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Analysis of Modeling Cumulative Noise from Simultaneous Flights

Volume 1: Analysis at Four National Parks

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13. ABSTRACT (Maximum 200 words)
This is the first of two volumes of the report on modeling cumulative noise from simultaneous flights. This volume includes: an overview of the time compression algorithms used to model simultaneous aircraft; revised summary of a preliminary study (which includes updated measured data); an expanded analysis of cumulative noise from simultaneous flights for several additional National Parks; and a discussion of the remaining issues and tasks that are recommended be addressed.

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS – WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS – WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

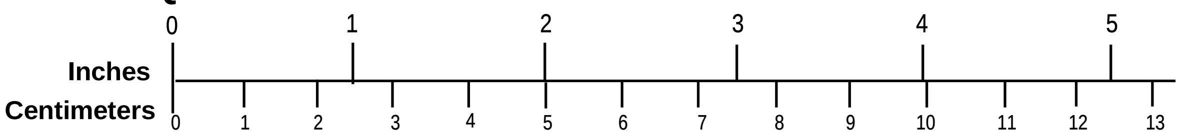
VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. SD Catalog No. C13 10286

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1 INTRODUCTION

The Federal Aviation Administration Office of Environment and Energy's (FAA AEE) Aviation Environmental Design Tool (AEDT) and Integrated Noise Model (INM) are integrated noise models which predict cumulative noise for aircraft operations but do not take into account flight scheduling. These methods can result in overpredictions when calculating cumulative, time-based noise metrics for simultaneously occurring flights because noise from these flights are accounted for independently.

In order to better account for noise from simultaneously occurring aircraft in AEDT/INM, empirical- and statistically-based relationships were developed for time-based metrics; these relationships are referred to as "time compression algorithms." The purpose of this technical report is to (a) review the previous analyses of the two time compression algorithms under consideration; (b) evaluate the performance of the algorithms using several National Park noise model studies; (c) derive conclusions regarding the applicability of the time compression algorithms over a variety of modeling scenarios; and (d) provide recommendations on how simultaneous aircraft modeling should be addressed in AEDT/INM.

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2 OVERVIEW OF THE TIME COMPRESSION ALGORITHMS

The "original" time compression algorithm was derived from air tour data collected at the Grand Canyon National Park (GCNP), and was validated for use in that park[1]. The algorithm is presented in Equation 1.

$$y = 100 - \{128.39 \cdot \ln[(10^{(100-9.29 \cdot x)/1400}) + 1]\} \qquad \text{Equation 1}$$

where

x = the uncorrected, cumulative Percent Time Audible (%TAUD) results; and
y = the "compressed" cumulative %TAUD result.

While the original time compression algorithm works well for modeling air tours in GCNP[2], it was unclear how well the algorithm would perform modeling other aircraft operations (e.g., commercial jets) and/or other National Parks. Therefore, a statistically based version of the time compression algorithm was proposed by the NPS Natural Sounds Program[*], and is being considered for use in AEDT/INM[3]. The "proposed" time compression algorithm is presented in Equation 2.

$$y = N \cdot [\frac{1-e^{(-\frac{(N+1)\cdot x_{min}}{N \cdot T})}}{N+1}] \qquad \text{Equation 2}$$

where

x_{min} = the uncorrected, cumulative TAUD results (minutes);
N = the number of aircraft operations occurring during the analysis time; and
T = the analysis time (minutes).

Both time compression algorithms are presented in Figure 1. Since the proposed time compression algorithm takes into account number of operations, the proposed time compression results are presented in Figure 1 for 0.1, 1, 10, 100 and 1000 operations for a 24 hour analysis period.

[*] http://www.nature.nps.gov/naturalsounds/

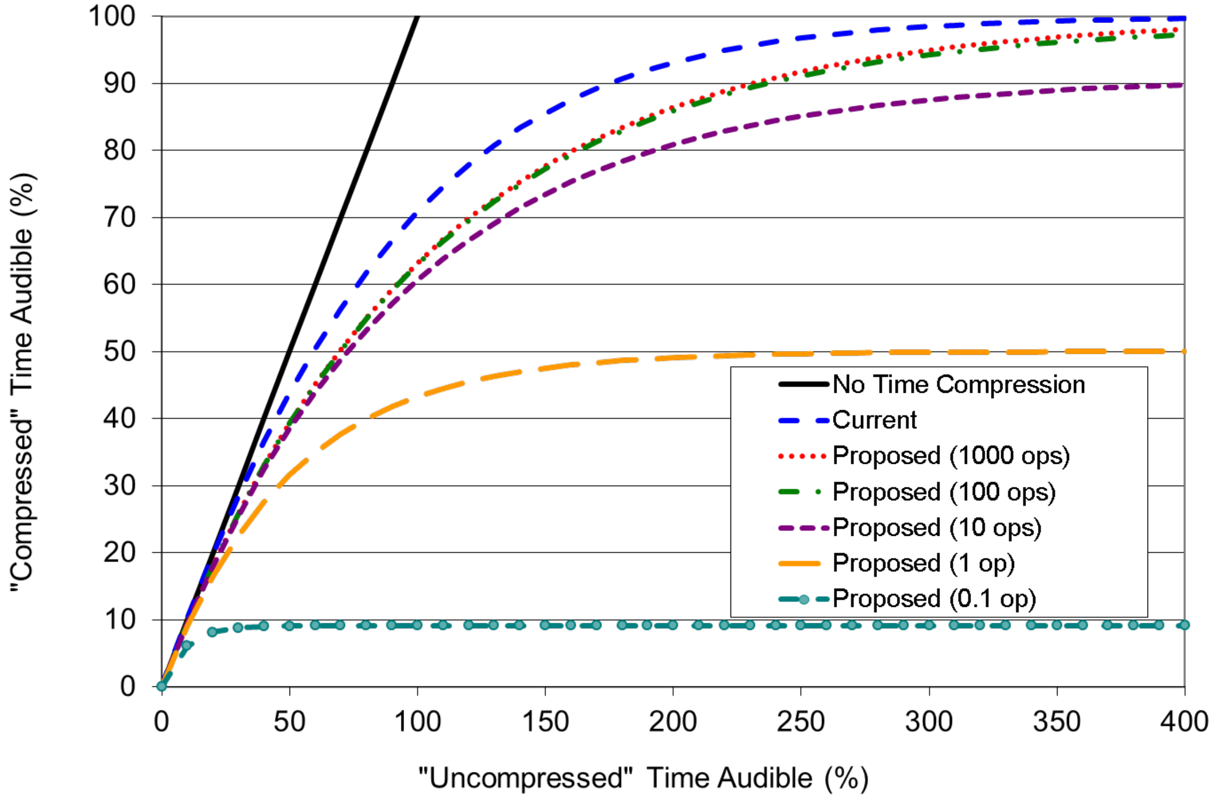

Figure 1: Time compression algorithm representations

Although neither time compression algorithm is included in the current public release of INM (or the beta release of AEDT), they are both included in research versions of INM and have been utilized for recent GCNP analyses, as well as some ongoing analysis of preliminary alternatives in support of the Air Tour Management Plan (ATMP) Program for national parks.

3 REVIEW OF PREVIOUS ANALYSES

3.1 Summary of Grand Canyon National Park 1999 and 2004 Analyses

Two previously conducted field studies at Grand Canyon National Park were evaluated to compare measured data against both the original and proposed time compression algorithms (Equations 1 and 2 above, respectively). The first study involved air tour aircraft noise measured in GCNP in 1999, and the second study involved high-altitude commercial jet overflights measured in GCNP in 2004[2]. For these studies, comparisons were undertaken between measured and modeled time audible data[*] for three scenarios modeled using the INM 5.1 for GCNP 1999 and INM 6.1 for GCNP 2004[†]: (1) without time compression (capped at 100% time audible); (2) with the original time compression algorithm; and (3) with the proposed time compression algorithm. Results from both studies were presented at the 7th Meeting of the Grand Canyon Working Group of the National Parks Overflights Advisory Group[3]. The results are summarized below.

The 1999 GCNP study focused on *air tour aircraft* (fixed-wing propellers and helicopters) operations. Measured time audible data[‡] are compared to corresponding modeled data for four days at 41 sites throughout the park. The results are presented in Table 1 and Figure 2. This study showed a noticeable improvement in the agreement between measured and modeled time audible results for air tour aircraft (median difference of 9.9% TAUD), when the proposed time compression algorithm is applied.

Table 1: Difference in measured and modeled time audible for GCNP 1999: *Fixed wing propeller aircraft and helicopters* (INM 5.1)

	Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**
Average	27.3	14.7	12.0
Standard Deviation	31.0	12.1	10.4
Median Difference	16.9	12.0	9.9

[*] Time audible is defined as the duration that an aircraft may be detected by an actively listening human observer with normal hearing.

[†] The significance of modeling with versions of INM prior to INM 7.0 is discussed in Section 4. It should also be noted that both these studies were modeled with research versions of INM, since time compression is not an option in the public release versions of INM.

[‡] Measured time audible data consisted of aircraft type and observed duration of audibility at each measurement site. Potential issues associated with measured time audible data are discussed later in Section 6.

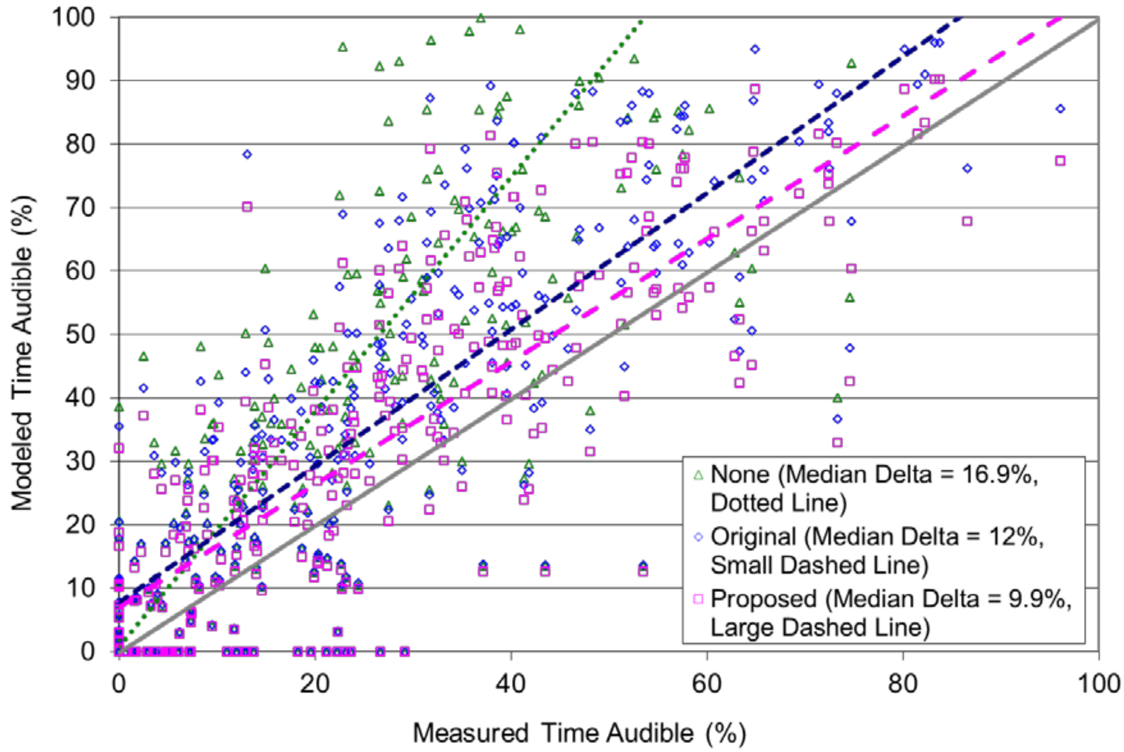

Figure 2: Comparison of measured and modeled time audible results with time compression for GCNP 1999 (linear trendlines)

The 2004 GCNP study focused on high-altitude commercial jet aircraft operations. Measured time audible data are compared to corresponding modeled data for 969 flights over four days at a single site. The results are presented in Table 2. This study also showed a noticeable improvement in the agreement between measured and modeled time audible results for high-altitude commercial jet aircraft (median difference of 10.3% TAUD), when the proposed time compression algorithm is applied.

Table 2: Difference in measured and modeled time audible for GCNP 2004: *Jet aircraft only* (INM 6.1)

	Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**
Average	26.2	14.5	9.2
Standard Deviation	13.4	9.5	7.1
Median Difference	27.8	16.6	10.3

3.2 Current Study: Grand Canyon National Park 2007 INM Version 6.2a Analysis

In a 2007 field study in GCNP, time audible data for air tour and high-altitude jet aircraft were measured and compared to corresponding modeled data for a variety of aircraft overflight operations for three scenarios modeled in the INM 6.2a: (1) without time compression (capped at 100% time audible); (2) with the original time compression algorithm; and (3) with the proposed time compression algorithm. Results from this study were presented in the August 2009 technical memorandum "FP01 FD7RC Task 2: Analysis of Modeling Cumulative Noise from Simultaneous Flights; Preliminary Study[4]." That study identified the need to reprocess the measured time audible data for GCNP in order to better discern between noises produced by different aircraft types (resolving several misidentified aircraft events). The results for the preliminary study, including the reprocessed and updated measured data, are summarized below.

Time audible data for air tour and high-altitude jet aircraft were measured in 2007 at 11 backcountry locations in GCNP[5]. Measured time audible data are compared to corresponding modeled data for a variety of aircraft overflight operations. Based on information provided by the FAA's Air Traffic and Flight Standards offices, as well as data obtained from the FAA's Enhanced Traffic Management System (ETMS), 1814 flights (1315 jets, 139 fixed wing propeller aircraft, and 360 helicopters) are modeled, representing all potentially audible overflights that occurred over GCNP on a single day (August 10, 2007) during daytime hours (7 am and 7 pm).

Unlike the previous studies, the 2007 study focused on differentiating between audibility results for different types of aircraft; separate comparisons are done for: (1) *fixed wing aircraft* (including air tours)[*]; (2) *high-altitude commercial jet aircraft*; (3) *helicopters*; and (4) a combination of *all aircraft*. The results from these scenarios are presented in Table 3 through 6[†]. Results for individual measurement locations are presented in Appendix A.

[*] It is important to note that it was not possible to distinguish between overflight and air tour fixed wing propeller aircraft in the measured data. Therefore, they were evaluated together for all four studies in this analysis. Furthermore, there are multiple environmental factors that may make aircraft type identification difficult during noise measurements, such as line of sight blockage.

[†] The results for the *all aircraft* and *jet scenarios* in the GCNP 2007 study (see Table 3 and Table 4, respectively) were computed without the effects of line-of-sight blockage in order to replicate the modeling conditions of the previous studies (GCNP 1999 and GCNP 2004). Note that thee previous studies did not take into account line-of-sight blockage for scenarios that included high-altitude jet aircraft.

Table 3: Difference in measured and modeled time audible for GCNP 2007 Study: *All aircraft* (INM 6.2a)

	Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**
Average	45.0	37.4	34.5
Standard Deviation	19.7	18.1	18.7
Median Difference	54.9	37.1	32.1

Table 4: Difference in measured and modeled time audible for GCNP 2007 Study: *Jet aircraft only* (INM 6.2a) and GCNP 2004 (INM 6.1)

	GCNP 2007 (INM 6.2a)			GCNP 2004 (INM 6)*		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average	68.7	50.4	43.5	26.2	14.5	9.2
Standard Deviation	20.5	16.2	15.2	13.4	9.5	7.1
Median	62.9	42.5	35.5	27.8	16.6	10.3

Table 5: Difference in measured and modeled time audible for GCNP 2007 Study: *Fixed wing propeller aircraft only* (INM 6.2a) and GCNP 1999 (INM 5.1)

	GCNP 2007 (INM 6.2a)			GCNP 1999 (INM 6)†		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average	21.4	7.4	5.7	27.3	14.7	12.0
Standard Deviation	32.1	17.4	15.7	31.0	12.1	10.4
Median	2.7	2.9	1.7	16.9	12.0	9.9

Table 6: Difference in measured and modeled time audible for GCNP 2007 Study: *Helicopters only* (INM 6.2a) and GCNP 1999 (INM 5.1)

	GCNP 2007 (INM 6.2a)			GCNP 1999 (INM 6)‡		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average	14.9	14.3	13.1	27.3	14.7	12.0
Standard Deviation	14.8	14.9	14.9	31.0	12.1	10.4
Median	14.5	14.5	13.2	16.9	12.0	9.9

* Reproduced from Table 2.
† Reproduced from Table 1.
‡ Reproduced from Table 1.

The results for the GCNP 2007 *all aircraft scenario* show a noticeable improvement in the agreement between measured and modeled time audible results, when the proposed time compression algorithm is applied. Furthermore, the results from the scenarios with the proposed time compression algorithm more closely match the measured time compression data than do the results using either the original time compression or no time compression. However, the median difference between the measured and modeled (with the proposed algorithm) time audible results are 32.1%, which is larger than the differences seen in the preliminary analyses. These results are for a combination of all aircraft types, whereas the studies in the preliminary analyses focused on air tour aircraft (1999) or high-altitude jet aircraft (2004). Therefore, time audible results are analyzed by aircraft type in order to identify the source of the increased difference relative to measured data.

The modeling results for the *fixed-wing aircraft scenario* better agree with the measured data (median difference of 1.7% TAUD), when the proposed time compression algorithm is applied. This trend is similar to that in the GCNP 1999 analysis with comparable standard deviation.

The *helicopter only scenario* results trended similarly to those for the *fixed-wing aircraft scenario* (median difference of 13.2% TAUD). Again, the proposed time compression algorithm showed improved performance over the original time compression and no time compression algorithms. These results are similar to those from the GCNP 1999 analysis, which included helicopters.

The one scenario that illustrated differing trends is the *high-altitude jet aircraft only scenario.* The median time audible difference for the *jet aircraft scenario* is 35.5%. The jet aircraft results do not closely agree with the GCNP 2004 analysis of high altitude jet aircraft. This indicates that the proposed time compression algorithm does not perform as well in the prediction of time audible for jet aircraft.

The preliminary study identified the need for time compression algorithms to be further evaluated for specific aircraft types in several different National Park environments in the most current version of INM (7.0b), in order to determine their applicability for modeling noise for other National Parks.

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4 FULL STUDY: FOUR NATIONAL PARK ANALYSES

INM 6.2a was released in November 2006. Since that time, the software has been updated three times to include database updates, software bug fixes and computational updates, many of which directly benefit noise modeling in National Parks. One such enhancement was an update of the helicopter noise prediction methodology. Thus, following the 2009 GCNP study, the simultaneous occurring aircraft analysis is modeled in INM 7.0b[*], as well as expanded to include noise studies for three additional National Parks: Lake Mead National Recreational Area (LMNRA), Great Smoky Mountains National Park (GRSM), and Zion National Park (ZION).

