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QUALITY ASSURANCE/QUALITY CONTROL DOCUMENTATION SERIES	
TITLE	**OPTEC LPV-2 TRANSMISSOMETER FIELD AUDIT PROCEDURES**
TYPE	**STANDARD OPERATING PROCEDURE**
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AUTHORIZATIONS		
TITLE	NAME	SIGNATURE
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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	

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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 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 receiver and transmitter windows.

This SOP serves as a guideline for the following:

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

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-2 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 reference 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.

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-2 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-2 Transmissometers (IMPROVE Protocol)*, for information related to the designation of ARS and on-site reference lamps.

- Audit transmissometer (without receiver computer) with calibrated lamps. The replacement transmissometer computer is used with the audit transmissometer. 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-2 Transmissometers (IMPROVE Protocol)*, for information regarding designation of the audit lamps.

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

- Handheld Rotronics air temperature/relative humidity sensor.

- Digital multimeter (DVM). The audit assistant uses the field specialist's calibrated DVM for lamp voltage measurements at the transmitter station.

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 transmitter control box cover plate.

3.3 EQUIPMENT

- Calculator

- Two 2-way radios with spare batteries and charger

- Documentation camera, preferably a 35 mm SLR with 35-135 zoom lens and color print or slide film

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 reference transmissometer

Refer to TI 4200-2100, *Calibration of Optec LPV-2 Transmissometers (IMPROVE Protocol)*, for information regarding the calibration memos.

CAMPBELL 21X DATALOGGER PROGRAM (TRANSMISSOMETER COMPUTER OUTPUT)

Program Description: Standard On-Site Operation

Author: _____ Date: _____

Instruct. Location	Program No.	Entry	Description
*4	01	1	Printer enable
	02	0	300 baud
*5			
	05	91	Year
	05		Julian Day
	05		Time
*1			
	01	1	
	01	P2	Diff voltage
	01	3	Reps
	02	5	Range
	03	1	in chan
	04	1	Location
	05	2.0	Multiplier
	06	000	Offset
	02	P92	If time
	01	0	Min into
	02	1	Min interval
	03	10	Set output flag
	03	P77	Real time
	01	110	Day/hr/min
	04	P78	Resolution
	01	1	High res
	05	P70	Sample to output
	01	5	Reps
	02	1	Start in *6 location 1
	06	P10	Battery voltage
	01	4	Location 4
	07	P17	Panel temp
	01	5	Location 5

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

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-2 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 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 reference transmissometer. The reference 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 reduce the amount of equipment shipped to and from a transmissometer site, the audit transmissometer system is operated with the replacement transmissometer computer during the audit. Gain measurements are made on all instruments during instrument servicing at ARS. (Refer to TI 4110-3400, *Annual Laboratory Maintenance Procedures for LPV-2 Transmissometer Systems (IMPROVE Protocol)*). These gain measurements are then incorporated into the calculation of calibration numbers generated for the audit transmissometer. (Refer to TI 4200-2100, *Calibration of Optec LPV-2 Transmissometers (IMPROVE Protocol)*).

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 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.

The transmissometer field audit also includes the window transmittance test, which verifies the combined transmittance of the transmitter and receiver station windows. This test is typically incorporated into the end of the audit, but can be performed separately if necessary. The window transmittance test is comprised of three 10-minute reading segments, typically using the first operational lamp of the installation transmissometer. The first and last segments should be performed with the receiver and transmitter windows installed. The middle segment is performed with both windows removed. This allows determination of the window transmittance and also provides an indication of stability of ambient conditions.

A complete audit (including window transmittance test) consists of 14 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 to use:

- The on-site instrument with two lamps, beginning with the last operational lamp, followed by the on-site reference lamp.

- The reference instrument with two lamps. If possible, use lamps that have been used in previous audits. This simplifies comparisons with other audits.

