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QUALITY ASSURANCE/QUALITY CONTROL DOCUMENTATION SERIES	
TITLE	**OPTEC LPV TRANSMISSOMETER FIELD AUDIT PROCEDURES**
TYPE	**STANDARD OPERATING PROCEDURE**
NUMBER	**4710**
DATE	**FEBRUARY 1994**

AUTHORIZATIONS		
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REVISION HISTORY			
REVISION NO.	CHANGE DESCRIPTION	DATE	AUTHORIZATIONS
0.1	Reduce number of lamps used during audits	March 1995	
0.2	Change originator/responsibilities	December 1997	
1.0	Changes to audit instrument configuration	November 2004	

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1.0 PURPOSE AND APPLICABILITY

This standard operating procedure (SOP) describes the procedures for performing a field audit of an Optec LPV-2 or LPV-3 transmissometer operated according to IMPROVE Protocol. The primary purpose of the field audit is to assure quality data capture by:

- Ensuring accurate on-site transmissometer readings by comparing to audit (reference) transmissometer readings.
- Ensuring accurate replacement transmissometer readings by comparing to audit (reference) transmissometer readings.
- Verifying the transmittance of the on-site transmissometer transmitter and receiver windows.

This SOP serves as a guideline for the following:

- Duties of the ARS project manager, ARS field specialist, and the audit assistant
- Necessary equipment, instrumentation, and materials
- Pre-audit preparation
- Audit methods, procedures, documentation, and evaluation

The field audit is performed with three instruments: the on-site (currently operational), the replacement (will be operational for the coming year), and an audit (reference) instrument. During the audit, the replacement instrument is installed adjacent to the on-site instrument (both transmitters are located side-by-side and both receivers are located side-by-side). The audit receiver is located at the on-site transmitter station and the audit transmitter is located at the on-site receiver station. All three instruments run concurrently during the audit.

2.0 RESPONSIBILITIES

Field audits are typically performed as part of annual routine servicing visits. Refer to TI 4115-3000, *Annual Site Visit Procedures for Optec LPV Transmissometer Systems (IMPROVE Protocol).*

2.1 PROJECT MANAGER

The project manager shall:

- Provide the ARS field specialist with calibration numbers for on-site, replacement, and audit transmissometers.
- Review all audit data to confirm correct system operation prior to the field specialist leaving the site.

- Direct appropriate corrective action if indicated by the audit results.
- Review and approve any changes to audit procedures.
- Review audit results.

2.2 FIELD SPECIALIST

The field specialist shall:

- Schedule and coordinate the field audit and verify that the site operator will be available to assist with the audit, or if the operator cannot assist with the audit, arrange for other assistance.
- Ensure that all instrumentation (and associated calibrations), equipment, materials, and tools are properly prepared and fully functional.
- Ensure that the audit assistant fully understands his/her tasks and is capable of adequately performing them.
- Perform all on-site procedures outlined in this SOP.
- Document audit results on the appropriate form(s).
- Forward the audit results to the project manager.

2.3 SITE OPERATOR OR AUDIT ASSISTANT

The site operator or audit assistant shall:

- Be available for training with the field specialist during the audit.
- Assist the field specialist during the field audit by performing all required tasks at the transmitter station.

3.0 REQUIRED INSTRUMENTATION, TOOLS, EQUIPMENT, AND MATERIALS

Refer to TI 4115-3000, *Annual Site Visit Procedures for Optec LPV Transmissometer Systems (IMPROVE Protocol)* for general instrumentation, tools, equipment, and materials required when performing servicing/testing tasks at transmissometer sites. Specific instrumentation, tools, equipment, and materials required for field audits are detailed in the following subsections.

3.1 INSTRUMENTATION

- Replacement transmissometer with calibrated lamps. Typically, 9 of the 10 lamps calibrated with an instrument accompany the instrument to the field site. Refer to TI 4200-2100, *Calibration of Optec LPV Transmissometers (IMPROVE Protocol)*, for information regarding designation of the lamps.

- Audit transmissometer (without receiver computer) with calibrated lamps. Five calibrated lamps (one traveling reference lamp, two audit lamps, and two spare lamps) accompany the audit transmissometer. Refer to TI 4200-2100, *Calibration of Optec LPV Transmissometers (IMPROVE Protocol)*, for information regarding designation of the audit lamps.

- Campbell 21X datalogger programmed to log receiver computer outputs, with associated cable and connector. Refer to Figure 3-1, Campbell 21X datalogger program (transmissometer computer output).

- Air temperature/relative humidity audit kit.

- Two digital voltmeters (DVMs) with pigtail cables and banana jacks, and two cables for measuring lamp voltage and audit receiver computer outputs.

- Switch box and two power cables.

3.2 TOOLS

On-site station/operator toolboxes should exist in both the transmissometer transmitter and receiver shelters. These toolboxes and on-site operational supplies should include all of the tools necessary to perform an audit. Specifically, the receiver station requires a 5/64" Allen hex wrench or hex screwdriver for attachment and removal of the transmissometer detector head from the receiver telescope. The transmitter station requires a small, flat-head screwdriver for removal of the transmitter control box cover plate (LPV- only).