These parks are chosen because of the availability of time audible and ambient noise data collected by the Volpe Center as part of the Air Tour Management Plan (ATMP) program. These parks also represent a wide range of park environments that are exposed to noise from aircraft operations (ground cover type, land use categories, etc.). For each of these parks, air tour and high-altitude jet aircraft time audible data were measured and compared to corresponding modeled data for a variety of aircraft overflight operations for three scenarios modeled in INM Version 7.0b[†]: (1) without time compression (capped at 100% time audible); (2) with the original time compression; and (3) with the proposed time compression. The results are presented below for each study.

4.1 Grand Canyon National Park 2007 Analysis in INM 7.0b

In order to assess the effect of these modeling updates on the simultaneous aircraft analysis, the 2007 GCNP study from the preliminary analysis (see Section 3.2) is rerun in INM 7.0b. Like the preliminary study run in INM 6.2a, the GCNP 2007 study in INM 7.0b focused on differentiating between noise results for a variety of aircraft, so separate comparisons are done for: (1) *all aircraft combined*; (2) *high-altitude commercial jet aircraft*; (3) *fixed-wing aircraft*; and (4) *helicopters*. The results from these scenarios are presented in Table 7 through Table 10[‡]. Results for individual measurement locations are presented in Appendix B. In addition, the air tour flight tracks for the study are presented in Appendix C and the measurement site descriptions are presented in Appendix D.

[*] It is important to note that a research version of INM 7.0b was used for this analysis, since the time compression algorithms are currently under investigation and are not included in a publically available release of INM.

[†] ZION was also modeled in a research version of INM 6.2a, for comparison purposes.

[‡] The results for the *all aircraft* and *jet scenarios* (see Table 7 and Table 8, respectively) were computed without the effects of line-of-sight blockage in order to replicate the modeling conditions of the previous studies.

Table 7: Difference in measured and modeled time audible for GCNP 2007: *All aircraft* (INM 7.0b and INM 6.2a)

	GCNP 2007 (INM7.0b)			GCNP 2007 (INM 6.2a)*		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average	46.6	38.9	35.6	45.0	37.4	34.5
Standard Deviation	20.9	18.0	17.9	19.7	18.1	18.7
Median	59.4	42.8	34.8	54.9	37.1	32.1

Table 8: Difference in measured and modeled time audible for GCNP 2007: *Jet aircraft only* (INM 7.0b and INM 6.2a)

	GCNP 2007 (INM7.0b)			GCNP 2007 (INM 6.2a)†		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average	70.9	51.8	44.8	68.7	50.4	43.5
Standard Deviation	19.0	15.3	14.4	20.5	16.2	15.2
Median	74.7	48.9	41.6	62.9	42.5	35.5

Table 9: Difference in measured and modeled time audible for GCNP 2007: *Fixed wing propeller aircraft only* (INM 7.0b and INM 6.2a)

	GCNP 2007 (INM7.0b)			GCNP 2007 (INM 6.2a)‡		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average	12.0	9.7	7.7	21.4	7.4	5.7
Standard Deviation	24.1	20.4	18.4	32.1	17.4	15.7
Median	-0.2	0.0	-0.8	2.7	2.9	1.7

Table 10: Difference in measured and modeled time audible for GCNP 2007: *Helicopters only* (INM 7.0b and INM 6.2a)

	GCNP 2007 (INM7.0b)			GCNP 2007 (INM 6.2a)§		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average	33.9	30.5	28.2	14.9	14.3	13.1
Standard Deviation	36.3	31.4	29.0	14.8	14.9	14.9
Median	28.1	28.1	27.7	14.5	14.5	13.2

[*] Reproduced from Table 3.
[†] Reproduced from Table 4.
[‡] Reproduced from Table 5.
[§] Reproduced from Table 6.

The results for GCNP 2007 run in INM 7.0b are similar to the results from the same study run in INM 6.2a (see Section 3.2). The agreement between measured and modeled time audible results showed a noticeable improvement for the *all aircraft scenarios* when the proposed time compression algorithm is applied. However, the median difference for the *all aircraft scenario* is 34.8%, which is slightly larger than the differences seen in the preliminary study run in INM 6.2a.

The results for the *fixed-wing aircraft scenario* show an improvement in the agreement between the measured and modeled (with the proposed algorithm) time audible results with a median difference of -0.8% TAUD. The *helicopter only scenario* trends similarly with a median difference of 27.7% TAUD. As seen in the preliminary study, the main outlier is the *high-altitude jet aircraft only scenario*, with a median difference of 41.6%.

In all four scenarios, the proposed time compression algorithms showed improved performance over the original time compression and no time compression algorithms. These results are similar to the results from the preliminary study. For the *all aircraft*, *jet only* and *helicopter only scenarios*, the average difference between the measured and modeled (with the proposed algorithm) time audible results in INM 7.0b are slightly larger than those seen in the preliminary study in INM 6.2a. This is particularly noticeable for the *helicopters only scenario*, where the median difference between the measured and modeled (with the proposed algorithm) time audible results is 13.2% TAUD in INM 6.2a and 27.7% in INM 7.0b.

4.2 Lake Mead National Recreational Area 2004 Analysis in INM 7.0b

Time audible data for air tour and high-altitude jet aircraft were measured in 2004 at seven backcountry locations in LMNRA[6]. Measured time audible data are compared to corresponding modeled data for a variety of aircraft overflight operations. Based on data obtained from the FAA's Enhanced Traffic Management System (ETMS), as well as air tour operational information from the air tour operators flying in LMNRA, 1800.589 flights (1614 jets, 29.381 fixed wing propeller aircraft, and 157.208 helicopters[*]) are modeled, estimating all potentially audible overflights that occurred over LMNRA on two days (May 14-15, 2004) during daytime hours (between 7:00 a.m. and 7:00 p.m.).

Like the previous studies, the 2004 INM 7.0b LMNRA study differentiated between noise results for different aircraft.[†] The results from these scenarios are presented in Table 11 through Table 14 [‡]. Results for individual measurement locations are presented in Appendix B. In addition,

[*] Fractional fixed wing propeller aircraft and helicopter operations are modeled for LMNRA 2004, because they are based on the number of operations during an average day.

[†] LMNRA 2004 was only run in INM 7.0b (not INM 6.2a) because similar results were seen for the GCNP 2007 runs in INM 6.2a and INM 7.0b. .

[‡] The results for the *all aircraft* and *jet scenarios* (see Table 11 and Table 14, respectively) were computed without the effects of line-of-sight blockage in order to replicate the modeling conditions of the previous studies.

the air tour flight tracks for the study are presented in Appendix C, and the measurement site descriptions are presented in Appendix D.

Table 11: Difference in measured and modeled time audible for LMNRA 2004 (INM 7.0b): *All aircraft*

	Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**
Average	48.0	38.5	33.0
Standard Deviation	17.0	13.6	13.3
Median	48.9	42.1	35.5

Table 12: Difference in measured and modeled time audible for LMNRA 2004 (INM 7.0b): *Jet aircraft only*

	Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**
Average	61.1	45.1	38.7
Standard Deviation	24.4	18.4	16.8
Median	68.4	50.0	43.3

Table 13: Difference in measured and modeled time audible for LMNRA 2004 (INM 7.0b): *Fixed wing propeller aircraft only*

	Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**
Average	-4.4	-4.8	-5.7
Standard Deviation	12.2	11.5	10.3
Median	-12.4	-12.4	-12.4

Table 14: Difference in measured and modeled time audible for LMNRA 2004 (INM 7.0b): *Helicopters only*

	Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**
Average	41.4	31.9	27.8
Standard Deviation	40.3	30.6	26.9
Median	39.1	35.6	32.0

The results for LMNRA 2004 run in INM 7.0b are similar to those from GCNP 2007 (see Sections 3.2 and 4.1). The results illustrate a noticeable improvement measured versus modeled time audible results for the *all aircraft scenarios* using the proposed time compression algorithm, except for the *fixed wing aircraft only scenario*, which essentially illustrated no change for either algorithm (a median difference between the measured and modeled with the proposed algorithm time audible results of -12.4% TAUD). However, the median difference is still large, even when the proposed time compression algorithm is applied (a median difference of 35.5% TAUD for the *all aircraft scenario*, 32.0% TAUD for the *helicopters only scenario*, and 43.3% TAUD for the *high-altitude jet aircraft only scenario*).

4.3 Great Smoky Mountains National Park 2006 Analysis in INM 7.0b

Time audible data for air tour and high-altitude jet aircraft were measured in 2004 at seven backcountry locations in GRSM[7]. Measured time audible data are compared to corresponding modeled data for a variety of aircraft overflight operations. Based on data obtained from the FAA's Enhanced Traffic Management System (ETMS), as well as air tour operational information from the air tour operators flying in GRSM, 972.955 flights (965 jets and 7.955 helicopters)[*] are modeled, representing all potentially audible overflights that occurred over GRSM on two days (June 7, 2006 and June 13, 2006) during daytime hours (7 am and 7 pm).

Like the previous studies, the GRSM 2006 study in INM 7.0b differentiated between noise results for a different aircraft.[†] The results from these scenarios are presented in Table 15 through Table 17[‡]. Results for individual measurement locations are presented in Appendix B. In addition, the air tour flight tracks for the study are presented in Appendix C, and the measurement site descriptions are presented in Appendix D.

Table 15: Difference in measured and modeled time audible for GRSM 2006 (INM 7.0b): *All aircraft*

	Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**
Average	57.2	33.9	26.1
Standard Deviation	11.4	8.2	8.2
Median	58.5	33.9	25.9

[*] There were no fixed wing air tours flown in GRSM during the study period. Also, fractional helicopter operations are modeled for GRSM 2006, because they are based on the number of operations during an average day.
[†] GRSM 2006 was only run INM 7.0b.
[‡] The results for the *all aircraft* and *jet scenarios* (see Table 15 and Table 16, respectively) were computed without the effects of line-of-sight blockage, in order to replicate the modeling conditions of the previous studies.

Table 16: Difference in measured and modeled time audible for GRSM 2006 (INM 7.0b): *Jet aircraft only*

	Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**
Average	68.6	44.9	37.3
Standard Deviation	6.9	3.6	3.7
Median	70.0	43.8	36.3

Table 17: Difference in measured and modeled time audible for GRSM 2006 (INM 7.0b): *Helicopters only*

	Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**
Average	1.7	1.8	1.6
Standard Deviation	1.9	2.0	1.9
Median	1.1	1.2	1.1

The results for GRSM 2006 run in INM 7.0b are similar to those from the previous studies. The results indicate a noticeable improvement in the agreement between measured and modeled time audible results for the *all aircraft scenarios*, when the proposed time compression algorithm is applied, except for the *helicopters only scenario*, which saw essentially no change for either algorithm (a median difference between the measured and modeled with the proposed algorithm time audible results of 1.1% TAUD). However, the median difference is still large, even when the proposed time compression algorithm is applied (a median difference of 25.9% TAUD for *the all aircraft scenario*, and 36.3% TAUD for the *high-altitude jet aircraft only scenario*).

4.4 Zion National Park 2000 Analysis in INM 6.2a and INM 7.0b

Time audible data for air tour and high-altitude jet aircraft were measured in 2000 and 2001 at 7 backcountry locations in ZION[8]. Measured time audible data are compared to corresponding modeled data for a variety of aircraft overflight operations. 1184.602 flights (1176.392 jets, 1.3261 fixed wing propeller aircraft, and 0.0712 helicopters) are modeled, representing all potentially audible overflights that occurred over ZION on an average day (October and November 2000) during daytime hours (7 am and 7 pm).

The ZION 2000 study differed from the other Parks study, as it was developed by an outside environmental contractor in INM 6.2a, and then converted to INM 7.0b. While care was taken to model this study with the minimum number of changes, in order to present the results as the contractor intended, several changes are made to the study in order to allow for the conversion to the INM 7.0b format. These changes are made to both the INM 6.2a and INM 7.0b versions of the study to insure consistency. A summary of these changes is presented in Appendix E.

The results from the ZION 2000 study run in INM 6.2a and INM 7.0b are presented in Table 18 through Table 21. Like the previous studies, the ZION 2000 study delineated between noise results for a variety of different aircraft.* Results for individual measurement locations are presented in Appendix B. In addition, the air tour flight tracks for the study are presented in Appendix C, and the measurement site descriptions are presented in Appendix D.

Table 18: Difference in measured and modeled time audible for ZION 2000: *All aircraft* (INM 7.0b and INM 6.2a)

	ZION 2000 (INM7.0b)			ZION 2000 (INM 6.2a)		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average	46.2	44.0	40.0	46.2	41.6	36.2
Standard Deviation	14.5	14.9	15.3	14.5	15.3	15.7
Median	44.5	42.4	38.8	44.5	40.7	35.3

Table 19: Difference in measured and modeled time audible for ZION 2000: *Jet aircraft only* (INM 7.0b and INM 6.2a)

	ZION 2000 (INM7.0b)			ZION 2000 (INM 6.2a)		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average	85.0	82.8	78.8	85.0	80.4	74.9
Standard Deviation	8.3	8.5	8.7	8.3	8.7	9.0
Median	83.6	82.0	78.4	83.6	79.3	72.9

Table 20: Difference in measured and modeled time audible for ZION 2000: *Fixed wing propeller aircraft only* (INM 7.0b and INM 6.2a)

	ZION 2000 (INM7.0b)			ZION 2000 (INM 6.2a)		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average	-33.2	-33.2	-33.2	-33.2	-33.2	-33.2
Standard Deviation	16.5	16.5	16.5	16.5	16.5	16.5
Median	-35.0	-35.0	-35.0	-35.0	-35.0	-35.0

* The results for the *all aircraft* and *jet scenarios* (see Table 18 and Table 19, respectively) were computed without the effects of line-of-sight blockage, in order to replicate the modeling conditions of the previous studies.

Table 21: Difference in measured and modeled time audible for ZION 2000: *Helicopters only* (INM 7.0b and INM 6.2a)

	ZION 2000 (INM7.0b) Difference in %TAUD (Modeled - Measured)			ZION 2000 (INM 6.2a) Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
Standard Deviation	1.0	1.0	1.0	1.0	1.0	1.0
Median	0.0	0.0	0.0	0.1	0.1	0.1

The results for ZION 2000 run in INM 6.2a and INM 7.0b produced similar results, which are also similar to the results from the previous studies in both INM 6.2a and INM 7.0b. It is important to note that the median difference between the measured and modeled (with the proposed algorithm) time audible results for the *all aircraft scenario* is 34.8% TAUD in INM 7.0b, which is slightly larger than the differences seen in the preliminary study run in INM 6.2a. Otherwise, the results followed the same trends in both INM 6.2a and INM 7.0b.

The study showed an improvement in the agreement between measured and modeled time audible results, when the proposed time compression algorithm is applied, except for the *fixed wing air tour aircraft* and *helicopters only scenarios*, which saw essentially no change for either algorithm (a median difference between the measured and modeled with the proposed algorithm time audible results of -35.0% for *fixed wing air tour aircraft*, and 0.0% for *helicopters*). The limited effect of the time compression algorithms on the *fixed wing air tour aircraft* and *helicopter scenarios* is due to the small number of operations in the ZION 2000 study (1.3261 fixed wing propeller aircraft, and 0.0712 helicopters). For the *all aircraft* and *jet aircraft only scenarios*, the median difference between the measured and modeled time audible results is still large, even when the proposed time compression algorithm is applied (a median difference between the measured and modeled with the proposed algorithm time audible results of 38.8% for the *all aircraft scenario* in INM 7.0b, and 78.4% TAUD for the *high-altitude jet aircraft only scenario*).

5 FURTHER ANALYSIS

While the results from the four individual National Parks studies provide insight as to the applicability of the time compression algorithms for individual parks studies, additional analyses are performed in order to determine (a) the average performance across the time compression algorithms; and (b) if additional factors influenced the results, such as the environment at the measurement sites, number of modeled operations, and measurement duration.

5.1 Average Results in INM 6.2a and INM 7.0b

The time audible results for all four studies are combined according to scenario type and analyzed in order to identify the average effect of the time compression algorithms in INM. The combined INM 7.0b results for GCNP 2007, LMNRA 2004, GRSM 2006 and ZION 2000 studies are presented alongside the combined INM 6.2a results for GCNP 2007 and ZION 2000 studies in Table 22 through Table 25.

Table 22: Difference in measured and modeled time audible for INM 7.0b (All 4 Studies) and INM 6.2a (GCNP 2007 and ZION 2000): *All aircraft*

	All 4 Studies (INM7.0b)			GCNP 2007 and ZION 2000 only (INM 6.2a)		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average	49.9	38.5	33.2	45.6	39.5	35.3
Standard Deviation	16.3	13.9	14.3	16.9	16.5	16.9
Median	54.0	37.8	32.8	45.5	38.9	33.2

Table 23: Difference in measured and modeled time audible for INM 7.0b (All 4 Studies) and INM 6.2a (GCNP 2007 and ZION 2000): *Jet aircraft only*

	All 4 Studies (INM7.0b)			GCNP 2007 and ZION 2000 only (INM 6.2a)		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average	70.6	54.8	48.5	76.9	65.4	59.2
Standard Deviation	18.2	19.7	20.2	17.4	19.9	20.2
Median	73.7	50.0	43.3	82.4	70.2	63.4

Table 24: Difference in measured and modeled time audible for INM 7.0b (All 4 Studies) and INM 6.2a (GCNP 2007 and ZION 2000): *Fixed wing propeller aircraft only*

	All 4 Studies (INM7.0b)*			GCNP 2007 and ZION 2000 only (INM 6.2a)		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average	-8.2	-9.0	-10.0	-5.9	-12.9	-13.8
Standard Deviation	25.1	23.4	22.1	37.5	26.6	25.4
Median	-11.2	-11.2	-11.9	-6.3	-9.5	-10.2

Table 25: Difference in measured and modeled time audible for INM 7.0b (All 4 Studies) and INM 6.2a (GCNP 2007 and ZION 2000): *Helicopters only*

	All 4 Studies (INM7.0b)			**GCNP 2007 and ZION 2000 only (INM 6.2a)**		
	Difference in %TAUD (Modeled - Measured)			**Difference in %TAUD (Modeled - Measured)**		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average	19.5	16.1	14.4	7.4	7.1	6.4
Standard Deviation	32.6	26.2	23.5	12.9	12.7	12.4
Median	1.0	1.1	1.0	0.1	0.2	0.1

The combined results produced similar results to those from the individual studies in both INM 6.2a and INM 7.0b. When looking at results combined according to scenario, the analysis showed an improvement in the agreement between measured and modeled time audible results, when the proposed time compression algorithm is applied, except for the f*ixed wing air tour aircraft* (a median difference between the measured and modeled (with the proposed algorithm) time audible results of -11.9% for *fixed wing air tour aircraft*). This followed the same trend as seen for the individual studies (see Sections 3.2 and 4.1 through 4.4). Furthermore, it should be noted that the median difference between the measured and modeled (with the proposed algorithm) time audible results for the *all aircraft scenario* is 32.8% TAUD in INM 7.0b, which is slightly smaller than the differences seen in INM 6.2a of 33.2% TAUD. Otherwise, the results followed the same trends in both INM 6.2a and INM 7.0b, with the modeled *fixed wing air tour aircraft* and *helicopter* results more closely matching the measured results, than for the *all aircraft* and *high-altitude jet aircraft scenarios*.