Table 4-1

Standard Audit Order for On-Site and Replacement Transmissometers

	Segment #	Transmissometer	Lamp	Comments
On-site	#1	On-site	Last Operational	
Transmissometer	#2	On-site	On-site Reference	
Audit	#3	Audit	Audit #1	
	#4	Audit	Audit #2	
	#5	Replacement	First Operational	
	#6	Replacement	On-site Reference	
Replacement	#7	Replacement	Last Operational	
Transmissometer	#8	Audit	Audit #2	
Audit	#9	Audit	Audit #1	
	#10	Replacement	Last Operational	
	#11	Replacement	On-site Reference	
Window	#12	Replacement	First Operational	Windows in Place
Transmittance	#13	Replacement	First Operational	Windows Removed
Test	#14	Replacement	First Operational	Windows in Place

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

- 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 on-site reference and the third is the last operational lamp in the series.

- The reference instrument with the same two lamps used earlier, but in reverse order.

- The installation instrument with the same three lamps used earlier, but in reverse order with the last audited lamp remaining as the first operational lamp.

The window transmittance test portion of the audit can include the last 10-minute reading of the intercomparison portion of the audit as the first segment of the transmittance test.

It is important that neither receiver nor transmitter telescope alignment is changed or adjusted during the 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.

Having used the last intercomparison reading as the first segment of the window transmittance test, the remaining two segments are:

- A 10-minute reading with both receiver and transmitter windows removed.

- A 10-minute reading with both receiver and transmitter windows reinstalled.

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 Preparation and Set-Up

Prior to the audit, the following preparatory tasks are performed at the transmitter station:

- Inspect and clean the on-site, replacement, and audit transmitter telescope objective lenses 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-2 Transmissometers*.

- Set-up the reference and replacement transmissometer transmitter units. The telescopes, 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.

- Inspect, and if necessary, clean the on-site, replacement, and reference transmitter lamps. The lamp filaments should also be inspected to verify that they are intact.

- Switch the on-site, replacement, and reference 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.

- Verify operation for the on-site, replacement, and reference transmitter systems, and the voltmeter.

Prior to the audit, the following preparatory tasks are performed at the receiver station:

- Inspect and clean the on-site, replacement, and audit receiver telescope lenses 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-2 Transmissometers*.

- Assemble the replacement and reference receiver detector heads and telescopes.

- Set-up the replacement (reference) 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.

- 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 the transmissometer transmitter units

- Cleans, inspects, and changes lamps

- Aligns the transmitter telescope

- Switches transmitter units

- Measures lamp voltages

- Inspects, and if necessary, cleans the shelter window and transmitter projection lens

- Troubleshoots transmitter malfunctions
- Operates the 2-way radio
- Documents 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 informs 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). 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. This should be done just prior to turning the instrument off when switching to another lamp or instrument.
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).

4.3.4 Receiver Station Audit Procedures and Documentation

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

- Operates and switches the transmissometer receiver units
- Operates the Campbell 21X datalogger
- Inspects and if necessary, cleans the shelter window and the receiver telescope objective lens
- Aligns the receiver telescope
- Operates the 2-way radio and communicates with the audit assistant regarding lamp and instrument changes
- 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) (Figure 4-2)
- 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) (Figure 4-3)

Documentation of the field specialist's actions are recorded on the On-Site Transmissometer Audit Form - Documentation Sheet (Receiver Station) (refer to Figure 4-2). Tasks and documentation at the receiver station are competed 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).
COMPUTER SETTINGS	Record the following transmissometer computer-related information for the on-site, replacement, and reference computers. Refer to the on-site, replacement, and reference instrument calibration memos for the path, gain, and lamp-specific calibration number settings.