3.3 EQUIPMENT

- Calculator

- Digital voltmeter (DVM)

- Two 2-way radios with spare batteries and charger

- Documentation camera, preferably a digital camera with zoom lens

- Laptop computer with Excel spreadsheet software and Trans Audit Template.XLT

- Alcohol and Kimwipes

```
TRANSAUD.CSI, Table 1

*Table 1 Program
01: 1.0000  Execution Interval (seconds)

1: Volt (Diff) (P2)
 1: 1     Reps
 2: 5     5000 mV Slow Range
 3: 1     DIFF Channel
 4: 1     Loc [A1    ]
 5: 2.0007   Mult
 6: 0     Offset

2: Volt (Diff) (P2)
 1: 1     Reps
 2: 5     5000 mV Slow Range
 3: 2     DIFF Channel
 4: 2     Loc [A2    ]
 5: 2.0004   Mult
 6: 0     Offset

3: Volt (Diff) (P2)
 1: 1     Reps
 2: 5     5000 mV Slow Range
 3: 3     DIFF Channel
 4: 3     Loc [Toggle    ]
 5: 2.0004   Mult
 6: 0.0    Offset

4: Volt (SE) (P1)
 1: 1     Reps
 2: 5     5000 mV Slow Range
 3: 10     SE Channel
 4: 4     Loc [Audit_AT    ]
 5: .1    Mult
 6: 0.0     Offset

5: Volt (SE) (P1)
 1: 1     Reps
 2: 5     5000 mV Slow Range
 3: 12     SE Channel
 4: 5     Loc [Site_AT    ]
 5: .1    Mult
 6: 0.0     Offset

6: Volt (SE) (P1)
 1: 1     Reps
 2: 5     5000 mV Slow Range
 3: 9     SE Channel
 4: 6     Loc [Audit_RH    ]
 5: .1    Mult
 6: 0.0     Offset

7: Volt (SE) (P1)
 1: 1     Reps
 2: 5     5000 mV Slow Range
 3: 11     SE Channel
 4: 4 7   Loc [Site_AT    ]
 5: .1    Mult
 6: 0.0     Offset

8: Z=X-Y (P35)
 1: 5     X Loc [Site_AT   ]
 2: 4     Y Loc [Audit_AT   ]
 3: 10    Z Loc [AT_Dev   ]

9: Z=X-Y (P35)
 1: 7     X Loc [Site_RH   ]
 2: 6     Y Loc [Audit_RH   ]
 3: 11    Z Loc [RH_Dev   ]

10: Z=ABS(X) (P43)
 1: 10     X Loc [AT_Dev   ]
 2: 12     Z Loc [ABS_T_Dev   ]

11: Z=ABS(X) (P43)
 1: 11     X Loc [RH_Dev   ]
 2: 13     Z Loc [ABS_H_Dev   ]

12: Batt Voltage (P10)
 1: 8     Loc [Batt_21x   ]

13: Internal Temperature (P17)
 1: 9     Loc [Panel_T   ]

14: If time is (P92)
 1: 0     Minutes into a
 2: 10     Minute Interval
 3: 10     Set Output Flag High
```

