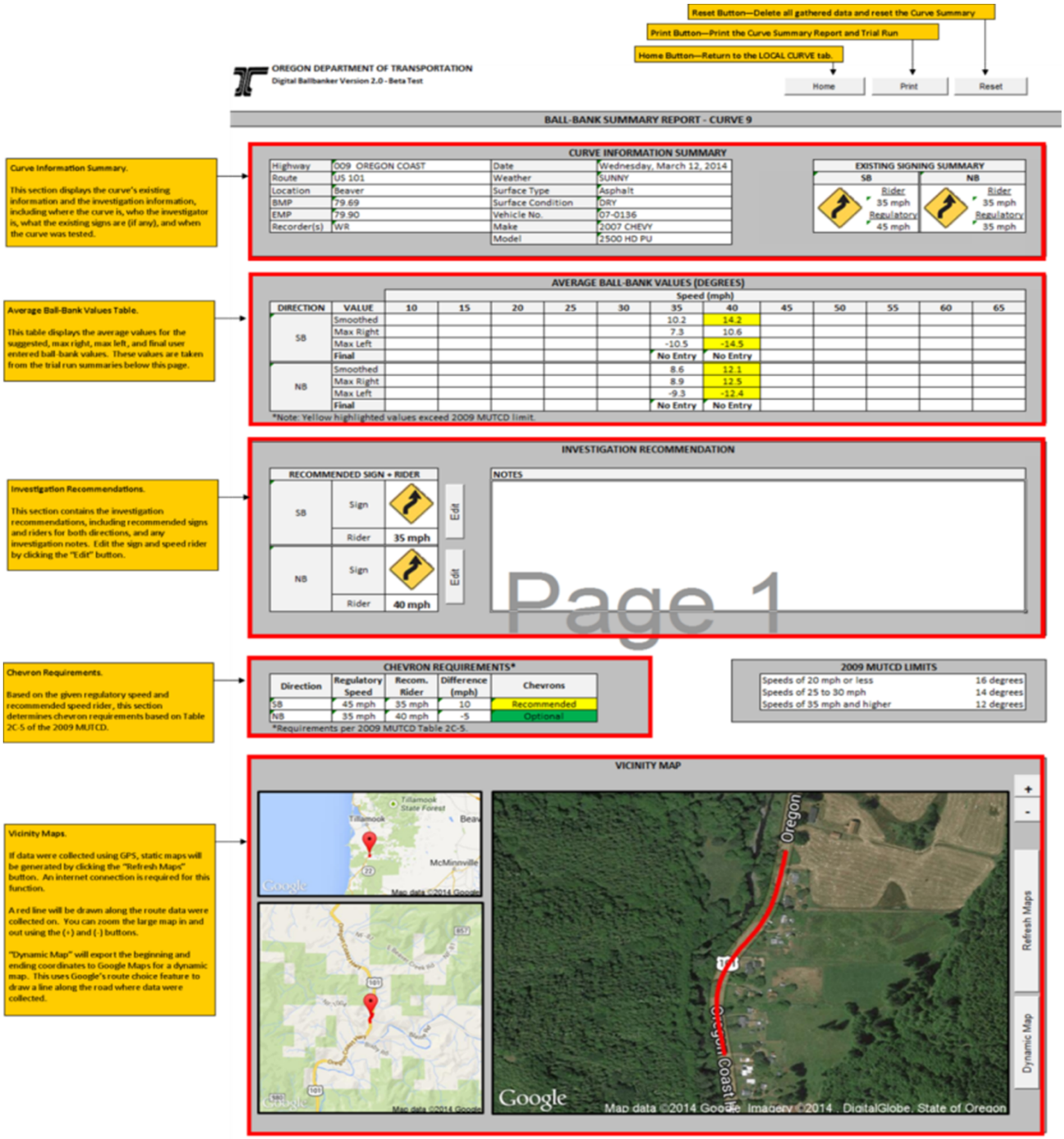
The spreadsheet collects and records data from the Rieker RDS7-BB and GPS every 0.25 seconds. The "Current Reading" value is updated every 0.50 seconds (for readability). The maximum values are updated every 0.25 seconds. All displayed values are rounded to the nearest 0.1 degrees of ball-bank.