Since several issues associated with the ZION 2000 study are identified (see Section 4.4 and Appendix E), the combined analysis is repeated for just GCNP 2007, LMNRA 2004 and GRSM 2006. Results for this analysis are presented in Appendix F. For all scenarios, the combined analysis without the ZION results showed a further improvement in the agreement between

* There were no fixed wing air tours flown in GRSM.

measured and modeled time audible results, when the proposed time compression algorithm is applied (on the order of a 2%-9% TAUD improvement to the average difference between measured and modeled with the proposed algorithm time audible results).

In addition, the overall time audible across all four studies are combined across all scenarios and analyzed. The combined results for GCNP 2007 and ZION 2000 studies run in INM 6.2a are presented in Table 26 and Figure 3, and the combined INM 7.0b results for GCNP 2007, LMNRA 2004, GRSM 2006 and ZION 2000 studies are presented in Table 26 and Figure 4.

Table 26: Difference in measured and modeled time audible for INM 7.0b (All 4 Studies) and INM 6.2a (GCNP 2007 and ZION 2000) – *All scenarios*

	All 4 Studies (INM7.0b)			GCNP 2007 and ZION 2000 only (INM 6.2a)		
	Difference in %TAUD (Modeled - Measured)			Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**	**None**	**Original**	**Proposed**
Average	33.5	25.5	21.8	29.0	23.2	20.3
Standard Deviation	37.7	31.7	29.6	38.4	34.4	32.4
Median	36.3	28.2	22.0	28.1	21.4	19.3

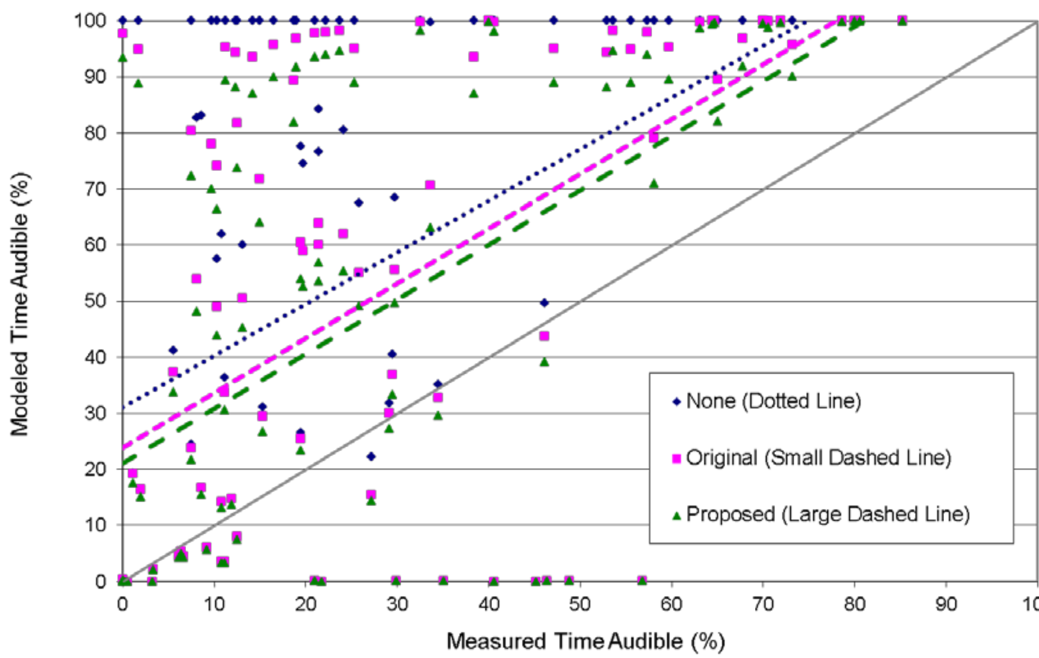

Figure 3: Comparison of measured and modeled time audible results with time compression for GCNP 2007 and ZION 2000 in INM 6.2a (with linear trendlines)

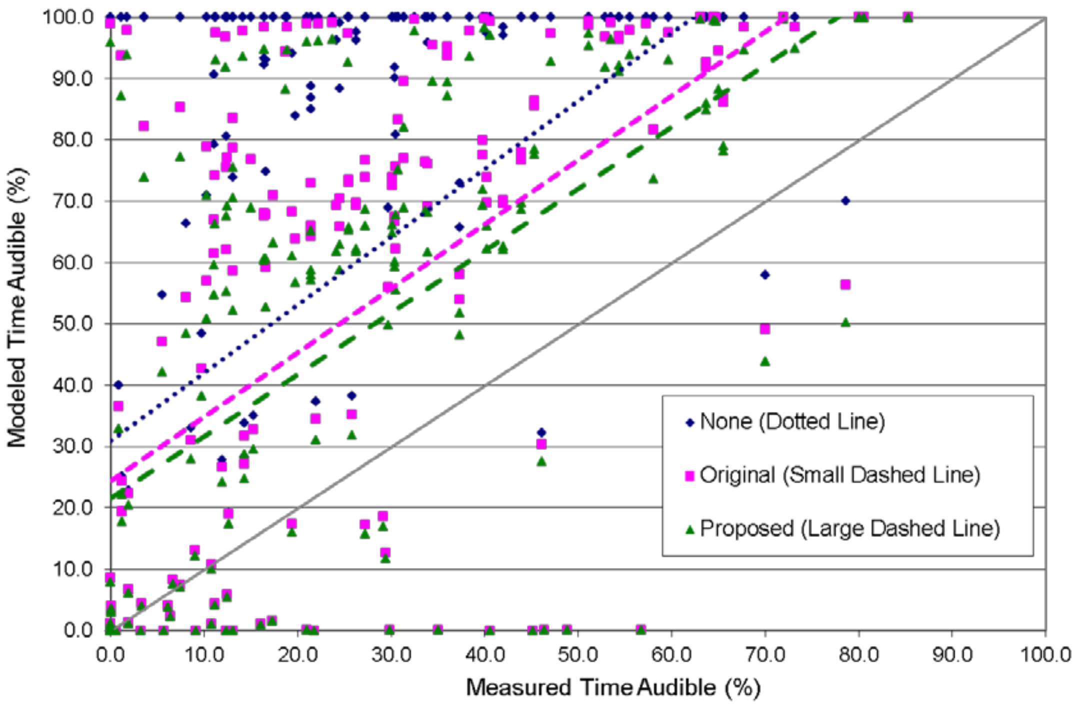

Figure 4: Comparison of measured and modeled time audible results with time compression for all four national parks studies in INM 7.0b (with linear trendlines)

The combined results across all studies and scenarios produced similar results to those from the individual studies and to those averaged across different scenarios in both INM 6.2a and INM 7.0b. Again, the agreement between measured and modeled time audible results improved, when the proposed time compression algorithm is applied. However, if is important to note two points when assessing the average data. First, the average difference between measured and modeled time audible results is still large, even when the proposed time compression algorithm is applied (a median difference between the measured and modeled with the proposed algorithm time audible results of 19.3% TAUD in INM 6.2a and 22.0% TAUD in INM 7.0b). Second, the standard deviation of the difference between measured and modeled time audible results across all the data is also large, even when the proposed time compression algorithm is applied (a standard deviation difference of 32.4% TAUD in INM 6.2a and 29.6% TAUD in INM 7.0b).

5.2 Influence of the Measurement Site Environment

Each of the measurement sites is reviewed; in order to determine if a measurement site bias may have led to poor agreement between the measured and modeled time audible data. This included

(a) a review of measurement site locations relative to the air tour flight tracks*; and (b) a review of the land cover at each of the sites. Of particular interest is if obscured line of sight to the aircraft at a forested site, or noise masking due to running water are adversely influences the measured time audible results. The air tour flight tracks are presented in Appendix C, and the measurement site descriptions are presented in Appendix D.

For GCNP 2007, three location points are identified as having significantly over-predicted modeled results when compared to measured data for the *fixed wing propeller* and *helicopter scenarios*; Dragon (G031), Hermit Trail/Dripping Springs (G055) and Hermit Rest Trailhead Parking (G058) (see Table 32 and Table 33 in Appendix B). When the sites and corresponding flight tracks are reviewed (see Figure 8 and Figure 9 in Appendix C), all three sites are found to be in close proximity of the flight tracks, where modeled flight track position and number of operations could have the largest effect. In addition, the measurement site locations are investigated further for all four scenarios, in order to determine if a measurement site environment is affecting the results (see Table 50 in Appendix D). A mix of forested and shrubland sites are modeled for GCNP 2007, and although not all of the forested sites resulted in poor correlation between measured and modeled time audible results, it should be noted that Dragon (G031), Hermit Trail/Dripping Springs (G055) and Hermit Rest Trailhead Parking (G058) are all forested sites in close proximity to the air tour flight tracks that resulted in a significant over-predicted modeled results when compared to measured data for the *fixed wing propeller* and *helicopter scenarios*.

For LMNRA 2004, relatively good agreement is seen between the measured and modeled time audible results for the *fixed wing propeller aircraft scenario* (see Table 36 in Appendix B). However, the *helicopter only scenario* had significantly over-predicted modeled results when compared to measured data for four location points; Bonelli Bay Landing (BONBAY), Boyscout Canyon (BOYSCT), Indian Pass (INDPASS) and Pinto Valley (PINTOV) (see Table 37 in Appendix B). All four of these location points are close to the flight tracks, as seen in Figure 11 for LMNRA 2004 in Appendix C. Although the measurement site locations are investigated further for all four scenarios (see Table 51 and Table 52 in Appendix D), almost all of the sites are shrubland sites, which made it difficult to determine if there is a connection between measurement site type and differences between measured and modeled time audible results..

Very good agreement is seen between the measured and modeled time audible results for the *helicopter scenario* for GRSM 2006 (see Table 40 in Appendix B). For this scenario, all of the measurement sites are located close to the flight tracks (see Figure 12 in Appendix C). Although the measurement site locations are investigated further for all four scenarios (see Table 51 and Table 52 in Appendix D), almost all of the sites are forested sites, which made it difficult to

* Flight tracks for high-altitude jet aircraft overflights were investigated for these studies, because they were so densely populated that all measurement sites were in close proximity to several overflight ground tracks. Therefore, only the results for fixed wing propeller aircraft and helicopter scenarios were included in this analysis.

determine if there is a connection between measurement site type and differences between measured and modeled time audible results.

Although most of the location points in ZION 2000 showed a large over-prediction of modeled time audible over measured time audible for the *all aircraft* and *high-altitude jet scenarios*, the *helicopter scenario* show good agreement between measured and modeled results, and the *fixed wing aircraft scenario* show a significant under-prediction across the board (see Table 43, Table 44, Table 47 and Table 48 in Appendix B). Unfortunately, the results for the *fixed wing aircraft* and *helicopter scenarios* are misleading, due to a significant difference between the number of aircraft events measured and modeled (see Section 5.3), so conclusions about the influence of measurement site locations relative to the air tour flight tracks could not be made. In addition, the measurement site locations are investigated further for all four scenarios in Table 53 in Appendix D); no direct connections between measurement site type and large difference between measured and modeled time audible results are observed. For all scenarios, the large differences between measured and modeled time audible are primarily related to poor correlation between the modeled study and measured data for ZION, and it is unclear given the information available as to whether this is a deficiency with the study, the measured data or both.

5.3 Influence of the Number of Operations Modeled

For each scenario in this analysis, both location point and detailed grid results are computed in INM 7.0b, in order to calculate the number of aircraft operations that contributed to the time audible results at that particular grid point. The number of aircraft events observed during that duration and the corresponding number of events modeled are presented in Appendix G.

Figure 5 illustrates the importance of representing the same number of events in the measured and modeled time audible data. As expected, the median difference between the measured and modeled (with the proposed algorithm) time audible results increased on average as the difference between the measured and modeled number of aircraft events[*]. Even though this relationship is slightly skewed by the ZION 2000 results, this trend is still apparent when the ZION results are included in or removed from the analysis. This difference is due in part to the fact that (a) the ETMS data from specific analysis days are combined with estimated air tour operations[†] for the modeled study, and (b) the measured time audible data were collected over a range of days.

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[*] The modeled number of aircraft events included aircraft operations that contributed to at least 0.1% TAUD to the cumulative results at the measurement site.

[†] While ETMS reliably captures the vast majority of airspace traffic, it has limitations. Due to limited radar coverage and incomplete messaging, ETMS may exclude certain flights that do not enter the en route airspace (some military operations) and other low-altitude flights (e.g., air tour operations). For many National Parks, detailed air tour route and schedule data have not been historically recorded. Thus, assumptions must be made in modeling these operations: (1) approximate air tour routes based on queries with local Flight Standards District Offices (FSDOs) and air tour operators, as well as observations during site visits and limited knowledge of points

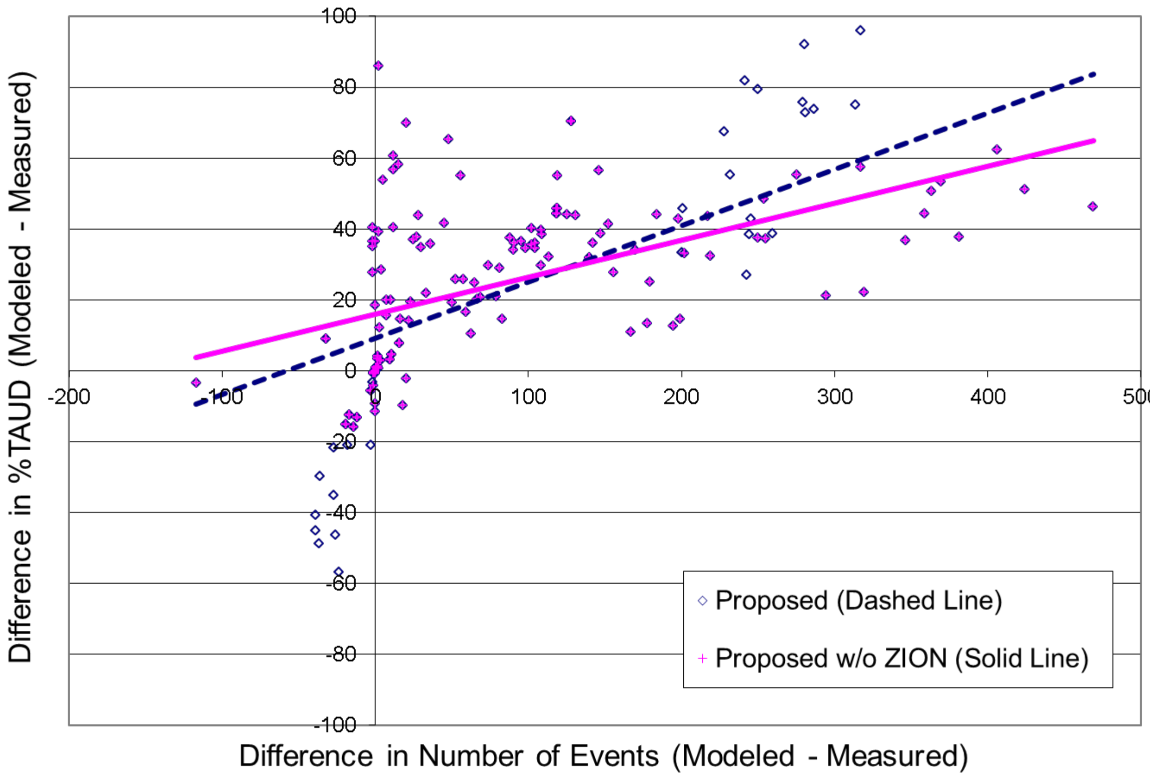

Figure 5: Change in difference in %TAUD with difference in number of events for all four national parks studies in INM 7.0b for the proposed time compression algorithm (with linear trendlines)

When the same data are sorted according to measurement type and plotted across all four National Parks studies (see Figure 6), the median difference between the measured and modeled (with the proposed algorithm) time audible results increased on average as the difference between the measured and modeled number of aircraft events at both the forest and shrubland measurement sites*. However, this increase is more significant for the forested measurement sites, indicating that the effects of line-of-sight blockage and absorption by the trees may have contributed to some extent to the differences between the number of events observed and modeled and the differences between the measured and modeled %TAUD results.

of interest; and (2) estimate the number of operations per “day” (for ATMPs, this is based on an average day of operations during the peak month (PMAD) of park visitation).

* While there were some measurements at sites on rock and near running water, there were not enough data points at those sites to make a meaningful comparison.

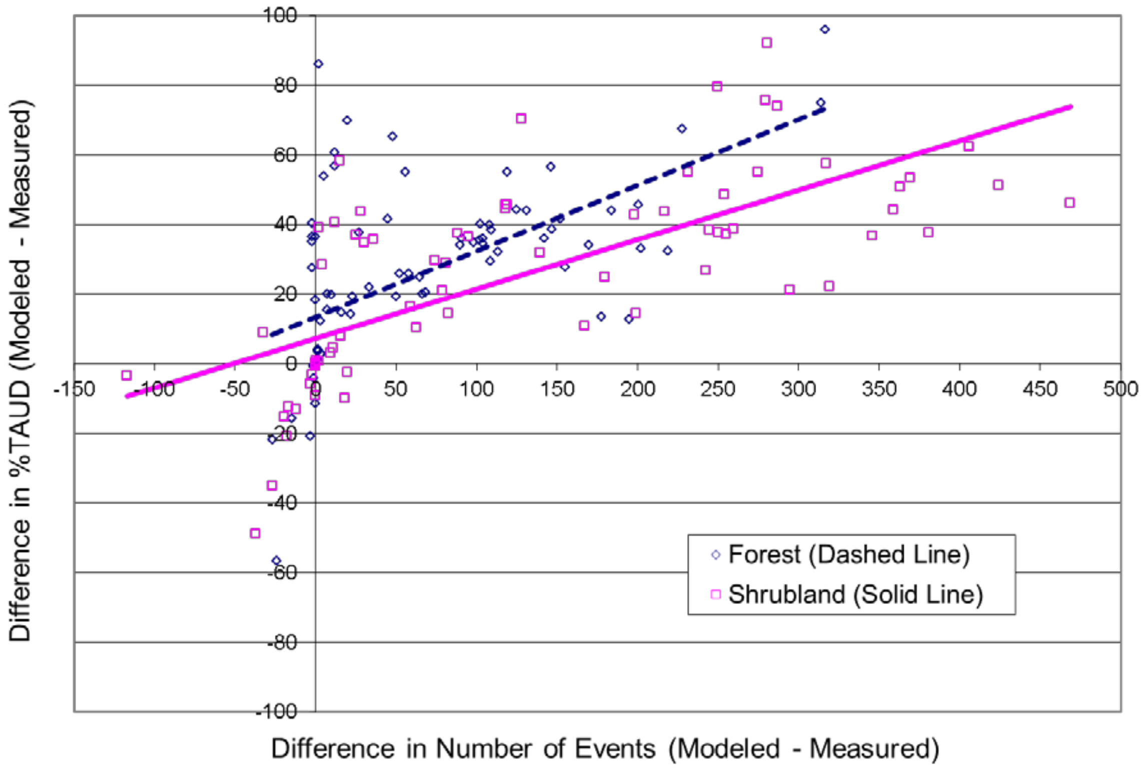

Figure 6: Change in difference in %TAUD with difference in number of events for all four national parks studies in INM 7.0b according to measurement site type for the proposed time compression algorithm (with linear trendlines)

5.4 Influence of Measurement Duration

The duration time audible measurements are also investigated, to determine its effect on the difference between the modeled and measured time audible results. The duration of each time audible measurement are presented in Appendix G. Figure 7 shows a decrease in the difference between the measured and modeled time audible results as measurement time increases[*]. This is expected, since the larger the sample size of measured time audible data is, the more representative it is of average daily aircraft operations.