Figure 3-1. Campbell 21X Datalogger Program (Transmissometer Computer Output).

```
15: Set Active Storage Area (P80)
 1: 1     Final Storage
 2: 100   Array ID

16: Real Time (P77)
 1: 1110     Year,Day,Hour/Minute (midnight =
0000)

17: Average (P71)
 1: 4     Reps
 2: 4     Loc [Audit_AT   ]

18: Average (P71)
 1: 2     Reps
 2: 12     Loc [ABS_T_Dev   ]

19: Serial Out (P96)
 1: 30     Storage Module

*Table 2 Program
 01: 0.0000   Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

TRANSAUD.CSI, Input Locations

Addr	Name	Flags	# Reads	# Writes	Blocks
1	[A1]	–W--	0	1	---- ----- ---
2	[A2]	–W--	0	1	Start ----- ---
3	[Toggle]	–W--	0	1	---- ----- ---
4	[Audit_AT]	RW--	2	1	Start ------ ---
5	[Site_AT]	RW--	2	1	---- ----- ---
6	[Audit_RH]	RW--	2	1	---- ----- ---
7	[Site_RH]	RW--	2	2	----- ------ ---
8	[Batt_21x]	–W--	0	1	---- ----- ---
9	[Panel_T]	–W--	0	1	---- ----- ---
10	[AT_Dev]	RW--	2	1	---- ----- ---
11	[RH_Dev]	RW--	2	1	---- ----- ---
12	[ABS_T_Dev]	RW--	1	1	---- ----- ---
13	[ABS_H_Dev]	RW--	1	1	---- ----- ---
14	[_____]	---	0	0	---- ----- ---
15	[_____]	---	0	0	---- ----- ---
16	[_____]	---	0	0	---- ----- ---
17	[_____]	---	0	0	---- ----- ---
18	[_____]	---	0	0	---- ----- ---
19	[_____]	---	0	0	---- ----- ---
20	[_____]	---	0	0	---- ----- ---
21	[_____]	---	0	0	---- ----- ---
22	[_____]	---	0	0	---- ----- ---
23	[_____]	---	0	0	---- ----- ---
24	[_____]	---	0	0	---- ----- ---
25	[_____]	---	0	0	---- ----- ---
26	[_____]	---	0	0	---- ----- ---
27	[_____]	---	0	0	---- ----- ---
28	[_____]	---	0	0	---- ----- ---

Figure 3-1 (continued). Campbell 21X Datalogger Program (Transmissometer Computer Output).

3.4 MATERIALS

The following documentation forms and information sheets are needed for the audit:

- On-Site Transmissometer Audit Form (Transmitter Station)
- On-Site Transmissometer Audit Form – Documentation Sheet (Receiver Station)
- On-Site Transmissometer Audit Form – Data Sheet (Receiver Station)
- Operational calibration memos for on-site and replacement transmissometers
- Audit calibration memo for the audit transmissometer

Refer to TI 4200-2100, *Calibration of Optec LPV Transmissometers (IMPROVE Protocol)* for information regarding the calibration memos.

4.0 METHODS

The transmissometer field audit is typically performed as part of the annual transmissometer servicing site visit. Refer to TI 4115-3000, *Annual Site Visit Procedures for Optec LPV Transmissometer Systems (IMPROVE Protocol)*, for tasks and procedures that are performed prior to the audit.

The primary tasks for the transmissometer field audit are:

- Pre-audit instrument preparation and set-up (transmitter and receiver stations)
- Pre-audit tasks and documentation
- Audit procedures and documentation (transmitter and receiver stations)

This section includes five (5) major subsections:

4.1 Pre- On-Site Audit Preparation
4.2 Audit Assistance
4.3 Audit Procedures
4.4 Audit Evaluation
4.5 Audit Record Archival

4.1 PRE- ON-SITE AUDIT PREPARATION

Prior to travel to the monitoring site, the following preparations need to be made (for individual responsibilities refer to Sections 2.1 – 2.3):

- Schedule and coordinate with site personnel for assistance with the audit. Approximately 4-6 hours should be allotted. It is advisable to also schedule an alternate period on the following day for the audit, in the event of adverse weather or visibility conditions.

- Verify transmissometer calibration numbers and the lamp testing order.

- Ensure preparedness of all instruments, equipment, tools, and materials.

4.2 AUDIT ASSISTANCE

The person who will assist with the audit should be contacted upon arrival at the site. The prearranged schedule for performing the audit should be confirmed at this time. Weather conditions and forecast should be considered to see if any change in scheduling is warranted.

It is assumed that the audit assistant (typically the site operator) has been trained in the operation of the transmissometer system. Specific tasks the audit assistant performs during the audit are outlined in Section 4.3.3, Transmitter Station Audit Procedures and Documentation.

4.3 AUDIT PROCEDURES

4.3.1 General Procedures

The transmissometer field audit is designed to verify accurate on-site and replacement transmissometer measurements by comparing to measurements made with the audit transmissometer. The audit transmissometer is calibrated at the ARS test facility before and after each field audit to ensure that the accuracy of the measurements has not been affected by instrument handling and/or transport.

To ensure a quality audit, it is important that the audit is performed during a period of good weather and stable conditions. If the weather and/or conditions are not suitable, the audit should be rescheduled. The audit is comprised of a series of 10-minute readings with various lamps calibrated with the on-site, audit, and replacement transmissometer units. The audit transmissometer runs concurrently with the on-site and replacement transmissometer units. The audit receiver unit is located at the on-site transmitter station, and the audit transmitter unit is located at the on-site receiver station. The reference instrument is installed on the side of the monitoring shelters and uses a 100% transmittance in its calculations of calibration numbers for each lamp. The sequence of instruments and lamps is configured to provide the best possible intercomparison between individual lamps calibrated with a transmissometer system and also between respective transmissometer systems.

A complete audit (including window transmittance test) consists of 10 test segments, performed in the order shown in Table 4-1, Standard Audit Order for On-Site and Replacement Transmissometers. This table specifies the transmissometer and lamp to be used for each test segment. To summarize, the audit order is:

Table 4-1

Standard Audit Order for On-Site and Replacement Transmissometers

	Segment #	Transmissometer	Lamp	Comments
On-site Transmissometer Audit	#1	On-site/Audit	Last Operational/Audit #1	
	#2	On-site/Audit	On-site Reference	Windows in Place
	#3	On-site/Audit	On-site Reference/Audit #1	Windows Removed
	#4	On-site/Audit	On-site Reference/Audit #1	Windows in Place
Replacement Transmissometer Audit	#5	Replacement/Audit	First Operational/Audit #1	
	#6	Replacement/Audit	Last Operational/Audit #1	
	#7	Replacement/Audit	On-site Reference/Audit #1	
	#8	Replacement/Audit	On-site Reference /Audit #2	
	#9	Replacement/Audit	Last Operational/Audit #2	
	#10	Replacement/Audit	First Operational/Audit #2	

Note: Receiver and transmitter windows are in place for the on-site and replacement transmissometer portions of the audit.

- To run the audit instrument concurrently with the on-site and replacement instruments, and with two lamps.

- To run the existing instrument with two lamps, beginning with the last operational lamp, followed by three runs for the windows transmittance test using the on-site reference lamp.

- To run the replacement instrument with three lamps, beginning with the lamp that will be the first operational one in the series. The second lamp is the last operational lamp in the series, and the third is the on-site reference.

- To run the audit instrument, changing lamps from Audit #1 to Audit #2. The replacement instrument will use the same three lamps but in reverse order, with the last audited lamp remaining as the first operational lamp.

It is important that neither the transmitter nor receiver telescope alignment is changed or adjusted during the windows transmittance test. Both alignments should be checked at the end of the test to confirm that there was no change in alignment from the initial reading segment of the test.

Refer to Sections 4.3.3, Transmitter Station Audit Procedures and Documentation and 4.3.4, Receiver Station Audit Procedures and Documentation, for specific tasks and related documentation at the transmitter and receiver stations during the audit.

4.3.2 Pre-Audit Instrument Configuration and Set-Up

At the transmitter station:

- Install an alti-azimuth base on the side of the monitoring shelter using a steel pipe for the audit receiver telescope.

- Inspect and clean the on-site and replacement transmitter telescopes and objective lenses, the audit receiver objective lens, and the shelter window with alcohol and Kimwipes. If the on-site transmitter telescope has a condition that could have affected instrument readings for an extended period of time (e.g., lens smear, cobweb in the telescope tube, etc.) audit the unit without correction of the condition. Instrument operation, prior to and after correction of the condition, will be determined during the post-field calibration of the instrument at the ARS test facility. Refer to TI 4200-2100, *Calibration of Optec LPV Transmissometers.*

- Set-up the replacement transmitter and audit receiver units. The receiver computer switch box cables, DVM, photometer cable, transmitter control cables, and control boxes should be connected so that the assistant need only change the power connections between control boxes and DVM connections between lamp voltage measurement pigtails when switching between transmitter systems. Refer to Table 4-2, Transmissometer Cable Setup Table.

- Inspect, and if necessary, clean the on-site and replacement transmitter lamps. Inspect the lamp filaments to verify that they are intact.

Table 4-2

Transmissometer Cable Setup Table

Component	Cable	Connection
Audit Receiver	Receiver telescope to photometer cable	Connect the photometer cable to the back of the receiver computer labeled “Photometer”
	Switchbox (9-pin connector cable)	Connect the switchbox (9-pin connector cable) to the back of the receiver computer labeled “Output”
	Switchbox (4-pin connector cable)	Connect the switchbox (4-pin connector cable) to the pigtail connecting to the DVM
	Power cable (from power supply or batteries)	Connect the power cable to the back of the receiver computer labeled “Power”
On-Site Transmitter	Telescope/control box cable	Connect the gray, 9-pin cable with the red and black banana jacks to the back of the transmitter telescope to the control box
	Red & black banana jacks cable	Connect the red & black banana jacks cable (attached to the gray cable) to the side of the transmitter telescope, with the other end connected to a pigtail cable connected to a DVM
	Power cable (from power supply or batteries)	Connect the power cable to the control box 4-pin connector
On-Site Receiver	Receiver telescope to photometer cable	Connect the photometer cable to the back of the receiver computer labeled “Photometer”
	21X datalogger cable	Connect the 21X datalogger cable to the back of the receiver computer labeled “Output”
	Power cable (from power supply or batteries)	Connect the power cable to the back of the receiver computer labeled “Power”
Audit Transmitter	Telescope/control box cable	Connect the gray, 9-pin cable with the red and black banana jacks to the back of the transmitter telescope to the control box
	Red & black banana jacks cable	Connect the red & black banana jacks cable (attached to the gray cable) to the side of the transmitter telescope, with the other end connected to a pigtail cable connected to a DVM
	Power cable (from power supply or batteries)	Connect the power cable to the control box 4-pin connector

- Switch the on-site and replacement transmitter units to the continuous run mode. This is done by setting the integration timing switch to the 64-minute position while the cycle timing switch remains in the 60-minute position.

- Set-up the audit computer with established settings. Refer to computer settings Section 4.3.4, Receiver Station Audit Procedures and Documentation.