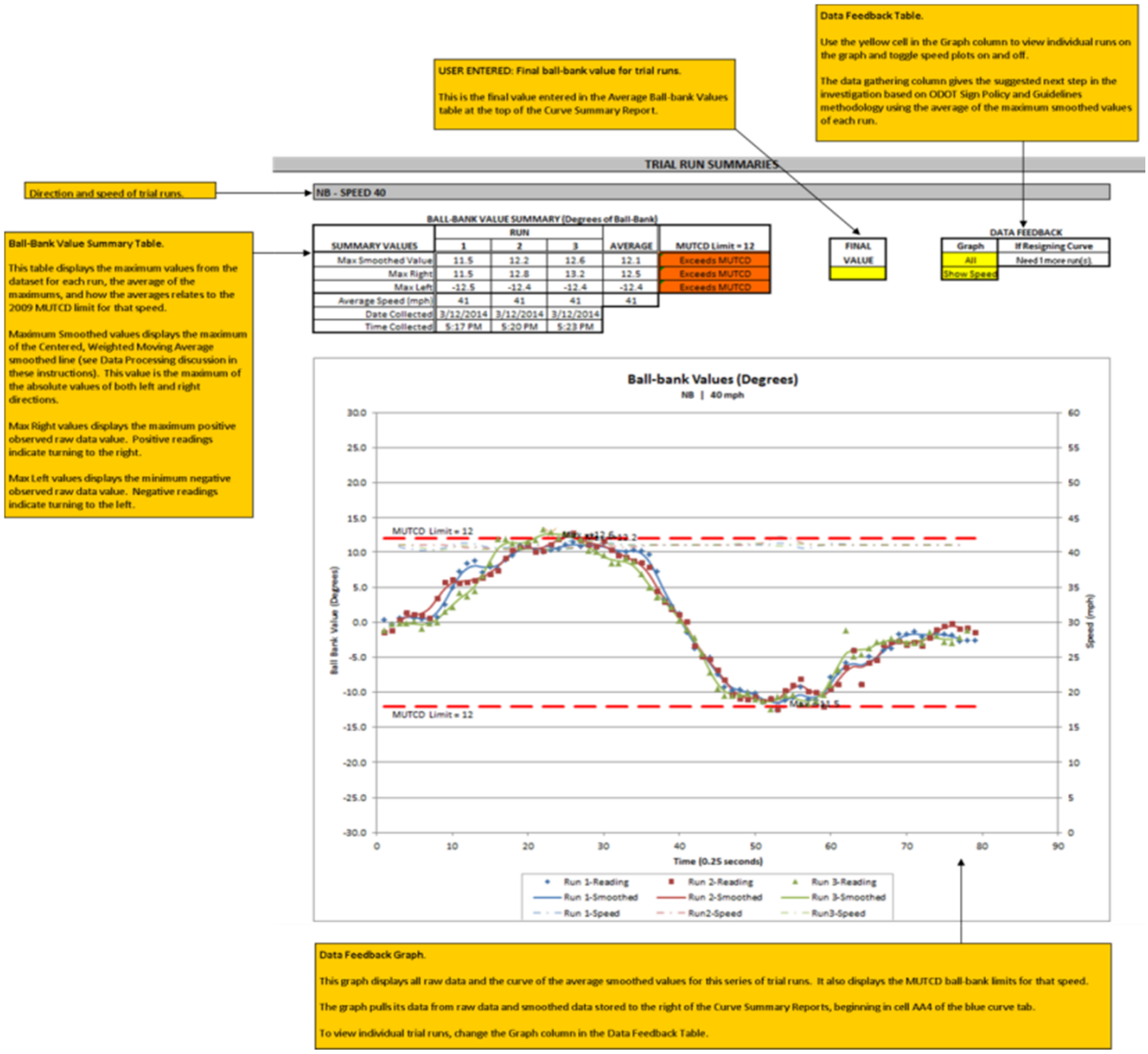
The background behind the values will change from yellow to orange when the raw value exceeds the MUTCD limit for that test speed.