[*] GCNP 2007 TAUD results were not included in this analysis, because they were computed off-site by using and observer logging process with audio recordings from each measurement site.

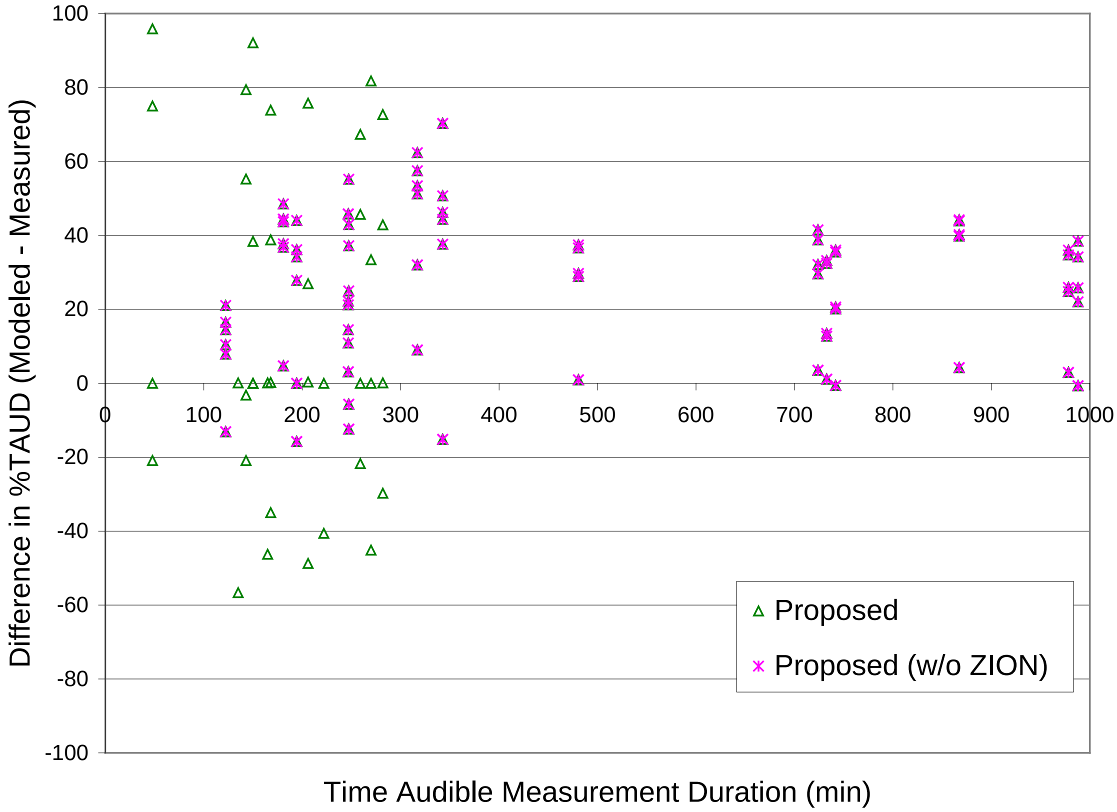

Figure 7: Change in difference in %TAUD with measurement duration for all four national parks studies in INM 7.0b for the proposed time compression algorithm

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6 ANALYSIS OF ISSUES

Upon further review of the four National Park analyses, several potential issues are identified that may have led to poor comparisons between measured and modeled data, and therefore may have led to poor performance of the proposed time compression algorithm. These issues are primarily related to the modeling of high-altitude jet aircraft over long distances, unidentified aircraft, measurement site effects, modeling assumptions, the INM software, and the time compression algorithms themselves. These issues are discussed below.

First, the measured and modeled results for high altitude jet aircraft showed relatively poor agreement, which adversely impacted the all aircraft results as well. These differences could be partially caused by the contributions from high-altitude jet aircraft at relatively large propagation distances (up to 40 miles from the receivers). It is unclear if these aircraft were actually audible during the field measurements, especially considering the large median differences observed between the measured and modeled (with the proposed algorithm) time audible results for jets (up to a median difference of 65% TAUD in GCNP 2007). These differences could be due in part to the lack of comprehensive high-altitude aircraft modeling capabilities in INM. While INM does allow users to model high-altitude jet aircraft, it does not include cruise-specific source noise data nor does it take into account the changes in meteorological effects over the course of those long propagation distances[9]. For these reasons, this research may directly benefit from further investigation into techniques for modeling high-altitude jet aircraft.

In addition, the use of the spectral cutoff calculator in INM is also investigated. The spectral cutoff calculator is an INM utility that takes the spectral class for each aircraft in an INM study and propagates it to the distance at which it becomes inaudible (dropping below the threshold of human hearing). These conservative, spectral class-specific distances are then used in INM to ensure that noise from aircraft segments at distances greater than the cutoff distance for that aircraft are not included in the noise computations. While the use of the spectral cutoff calculator does improve run-time, it had only a negligible impact on the modeled %TAUD results.

Second, it is sometimes noted by the field measurement team that the aircraft type of some audible events are difficult to discern due to variations in aircraft noise, and are inaudible in some cases. These variations in aircraft noise (both sound level and noise spectra) observed on the ground may be due to aircraft source noise and performance (variations in aircraft performance at different speeds and altitudes) and noise propagation effects (variations in propagation conditions, such as scattering due to wind, and attenuation due to varied atmospheric and ground conditions). Such effects can cause an aircraft's type to be misidentified, or even be dismissed as a non-aircraft even by the measurement team, both of which can result in the incorrect calculation of time audible for a measurement site (as discussed in Section 5.3). In a future analysis, it may be beneficial to model only the observer-logged events in INM and compare those to the results from this analysis, in order to better understand the full extent of this effect.

These issues are often compounded, when simultaneous aircraft events occur. First, the audibility from certain aircraft types may not be discernible from other, louder noise events and therefore are not noted in the measured data. This can be especially problematic for barely audible, high-altitude jet aircraft that are often masked by louder, low-flying air tour aircraft. For these reasons, there will always be some small level of discrepancy between measured and modeled results due to differences between the observed and modeled number of events. This issue may contribute to the poor performance of the time compression algorithm when compared against measured results.

Third, measurement site location is seen to have a small effect on the time audible results. This effect can be due to the proximity of a measurement site to the air tour tracks and the environment at a measurement site. As discussed in Section 5.2, many of the largest differences between measured and modeled time audible results occurred at measurement sites in close proximity to the air tour tracks. At these locations, the loudest portions of certain aircraft events not on the air tour tracks may be masked by other, louder aircraft events on the air tour tracks and therefore are not noted in the measured data (e.g., the onset and fadeout of a barely audible, high-altitude jet aircraft may not be noted in the measured time audible data because the loudest portion of that event is masked by a louder, low-flying air tour aircraft of a shorter duration).

The measurement site environment can also have an effect on the measured time audible results. Figure 6 in Section 5.2 showed that the difference between the measured and modeled %TAUD is on average larger for forested sites than it is for shrubland sites as the difference between the measured and modeled number of aircraft events increased. Although the measured ambient data is able to take into account the masking effects between different land cover environments in the spectral content of the ambient data used, the ability to model the effects of line-of-sight blockage and noise absorption by the trees are not in the current version of INM. If further analyses at additional National Parks confirm that the environment at forested sites impacts time audible results, then it may be worthwhile to explore the possibility of modeling noise adjustments due to measurement site environment (especially for forested zones) in AEDT.

Fourth, some of the modeling assumptions made in the development of the National Parks INM studies may have had an effect on the measured versus modeled time audible comparison. As mentioned in Section 5.3, the jet aircraft data are modeled from ETMS data from specific analysis days, which are then combined with estimated air tour operations for each Park-specific INM study. There will be a disconnect between the day-specific events and average air tour events – particularly for parks with very few air tours. Since some of the largest median differences between the measured and modeled (with the proposed algorithm) time audible results are seen in relative close proximity to air tour tracks, the lack of both detailed air tour route and schedule data make audibility comparisons especially difficult to evaluate. Any improvement to the accuracy of the modeled air tour tracks will directly impact the modeled noise levels at these locations.

Furthermore, the measured time audible data were collected over a range of days during limited time periods, which may not directly correspond to the daytime ETMS data modeled. To compound this difference, average ambient spectral data are used at each measurement site, as opposed to day-specific ambient data. To facilitate a better time audible analysis, future measured and modeled aircraft data sets (both ETMS and air tour) and ambient data should either all correspond to the same calendar days/time periods or all represent average data. The GCNP 1999 analysis tried to account for this by evaluating time audible on an hour-by-hour basis, and a similar approach might be beneficial for a future analysis, if the supporting data are available. In order to better understand the full extent of this effect, it may be beneficial to compare results from a day-specific analysis (with day-specific operations and ambient data) and an average analysis. If day-specific tour operation data are not available, it may also be beneficial to consider modeling dispersed tracks for the air tour operations, in order to better capture the potential day-to-day variation in aircraft position for the air tours.

Fifth, the preliminary GCNP 2007 study was run in INM 6.2a, and one of the primary recommendations was to continue the analysis in the most current version of INM (INM 7.0b), in order to determine if the enhancements in the INM 7 series would result in an improved performance of the proposed time compression algorithm. These improvements include database updates, improved helicopter modeling capabilities, and the capability to better account for lateral directivity of helicopters, an issue directly related to time-based modeling. Therefore, both GNCP 2007 and ZION 2000 are run in INM 6.2a and INM 7.0b, and their results are compared (see Sections 3.2, 4.1, 4.4 and 5.1), while LMNRA and GRSM are modeled solely in INM 7.0b. For the most part, both GCNP 2007 and ZION 2000 had similar results for the corresponding INM 6.2a and INM 7.0b studies (average difference between the measured and modeled with the proposed algorithm time audible results within 4% TAUD for the *all aircraft*, *fixed wing propeller* and *high-altitude jet aircraft scenarios*). The only exception is the *helicopter only scenario*, which showed a significant increase in the median difference between the measured and modeled (with the proposed algorithm) time audible results in INM 7.0b when compared to results from INM 6.2a (with the median difference between the measured and modeled with the proposed algorithm time audible results being 15.1% greater in INM 7.0b for GCNP 2007[*]). This difference helped to identify a software bug in INM 7.0b associated with helicopter speed on select flight track segments. Once this issue is resolved in a future version of INM or AEDT, the GCNP 2007 *helicopter scenario* should be remodeled, and the results in this report should be updated.

[*] The number of helicopter operations modeled in ZION 2000 was so small that no meaningful comparisons could be conducted.

Finally, this analysis showed that the proposed time compression algorithm could be used to accurately model time audible from simultaneously occurring aircraft events with mixed results. For most of the *fixed wing propeller aircraft scenarios*[*], the modeled time audible results are relatively similar to the measured time audible when the proposed time compression algorithm is used (the median difference between the measured and modeled with the proposed algorithm time audible results within 15% in most cases). It is unclear if the *helicopter scenarios* would show similar performance once the INM 7.0b issue mentioned earlier is resolved, but the current modeled results do not closely match the measured results. However, it is clear that time audible for the modeled *high-altitude jet* and *all aircraft scenarios* did not closely match the measured results. On average, the modeled TAUD results with the proposed time compression algorithm are 20% higher than measured results. While this difference is most likely due to many of the issues previously discussed in the section, it may be worthwhile to develop aircraft type specific time compression algorithms; in particular, a separate time compression algorithm for high-altitude jets. It may also be necessary to modify the time audible data collection procedure, in order to facilitate the data needed to develop additional time compression algorithms.

As an alternative to developing new time compression algorithms, the combined effect of the aforementioned issues could be addressed by calibrating the proposed time compression algorithm. While individually each of the aforementioned issues may contribute to a portion of the difference between the measured and modeled time audible results and may be resolved by individual measures (as mentioned above), the combination of these issues may still result in a bias between the measured and modeled results due to differences in number of events, aircraft type, measurement site environment, propagation distance, aircraft altitude, and other parameters. For future analyses, it may be beneficial to calibrate the proposed time compression algorithm for these study-specific, operation-specific and receiver-specific parameters, in order to improve the agreement between the measured and modeled time audible results and reduce some of the data scatter seen in this analysis. The development of such a calibration procedure for the proposed time compression algorithm would be a separate effort, and may require supplemental aircraft operation and noise measurements.

Even if revised or additional time compression algorithms are developed for INM and AEDT, it is important to note that these are just methods estimate noise due to simultaneous aircraft events in an integrated noise model, which does not have a scheduling capability to allow for modeling simultaneous aircraft events. In the future, it may be worthwhile to expand this analysis to explore the possibility of modeling flight schedules in AEDT.

[*] Excluding ZION 2000.

7 CONCLUSIONS

This study confirmed the trends observed in the preliminary analysis; primarily that the proposed time compression algorithm (a statistically based modeling algorithm used to account for noise from simultaneously occurring aircraft in AEDT/INM in the time audible results) outperformed the original time compression algorithm (an empirically based time compression algorithm derived from air tour data collected in Grand Canyon National Park) when compared to measured data. Furthermore, both time compression algorithms outperformed the baseline case of no time compression algorithm. This analysis also confirmed that similar performance is seen across a range of different National Parks studies and for various different aircraft types. While the analysis showed that the proposed time compression algorithm performed reasonably well for the fixed-wing aircraft, it did not perform well for helicopters, and high-altitude jet aircraft. In order to improve the agreement between the measured and modeled time audible results, several updates to the measurement and modeling processes are recommend, including the collection of additional measurement data, the possible development of a second time compression algorithm for modeling time audible from high-altitude jet aircraft, and the possible development of a calibration procedure for the proposed time compression algorithm.

In general, this analysis showed that it is very difficult to accurately account for variable, simultaneously occurring aircraft events in an integrated aircraft noise model. For the meantime, the proposed time compression algorithm offers an improvement in the INM results when compared to measured time audible data, but it is not the end solution. If further analyses at additional National Parks fail to fine tune the time compression algorithm in AEDT/INM (either the general algorithm or possible future aircraft specific algorithms), it may be worthwhile to explore the possibility of modeling flight schedules in AEDT.

Regardless of the noise modeling methods used, it can also be inferred from this analysis that the difference between the measured and modeled time audible results would improve as the modeled data more closely represents the measurement day aircraft operations. While this is a straight-forward observation, it is important to keep in mind when considering the verification and validation of the time audible and time compression algorithms in INM and AEDT.

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8 FUTURE WORK

The following tasks are recommended for future time compression analyses:

1. Since both the original and proposed algorithms consistently demonstrate an overprediction of modeled %TAUD values, alternative methods to account for simultaneous aircraft events in integrated noise models should be developed and validated (e.g., aircraft type-specific time compression algorithms, updated empirical time compression algorithm, time compression algorithm calibration, scheduling, etc.). If additional aircraft operation and noise measurements are necessary, they could be done in conjunction with currently planned ATMP measurements in order to best leverage those resources.

2. Reevaluate the time audible implementation in INM/AEDT. Single event and study-wide comparisons between measured and modeled data should be used to improve/validate TAUD.