- Verify operation for the on-site and replacement transmitter systems, and the audit receiver system, with the voltmeter.

At the receiver station:

- Install the alti-azimuth base on the side of the monitoring shelter, using a steel pipe for the audit transmitter telescope.

- Inspect and clean the on-site and replacement receiver telescopes and objective lenses, the audit transmitter telescope objective lens, and the shelter window. If the on-site receiver telescope has a condition that could have affected data for an extended period of time (e.g., lens smear, cobweb in the telescope tube, etc.) audit the unit without correction of the condition. Instrument operation, prior to and after correction of the condition, will be determined during the post-field calibration of the instrument at the ARS test facility. Refer to TI 4200-2100, *Calibration of Optec LPV Transmissometers*.

- Set-up the replacement computer with established settings. Refer to Computer Settings, Section 4.3.4, Receiver Station Audit Procedures and Documentation.

- Connect the Campbell 21X datalogger to the output connector of the on-site receiver computer. During the audit the datalogger is connected to the computer in use.

- Switch the audit transmitter unit to the continuous run mode. Refer above for instructions.

- Verify that all instrumentation is fully operational.

4.3.3 Transmitter Station Audit Procedures and Documentation

The audit assistant at the transmitter station performs the following tasks during the audit:

- Operates and switches the transmissometer transmitter units

- Operates the audit receiver unit

- Cleans, inspects, and changes lamps

- Aligns the transmitter and receiver telescopes

- Operates a digital voltmeter and switch box connected to the audit receiver computer

- Measures lamp voltages
- Inspects, and if necessary, cleans the shelter window and transmitter objective lens
- Troubleshoots transmitter malfunctions
- Operates the 2-way radio and communicates with the field specialist regarding lamp and instrument changes and readings
- Documents audit receiver computer readings, lamp voltages, and lamp and instrument changes, in addition to any miscellaneous events or conditions that might affect instrument operation and/or audit results

The assistant changes lamps and switches instruments upon request of the field specialist at the receiver station. Upon completion of the request, the assistant verifies transmitter operation and alignment and radios information to the field specialist at the receiver of the status.

Documentation of the assistant's actions are recorded on the On-Site Transmissometer Audit Form (Transmitter Station) (Figure 4-1). A completed example of the form is provided as Figure 4-2. Tasks and documentation at the transmitter station are completed as follows:

ARS FIELD SPECIALIST	Record the name of the ARS field specialist or person performing the audit.
AUDIT ASSISTANT	Record the name(s) of the audit assistant(s) at the transmitter station.
SITE	Record the location name of the transmissometer installation.
DATE	Record the current date (month, day, year).
TIME (ON/OFF)	Record the times when a lamp is turned on and off.
LPV #	Record the transmitter unit number the lamp is operated in.
LAMP	Record the lamp number.
LAMP VOLTAGE	Record the lamp voltage from the voltmeter (LPV-2 only). This should be done just prior to turning the instrument off when switching to another lamp or instrument. Lamp voltage cannot be recorded for LPV-3 instruments.
WINDOWS (IN/OUT)	Record whether the transmitter window was in or out for that testing segment. Typically the window is only removed during the window transmittance test.
COMMENTS	Record any comments regarding weather conditions, instrument malfunctions, etc. that might influence instrument operation and/or readings during the audit.

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ON-SITE TRANSMISSOMETER AUDIT FORM
(TRANSMITTER STATION)

ARS FIELD SPECIALIST _____ SITE _____

AUDIT ASSISTANT _____ DATE _____

TIME ON	TIME OFF	LPV #	LAMP #	LAMP VOLTAGE	WINDOWS IN/OUT

COMMENTS (Weather/Visibility/Equipment/etc.):

_____

_____

_____

_____

_____

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Figure 4-1. On-Site Transmissometer Audit Form – Transmitter Station.

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ON-SITE TRANSMISSOMETER AUDIT FORM (TRANSMITTER STATION)

ARS FIELD SPECIALIST: Ivar Rennat SITE: GRBA

AUDIT ASSISTANT: Kurt Peaff DATE: 11/18/93

TIME ON	TIME OFF	LPV #	LAMP #	LAMP VOLTAGE	WINDOWS IN/OUT
09':52	10':04	005	714	5.985	In
10':06	:17	↓	668	6.084	↓
:28	:41	006	838	5.869	↓
:44	:58	↓	839	6.001	↓
11':06	11':20	020	1007	5.657	↓
:24	:37	↓	1011	5.750	↓
:39	:53	↓	1015	5.682	↓
:59	12':18	006	839	5.998	↓
12':20	:32	↓	838	5.851	↓
:38	:52	020	1015	5.681	↓
:54	13':06	↓	1011	5.742	↓
13':09	:21	↓	1007	5.655	↓
:21	:36	↓	↓	↓	Out
:36		↓	↓	↓	In

COMMENTS (Weather/Visibility/Equipment/etc.):

11':30 Estimated visual range is ~ 100 mi.

13':20 No apparent change in visual range.

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Figure 4-2. Completed Example of On-Site Transmissometer Audit Form (Transmitter Station).

4.3.4 Receiver Station Audit Procedures and Documentation

The field specialist at the receiver station performs the following tasks during the audit:

- Sets the focus on both the replacement and audit receiver telescopes
- Operates and switches the transmissometer receiver units
- Operates the reference transmitter unit
- Operates the Campbell 21X datalogger
- Inspects and if necessary, cleans the shelter window and the receiver and transmitter telescope's objective lenses
- Aligns the receiver and transmitter telescopes
- Operates the 2-way radio and communicates with the audit assistant regarding lamp and instrument changes and readings.