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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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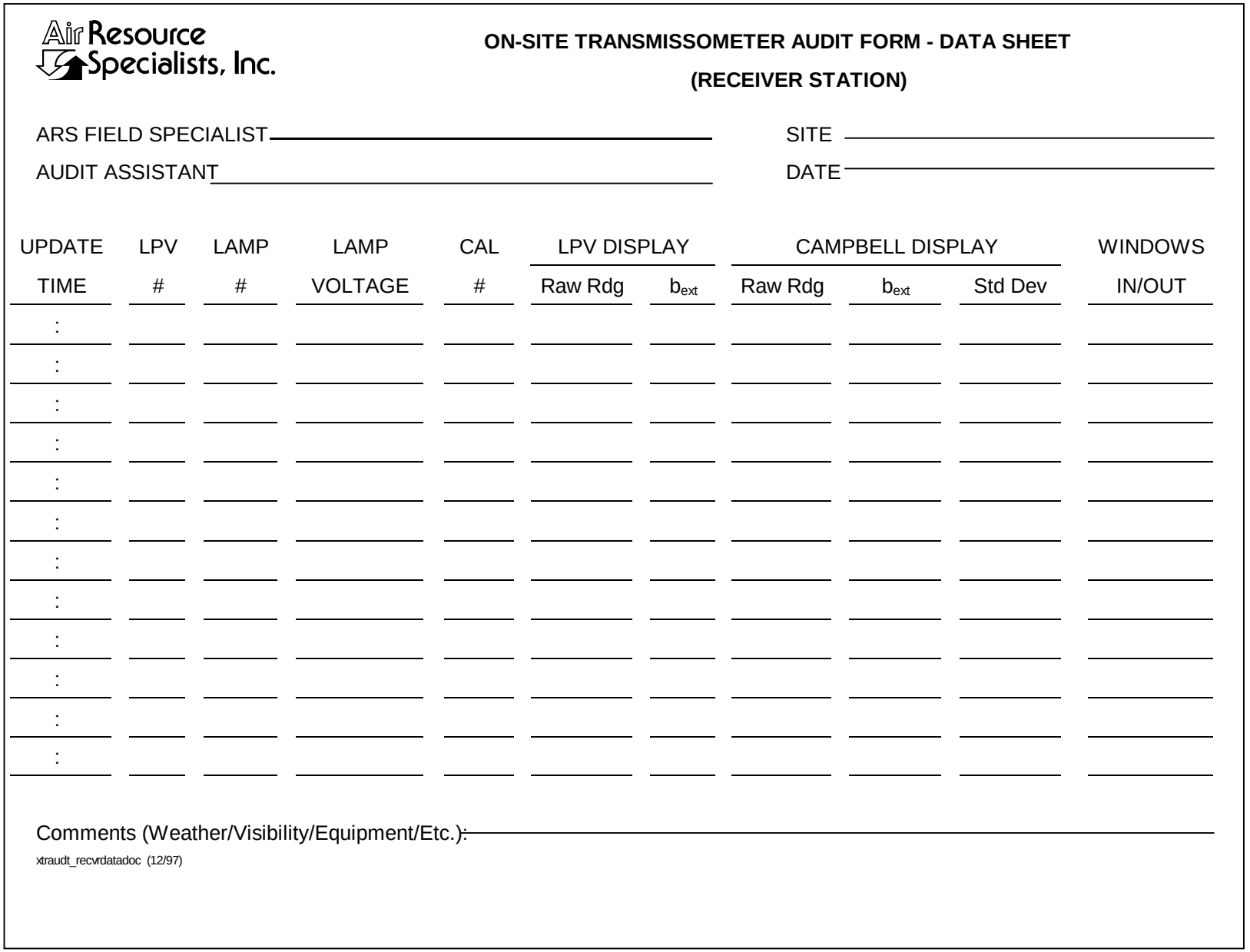
Figure 4-2. On-Site Transmissometer Audit Form - Documentation Sheet (Receiver Station).



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

	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 reference 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).

CALIBRATION (CAL) NUMBER

Note: The calibration number is recorded on the On-Site Transmissometer Audit Form - Data Sheet (Receiver Station). Refer to Figure 4-3. The calibration number is instrument- and transmitter lamp-specific and will be changed for each audit segment.