ODOT Digital Ballbanker Version 2.0
Curve Information
Curve # 1
Speed 45 mph
Direction Northbound
Run # 1
BMP 2.34
EMP 2.56
Exgt. Sign
45 mph
Ballbank Port
COM3
Test Port
Com OK
GPS Port
COM7
Test Port
Use GPS
Ball Bank Reading
Max (Rt.)
+10.0
+7.8
Min (Lt.)
-0.2
Current Reading
Speed
30°
12°
12°
30°
View max/min for last
5
seconds
Begin Recording
Next Curve
Mark Curve
End Recording
Information for the curve being investigated. This information corresponds to where you clicked in the green "LOCAL CURVE" tab to being collecting data.
The yellow highlighted speed is the speed selected for this test run.
Current ball-bank reading (degrees). This display updates every 0.50 seconds.
Left curve = negative numbers.
Right curve = positive numbers.
If reading exceeds MUTCD limit, the background will change from yellow to orange.
Graphical display of current reading. The center of the black ball is the current reading. The red areas exceed the MUTCD limit for the test speed (in this graphic, 45 mph corresponds to an MUTCD limit of 12 degrees). If GPS is enabled, your current speed is also shown here.
Begin recording ball-bank data. Data are recorded to the individual curve investigation reports (blue tabs).
Hint: once the comm settings have been set up, you can hit enter to begin collecting when you're close to the test curve.
Parameters for communication with the Rieker RDS7-BB. Check your computer's devices for the default port. Default with Serial (9-pin) connection should be COM1.
Parameters for communication with the GPS unit. Check your computer's devices for the default port.
If there are no GPS data, default turns GPS off.
Maximum/minimum raw data readings. This display updates every 0.25 seconds.
Left curve = negative numbers.
Right curve = positive numbers.
If reading exceeds MUTCD limit, the background will change from yellow to orange.
View the max/min raw data reading for the last 5, 10, or 15 seconds. This shows a snapshot of the last 5, 10, or 15 seconds while collecting data—these data are not smoothed.
Available in LOCAL CURVE only: If recording multiple curves in a row, click "Next Curve" to advance to the next curve.
Hint: hit ENTER to finish collecting for this curve, and hit ENTER again to begin collecting for the next curve.
Available in FREE DRIVE only: Click "Mark Curve" at approximately the middle of the curve to mark the curve in your investigation. This will tell the spreadsheet to find the max smoothed value for that curve.
Hint: Hit ENTER to mark the curve.
Stop recording ball-bank data.

Curve Investigation Reports

The Curve Investigation Report Tabs (blue tabs) contain the raw data, smoothed data, summary graphs, and summary tables in a printable report format.





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Interpreting Results

After completing a series of trial runs, review the summary data and graph to determine a final ball-bank value for the direction and speed of the trial runs. The average of the maximum smoothed values will likely be the final value, if not close to the final value. An example of when the average of the maximum smoothed values may not be the final value is when there is a temporary spike in the data readings that is separate from the peak reading while traveling through the curve. If this happens, you can record over the erroneous data by restarting the data collection process for that trial.

Review the graph and summary data and enter the final value in the yellow cell below the FINAL VALUE header. This final value will be shown in the average ball-bank value table at the top of the Curve Investigation Report.

Delete Curves from Investigation

To delete curves from the investigation:

1) Go to the green LOCAL CURVE tab
2) Choose the curve you want to delete, and click the EDIT CURVE button to the right of the curve information.
3) Click the red "Delete Curve" button in the curve information window that pops up.
4) You will be asked if you really want to delete the curve; click yes.

This will delete the curve information from the LOCAL CURVE tab, and delete the blue curve investigation report tab.