- Documents receiver settings, AT/RH measurements, b_{ext} estimates, documentation photographs, ambient conditions (weather and visibility), and miscellaneous comments related to the audit on the On-Site Transmissometer Audit Form – Documentation Sheet (Receiver Station).
- Documents instrument and lamp changes, lamp voltages, calibration numbers, transmissometer test data, and miscellaneous events or conditions that could affect the audit data on the On-Site Transmissometer Audit Form – Data Sheet (Receiver Station).
- Operates a laptop computer to record audit data digitally (if applicable; line power required).

Documentation of the field specialist's actions are recorded on the On-Site Transmissometer Audit Form – Documentation Sheet (Receiver Station) (Figure 4-3). A completed example of the form is provided as Figure 4-4. Tasks and documentation at the receiver station are completed as follows:

ARS FIELD SPECIALIST	Record the name of the ARS field specialist or person performing the audit.
AUDIT ASSISTANT	Record the name(s) of the person(s) assisting with the audit at the transmitter station.
SITE	Record the location name of the transmissometer installation.
DATE	Record the current date (month, day, year).

Air Resource Specialists, Inc.

ON-SITE TRANSMISSOMETER AUDIT FORM
DOCUMENTATION SHEET - (RECEIVER STATION)

ARS FIELD SPECIALIST _____ SITE _____

AUDIT ASSISTANT _____ DATE _____

Computer Settings	LPV #	Gain	Path	Integration	Cycle
On-Site Computer					
Replacement Computer					
Reference Computer					

AT/RH Measurements	Time	AT	RH
Audit Begin	:		
Mid-Audit	:		
Audit End	:		

AT/RH Handheld Sensor MFR/Model/SN_____

b_{ext} Estimate	Time	B_{ext}	Comments
Audit Begin	:		
Audit End	:		

Photo Documentation	Time	Direction(s)	Lens Size (mm)
Audit Begin	:		
	:		
Audit End	:		
	:		

Weather and Visibility Conditions _____

_____

Miscellaneous Comments _____

_____

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Figure 4-3. On-Site Transmissometer Audit Form – Documentation Sheet (Receiver Station).

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ON-SITE TRANSMISSOMETER AUDIT FORM
DOCUMENTATION SHEET - (RECEIVER STATION)

ARS FIELD SPECIALIST Ivar Rennat SITE GRBA

AUDIT ASSISTANT Kurt PFaff DATE 11-18-93

Computer Settings	LPV #	Gain	Path	Integration	Cycle
On-Site Computer	005	500	3.91	10 min.	C
Replacement Computer	020	700	3.91	10 min.	C
Reference Computer	020	700	3.91	10 min.	C

AT/RH Measurements	Time	AT	RH
Audit Begin	09:20	4.1°C	47.7 %
Mid-Audit	11:00	6.4°C	39.2 %
Audit End	14:15	5.1°C	28.8 %

AT/RH Handheld Sensor MFR/Model/SN Rotronic/Hygroskop GT/#27034

b_{ext} Estimate	Time	B_{ext}	Comments
Audit Begin	09:20	0.025	Correlates well w/Trans. reading
Audit End	14:15	0.020	

Photo Documentation	Time	Direction(s)	Lens Size (mm)
Audit Begin	09:30	Notch Peak (~E)	135
	" : "	~N	"
Audit End	14:20	Notch Peak (~E)	"
	" : "	~N	"

Weather and Visibility Conditions winds gusty from SW (5-20 mph). Partly cloudy. Bluish haze in distance. 11:30 Estimate visual range 100 miles.

Miscellaneous Comments Appeared to have little change in visibility conditions during audit.

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Figure 4-4. Completed Example of On-Site Transmissometer Audit Form – Documentation Sheet (Receiver Station).

COMPUTER SETTINGS

Record the following transmissometer computer-related information for the on-site, replacement, and audit computers. Refer to the on-site, replacement, and audit instrument calibration memos for the path, gain, and lamp-specific calibration number settings.

- LPV # — Record the number of the computer. The replacement computer is typically used as the reference instrument computer.
- GAIN — Record the gain setting. Note that since the replacement computer is used with the audit instrument, the gain used might vary from one instrument system to the next.
- PATH — Record the path length dialed in the computer.
- INTEGRATION — Record the time to which the computer integration switch is set; 10-minute integrations are standard during audits.
- CYCLE — Record the cycle-switch setting. The standard audit setting is "C" (continuous).

AT/RH MEASUREMENTS

Record the time of measurement, and the air temperature (AT) and relative humidity (RH) measurements made with the handheld AT/RH sensor. These measurements are made at the beginning, middle, and end of the audit. Also record the manufacturer (MFR), model, and serial number (SN) of the handheld AT/RH sensor.

b_{EXT} ESTIMATE

Record the b_{ext} estimate and time it was made at the beginning and end of the audit. Also comment on any conditions or factors that pertain to this estimate.

PHOTO DOCUMENTATION

Record the time, direction(s), and lens used (e.g., 50mm, 135mm) for the photographs taken to document visibility conditions. These photographs are taken at the beginning and end of the audit and should be of the longest vistas possible, with at least one including all or a portion of the site path.

WEATHER AND VISIBILITY CONDITIONS

Describe the weather and visibility conditions and any changes that occur during the audit.

MISCELLANEOUS COMMENTS

Record any miscellaneous information that is relevant to the audit.

Performance of tasks and documentation of data and audit segment information during the audit is done using the On-Site Transmissometer Audit Form – Data Sheet (Receiver Station). (Figure 4-5). A completed example of the form is provided as Figure 4-6. Information is documented on the form as follows:

ARS FIELD SPECIALIST	Record the name of the ARS field specialist or person performing the audit.
AUDIT ASSISTANT	Record the name(s) of the audit assistant(s) at the transmitter station.
SITE	Record the location name of the transmissometer installation.
DATE	Record the current date (month, day, year).