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). Refer to Figure 4-3. 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 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).

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.
CAL #	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).
CAMPBELL DISPLAY	Record the instrument raw reading, the calculated b_{ext}, and the standard deviation from the Campbell 21X datalogger. The raw reading or b_{ext} value (dependent on A1 switch setting) is displayed on the Campbell datalogger in the *6-mode, Input Storage Location 1. The standard deviation (SD) is displayed in the *6-mode, Input Storage Location 2.
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.

Refer to Figures 4-4, 4-5, and 4-6 for examples of completed transmitter and receiver station audit forms.

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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 4-4. Completed Example of On-Site Transmissometer Audit Form (Transmitter 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 4-5. Completed Example of On-Site Transmissometer Audit Form - Documentation Sheet (Receiver Station).

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

ARS FIELD SPECIALIST Ivar Rennat SITE GRBA
AUDIT ASSISTANT Kurt Pfaff 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 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 receiver station documentation sheet.
- Reviewing the transmitter station audit form.
- Entering specific audit data from receiver station data sheet into the Audit Evaluation Worksheet.
- Entering accumulated operational hours for lamps audited with the on-site transmissometer into the Audit Evaluation Worksheet.
- Analyzing instrument and lamp comparison data and statistics from the Audit Evaluation Worksheet.
- 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 4.4.4 provide detailed descriptions of the procedures for evaluating field audit results.

4.4.1 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.

4.4.2 Review of Transmitter Station Audit Form

Review of the transmitter station audit form includes:

- 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-2 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-2 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.

4.4.3 Data Entry of Audit Evaluation Worksheet

The computer-based Audit Evaluation Worksheet (Figure 4-7) is used by the project manager to calculate statistical parameters that indicate the quality of the audit and identify instrument or lamp inconsistencies.

For each audit segment, the lamp number (LAMP#), calibration number (CAL#), receiver raw reading (RAW RDG), and standard deviation (STD DEV) are entered into the worksheet from the receiver station data sheet. LAMP# and CAL# are entered directly as recorded on the receiver station data sheet. RAW RDG and STD DEV are taken from the Campbell datalogger display data and must be divided by 10 and rounded off to one decimal place (e.g., a raw reading of 6365.2 is entered on the worksheet as 636.5). The on-site instrument section of the worksheet includes an entry for lamp hours. Since the operational lamps for this instrument will have accumulated approximately 400 "on" hours (typical operational period of two months), the raw readings must be corrected for lamp brightening (Refer to TI 4400-5000, *Transmissometer Data Reduction and Validation (IMPROVE Protocol)*). For operational lamps, the value to be entered for LAMP HOURS is obtained from the lamp change records maintained by the ARS Data Collection Center (Refer to TI 4300-4023, *Transmissometer Daily Compilation and Review of DCP-Collected Data (IMPROVE Protocol)*). When the on-site reference lamp is being audited, the LAMP HOURS entry should be zero (0).

After the required data are entered into the worksheet, the parameters used to evaluate the audit are automatically calculated for each audit segment by the worksheet. These parameters are defined as follows:

AUDIT EVALUATION WORKSHEET
LPV-2 TRANSMISSOMETER
GRBA - 11/18/93

AUDIT BLOCK #1 ON SITE TRANSMISSOMETER LPV# 005

LAMP#	CAL#	LAMP HOURS	MEAN RAW RDG	STD DEV	T(meas)	T(corr)	SD/MEAN
668	737	544	681.3	5.2	0.924	0.886	0.76%
713	724	537	658.1	7.6	0.909	0.871	1.15%
						0.878	0.96%

AUDIT BLOCK #2 AUDIT TRANSMISSOMETER LPV# 006

LAMP#	CAL#	MEAN RAW RDG	STD DEV	T(meas)	SD/MEAN
838	918	845.7	8.2	0.921	0.97%
713	724	839.6	4.6	0.910	0.55%
				0.915	0.76%