Note: Curve 1 cannot be deleted. To reset the curve information, go to the blue curve investigation report tab and click the "Reset" button in the top right corner.

4.3 Free Drive Mode

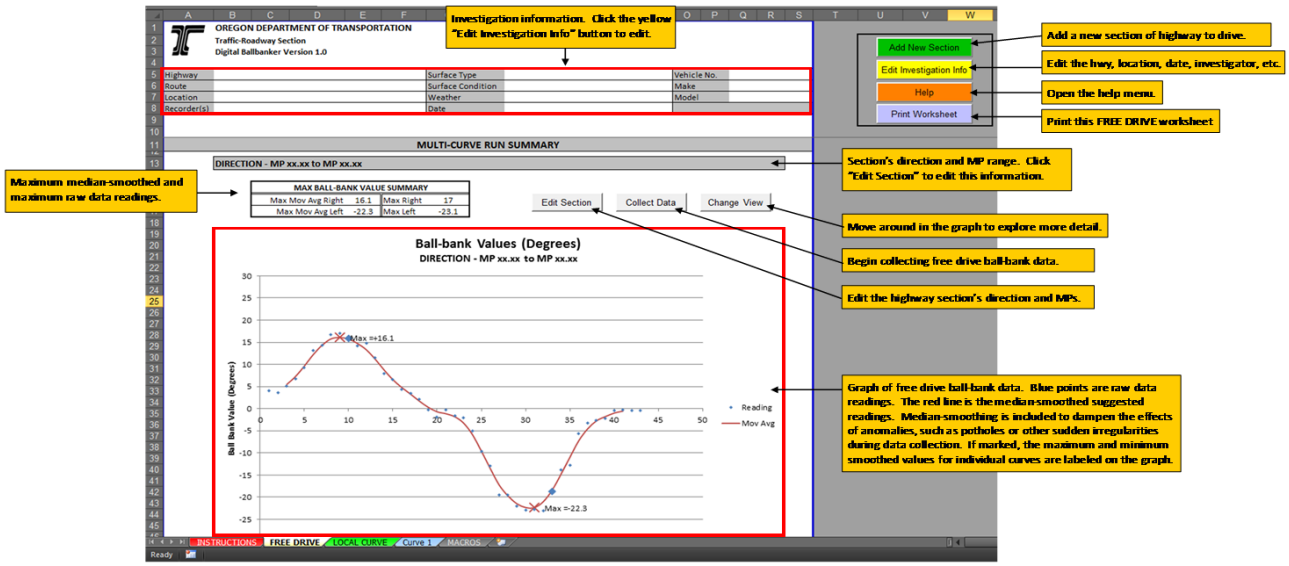
Use Free Drive Mode to gather ball-bank information for multiple curves at various speeds. Free Drive Mode is not meant for formal investigation of curves to determine recommended signing as it does not average multiple runs and does not account for vehicle speed. It is meant to provide cursory feedback to the investigator on ball-bank values over a section of highway.

For example, Free Drive Mode can be used to prioritize which curves should be formally investigated on a given section of highway. Drive a section of highway using Free Drive Mode at the recommended advisory speeds, and review the data collected by matching the curve to the peak or valley of the graph to the corresponding curve (first curve would be the first peak/valley on the graph, etc.). If the results exceed the MUTCD limiting values for the recommended advisory speed, mark that curve for further investigation using LOCAL CURVE mode. The 2009 MUTCD limiting values are:

16 degrees of ball-bank for speeds of 20 mph or less
14 degrees of ball-bank for speeds of 25 to 30 mph
12 degrees of ball-bank for speeds of 35 mph and higher

See the background section of these instructions and 2009 MUTCD Section 2C.08 for more information.

Free Drive Mode is controlled in the Yellow FREE DRIVE tab at the bottom of the spreadsheet. This tab contains the summary information for the free drive and ball-bank information for that section of highway. Run data is organized by highway section and summarized in a maximum value table and graph.