For each 10-minute audit segment, document the following information:

UPDATE TIME	Record the local time when the receiver computer updates with the 10-minute averaged reading.
LPV #	Record the number of the transmissometer system used during the audit segment.
LAMP #	Record the number of the transmitter lamp used.
LAMP VOLTAGE	Record the transmitter lamp voltage reported by the audit assistant (LPV-2 only). Lamp voltage cannot be measured for LPV-3 instruments.
CALIBRATION (CAL) NUMBER	The calibration number is instrument- and transmitter lamp-specific and will be changed for each audit segment. Record the calibration number used for the audit segment.
LPV DISPLAY	Record the instrument raw reading and the calculated b_{ext} from the computer display. (A1 switch set to C and B, respectively).
DIGITAL VOLTMETER DISPLAY	Record the instrument raw reading, the calculated b_{ext} and the standard deviation from the digital voltmeter using the switch box. When the switch box is set to A1 switch the voltmeter reads either the raw reading or b_{ext} value depending on what the A1 switch on the receiver computer is set at. When the switch box is set to A2 position the voltmeter will read the standard deviation if the A2 switch on the computer is set to SD.
WINDOWS IN/OUT	Record whether the receiver window was in or out for the testing segment. Typically the window is only removed during the window transmittance test, when the transmitter window is also removed.
COMMENTS	Record any comments regarding events, conditions, instrument operation, etc. that could affect the audit.

Air Resource Specialists, Inc.

ON-SITE TRANSMISSOMETER AUDIT FORM - DATA SHEET

(RECEIVER STATION)

ARS FIELD SPECIALIST _____ SITE _____

AUDIT ASSISTANT _____ DATE _____

UPDATE	LPV	LAMP	LAMP	CAL	LPV DISPLAY		CAMPBELL DISPLAY			WINDOWS
TIME	#	#	VOLTAGE	#	Raw Rdg	b_{ext}	Raw Rdg	b_{ext}	Std Dev	IN/OUT
:										
:										
:										
:										
:										
:										
:										
:										
:										
:										
:										
:										

Comments (Weather/Visibility/Equipment/Etc.): _____

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Figure 4-5. On-Site Transmissometer Audit Form – Data sheet (Receiver Station).

Air Resource Specialists, Inc.

ON-SITE TRANSMISSOMETER AUDIT FORM - DATA SHEET
(RECEIVER STATION)

ARS FIELD SPECIALIST: Ivar Rennat
AUDIT ASSISTANT: Kurt Pfaff
SITE: GRBA
DATE: 11-18-93

UPDATE TIME	LPV #	LAMP #	LAMP VOLTAGE	CAL #	LPV DISPLAY Raw Rdg	LPV DISPLAY b_{ext}	CAMPBELL DISPLAY Raw Rdg	CAMPBELL DISPLAY b_{ext}	CAMPBELL DISPLAY Std Dev	WINDOWS IN/OUT
10:02	005	714	5.985	713	635	0.029	6365.2	289.58	25.892	In
:16	↓	668	6.084	737	679	0.020	6813.0	199.64	51.784	↓
:39	006	838	5.869	918	846	0.021	8457.1	209.15	82.425	↓
:55	↓	839	6.001	923	840	0.024	8396.4	238.40	45.636	↓
11:18	020	1007	5.657	837	789	0.015	7887.2	148.20	59.832	↓
:35	↓	1011	5.750	852	807	0.014	8066.0	138.20	45.621	↓
:50	↓	1015	5.682	843	786	0.018	7850.8	179.75	60.370	↓
12:16	006	839	5.998	923	846	0.022	8458.7	218.85	38.624	↓
:31	↓	838	5.851	918	845	0.021	8443.8	209.39	50.144	↓
:50	020	1015	5.681	843	778	0.021	7772.8	208.85	35.938	↓
13:04	↓	1011	5.742	852	794	0.018	7938.9	179.84	42.755	↓
:19	↓	1007	5.655	837	781	0.018	7805.1	179.29	45.493	↓
:33	↓	↓	↓	↓	966	–	9656.8	–	40.078	Out
:46	↓	↓	↓	↓	777	0.019	7760.9	189.59	26.499	In
14:13	↓	↓	↓	↓	774	0.020	7731.5	199.86	31.271	↓

Comments (Weather/Visibility/Equipment/Etc.):

xtraudt_recvrdatadoc (12/97)

Figure 4-6. Completed Example of On-Site Transmissometer Audit Form – Data sheet (Receiver Station).

If power is available, or a good laptop battery, a laptop may be used in conjunction with the audit forms for rapid analyses between the on-site and audit transmissometer, and to create a digital copy of the audit. Using the laptop, open Microsoft Excel. Under File, open Trans Audit Template.XLT in whatever directory it is stored in. Perform a "Save As" to rename the file to its 5-character site code, month, day, year, trans audit.xls (e.g., BADL1 071204 Trans Audit.XLS). Record the official site name, and date. Record the name of the field specialist, the on-site replacement, and the audit instrument number. Record weather and visibility conditions. Record the site path.

In the table for each 10-minute segment, record both readings from the on-site and audit transmissometer. For each instrument, record instrument #, lamp #, lamp voltage, calibration voltage, CAL #, and raw counts from either the 21X datalogger or the digital voltmeter. The table will automatically calculate the b_{ext}, calculate a new calibration number based on the lamp voltage offset, and calculate a new adjusted b_{ext} for each instrument. The table will also calculate the b_{ext} offset and the adjusted b_{ext} offset between the on-site instrument and the reference instrument by subtracting the reference values from the on-site values.

Below the table record the readings from the window transmittance test. Record raw counts from the on-site instrument off the 21X datalogger during the window transmittance run. The window transmittance is automatically recorded on the form. Record any comments the happen during the audit that may have affected the readings.

On the second sheet a graph is made depicting the b_{ext} and adjusted b_{ext} offset. Refer to Figures 4-7 and 4-8 for examples of a completed laptop audit form.

If the standard deviation (SD) for an audit segment is 10 or more, that segment should be repeated. If the second segment also has a high standard deviation, another lamp from the series should be used instead. Continued high standard deviations indicate an instrument malfunction or unacceptable testing conditions. If the malfunction cannot be quickly resolved or conditions do not stabilize, the audit should be terminated and rescheduled.

4.4 AUDIT EVALUATION