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APPENDIX A: MEASURED AND MODELED TIME AUDIBLE FOR THE PRELIMINARY STUDY

A.1 GCNP 2007 in INM 6.2a

Table 27: Measured and modeled time audible for GCNP 2007 (INM 6.2a):
All aircraft

Site	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
			None	Original	Proposed	None	Original	Proposed
G010	Tuweep Valley	19.7	74.6	58.9	52.6	54.9	39.2	32.9
G015	Rainbow Plateau	32.5	100.0	99.7	98.3	67.5	67.2	65.8
G031	Dragon	80.0	100.0	100.0	99.9	20.0	20.0	19.9
G032	Zuni	40.6	100.0	99.7	98.1	59.4	59.1	57.5
G033	Fossil	33.6	99.8	70.7	63.1	66.2	37.1	29.5
G053	Tuweep Campground	21.4	76.7	60.0	53.5	55.3	38.6	32.1
G054	North Rim Basin	64.7	100.0	100.0	99.6	35.3	35.3	34.9
G055	Hermit Trail/Dripping Springs	80.6	100.0	100.0	99.9	19.4	19.4	19.3
G056	Papago Canyon	40.0	100.0	100.0	99.7	60.0	60.0	59.7
G057	Old Cape Solitude Trail	58.1	100.0	79.0	71.0	41.9	20.9	12.9
G058	Hermit Rest Trailhead Parking	85.3	100.0	100.0	99.9	14.7	14.7	14.6

Table 28: Measured and modeled time audible for GCNP 2007 (INM 6.2a):
Jet aircraft only

Site	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
			None	Original	Proposed	None	Original	Proposed
G010	Tuweep Valley	13.1	60.1	50.5	45.2	47.0	37.4	32.1
G015	Rainbow Plateau	24.2	80.5	62.0	55.3	56.3	37.8	31.1
G031	Dragon	10.3	100.0	74.2	66.4	89.7	63.9	56.1
G032	Zuni	15.0	100.0	71.8	64.1	85.0	56.8	49.1
G033	Fossil	21.4	84.3	63.9	56.9	62.9	42.5	35.5
G053	Tuweep Campground	10.3	57.6	49.0	43.8	47.3	38.7	33.5
G054	North Rim Basin	19.4	77.6	60.5	54.0	58.2	41.1	34.6
G055	Hermit Trail/Dripping Springs	12.5	100.0	81.8	73.7	87.5	69.3	61.2
G056	Papago Canyon	9.7	100.0	78.0	70.0	90.3	68.3	60.3
G057	Old Cape Solitude Trail	29.7	68.5	55.6	49.6	38.8	25.9	19.9
G058	Hermit Rest Trailhead Parking	7.5	100.0	80.4	72.3	92.5	72.9	64.8

Table 29: Measured and modeled time audible for GCNP 2007 (INM 6.2a):
Fixed wing propeller aircraft only

Site	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
			None	Original	Proposed	None	Original	Proposed
G010	Tuweep Valley	6.1	4.3	4.5	4.2	-1.8	-1.6	-1.9
G015	Rainbow Plateau	6.4	5.1	5.3	5.0	-1.3	-1.1	-1.4
G031	Dragon	5.6	41.2	37.4	33.7	35.6	31.8	28.1
G032	Zuni	15.3	31.1	29.5	26.7	15.8	14.2	11.4
G033	Fossil	9.2	5.7	6.0	5.6	-3.5	-3.2	-3.6
G053	Tuweep Campground	10.8	3.3	3.5	3.3	-7.5	-7.3	-7.5
G054	North Rim Basin	11.9	14.6	14.8	13.6	2.7	2.9	1.7
G055	Hermit Trail/Dripping Springs	8.6	83.1	16.7	15.4	74.5	8.1	6.8
G056	Papago Canyon	10.8	62.0	14.2	13.1	51.2	3.4	2.3
G057	Old Cape Solitude Trail	27.2	22.2	15.5	14.3	-5.0	-11.7	-12.9
G058	Hermit Rest Trailhead Parking	8.1	82.7	54.0	48.1	74.6	45.9	40.0

Table 30: Measured and modeled time audible for GCNP 2007 (INM 6.2a):
Helicopters only

Site	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
			None	Original	Proposed	None	Original	Proposed
G010	Tuweep Valley	0.6	0.0	0.0	0.0	-0.6	-0.6	-0.6
G015	Rainbow Plateau	1.1	19.4	19.2	17.6	18.3	18.1	16.5
G031	Dragon	64.4	100.0	100.0	99.3	35.6	35.6	34.9
G032	Zuni	11.1	36.4	33.7	30.5	25.3	22.6	19.4
G033	Fossil	3.3	2.1	2.2	2.0	-1.2	-1.1	-1.3
G053	Tuweep Campground	0.3	0.0	0.0	0.0	-0.3	-0.3	-0.3
G054	North Rim Basin	34.4	35.1	32.7	29.6	0.7	-1.7	-4.8
G055	Hermit Trail/Dripping Springs	63.1	100.0	99.8	98.6	36.9	36.7	35.5
G056	Papago Canyon	19.4	26.5	25.5	23.3	7.1	6.1	3.9
G057	Old Cape Solitude Trail	1.9	16.4	16.4	15.1	14.5	14.5	13.2
G058	Hermit Rest Trailhead Parking	71.9	100.0	100.0	99.6	28.1	28.1	27.7

APPENDIX B: MEASURED AND MODELED TIME AUDIBLE FOR THE FULL STUDY

B.1 GCNP 2007 in INM 7.0b

Table 31: Measured and modeled time audible for GCNP 2007 (INM 7.0b):
All aircraft

Site	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
			None	Original	Proposed	None	Original	Proposed
G010	Tuweep Valley	19.7	84.0	63.8	56.8	64.3	44.1	37.1
G015	Rainbow Plateau	32.5	100.0	99.6	97.8	67.5	67.1	65.3
G031	Dragon	80.0	100.0	100.0	99.9	20.0	20.0	19.9
G032	Zuni	40.6	100.0	99.3	97.1	59.4	58.7	56.5
G033	Fossil	33.6	100.0	76.4	68.4	66.4	42.8	34.8
G053	Tuweep Campground	21.4	85.0	64.2	57.2	63.6	42.8	35.8
G054	North Rim Basin	64.7	100.0	99.9	99.3	35.3	35.2	34.6
G055	Hermit Trail/Dripping Springs	80.6	100.0	100.0	99.9	19.4	19.4	19.3
G056	Papago Canyon	40.0	100.0	99.7	98.3	60.0	59.7	58.3
G057	Old Cape Solitude Trail	58.1	100.0	81.7	73.6	41.9	23.6	15.5
G058	Hermit Rest Trailhead Parking	85.3	100.0	100.0	99.9	14.7	14.7	14.6

Table 32: Measured and modeled time audible for GCNP 2007 (INM 7.0b):
Jet aircraft only

Site	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
			None	Original	Proposed	None	Original	Proposed
G010	Tuweep Valley	13.1	73.9	58.6	52.2	60.8	45.5	39.1
G015	Rainbow Plateau	24.2	96.3	69.3	61.8	72.1	45.1	37.6
G031	Dragon	10.3	100.0	78.9	70.9	89.7	68.6	60.6
G032	Zuni	15.0	100.0	76.9	68.9	85.0	61.9	53.9
G033	Fossil	21.4	100.0	73.0	65.2	78.6	51.6	43.8
G053	Tuweep Campground	10.3	71.0	57.0	50.8	60.7	46.7	40.5
G054	North Rim Basin	19.4	94.1	68.3	61.0	74.7	48.9	41.6
G055	Hermit Trail/Dripping Springs	12.5	100.0	77.1	69.2	87.5	64.6	56.7
G056	Papago Canyon	9.7	48.4	42.7	38.3	38.7	33.0	28.6
G057	Old Cape Solitude Trail	29.7	69.0	55.9	49.8	39.3	26.2	20.1
G058	Hermit Rest Trailhead Parking	7.5	100.0	85.3	77.3	92.5	77.8	69.8

Table 33: Measured and modeled time audible for GCNP 2007 (INM 7.0b):
Fixed wing propeller aircraft only

Site	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
			None	Original	Proposed	None	Original	Proposed
G010	Tuweep Valley	6.1	3.9	4.1	3.8	-2.2	-2.0	-2.3
G015	Rainbow Plateau	6.4	2.2	2.3	2.2	-4.2	-4.1	-4.2
G031	Dragon	5.6	54.8	47.1	42.1	49.2	41.5	36.5
G032	Zuni	15.3	35.1	32.7	29.5	19.8	17.4	14.2
G033	Fossil	9.2	0.0	0.0	0.0	-9.2	-9.2	-9.2
G053	Tuweep Campground	10.8	1.0	1.0	1.0	-9.8	-9.8	-9.8
G054	North Rim Basin	11.9	27.8	26.6	24.2	15.9	14.7	12.3
G055	Hermit Trail/Dripping Springs	8.6	33.0	31.0	28.0	24.4	22.4	19.4
G056	Papago Canyon	10.8	10.6	10.8	10.0	-0.2	0.0	-0.8
G057	Old Cape Solitude Trail	27.2	17.2	17.2	15.8	-10.0	-10.0	-11.4
G058	Hermit Rest Trailhead Parking	8.1	66.4	54.4	48.4	58.3	46.3	40.3

Table 34: Measured and modeled time audible for GCNP 2007 (INM 7.0b):
Helicopters only

Site	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
			None	Original	Proposed	None	Original	Proposed
G010	Tuweep Valley	0.6	0.0	0.0	0.0	-0.6	-0.6	-0.6
G015	Rainbow Plateau	1.1	100.0	93.7	87.2	98.9	92.6	86.1
G031	Dragon	64.4	100.0	100.0	99.5	35.6	35.6	35.1
G032	Zuni	11.1	100.0	74.1	66.2	88.9	63.0	55.1
G033	Fossil	3.3	4.1	4.3	4.0	0.8	1.0	0.7
G053	Tuweep Campground	0.3	0.0	0.0	0.0	-0.3	-0.3	-0.3
G054	North Rim Basin	34.4	100.0	95.5	89.6	65.6	61.1	55.2
G055	Hermit Trail/Dripping Springs	63.1	100.0	100.0	99.6	36.9	36.9	36.5
G056	Papago Canyon	19.4	17.4	17.4	16.0	-2.0	-2.0	-3.4
G057	Old Cape Solitude Trail	1.9	22.8	22.3	20.4	20.9	20.4	18.5
G058	Hermit Rest Trailhead Parking	71.9	100.0	100.0	99.6	28.1	28.1	27.7

B.2 LMNRA 2004 in INM 7.0b

Table 35: Measured and modeled time audible for LMNRA 2004 (INM 7.0b): ***All aircraft***

Date Modeled	Site (INM ID)	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
				None	Original	Proposed	None	Original	Proposed
05/14/2004	L03 (BONBAY)	Bonelli Bay Landing	54.4	100.0	97	92.1	45.6	42.6	37.7
	L05 (BOYSCT)	Boyscout Canyon	36.0	100.0	95.2	89.4	64.0	59.2	53.4
	L04 (GRDWSH)	Grand Wash Bay	*no data*	100.0	99.9	99.3	*N/A*	*N/A*	*N/A*
	L07 (INDPAS)	Indian Pass	63.7	100.0	92.7	85.9	36.3	29.0	22.2
	L08 (KATHLD)	Katherine Landing	14.3	28.4	27.1	24.7	14.1	12.8	10.4
	L01 (LIMECV)	Lime Cove	30.5	100.0	75.7	67.7	69.5	45.2	37.2
	L02 (PINTOV)	Pinto Valley	51.1	100.0	99.4	97.3	48.9	48.3	46.2
	L06 (SHIVWT)	Shivwits Plateau	33.9	100.0	76	68.1	66.1	42.1	34.2
05/15/2004	L03 (BONBAY)	Bonelli Bay Landing	54.4	100.0	96.4	91.2	45.6	42.0	36.8
	L05 (BOYSCT)	Boyscout Canyon	36.0	100.0	93.7	87.2	64.0	57.7	51.2
	L04 (GRDWSH)	Grand Wash Bay	*no data*	100.0	99.9	99.2	*N/A*	*N/A*	*N/A*
	L07 (INDPAS)	Indian Pass	63.7	100.0	91.9	84.9	36.3	28.2	21.2
	L08 (KATHLD)	Katherine Landing	14.3	33.9	31.7	28.8	19.6	17.4	14.5
	L01 (LIMECV)	Lime Cove	30.5	80.9	62.2	55.5	50.4	31.7	25.0
	L02 (PINTOV)	Pinto Valley	51.1	100.0	98.7	95.4	48.9	47.6	44.3
	L06 (SHIVWT)	Shivwits Plateau	33.9	95.9	69.1	61.7	62.0	35.2	27.8

Table 36: Measured and modeled time audible for LMNRA 2004 (INM 7.0b): ***Jet aircraft only***

Date Modeled	Site (INM ID)	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
				None	Original	Proposed	None	Original	Proposed
05/14/2004	L03 (BONBAY)	Bonelli Bay Landing	11.1	90.7	66.9	59.6	79.6	55.8	48.5
	L05 (BOYSCT)	Boyscout Canyon	13.1	100.0	83.6	75.5	86.9	70.5	62.4
	L04 (GRDWSH)	Grand Wash Bay	*no data*	83.9	63.7	56.8	*N/A*	*N/A*	*N/A*
	L07 (INDPAS)	Indian Pass	37.3	72.9	58.1	51.8	35.6	20.8	14.5
	L08 (KATHLD)	Katherine Landing	1.2	19.5	19.3	17.7	18.3	18.1	16.5
	L01 (LIMECV)	Lime Cove	12.4	100.0	75.5	67.6	87.6	63.1	55.2
	L02 (PINTOV)	Pinto Valley	31.4	100.0	89.6	82.1	68.6	58.2	50.7
	L06 (SHIVWT)	Shivwits Plateau	16.6	93.1	67.9	60.6	76.5	51.3	44.0
05/15/2004	L03 (BONBAY)	Bonelli Bay Landing	11.1	79.3	61.4	54.8	68.2	50.3	43.7
	L05 (BOYSCT)	Boyscout Canyon	13.1	100.0	78.7	70.6	86.9	65.6	57.5
	L04 (GRDWSH)	Grand Wash Bay	*no data*	70.5	56.7	50.6	*N/A*	*N/A*	*N/A*
	L07 (INDPAS)	Indian Pass	37.3	65.7	53.9	48.2	28.4	16.6	10.9
	L08 (KATHLD)	Katherine Landing	1.2	25.1	24.3	22.2	23.9	23.1	21.0
	L01 (LIMECV)	Lime Cove	12.4	80.6	62.1	55.3	68.2	49.7	42.9
	L02 (PINTOV)	Pinto Valley	31.4	100.0	77	69	68.6	45.6	37.6
	L06 (SHIVWT)	Shivwits Plateau	16.6	74.8	59.1	52.7	58.2	42.5	36.1

Table 37: Measured and modeled time audible for LMNRA 2004 (INM 7.0b):
Fixed wing propeller aircraft only

Date Modeled	Site (INM ID)	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
				None	Original	Proposed	None	Original	Proposed
05/14/2004	L03 (BONBAY)	Bonelli Bay Landing	12.6	19.1	18.9	17.3	6.5	6.3	4.7
	L05 (BOYSCT)	Boyscout Canyon	22.0	37.3	34.5	31	15.3	12.5	9.0
	L04 (GRDWSH)	Grand Wash Bay	*no data*	34.1	31.9	28.7	*N/A*	*N/A*	*N/A*
	L07 (INDPAS)	Indian Pass	9.0	12.9	13.1	12.1	3.9	4.1	3.1
	L08 (KATHLD)	Katherine Landing	13.1	0.0	0	0	-13.1	-13.1	-13.1
	L01 (LIMECV)	Lime Cove	12.4	0.0	0	0	-12.4	-12.4	-12.4
	L02 (PINTOV)	Pinto Valley	16.1	0.9	1	0.9	-15.2	-15.1	-15.2
	L06 (SHIVWT)	Shivwits Plateau	17.3	1.5	1.6	1.5	-15.8	-15.7	-15.8
05/15/2004	L03 (BONBAY)	Bonelli Bay Landing	12.6	19.1	18.9	17.3	6.5	6.3	4.7
	L05 (BOYSCT)	Boyscout Canyon	22.0	37.3	34.5	31	15.3	12.5	9.0
	L04 (GRDWSH)	Grand Wash Bay	*no data*	34.1	31.9	28.7	*N/A*	*N/A*	*N/A*
	L07 (INDPAS)	Indian Pass	9.0	12.9	13.1	12.1	3.9	4.1	3.1
	L08 (KATHLD)	Katherine Landing	13.1	0.0	0	0	-13.1	-13.1	-13.1
	L01 (LIMECV)	Lime Cove	12.4	0.0	0	0	-12.4	-12.4	-12.4
	L02 (PINTOV)	Pinto Valley	16.1	0.9	1	0.9	-15.2	-15.1	-15.2
	L06 (SHIVWT)	Shivwits Plateau	17.3	1.5	1.6	1.5	-15.8	-15.7	-15.8

Table 38: Measured and modeled time audible for LMNRA 2004 (INM 7.0b):
Helicopters only

Date Modeled	Site (INM ID)	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
				None	Original	Proposed	None	Original	Proposed
05/14/2004	L03 (BONBAY)	Bonelli Bay Landing	30.7	100.0	83.3	75.1	69.3	52.6	44.4
	L05 (BOYSCT)	Boyscout Canyon	0.9	40.0	36.5	32.9	39.1	35.6	32.0
	L04 (GRDWSH)	Grand Wash Bay	*no data*	100.0	98.2	93.9	*N/A*	*N/A*	*N/A*
	L07 (INDPAS)	Indian Pass	17.4	100.0	71	63.2	82.6	53.6	45.8
	L08 (KATHLD)	Katherine Landing	0.0	8.2	8.5	7.9	8.2	8.5	7.9
	L01 (LIMECV)	Lime Cove	5.7	0.0	0	0	-5.7	-5.7	-5.7
	L02 (PINTOV)	Pinto Valley	3.6	100.0	82.2	73.9	96.4	78.6	70.3
	L06 (SHIVWT)	Shivwits Plateau	0.0	0.0	0	0	0.0	0.0	0.0
05/15/2004	L03 (BONBAY)	Bonelli Bay Landing	30.7	100.0	83.3	75.1	69.3	52.6	44.4
	L05 (BOYSCT)	Boyscout Canyon	0.9	40.0	36.5	32.9	39.1	35.6	32.0
	L04 (GRDWSH)	Grand Wash Bay	*no data*	100.0	98.2	93.9	*N/A*	*N/A*	*N/A*
	L07 (INDPAS)	Indian Pass	17.4	100.0	71	63.2	82.6	53.6	45.8
	L08 (KATHLD)	Katherine Landing	0.0	8.2	8.5	7.9	8.2	8.5	7.9
	L01 (LIMECV)	Lime Cove	5.7	0.0	0	0	-5.7	-5.7	-5.7
	L02 (PINTOV)	Pinto Valley	3.6	100.0	82.2	73.9	96.4	78.6	70.3
	L06 (SHIVWT)	Shivwits Plateau	0.0	0.0	0	0	0.0	0.0	0.0

B.3 GRSM 2006 in INM 7.0b

Table 39: Measured and modeled time audible for GRSM 2006 (INM 7.0b): *All aircraft*

Date Modeled	Site (INM ID)	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
				None	Original	Proposed	None	Original	Proposed
06/07/2006	GR5 (BULLHD)	Bull Head Trail	25.5	100.0	73.5	65.7	74.5	48.0	40.2
	GR6 (CADES)	Cades Cove	30.4	91.9	67.4	60.1	61.5	37.0	29.7
	GR1 (MTCOLL)	Mt. Collins	39.8	100.0	79.9	71.9	60.2	40.1	32.1
	GR7 (NOLAND)	Noland Divide	40.2	100.0	73.9	66.0	59.8	33.7	25.8
	GR2 (PARSON)	Parson Brach	65.5	100.0	86.9	79.0	34.5	21.4	13.5
	GR3 (PORTER)	Porters Flat	43.9	100.0	77.9	69.8	56.1	34.0	25.9
	GR4 (PURCHS)	Purchase Knob	42.0	98.4	70.1	62.6	56.4	28.1	20.6
06/13/2006	GR5 (BULLHD)	Bull Head Trail	25.5	100.0	73.1	65.3	74.5	47.6	39.8
	GR6 (CADES)	Cades Cove	30.4	90.1	66.6	59.3	59.7	36.2	28.9
	GR1 (MTCOLL)	Mt. Collins	39.8	100.0	77.5	69.4	60.2	37.7	29.6
	GR7 (NOLAND)	Noland Divide	40.2	97.4	69.7	62.2	57.2	29.5	22.0
	GR2 (PARSON)	Parson Brach	65.5	100.0	86.1	78.2	34.5	20.6	12.7
	GR3 (PORTER)	Porters Flat	43.9	100.0	76.7	68.7	56.1	32.8	24.8
	GR4 (PURCHS)	Purchase Knob	42.0	97.1	69.6	62.1	55.1	27.6	20.1