Information in the FREE DRIVE tab can be edited and viewed using the buttons to the right of the sheet. These buttons include:

1. **Add New Section** - This will add a new section of highway to gather data for.
2. **Edit Investigation Info** - Use this to edit highway, location, date, investigator, etc. information for the investigation.
4. **Help** - Open the help menu.
4. **Print Worksheet** - Prints the FREE DRIVE worksheet.

To edit section information, such as direction and milepoint ranges, click the "Edit Section" button corresponding to the section you wish to edit.

To collect data, click the "Collect Data" button corresponding to the section you wish to collect data for. Use the data collection window to collect ball-bank data. Ball-bank data is stored to the right of the Multi-Curve Run Summaries, starting in column AA.

During FREE DRIVE mode, you can mark curves while collecting data by clicking "Mark Curve" in the data collection window. Do this at approximately the middle of the curve (Hint: hit ENTER to mark the curve without clicking the mouse). This will tell the spreadsheet that this point in time is a curve you're investigating. After data collection is done, the spreadsheet goes back through the collected data and finds the points in time you marked. It then searches for the closest maximum (or minimum) average smoothed value that is greater than 3 degrees and marks it in the graph (data points you marked while collecting data will appear bold, underlined, and red in the raw data columns). It does this by collecting data points before and after the point you marked until it finds absolute values less than 3 degrees, and then searches within this range for the maximum/minimum values. (Note: 3 degrees seemed to be a practical lower limit during test phases).

For more information on the data collection process, see the Local Curve Mode section above.

5.0 DATA PROCESSING

The spreadsheet takes a reading from the Digital Inclinometer once every 0.25 seconds. The number of readings and many environmental variables during data collection (speed, surface condition, driver, road hazards, etc.) can cause the dataset to become "noisy", especially in areas of poor pavement condition. Potholes or other road surface anomalies can cause brief spikes in ball-bank readings that do not fit in the context of the surrounding data points. In ball-and-vial ball-bank tools, some of the effects of these anomalies were dampened by the fluid in the vial.

In order to dampen the effects of surface anomalies when using the Rieker RDS7-BB unit, the spreadsheet develops a smoothing curve using Centered, Weighted Moving Average smoothing. At each data point, the smoothed value is calculated by taking the average of gathered data between 0.50 seconds before and 0.50 seconds after the data point (5 data points total), with decreasing weight assigned to points farther away from the central data point, summarized in the equation below. The spreadsheet rounds this calculated smoothed value to the same significant digits provided by the Rieker RDS7-BB unit - the nearest 0.01 degrees of ball-bank. (While this calculation rounds to the nearest 0.01 degrees, this level of precision is not practical to report for a final value. Final reported values should be rounded to the nearest whole degree.) A sample smoothed plot for a reversing curve is given in Figure 1, and a sample calculation is given below.

$$\boldsymbol{Smoothed\ Value, S_t = \frac{1(BB_{t-0.50}) + 2(BB_{t-0.25}) + 3(BB_t) + 2(BB_{t+0.25}) + 1(BB_{t+0.50})}{\sum Weights}}$$

Where:

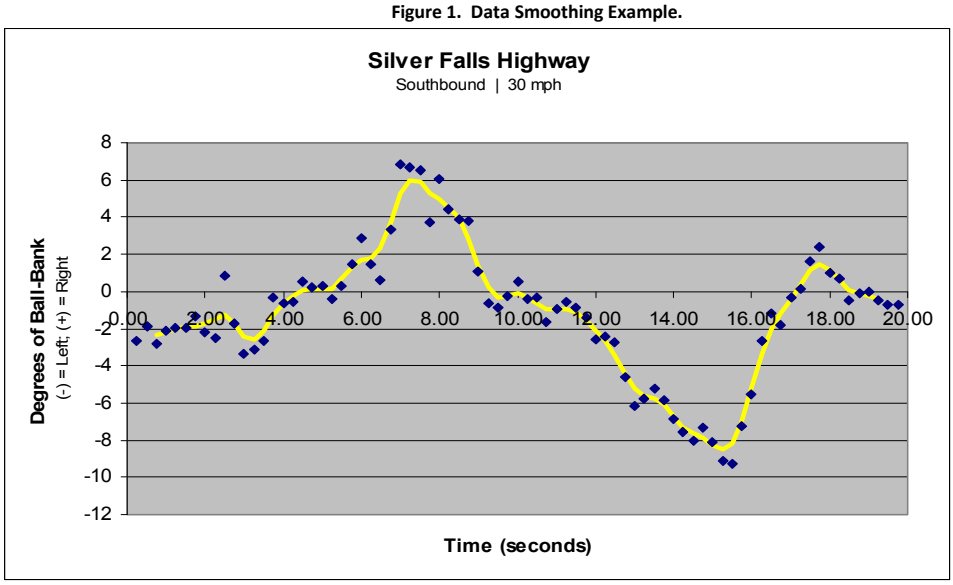
$S_t = Smoothed\ ball - bank\ value\ at\ time = t\ seconds\ (degrees\ of\ ballbank)$

$BB_t = Raw\ ball - bank\ reading\ for\ time = t\ seconds\ (degrees\ of\ ballbank)$

$t = time\ (seconds)$

$\sum Weights = Sum\ of\ the\ weights\ assigned\ to\ each\ BB_t\ value\ (typically\ 1 + 2 + 3 + 2 + 1 = 9)$

Figure 1. Data Smoothing Example.



Blue points = Raw Digital Inclinometer Data
Yellow Line = Centered, Weighted Moving Average smoothed estimate

Smoothing Example

Given: Raw Data Readings

Time (sec)	BB Reading (deg)
6.00	2.89
6.25	1.50
6.50	0.59
6.75	3.34
7.00	6.86
7.25	6.71
7.50	6.50
7.75	3.69
8.00	6.08
8.25	4.44
8.50	3.86
8.75	3.82
9.00	1.09

Required: Smoothed point for t=7.25 seconds and t=8.00 seconds.

Solution: Select the window surrounding the required smoothed point at t=7.25 seconds and calculate S using Equation 1.

Time (sec)	BB Reading (deg)
6.00	2.89
6.25	1.50
6.50	0.59
6.75	3.34
7.00	6.86
7.25	**6.71**
7.50	6.50
7.75	3.69
8.00	6.08
8.25	4.44
8.50	3.86
8.75	3.82
9.00	1.09

$$S_{t=7.25} = \frac{1(BB_{6.75}) + 2(BB_{7.00}) + 3(BB_{7.25}) + 2(BB_{7.50}) + 0(BB_{7.75})}{\sum Weights}$$

$$S_{t=7.25} = \frac{1(3.34°) + 2(6.86°) + 3(6.71°) + 2(6.50°) + 1(3.69°)}{(1+2+3+2+1)}$$

$$\boxed{S_{t=7.25} = 5.99°}$$

Select the window surrounding the required smoothed point at t=8.00 seconds and calculate S using Equation 1.