AUDIT BLOCK #3 REPLACEMENT TRANSMISSOMETER LPV# 020

LAMP#	CAL#	MEAN RAW RDG	STD DEV	T(meas)	SD/MEAN
1011	852	806.6	4.5	0.947	0.56%
1007	837	788.7	6.0	0.942	0.76%
1015	843	785.1	6.0	0.931	0.76%
				0.940	0.69%

AUDIT BLOCK #4 AUDIT TRANSMISSOMETER LPV# 006

LAMP#	CAL#	MEAN RAW RDG	STD DEV	T(meas)	SD/MEAN
839	923	845.9	3.9	0.916	0.46%
838	918	844.4	5.0	0.920	0.59%
				0.918	0.53%

AUDIT BLOCK #5 REPLACEMENT TRANSMISSOMETER LPV# 020

LAMP#	CAL#	MEAN RAW RDG	STD DEV	T(meas)	SD/MEAN
1015	843	777.3	3.6	0.922	0.46%
1011	852	793.9	4.3	0.932	0.54%
1007	837	780.5	4.5	0.932	0.58%
				0.929	0.53%

AUDIT BLOCK COMPARISONS

MEAN T (meas) COMPARISON	MEAN OFFSET
Block #3 - Block #2	2.62%
Block #3 - Block #4	2.34%
Block #5 - Block #4	1.15%

Figure 4-7. Example Audit Evaluation Worksheet.

- T(meas) - The atmospheric transmittance over the sight path. This is the ratio of the ten-minute mean raw reading (RAW RDG) to the calibration number (CAL#).

- T(corr) - This is T(meas) for on-site instrument lamps adjusted for lamp brightening (Refer to TI 4400-5000).

- SD/MEAN - This parameter is the ratio (expressed as a percent) of the standard deviation (STD DEV) to the mean raw reading (RAW RDG) and indicates the stability of sight path transmittance during the 10-minute audit segment.

A mean T(meas) value is calculated for each audit block. Replacement transmissometer audit blocks are compared to adjacent Audit transmissometer audit blocks to determine a mean offset in T(meas).

4.4.4 Evaluation of Audit Results

Procedures for evaluating transmissometer field audit results are currently being developed. Over the past two years, over 30 field audits of LPV-2 transmissometers have been conducted. Data from these audits are being entered into an Audit Results Database. Audit results statistics will be used to define error limits for comparison of path transmittance measurements obtained with an instrument being audited to path transmittance measurements obtained with an audit instrument.

Lamps used operationally with transmissometers being removed from the field (on-site instruments) typically have accumulated 400 to 600 hours of "on" time. This accumulated operating time results in a shift in lamp brightness as described in TI 4400-5000. Audit data for lamps used in the field are corrected for lamp brightening following the procedures outlined in the previously referenced TI. Three sets of audit results statistics will be created as follows:

- One set of audit result statistics is generated for audit instrument and on-site instrument comparisons applying the standard lamp brightening correction factor. This data set is used only as an early indication of the quality of the data collected during the operational period for the on-site transmissometer.

- Operational instruments are post-calibrated after removal from a field site (Refer to TI 4200-2100, *Calibration of Optec LPV-2 Transmissometer*). On-site instrument audit data will be corrected using post-calibration lamp brightening factors. The second set of audit result statistics is generated using these data. This data set is incorporated into ongoing analyses of lamp brightening effects on data quality.

- The third set of audit results statistics is based on measurement comparisons between the replacement transmissometer and the audit transmissometer. Because replacement instrument lamps are calibrated prior to installing the instrument at a field site (see TI 4200-2100), the lamps have not accumulated any "on" time prior to the audit and lamp brightening is not a factor. These statistics will be used to define error limits for acceptance of replacement instrument audits.

As additional field audits are conducted, the audit results will be added to the database, allowing a more accurate description of the error limits.

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)
- Audit Evaluation Worksheet