Upon completion of the field audit, the following forms are faxed to the project manager for review:

- On-site Transmissometer Audit Form (Transmitter Station)
- On-site Transmissometer Audit Form – Documentation Sheet (Receiver Station)
- On-Site Transmissometer Audit Form – Data sheet (Receiver Station)

Evaluation of the field audit results includes:

- Reviewing the transmitter and receiver station audit forms.
- Entering specific audit data from both transmitter and receiver station forms into the Trans Audit worksheet in Excel from the laptop if not done during the audit.
- Analyzing instrument and lamp comparison data and statistics from the Trans Audit Excel worksheet.

BADLANDS MOUNTAIN NATIONAL PARK TRANSMISSOMETER AUDIT
July 13, 2004

On Site Instrument: LPV-012
Replacement Instrument: LPV-021
Audit Instrument: LPV-991

Weather Conditions: Pfly cloudy, slight breeze from the south, warm.
Visibility Conditions: Visibility good to fair. Can see Eagle butte 30 miles SE and a ridge behind 40 - 50 miles. Detail good around park. Bext about .030s

Site Path: 4,151

	ON SITE INSTRUMENT									AUDIT SITE INSTRUMENT									
#	Inst #	Lamp #	Lamp Volt	Cal Volt	Cal #	New Cal #	Raw Count	Bext	Adj Bext	Inst #	Lamp #	Lamp Volt	Cal Volt	Cal #	New Cal #	Raw Count	Bext	Bext Adj	Bext Off Set	Adj Bext Off Set
1	12	3192	5.315	5.271	786.7	811	701.91	0.027	0.035	991	3378	5.358	5.363	627	625	558.9	0.028	0.027	0.000	0.008
2	12	3196	5.543	5.541	811.1	812	722.8	0.028	0.028	991	3378	5.360	5.363	627	626	558.9	0.028	0.027	0.000	0.001
3	12	3196	5.343	5.541	811.1	697	903.66	-0.026	-0.063	991	3378	5.364	5.363	876	877	776.9	0.029	0.029	0.000	0.000
4	12	3196	5.540	5.541	811.1	811	728.86	0.026	0.026	991	3378	5.365	5.363	876	877	756.3	0.035	0.036	-0.010	-0.010
5	12	3196	5.542	5.541	811.1	812	726.91	0.026	0.027	991	3378	5.364	5.363	876	877	779.2	0.028	0.028	-0.002	-0.002
6	27	3079	5.568	5.562	838.3	842	745.71	0.028	0.029	991	3378	5.366	5.363	876	878	766.1	0.032	0.033	-0.004	-0.004
7	27	3419	5.547	5.546	863.6	864	764.57	0.029	0.030	991	3378	5.368	5.363	876	879	767.3	0.032	0.033	-0.003	-0.003
8	27	3422	5.506	5.506	910.9	911	791.5	0.034	0.034	991	3378	5.368	5.363	876	879	763.8	0.033	0.034	0.001	0.000
9	27	3422	5.505	5.506	910.9	910	796.23	0.032	0.032	991	3378	5.367	5.363	876	879	761.9	0.034	0.034	-0.001	-0.002
10	27	3422	5.504	5.506	910.9	910	800.27	0.031	0.031	991	3379	5.402	5.399	906	908	794.9	0.032	0.032	0.000	-0.001
11	27	3419	5.549	5.546	863.6	865	760.53	0.031	0.031	991	3379	5.403	5.399	906	909	766.8	0.040	0.041	-0.010	-0.010
12	27	3079	5.561	5.562	838.3	838	732.91	0.032	0.032	991	3379	5.405	5.399	906	910	771.6	0.039	0.040	-0.006	-0.008
13										991	3379	5.402	5.399	906	908	786.7	0.034	0.035		

Window Transmittance:

WT = 0.8021

1st Raw C (Window In): 7228.00
Raw C (Window Out): 9036.60
2nd Raw C (Window In): 7269.10

Comments: Audit computer not calculating correct bext value. Installed apreture ring, changed gain to 700, and cal number for third run. Third run has windows out. Fourth run audit receiver drifted creating a higher bext and high standard deviation (30), reran run. Run #8 027 had high standard deviation - reran. After audit ran extra run on audit instrument (not sure why bext jumped to the .040. Last run with audit only readings return to normal but still a little high. However standard deviation was also high for the run, so the readings may have been ok.

Figure 4-7. Example Completed Laptop Audit Form.

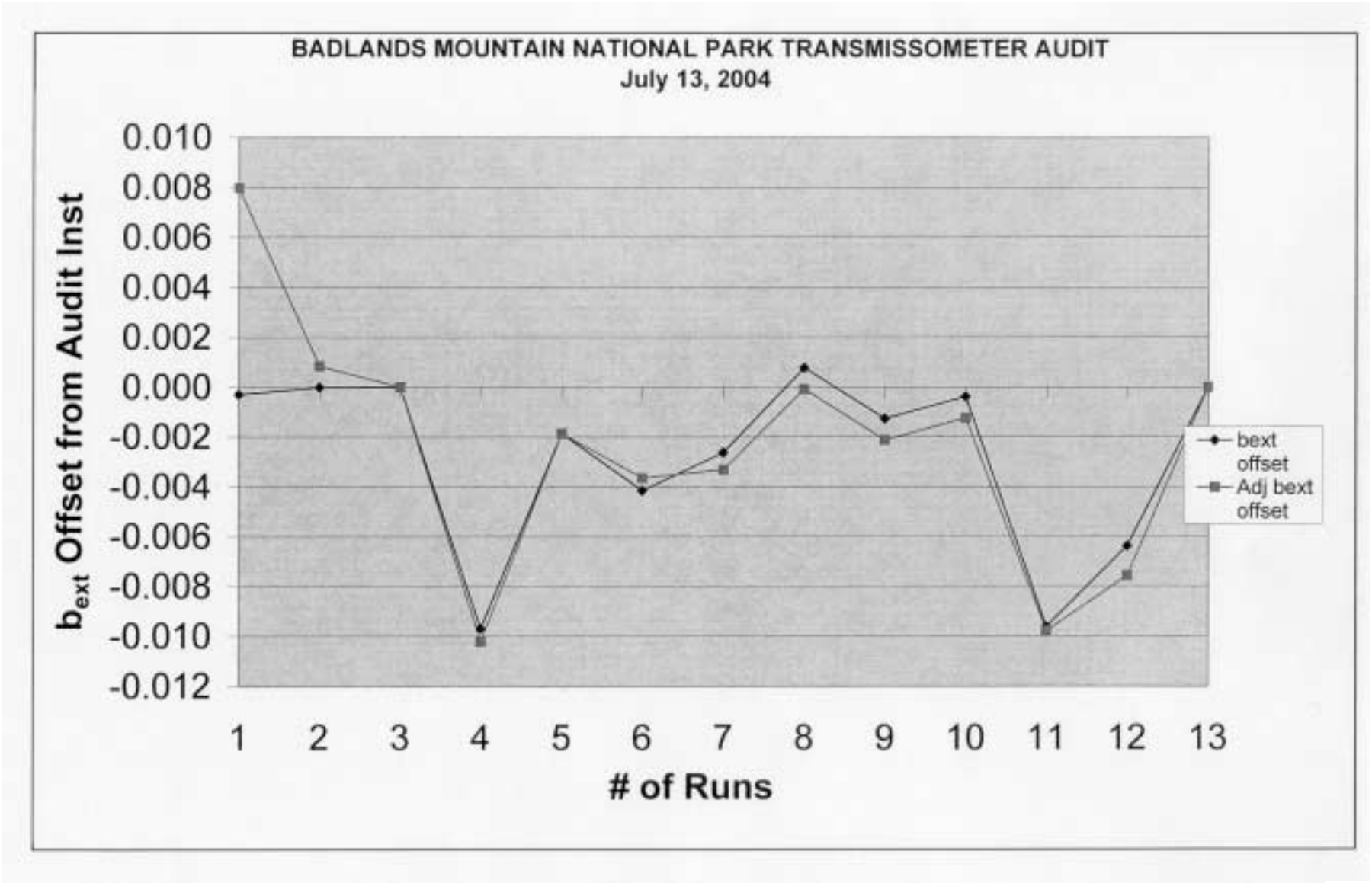

Figure 4-8. Example Graph Depicting b_{ext} and Adjusted b_{ext} Offset From Laptop Computer.

- Informing the field specialist of the audit results including the need to repeat all or part of the field audit.

Subsections 4.4.1 through 4.4.3 provide detailed descriptions of the procedures for evaluating field audit results.

4.4.1 Review of Transmitter Station Audit Form

Review of the transmitter station audit forms include:

- Verifying that the instrument number and lamp number recorded for each audit segment matches the corresponding instrument and lamp numbers recorded on the receiver station data sheet.

- Comparing the lamp voltages measured during the individual audit segments with corresponding lamp voltages measured during instrument servicing and calibration. Lamp voltages recorded during the audit are added to the Transmissometer Lamp Voltage Measurements Log (Refer to TI 4110-3400, *Annual Laboratory Maintenance Procedures for LPV Transmissometers (IMPROVE Protocol)*.

Lamp voltage measurements for individual lamps used with the audit instrument and replacement instrument may vary (minimum to maximum) over a range of fifty (50) millivolts. Due to lamp brightening (Refer to TI 4200-2100, *Calibration of Optec LPV Transmissometers)*, lamp voltages for operational lamps used by the on-site instrument will exhibit much larger (300-500 millivolt) variations from the instrument servicing and calibration measurements.

4.4.2 Review of Receiver Station Documentation Sheet

Project manager review of the receiver station documentation sheet is to ensure that the documentation is complete and provides a thorough assessment of on-site conditions during the audit.

4.4.3 Evaluation of Audit Results

Review the Trans Audit Excel worksheet to see how far the on-site instrument readings differ from the audit instrument.

4.5 AUDIT RECORD ARCHIVAL

Upon completion of the audit review, the project manager transfers all field audit records and documentation to site-specific operations notebooks located in the ARS Data Collection Center. Specific field audit documentation archived includes:

- On-Site Transmissometer Audit Form (Transmitter Station)

- On-Site Transmissometer Audit Form – Documentation Sheet (Receiver Station)

- On-Site Transmissometer Audit Form – Data Sheet (Receiver Station)

- Trans Audit Excel worksheet