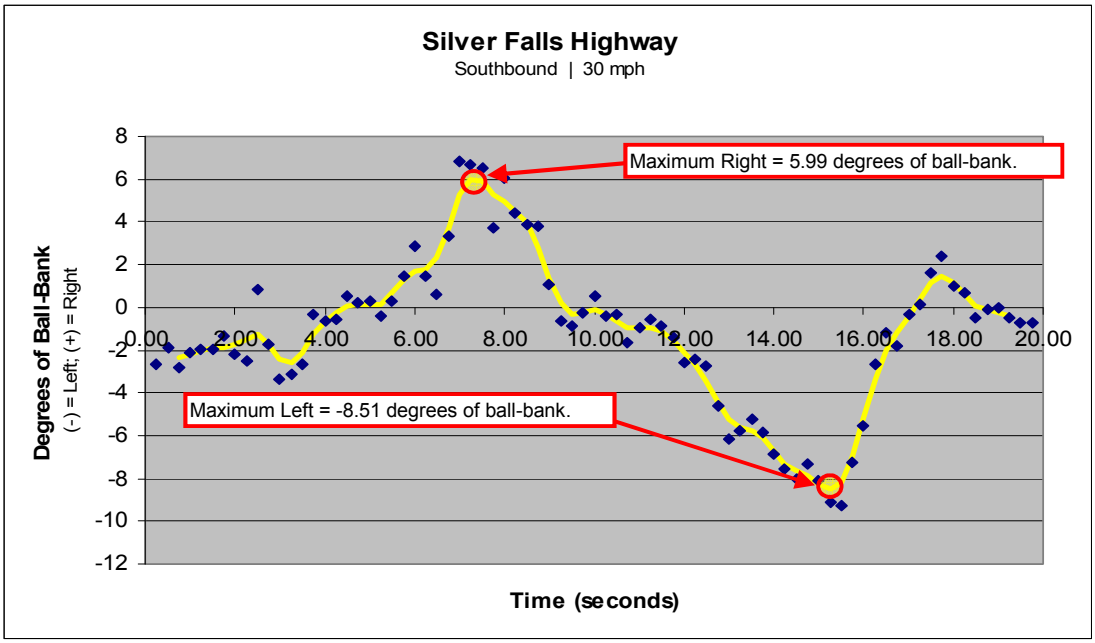
Time (sec)	BB Reading (deg)
6.00	2.89
6.25	1.50
6.50	0.59
6.75	3.34
7.00	6.86
7.25	6.71
7.50	6.50
7.75	3.69
8.00	**6.08**
8.25	4.44
8.50	3.86
8.75	3.82
9.00	1.09

$$S_{t=8.00} = \frac{1(BB_{7.50}) + 2(BB_{7.75}) + 3(BB_{8.00}) + 2(BB_{8.25}) + 0(BB_{8.50})}{\sum Weights}$$

$$S_{t=8.00} = \frac{1(6.50°) + 2(3.69°) + 3(6.08°) + 2(4.44°) + 1(3.86°)}{(1+2+3+2+1)}$$

$$\boxed{S_{t=8.00} = 4.98°}$$

The spreadsheet will give a suggested ball-bank value for each run based on the maximum calculated smoothed value. For the example graph, the maximum calculated smoothed value for the run would be -8.51 degrees of ball-bank (negative denoting direction to the left).



Over Range

The RDS7-BB has a reading range of -30° to +30° (negative indicating curve to the left, positive indicating curve to the right). If the RDS7-BB collects a reading outside this range, it displays "OVER RANGE" on the unit's screen and returns a value of -99.99° or +99.99° to the spreadsheet.

The spreadsheet monitors for over range readings during data collection. If the RDS7-BB returns a value less than -30° or greater than +30°, the data collection window will display "OVER RANGE" as the current reading, and store 100° as the raw data for that data point.

During smoothing, the spreadsheet monitors for these outliers. If a value of 100° is found in the raw data (indicating an OVER RANGE reading), the smoothing process will ignore the outlier by assigning it a weight of zero. The smoothed value for the outlier will be calculated using the weighted moving average of data points surrounding the outlier. This will also affect smoothed points surrounding the outlier, since the outlier is included in the smoothing calculation for smoothed points 0.50 seconds before through 0.50 seconds after the outlier.

For example, see the sample data given below. There was an OVER RANGE reading at t=20.00 seconds. The smoothing calculation for smoothed points at t=19.50 and t=20.00 is shown.