Table 40: Measured and modeled time audible for GRSM 2006 (INM 7.0b): *Jet aircraft only*

Date Modeled	Site (INM ID)	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
				None	Original	None	Original	None	Original
06/07/2006	GR5 (BULLHD)	Bull Head Trail	16.4	93.3	68.0	60.6	76.9	51.6	44.2
	GR6 (CADES)	Cades Cove	21.4	88.8	66.0	58.8	67.4	44.6	37.4
	GR1 (MTCOLL)	Mt. Collins	27.2	100.0	76.7	68.7	72.8	49.5	41.5
	GR7 (NOLAND)	Noland Divide	24.5	99.1	70.4	62.9	74.6	45.9	38.4
	GR2 (PARSON)	Parson Brach	45.3	100.0	86.4	78.5	54.7	41.1	33.2
	GR3 (PORTER)	Porters Flat	30.1	100.0	73.9	66.1	69.9	43.8	36.0
	GR4 (PURCHS)	Purchase Knob	26.3	97.6	69.8	62.3	71.3	43.5	36.0
06/13/2006	GR5 (BULLHD)	Bull Head Trail	16.4	92.3	67.6	60.3	75.9	51.2	43.9
	GR6 (CADES)	Cades Cove	21.4	86.9	65.1	58.0	65.5	43.7	36.6
	GR1 (MTCOLL)	Mt. Collins	27.2	100.0	73.9	66.0	72.8	46.7	38.8
	GR7 (NOLAND)	Noland Divide	24.5	88.4	65.8	58.7	63.9	41.3	34.2
	GR2 (PARSON)	Parson Brach	45.3	100.0	85.6	77.7	54.7	40.3	32.4
	GR3 (PORTER)	Porters Flat	30.1	100.0	72.5	64.8	69.9	42.4	34.7
	GR4 (PURCHS)	Purchase Knob	26.3	96.3	69.3	61.8	70.0	43.0	35.5

Table 41: Measured and modeled time audible for GRSM 2006 (INM 7.0b): *Helicopters only*

Date Modeled	Site (INM ID)	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
				None	Original	Proposed	None	Original	Proposed
06/07/2006	GR5 (BULLHD)	Bull Head Trail	1.9	6.3	6.6	6.1	4.4	4.7	4.2
	GR6 (CADES)	Cades Cove	0.0	0.9	1.0	0.9	0.9	1.0	0.9
	GR1 (MTCOLL)	Mt. Collins	0.1	3.7	3.9	3.6	3.6	3.8	3.5
	GR7 (NOLAND)	Noland Divide	1.9	1.2	1.3	1.2	-0.7	-0.6	-0.7
	GR2 (PARSON)	Parson Brach	0.0	1.1	1.2	1.1	1.1	1.2	1.1
	GR3 (PORTER)	Porters Flat	0.1	3.1	3.3	3.0	3.0	3.2	2.9
	GR4 (PURCHS)	Purchase Knob	0.6	0.0	0.0	0.0	-0.6	-0.6	-0.6
06/13/2006	GR5 (BULLHD)	Bull Head Trail	1.9	6.3	6.6	6.1	4.4	4.7	4.2
	GR6 (CADES)	Cades Cove	0.0	0.9	1.0	0.9	0.9	1.0	0.9
	GR1 (MTCOLL)	Mt. Collins	0.1	3.7	3.9	3.6	3.6	3.8	3.5
	GR7 (NOLAND)	Noland Divide	1.9	1.2	1.3	1.2	-0.7	-0.6	-0.7
	GR2 (PARSON)	Parson Brach	0.0	1.1	1.2	1.1	1.1	1.2	1.1
	GR3 (PORTER)	Porters Flat	0.1	3.1	3.3	3.0	3.0	3.2	2.9
	GR4 (PURCHS)	Purchase Knob	0.6	0.0	0.0	0.0	-0.6	-0.6	-0.6

B.4 ZION 2000 in INM 7.0b

Table 42: Measured and modeled time audible for ZION 2000 (INM 7.0b): *All aircraft*

Site	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
			None	Original	Proposed	None	Original	Proposed
CHINLE	Chinle Trail	67.75	100.0	98.4	94.7	32.3	30.7	27.0
CRZQLT	Crazy Quilt Mesa	53.54	100.0	99.1	96.4	46.5	45.6	42.9
EASTRM	East Rim Trail	57.30	100.0	99.0	96.1	42.7	41.7	38.8
HOPVAL	Hop Valley trail	55.50	100.0	97.9	93.9	44.5	42.4	38.4
KOLOBC	Kolob Finger Canyons	21.01	100	98.9	96.0	79.0	77.9	75.0
LAVAPT	Lava Point Overlook	*no data*	100.0	97.5	93.0	*N/A*	*N/A*	*N/A*
LCREEK	Kolob Terrace Road	38.38	100.0	97.8	93.6	61.6	59.4	55.2
LFRKTD	Tabernacle Dome	47.09	100.0	97.3	92.8	52.9	50.2	45.7
NCREEK	North Creek River	59.66	100.0	97.5	93.1	40.3	37.8	33.4
PRWEAP	Parunuweap Canyon	52.91	100	96.8	91.8	47.1	43.9	38.9
SCOUTS	Scouts Lookout	65.03	100.0	94.5	88.3	35.0	29.5	23.3
WILDCT	Wildcat Canyon Trail	73.21	100.0	98.4	94.9	26.8	25.2	21.7
ZHQ	Zion Park Headquarters	*no data*	100.0	88.2	80.5	*N/A*	*N/A*	*N/A*

Table 43: Measured and modeled time audible for ZION 2000 (INM 7.0b): *Jet aircraft only*

Site	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
			None	Original	Proposed	None	Original	Proposed
CHINLE	Chinle Trail	18.92	100.0	98.4	94.7	81.1	79.5	75.8
CRZQLT	Crazy Quilt Mesa	23.68	100.0	99.1	96.4	76.3	75.4	72.7
EASTRM	East Rim Trail	22.22	100.0	99.0	96.1	77.8	76.8	73.9
HOPVAL	Hop Valley trail	1.73	100.0	97.9	93.8	98.3	96.2	92.1
KOLOBC	Kolob Finger Canyons	0.00	100	98.9	95.9	100.0	98.9	95.9
LAVAPT	Lava Point Overlook	*no data*	100.0	97.5	93.0	*N/A*	*N/A*	*N/A*
LCREEK	Kolob Terrace Road	14.16	100.0	97.8	93.6	85.8	83.6	79.4
LFRKTD	Tabernacle Dome	25.35	100.0	97.3	92.7	74.7	72.0	67.4
NCREEK	North Creek River	11.22	100.0	97.5	93.0	88.8	86.3	81.8
PRWEAP	Parunuweap Canyon	12.29	100	96.8	91.8	87.7	84.5	79.5
SCOUTS	Scouts Lookout	18.67	100.0	94.4	88.2	81.3	75.7	69.5
WILDCT	Wildcat Canyon Trail	16.45	100.0	98.4	94.8	83.6	82.0	78.4
ZHQ	Zion Park Headquarters	*no data*	100.0	88.1	80.4	*N/A*	*N/A*	*N/A*

Table 44: Measured and modeled time audible for ZION 2000 (INM 7.0b):
Fixed wing propeller aircraft only

Site	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
			None	Original	Proposed	None	Original	Proposed
CHINLE	Chinle Trail	48.83	0.1	0.1	0.1	-48.7	-48.7	-48.7
CRZQLT	Crazy Quilt Mesa	29.86	0.1	0.1	0.1	-29.8	-29.8	-29.8
EASTRM	East Rim Trail	35.09	0.1	0.1	0.1	-35.0	-35.0	-35.0
HOPVAL	Hop Valley trail	0.00	0.0	0.0	0.0	0.0	0.0	0.0
KOLOBC	Kolob Finger Canyons	21.01	0.1	0.1	0.1	-20.9	-20.9	-20.9
LAVAPT	Lava Point Overlook	*no data*	0.0	0.1	0.0	*N/A*	*N/A*	*N/A*
LCREEK	Kolob Terrace Road	20.99	0.1	0.1	0.1	-20.9	-20.9	-20.9
LFRKTD	Tabernacle Dome	21.75	0.0	0.0	0.0	-21.7	-21.7	-21.7
NCREEK	North Creek River	45.16	0.0	0.0	0.0	-45.2	-45.2	-45.2
PRWEAP	Parunuweap Canyon	40.62	0	0	0.0	-40.6	-40.6	-40.6
SCOUTS	Scouts Lookout	46.36	0.1	0.1	0.1	-46.3	-46.3	-46.3
WILDCT	Wildcat Canyon Trail	56.76	0.1	0.1	0.1	-56.7	-56.7	-56.7
ZHQ	Zion Park Headquarters	*no data*	0.1	0.1	0.1	*N/A*	*N/A*	*N/A*

Table 45: Measured and modeled time audible for ZION 2000 (INM 7.0b):
Helicopters only

Site	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
			None	Original	Proposed	None	Original	Proposed
CHINLE	Chinle Trail	0.00	0.4	0.4	0.3	0.4	0.4	0.3
CRZQLT	Crazy Quilt Mesa	0.00	0.1	0.2	0.1	0.1	0.2	0.1
EASTRM	East Rim Trail	0.00	0.2	0.3	0.2	0.2	0.3	0.2
HOPVAL	Hop Valley trail	0.00	0.0	0.0	0.0	0.0	0.0	0.0
KOLOBC	Kolob Finger Canyons	0.00	0	0	0.0	0.0	0.0	0.0
LAVAPT	Lava Point Overlook	*no data*	0.0	0.0	0.0	*N/A*	*N/A*	*N/A*
LCREEK	Kolob Terrace Road	3.23	0.0	0.0	0.0	-3.2	-3.2	-3.2
LFRKTD	Tabernacle Dome	0.00	0.0	0.0	0.0	0.0	0.0	0.0
NCREEK	North Creek River	0.00	0.0	0.0	0.0	0.0	0.0	0.0
PRWEAP	Parunuweap Canyon	0.00	0	0	0.0	0.0	0.0	0.0
SCOUTS	Scouts Lookout	0.00	0.1	0.2	0.1	0.1	0.2	0.1
WILDCT	Wildcat Canyon Trail	0.00	0.1	0.2	0.1	0.1	0.2	0.1
ZHQ	Zion Park Headquarters	*no data*	0.1	0.2	0.1	*N/A*	*N/A*	*N/A*

B.5 ZION 2000 in INM 6.2a

Table 46: Measured and modeled time audible for ZION 2000 (INM 6.2a): *All aircraft*

Site	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
			None	Original	Proposed	None	Original	Proposed
CHINLE	Chinle Trail	67.75	100.0	96.8	91.9	32.3	29.1	24.2
CRZQLT	Crazy Quilt Mesa	53.54	100.0	98.3	94.7	46.5	44.8	41.2
EASTRM	East Rim Trail	57.30	100.0	98.0	94.0	42.7	40.7	36.7
HOPVAL	Hop Valley trail	55.50	100.0	94.9	89.0	44.5	39.4	33.5
KOLOBC	Kolob Finger Canyons	21.01	100.0	97.8	93.6	79.0	76.8	72.6
LAVAPT	Lava Point Overlook	*no data*	100.0	93.5	87.0	*N/A*	*N/A*	*N/A*
LCREEK	Kolob Terrace Road	38.38	100.0	93.6	87.1	61.6	55.2	48.7
LFRKTD	Tabernacle Dome	47.09	100.0	95.0	89.0	52.9	47.9	41.9
NCREEK	North Creek River	59.66	100.0	95.3	89.5	40.3	35.6	29.8
PRWEAP	Parunuweap Canyon	52.91	100.0	94.4	88.2	47.1	41.5	35.3
SCOUTS	Scouts Lookout	65.03	100.0	89.5	82.0	35.0	24.5	17.0
WILDCT	Wildcat Canyon Trail	73.21	100.0	95.7	90.1	26.8	22.5	16.9
ZHQ	Zion Park Headquarters	*no data*	100.0	82.6	74.6	*N/A*	*N/A*	*N/A*

Table 47: Measured and modeled time audible for ZION 2000 (INM 6.2a): *Jet aircraft only*

Site	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
			None	Original	Proposed	None	Original	Proposed
CHINLE	Chinle Trail	18.92	100.0	96.8	91.8	81.1	77.9	72.9
CRZQLT	Crazy Quilt Mesa	23.68	100.0	98.3	94.6	76.3	74.6	70.9
EASTRM	East Rim Trail	22.22	100.0	98.0	93.9	77.8	75.8	71.7
HOPVAL	Hop Valley trail	1.73	100.0	94.9	88.9	98.3	93.2	87.2
KOLOBC	Kolob Finger Canyons	0.00	100.0	97.7	93.4	100.0	97.7	93.4
LAVAPT	Lava Point Overlook	*no data*	100.0	93.5	87.0	*N/A*	*N/A*	*N/A*
LCREEK	Kolob Terrace Road	14.16	100.0	93.6	87.1	85.8	79.4	72.9
LFRKTD	Tabernacle Dome	25.35	100.0	95.0	89.0	74.7	69.7	63.7
NCREEK	North Creek River	11.22	100.0	95.3	89.4	88.8	84.1	78.2
PRWEAP	Parunuweap Canyon	12.29	100.0	94.4	88.2	87.7	82.1	75.9
SCOUTS	Scouts Lookout	18.67	100.0	89.4	81.9	81.3	70.7	63.2
WILDCT	Wildcat Canyon Trail	16.45	100.0	95.7	90.0	83.6	79.3	73.6
ZHQ	Zion Park Headquarters	*no data*	100.0	82.6	74.5	*N/A*	*N/A*	*N/A*

Table 48: Measured and modeled time audible for ZION 2000 (INM 6.2a):
Fixed wing propeller aircraft only

Site	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
			None	Original	Proposed	None	Original	Proposed
CHINLE	Chinle Trail	48.83	0.1	0.1	0.1	-48.7	-48.7	-48.7
CRZQLT	Crazy Quilt Mesa	29.86	0.1	0.1	0.1	-29.8	-29.8	-29.8
EASTRM	East Rim Trail	35.09	0.1	0.1	0.1	-35.0	-35.0	-35.0
HOPVAL	Hop Valley trail	0.00	0.0	0.0	0.0	0.0	0.0	0.0
KOLOBC	Kolob Finger Canyons	21.01	0.1	0.1	0.1	-20.9	-20.9	-20.9
LAVAPT	Lava Point Overlook	*no data*	0.0	0.1	0.0	*N/A*	*N/A*	*N/A*
LCREEK	Kolob Terrace Road	20.99	0.1	0.1	0.1	-20.9	-20.9	-20.9
LFRKTD	Tabernacle Dome	21.75	0.0	0.0	0.0	-21.7	-21.7	-21.7
NCREEK	North Creek River	45.16	0.0	0.0	0.0	-45.2	-45.2	-45.2
PRWEAP	Parunuweap Canyon	40.62	0.0	0.0	0.0	-40.6	-40.6	-40.6
SCOUTS	Scouts Lookout	46.36	0.1	0.1	0.1	-46.3	-46.3	-46.3
WILDCT	Wildcat Canyon Trail	56.76	0.1	0.1	0.1	-56.7	-56.7	-56.7
ZHQ	Zion Park Headquarters	*no data*	0.1	0.1	0.1	*N/A*	*N/A*	*N/A*

Table 49: Measured and modeled time audible for ZION 2000 (INM 6.2a):
Helicopters only

Site	Site Name	Measured %TAUD	Modeled %TAUD			Difference in %TAUD (Modeled - Measured)		
			None	Original	Proposed	None	Original	Proposed
CHINLE	Chinle Trail	0.00	0.4	0.4	0.3	0.4	0.4	0.3
CRZQLT	Crazy Quilt Mesa	0.00	0.1	0.2	0.1	0.1	0.2	0.1
EASTRM	East Rim Trail	0.00	0.2	0.2	0.2	0.2	0.2	0.2
HOPVAL	Hop Valley trail	0.00	0.0	0.0	0.0	0.0	0.0	0.0
KOLOBC	Kolob Finger Canyons	0.00	0.1	0.1	0.1	0.1	0.1	0.1
LAVAPT	Lava Point Overlook	*no data*	0.0	0.0	0.0	*N/A*	*N/A*	*N/A*
LCREEK	Kolob Terrace Road	3.23	0.0	0.0	0.0	-3.2	-3.2	-3.2
LFRKTD	Tabernacle Dome	0.00	0.0	0.0	0.0	0.0	0.0	0.0
NCREEK	North Creek River	0.00	0.0	0.0	0.0	0.0	0.0	0.0
PRWEAP	Parunuweap Canyon	0.00	0.0	0.0	0.0	0.0	0.0	0.0
SCOUTS	Scouts Lookout	0.00	0.1	0.2	0.1	0.1	0.2	0.1
WILDCT	Wildcat Canyon Trail	0.00	0.1	0.2	0.1	0.1	0.2	0.1
ZHQ	Zion Park Headquarters	*no data*	0.1	0.2	0.1	*N/A*	*N/A*	*N/A*

APPENDIX C: FLIGHT TRACKS IN THE FOUR INM STUDIES

Appendix C presents the air tour flight tracks modeled in INM for this analysis. Flight tracks for high-altitude jet aircraft overflights are not presented, because they are so densely populated that the resulting graphics are unreadable.