Time (sec)	BB Reading (deg)
19.00	-28.24
19.25	-25.03
19.50	-27.78
19.75	-29.32
20.00	100.00
20.25	-29.88
20.50	-21.79
20.75	-20.05
21.00	-19.49

Over Range outlier - assign weight of 0 to this data point when calculating the smoothed value.

$$S_{t=19.50} = \frac{1(BB_{19.00}) + 2(BB_{19.25}) + 3(BB_{19.50}) + 2(BB_{19.75}) + 0(BB_{20.00})}{\sum Weights}$$

$$S_{t=19.50} = \frac{1(-28.24°) + 2(-25.03°) + 3(-27.78°) + 2(-29.32°) + 0(100.00°)}{(1+2+3+2+0)}$$

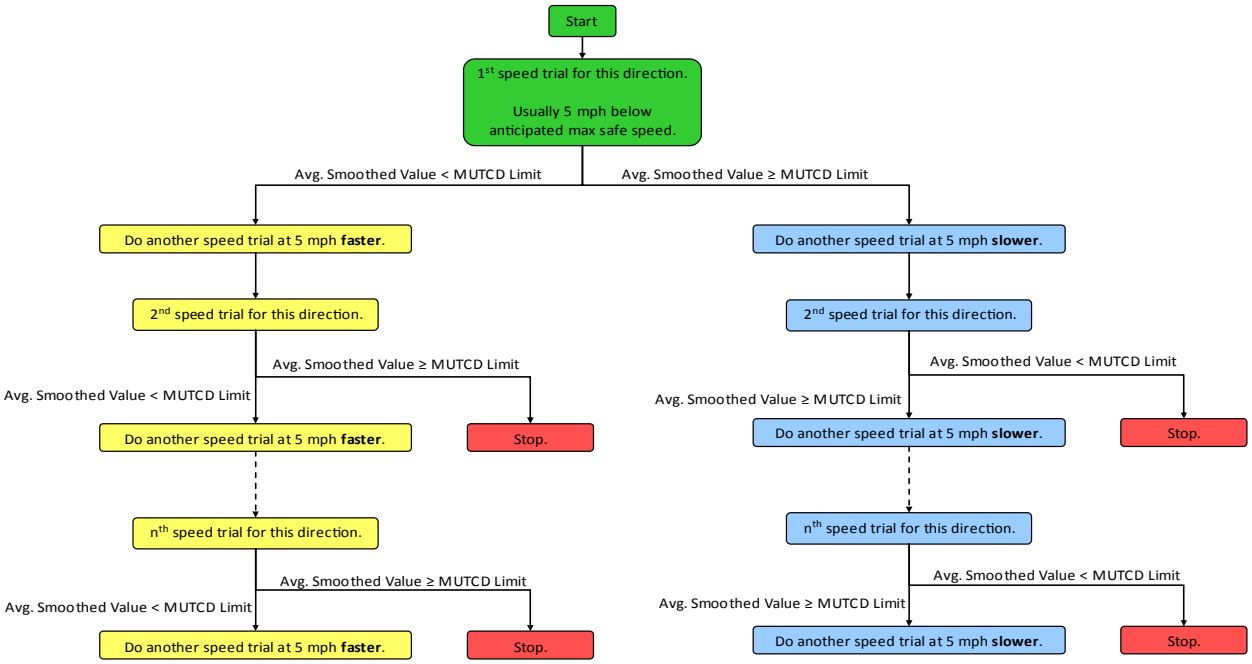
$$\boxed{S_{t=19.50} = -27.54°}$$

$$S_{t=20.00} = \frac{1(BB_{19.50}) + 2(BB_{19.75}) + 0(BB_{20.00}) + 2(BB_{20.25}) + 0(BB_{20.50})}{\sum Weights}$$

$$S_{t=20.00} = \frac{1(-27.78°) + 2(-29.32°) + 0(100.00°) + 2(-29.88°) + 1(-21.79°)}{(1+2+0+2+1)}$$

$$\boxed{S_{t=20.00} = -28.00°}$$

Data Gathering Feedback

After each run, the spreadsheet gives a recommendation for how many more runs need to be done at that speed and direction, what speed the next series of runs should be tested at (if needed), and if you need to test at any other speeds.

Curves should be run three times in each direction at the new advisory speed in order to get an average ball-bank reading to change the advisory speed. Once all three runs are complete, the spreadsheet goes through the logic in the flowchart below, using the average Maximum Smoothed Value of the three runs, to determine the next step for the investigation.