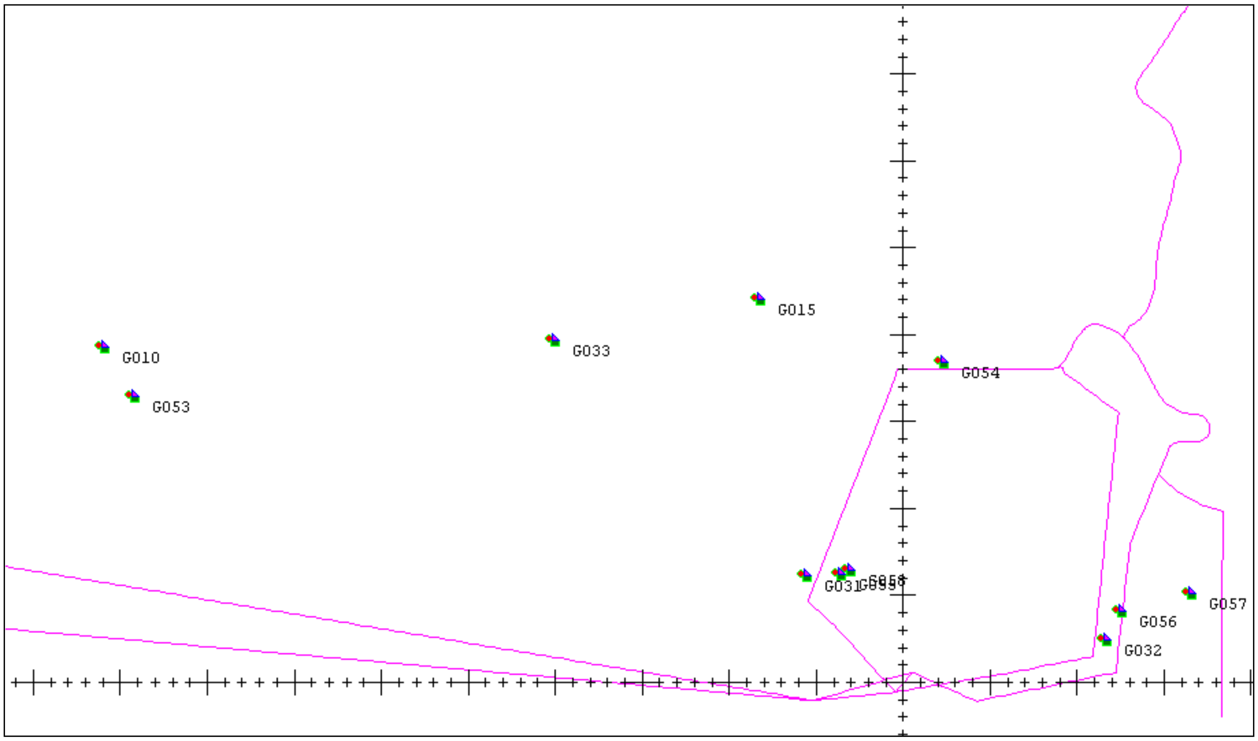

Figure 8: GCNP 2007 fixed wing propeller aircraft tracks

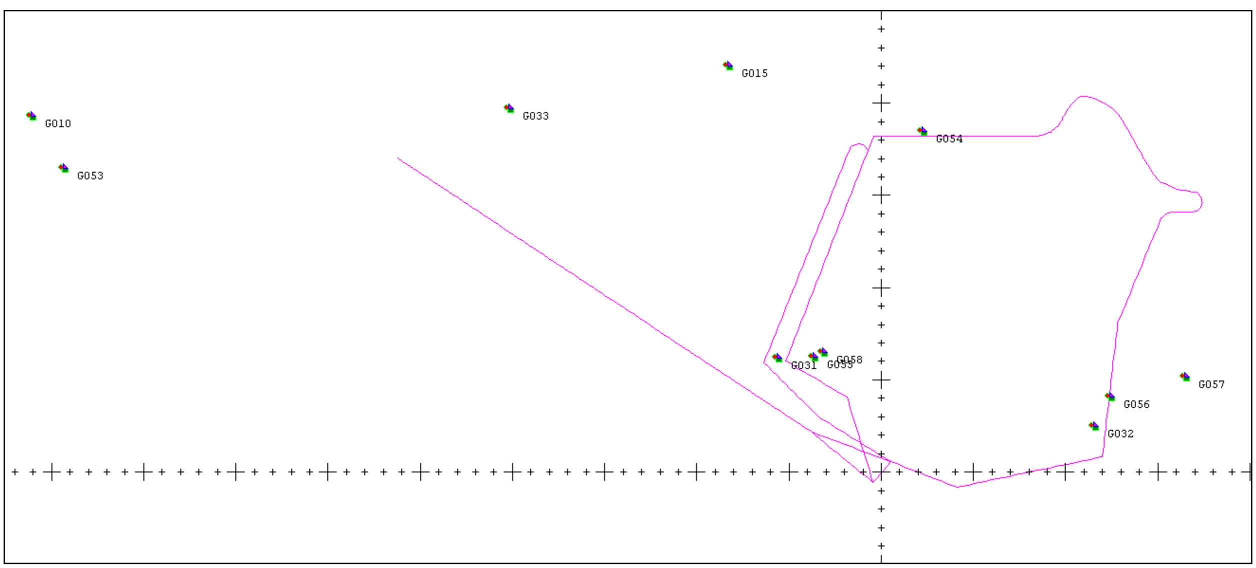

Figure 9: GCNP 2007 helicopter tracks

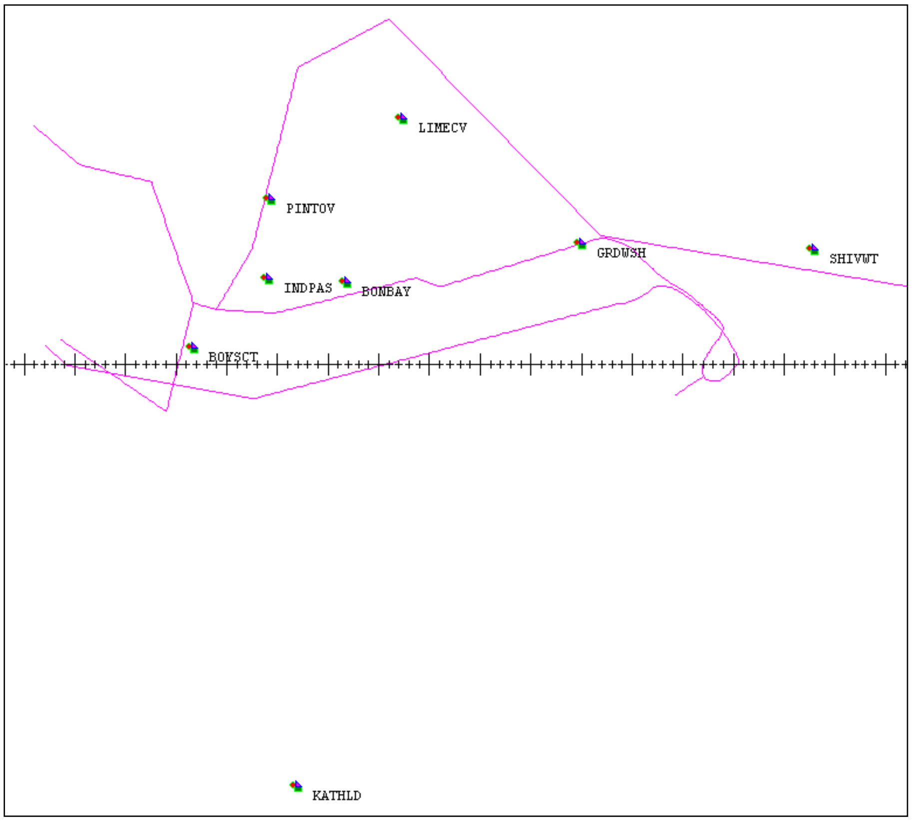

Figure 10: LMNRA 2004 fixed wing propeller aircraft tracks

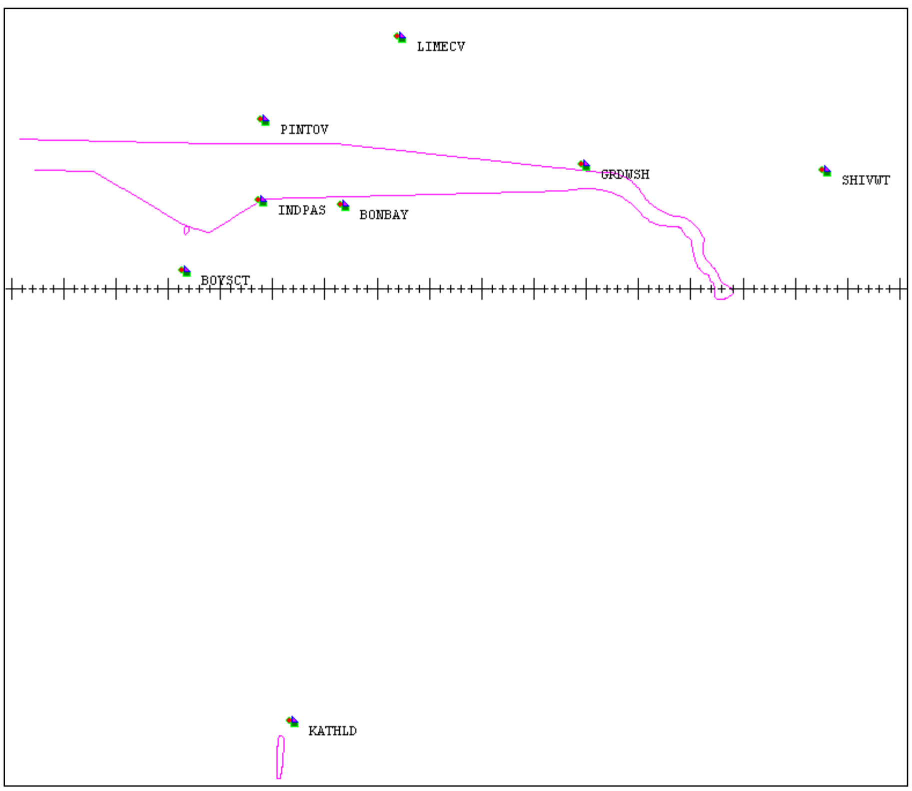

Figure 11: LMNRA 2004 helicopter tracks

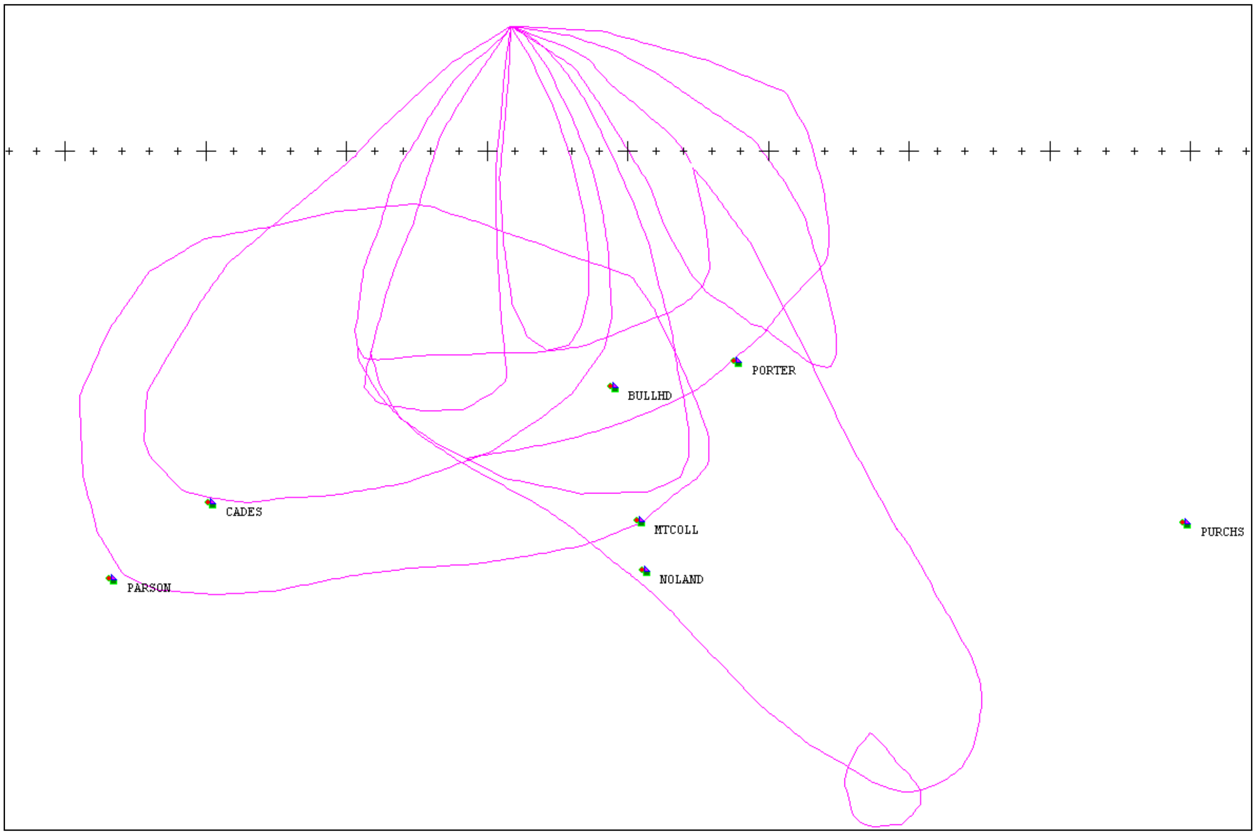

Figure 12: GRSM 2006 helicopter tracks

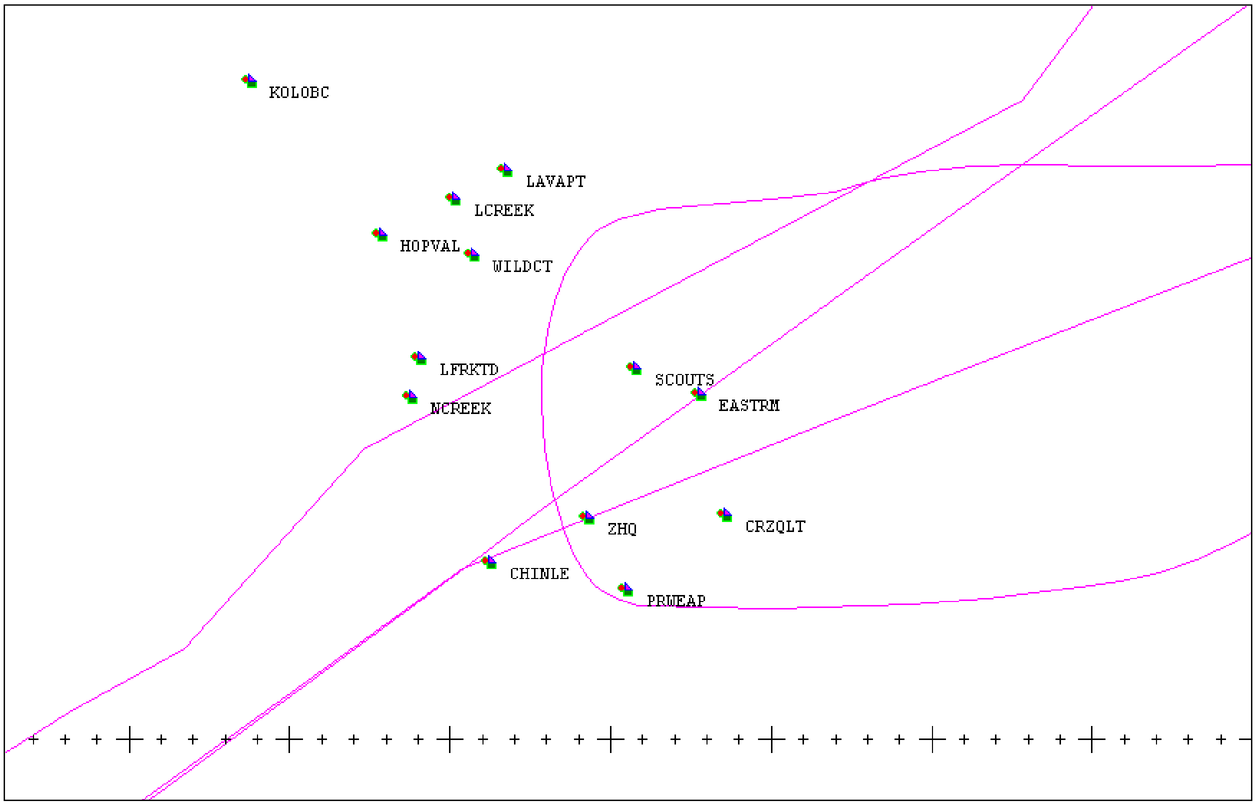

Figure 13: ZION 2000 fixed wing propeller aircraft tracks

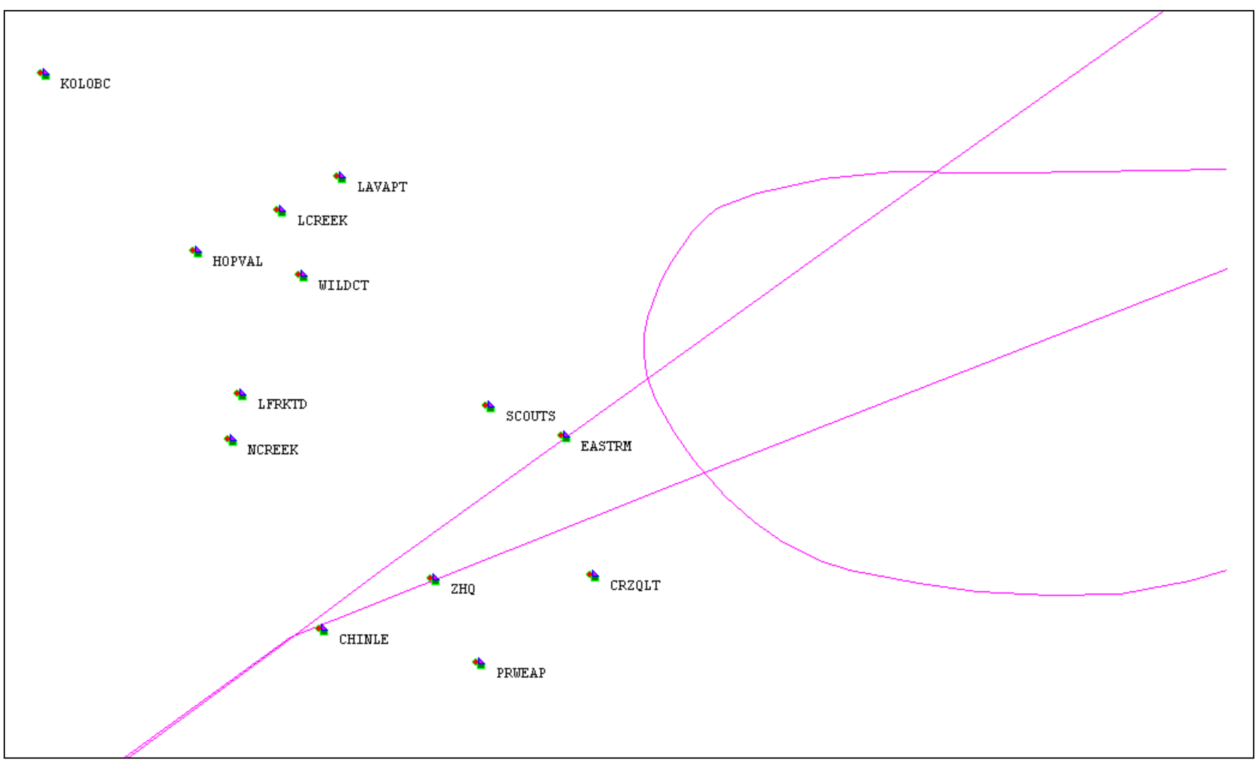

Figure 14: ZION 2000 helicopter tracks

APPENDIX D: MEASUREMENT SITE DESCRIPTIONS

Table 50: GCNP 2007 Measurement site descriptions

Site	Site Name	Latitude	Longitude	Description	Land Cover Classification (NLCD)*
G010	Tuweep Valley	36.270923	-113.096842	Mostly flat, sparse shrubland area	(51) Shrubland
G015	Rainbow Plateau	36.319465	-112.318826	Primarily evergreen forest with limited underbrush	(42) Evergreen Forest
G031	Dragon	36.055182	-112.263543	Pinyon-Juniper trees	(42) Evergreen Forest
G032	Zuni	35.993157	-111.910267	Pinyon-Juniper trees	(42) Evergreen Forest
G033	Fossil	36.280362	-112.562883	Mostly flat with scrubbrush	(51) Shrubland
G053	Tuweep Campground	36.22373	-113.060436	Slightly rocky shrubland with some small hills	(51) Shrubland
G054	North Rim Basin	36.260136	-112.101737	Evergreen forest	(42) Evergreen Forest
G055	Hermit Trail/Dripping Springs	36.056531	-112.223091	Scrubbrush on edge of evergreen forest	(42) Evergreen Forest
G056	Papago Canyon	36.020124	-111.892738	Scrubbrush	(51) Shrubland
G057	Old Cape Solitude Trail	36.037653	-111.809139	Rocky and hilly with evergreen trees and scrubbrush	(42) Evergreen Forest
G058	Hermit Rest Trailhead Parking	36.060576	-112.212304	Rocky and hilly with evergreen trees	(42) Evergreen Forest

Table 51: LMNRA 2004 Measurement site descriptions

Site (INM ID)	Site Name	Latitude	Longitude	Description	Land Cover Classification (NLCD)
L03 (BONBAY)	Bonelli Bay Landing	36.06424	-114.47659	Mostly flat, sparse shrubland area	(51) Shrubland
L05 (BOYSCT)	Boyscout Canyon	35.951167	-114.78377	Mostly barren, hilly terrain with sparse scrub brush	(51) Shrubland
L04 (GRDWSH)	Grand Wash Bay	36.13611	-114.0027	Rocky sparse shrubland overlooking a cove in Grand Wash Bay	(51) Shrubland
L07 (INDPAS)	Indian Pass	36.06819	-114.63693	Rocky terrain with sparse shrubland overlooking Boulder Basin	(51) Shrubland
L08 (KATHLD)	Katherine Landing	35.23303	-114.55139	Very smooth and flat terrain with sparse scrub brush	(51) Shrubland
L01 (LIMECV)	Lime Cove	36.33606	-114.37229	Sandy with some vegetation that consisted of grass and scrub brush	(51) Shrubland
L02 (PINTOV)	Pinto Valley	36.19798	-114.63631	Barren, hilly area that consisted of scrub brush and grass	(51) Shrubland
L06 (SHIVWT)	Shivwits Plateau	36.13305	-113.52999	Primarily evergreen forest with very soft soil	(42) Evergreen Forest

* Developed by the U.S. Geological Survey (USGS), the NLCD is the only nationally consistent land cover data set in existence and is comprised of twenty-one NLCD subclass categories for the entire U.S. (Vogelmann, J.E., S.M. Howard, L. Yang, C.R. Larson, B.K. Wylie, N. Van Driel, Completion of the 1990s National Land Cover Data Set for the Conterminous United States from Landsat Thematic Mapper Data and Ancillary Data Sources, Photogrammetric Engineering and Remote Sensing, 67:650-652, 2001.)

Table 52: GRSM 2006 Measurement site descriptions

Site (INM ID)	Site Name	Latitude	Longitude	Description	Land Cover Classification (NLCD)
GR5 (BULLHD)	Bull Head Trail	35.67185	-83.49243	Cove hardwood forest with soft ground off Bull Head Trail	(41) Deciduous Forest
GR6 (CADES)	Cades Cove	35.60352	-83.78535	Open field grass/pasture/shrubbery	(51) Shrubland
GR1 (MTCOLL)	Mt. Collins	35.59221	-83.47369	Evergreen Forest with soft ground covered in decaying pine needles	(42) Evergreen Forest
GR7 (NOLAND)	Noland Divide	35.56301	-83.47028	High, altitude mixed forest with soft ground	(43) Mixed Forest
GR2 (PARSON)	Parson Brach	35.55863	-83.85697	Northern hardwood forest with soft ground covered with decaying leaves	(41) Deciduous Forest
GR3 (PORTER)	Porters Flat	35.68648	-83.4022	Hardwood forest off Brushy Mountain Trail near a small stream	(41) Deciduous Forest
GR4 (PURCHS)	Purchase Knob	35.58825	-83.077	Hardwood forest 500 feet off the Cataloochee Divide Trail.	(41) Deciduous Forest

Table 53: ZION 2000 Measurement site descriptions

Site	Site Name	Latitude	Longitude	Description	Land Cover Classification (NLCD)
CHINLE	Chinle Trail	37.181457	-113.04667	Desert Scrub	*not yet assigned (Shrubland)*
CRZQLT	Crazy Quilt Mesa	37.205282	-112.89382	Slickrock, the area around the site has few trees or bushes	*not yet assigned*
EASTRM	East Rim Trail	37.267541	-112.90939	Mountain Brush	*not yet assigned (Shrubland)*
HOPVAL	Hop Valley trail	37.351732	-113.11612	Desert Scrub, plus a stand of Oak	*not yet assigned (Shrubland)*
KOLOBC	Kolob Finger Canyons	37.431785	-113.20156	Pinion/Juniper, the area around the site has numerous trees	*not yet assigned (Evergreen Forest)*
LAVAPT	Lava Point Overlook	37.384936	-113.03502	Conifer Forest, the site is located inside a stand of pine trees	*not yet assigned (Evergreen Forest)*
LCREEK	Kolob Terrace Road	37.370119	-113.06865	Mountain Brush	*not yet assigned (Shrubland)*
LFRKTD	Tabernacle Dome	37.28724	-113.09148	Pinion Juniper, the area around the site has some trees, bushes, and bare ground	*not yet assigned (Evergreen Forest)*
NCREEK	North Creek River	37.267185	-113.09701	Riparian, presence of running water	*not yet assigned*
PRWEAP	Parunuweap Canyon	37.166276	-112.95842	canyon, presence of running water	*not yet assigned*
SCOUTS	Scouts Lookout	37.281349	-112.95161	Slickrock, bare rock with few bushes or trees	*not yet assigned*
WILDCT	Wildcat Canyon Trail	37.340927	-113.0565	Conifer Forest	*not yet assigned (Evergreen Forest)*
ZHQ	Zion Park Headquarters	37.203906	-112.9833	bare ground with rocks and the occasional tree (water 300m away)	*not yet assigned*

APPENDIX E: SUMMARY OF CHANGES MADE TO THE ZION 2000 STUDY FOR THIS ANALYSIS

As mentioned in Section 4.4, the ZION 2000 study was developed by an outside environmental contractor in INM 6.2a, and then converted to INM 7.0b for this analysis. While care is taken to model this study with the minimum number of changes, in order to present the results as the contractor intended, several changes are made to the study in order to allow for the conversion to the INM 7.0b format. In fact, many of the changes for the INM 7.0b conversion resolved errors that were not identified in INM 6.2a, due to more advanced error checking capabilities in INM 7.0b. For this reason, changes are made to both the INM 6.2a and INM 7.0b versions of the study (where applicable), which also insured consistency between the results run in both versions of INM. The changes are listed below:

1. Converted helicopters modeled as user-defined aircraft in INM 6.2a to helicopters in INM 7.0b, combined operations where appropriate and created helicopter profiles in INM 7.0b that are based on the user-defined aircraft profiles for the corresponding helicopters in INM 6.2a.

2. CNA206 approach noise-power-distance curves (NPD) are added to the user defined Cessna C207 NPDs since the user defined aircraft lacked approach NPDs in INM 6.2a. Although no approach operations existed for the C207, INM 7.0b requires a complete set of NPDs for aircraft with any operation to run.

3. Removed helicopter approach and departure operations due to identified helicopter speed related software issue.

4. Updated helicopter tracks to remove negative distances, the positive (reverse) direction is modeled instead.

5. Changed elevation of overflight operations with 0.0 or negative elevations.

6. Removed single point profiles (primarily overflight profiles).

7. Removed or modified profiles with 0.0 speed (primarily overflight operations).

8. Removed military operations as they are not relevant to this study.

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APPENDIX F: AVERAGE RESULTS IN INM 7.0B EXCLUDING THE ZION 2000 STUDY

Appendix F includes combined time audible results for GCNP 2007, LMNRA 2004 and GRSM 2006 studies run in INM 7.0b. They do not include results for the ZION 2000 study run in INM 7.0b. The combined results for the studies run in INM 6.2a are not included in this appendix, because they are identical to the results for the GCNP 2007 study run in INM 6.2a (see Section 3.2).

Table 54: Difference in measured and modeled time audible for GCNP 2007, LMNRA 2004 and GRSM 2006 (INM 7.0b): *All aircraft*

	Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**
Average	50.9	37.0	31.3
Standard Deviation	16.8	13.3	13.6
Median Difference	56.4	36.2	29.6

Table 55: Difference in measured and modeled time audible for GCNP 2007, LMNRA 2004 and GRSM 2006 (INM 7.0b): *Jet aircraft only*

	Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**
Average	66.5	46.9	39.9
Standard Deviation	18.3	13.8	12.9
Median Difference	69.9	45.9	38.8

Table 56: Difference in measured and modeled time audible for GCNP 2007, LMNRA 2004 and GRSM 2006 (INM 7.0b): *Fixed wing propeller aircraft only**

	Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**
Average	2.8	1.6	0.2
Standard Deviation	19.8	17.3	15.6
Median Difference	-2.2	-2.0	-2.3

* There were no fixed wing air tours flown in GRSM.

Table 57: Difference in measured and modeled time audible for GCNP 2007, LMNRA 2004 and GRSM 2006 (INM 7.0b): *Helicopters only*

	Difference in %TAUD (Modeled - Measured)		
Time Compression	**None**	**Original**	**Proposed**
Average	25.0	20.7	18.5
Standard Deviation	35.0	28.0	25.2
Median Difference	3.6	3.8	3.5

APPENDIX G: NUMBER OF OPERATIONS IN EACH SCENARIO

Table 58: Audible Aircraft Operations at GCNP 2007*

		All Aircraft		Fixed Wing Propeller		Helicopters		High-Altitude Jets	
Site	Total Time Observed (min)	Total Operations Observed	Total Operations Modeled	Total Operations Observed	Total Operations Modeled	Total Operations Observed	Total Operations Modeled	Total Operations Observed	Total Operations Modeled
G010	720	157	182	8	28	0	0	149	151
G015	720	339	387	14	13	130	132	195	222
G031	720	515	525	65	65	216	214	234	246
G032	720	303	449	31	53	39	158	233	238
G033	720	184	214	9	9	2	4	173	201
G053	720	150	186	7	25	0	0	143	155
G054	720	364	468	28	31	156	212	180	225
G055	720	483	533	27	50	216	214	240	252
G056	720	418	433	29	29	156	39	233	237
G057	720	200	207	29	29	13	13	158	165
G058	720	543	559	69	67	216	214	258	278

Table 59: Audible Aircraft Operations at LMNRA 2004

			All Aircraft		Fixed Wing Propeller		Helicopters		High-Altitude Jets	
Date Modeled	INM ID	Total Time Observed (min)	Total Operations Observed	Total Operations Modeled	Total Operations Observed	Total Operations Modeled	Total Operations Observed	Total Operations Modeled	Total Operations Observed	Total Operations Modeled
5/14/2004	BONBAY	181.0	53.0	434.0	17.0	27.8	17.0	135.2	19.0	273.0
	BOYSCT	317.0	100.0	469.6	55.0	22.6	2.0	141.6	43.0	449.0
	GRDWSH	*no data*	*no data*	372.6	*no data*	29.4	*no data*	135.2	*no data*	208.0
	INDPAS	246.9	77.0	396.3	20.0	29.4	17.0	135.9	40.0	239.0
	KATHLD	122.4	15.0	77.6	12.0	0.0	0.0	15.6	3.0	62.0
	LIMECV	247.3	42.0	297.0	17.0	0.0	3.0	0.0	22.0	297.0
	PINTOV	342.8	47.0	515.7	21.0	1.5	7.0	135.2	19.0	382.0
	SHIVWT	194.6	34.0	203.5	16.0	1.5	0.0	0.0	18.0	202.0
5/15/2004	BONBAY	181.0	53.0	399.0	17.0	27.8	17.0	135.2	19.0	236.0
	BOYSCT	317.0	100.0	524.3	55.0	22.6	2.0	141.6	43.0	360.0
	GRDWSH	*no data*	*no data*	343.6	*no data*	27.8	*no data*	135.2	*no data*	179.0
	INDPAS	246.9	77.0	371.6	20.0	29.4	17.0	135.2	40.0	207.0
	KATHLD	122.4	15.0	97.6	12.0	0.0	0.0	15.6	3.0	82.0
	LIMECV	247.3	42.0	221.5	17.0	0.0	3.0	0.0	22.0	220.0
	PINTOV	342.8	47.0	405.7	21.0	1.5	7.0	135.2	19.0	269.0
	SHIVWT	194.6	34.0	189.4	16.0	1.5	0.0	0.0	18.0	160.0

* GCNP 2007 TAUD results were computed off-site by using and observer logging process with audio recordings from each measurement site. This process involves monitoring 10 seconds out of every 2 minutes of audio recordings, in order to determine time audible. Previous analyses have shown that off-site logging and field logging are very close (<5% difference), using this sampling schema.

Table 60: Audible Aircraft Operations at GRSM 2006

			All Aircraft		Helicopters		High-Altitude Jets	
Date Modeled	**INM ID**	**Total Time Observed (min)**	**Total Operations Observed**	**Total Operations Modeled**	**Total Operations Observed**	**Total Operations Modeled**	**Total Operations Observed**	**Total Operations Modeled**
6/7/2006	BULLHD	867.2	78.0	180.2	5.0	6.5	48.0	173.0
	CADES	480.6	53.0	127.0	0.0	0.5	38.0	126.0
	MTCOLL	724.0	93.0	206.4	4.0	5.7	47.0	199.0
	NOLAND	988.1	137.0	189.4	4.0	2.8	74.0	183.0
	PARSON	732.8	70.0	247.6	0.0	1.6	43.0	245.0
	PORTER	978.4	133.0	190.7	1.0	4.4	93.0	184.0
	PURCHS	741.8	96.0	164.5	1.0	0.0	59.0	163.0
6/13/2006	BULLHD	867.2	78.0	186.2	5.0	6.5	48.0	179.0
	CADES	480.6	53.0	134.0	0.0	0.5	38.0	133.0
	MTCOLL	724.0	93.0	201.4	4.0	5.7	47.0	194.0
	NOLAND	988.1	137.0	170.4	4.0	2.8	74.0	164.0
	PARSON	732.8	70.0	264.6	0.0	1.6	43.0	262.0
	PORTER	978.4	133.0	197.7	1.0	4.4	93.0	191.0
	PURCHS	741.8	96.0	162.5	1.0	0.0	59.0	161.0

Table 61: Audible Aircraft Operations at ZION 2000

		All Aircraft		Fixed Wing Propeller		Helicopters		High-Altitude Jets	
Site	**Total Time Observed (min)**	**Total Operations Observed**	**Total Operations Modeled**	**Total Operations Observed**	**Total Operations Modeled**	**Total Operations Observed**	**Total Operations Modeled**	**Total Operations Observed**	**Total Operations Modeled**
CHINLE	206.0	52.0	294.4	37.0	0.1	0.0	0.1	15.0	294.4
CRZQLT	282.0	67.0	312.1	36.0	0.0	0.0	0.1	31.0	312.1
EASTRM	168.0	50.0	309.6	27.0	0.0	0.0	0.1	23.0	309.6
HOPVAL	150.0	38.0	282.4	0.0	0.0	0.0	0.0	2.0	282.4
KOLOBC	48.0	3.0	316.8	3.0	0.0	0.0	0.0	0.0	316.8
LAVAPT	*no data*	*no data*	262.8	*no data*	0.0	*no data*	0.0	*no data*	262.8
LCREEK	143.0	34.0	265.7	18.0	0.0	2.0	0.0	16.0	265.7
LFRKTD	259.0	65.0	265.8	27.0	0.0	0.0	0.0	38.0	265.8
NCREEK	270.0	55.0	N/A*	39.0	0.0	0.0	0.0	14.0	N/A
PRWEAP	222.0	54.0	N/A	39.0	0.0	0.0	0.0	15.0	N/A
SCOUTS	165.0	40.0	N/A	26.0	0.0	0.0	0.1	14.0	N/A
WILDCT	135.0	34.0	N/A	24.0	0.1	0.0	0.1	10.0	N/A
ZHQ	*no data*	*no data*	N/A	*no data*	0.1	*no data*	0.1	*no data*	N/A

* Due to the large number of flights in the ZION 2000 study and practical limitations in the analysis software, detailed results for five measurement locations (NCREEK, PRWEAP, SCOUTS, WILDCT and ZHQ) were not be analyzed for information on individual operations.

REFERENCES

1. Miller, N. P., et al., Aircraft Noise Model Validation Study, Harris, Miller, Miller and Hanson Inc. Project 295860.20, June 2002.

2. Fleming, G. G., et al., Assessment of Tools for Modeling Aircraft Noise in the National Parks, Federal Interagency Committee on Aviation Noise Report, March 2005.

3. "Overview of Grand Canyon Noise Analysis Results," 7th Meeting of the Grand Canyon Working Group of the National Parks Overflights Advisory Group, September 2006.

4. Boeker, Eric, "FP01 FD7RC Task 2: Analysis of Modeling Cumulative Noise from Simultaneous Flights; Preliminary Study," Technical Memorandum, August 11, 2009.

5. Lee, Cynthia, "INM Modeling in Support of Assessment of INM Accuracy for Grand Canyon National Park Backcountry Locations," Technical Memorandum, Cambridge, MA: John A. Volpe National Transportation Systems Center, June 2, 2009.

6. Lee, Cynthia, et al., Baseline Ambient Sound Levels in Lake Mead National Recreation Area, Report No. DOT-VNTSC-FAA-06-13, Cambridge, MA: John A. Volpe National Transportation Systems Center, April 2006 (draft).

7. Lee, Cynthia, Baseline Ambient Sound Levels in Great Smoky Mountains National Park, Report No. DOT-VNTSC-FAA-06-13, Technical Memorandum, Cambridge, MA: John A. Volpe National Transportation Systems Center, August 24, 2007 (draft).

8. The Soundscape in Zion National Park, Wyle Report No. WR 02-07, Arlington, VA: Wyle Acoustics Group, May 2002 (draft).

9. He, Hua, et al., "Overview of Aircraft En Route Noise Prediction Using an Integrated Model," Noise-Con 2010 conference paper, Baltimore, MD, April 19-21, 2010.