Research Studies Related to Snowmobiling Impacts

SOUND

Sound levels for snowmobiles have been reduced 94% since inception. Pre-1969 snowmobiles were noisy. At full throttle, these machines emitted sound levels as high as 102 dB(A) at a distance of 50 feet.

Snowmobiles produced since February 1, 1975 and certified by the Snowmobile Safety and Certification Committee's independent testing company emit no more than 78 dB(A) from a distance of 50 feet while traveling at full throttle when tested under the Society of Automotive Engineers (SAE) J192 procedures. Additionally, those produced after June 30, 1976 and certified by the Snowmobile Safety and Certification Committee's independent testing company emit no more than 73 dB(A) at 50 feet while traveling at 15 mph when tested under SAE J1161 procedures.

For comparison purposes, normal conversation at three feet produces approximately 70 dB(A).
It would take 256 78 dB(A) snowmobiles operating together at wide open throttle to equal the noise level of just one of the pre-1969 snowmobiles.

Problems with excessive noise levels do occur when irresponsible snowmobilers modify the snowmobile exhaust system or substitute the factory system with an after-market racing exhaust. In most States this practice is illegal and grossly misrepresents the sport.

The Basics of Sound and Noise: Every kind of sound is produced by vibration. The sound source may be a violin, an automobile horn, or a barking dog. Whatever it is, some part of it is vibrating while it is producing sound. The vibrations from the source disturb the air in such a way that sound waves are produced. These waves travel out in all directions, expanding in balloon like fashion from the source of the sound. If the waves happen to reach someone's ear, they set up vibrations that are perceived as sound.

Sound then depends on three things. There must be: 1) a vibrating source to set up sound waves, 2) a medium such as air to carry the waves, and 3) a receiver to detect them.

Noise is defined as unwanted sound, a definition that includes both the psychological and physical nature of the sound. The term "sound" and "noise" are often interchangeable.

How Sound is Produced and Carried: It is easy to detect the vibrations of many sources of sound. A radio loudspeaker, for example, vibrates strongly, especially when the volume is turned up. If you lightly touch the speaker cone, you can feel its vibrations as a kind of tickling sensation in your fingertips.

Sound waves are often compared with water waves but are actually a very different sort of wave. What they are can be seen by considering what happens when an object vibrated in the air. Suppose someone strikes a gong, as the gong vibrates, it bends outward and inward very rapidly. This movement pushes and pulls at the air next to the surface of the metal. Air is made up of tiny molecules, and when the metal gong bends inward and outward, it creates a wave. The wave travels outward from the gong, becoming weaker and weaker until it dies away.

The Speed of Sound: Sound waves travel at a constant speed, regardless of the loudness or softness of a sound. Temperature, however, does affect their speed. At room temperature sound travels in air at a speed of 1,130 feet per second. Sound waves travel one mile in about five seconds. At freezing (32 degrees F), sound waves travel at 1,087 feet per second or one mile in about 5 seconds.

Some sounds are high and others are low; some are loud and others barely audible; some are pleasant and others harsh. The three basic properties of any pure sound are its pitch, its intensity, and its quality.

The Pitch of Sounds: Pitch is simply the rate at which vibrations are produced. Another way to define the pitch of a tone is to find its wavelength. The wavelength of a particular tone is equal to the velocity of sound divided by the frequency of the tone.

Intensity and Tone Quality: The intensity of a sound has nothing to do with its pitch. Intensity depends upon the strength of the vibrations producing the sound. The loudness of sounds is measured in decibels (dB).

Reflecting and Forcing Sound Waves: Like light waves, sound waves can be reflected and focused. An echo is simply a reflection of sound. A flat surface, like that of a cliff or wall, reflects sound better than an irregular surface, like a tree, which tends to break up sound waves.

Specific snowmobiling related sound studies include:

1. **Natural Soundscape Monitoring in Yellowstone National Park December 2010 – March 2011.** Burson, S. (2011) National Park Service – Grand Teton National Park, Division of Science and Resource Management. http://www.nps.gov/yell/parkmgmt/upload/YNPWinter_natural_soundscape_monitoring29June11.pdf

Abstract: Sounds associated with oversnow vehicles (snowmobiles and snowcoaches) are an important management concern at Yellowstone National Park. Acoustical standards and thresholds have been defined in park planning documents for the winter use season. The primary purpose of this study was to monitor the impact of oversnow vehicles on the natural soundscape. Acoustical data were collected at two shorter-term sites in Yellowstone National Park during the winter use season, 15 December 2010-15 March 2011.

Oversnow vehicles were audible in the most heavily used developed area, Old Faithful, an average of 61% of the day between 8 am and 4 pm. At Old Faithful, oversnow vehicles were audible over 75% for 0 (0%) of 31 days analyzed. Oversnow vehicles were audible for an average of 51% of the day near Madison Junction along the corridor between Old Faithful and the West Entrance. At Madison Junction oversnow vehicles were audible over 50% for 13 (46%) of the 28 days analyzed. The average noise-free interval between 8 am and 4 pm at Madison Junction was three minutes and 42 seconds. Oversnow vehicles were audible 24% of the day at Pumice Point Roadside along the Lake to West Thumb corridor and 44% of the day at Caldera Rim Picnic Area between Madison Junction and Norris. The average noise-free interval at Caldera Rim Picnic Area was 2 minutes and 27 seconds and four minutes and seventeen seconds at Pumice Point Roadside. The maximum sound levels of oversnow vehicles sometimes exceeded 70 A-weighted decibels (dBA) along the groomed travel corridors at the Madison Junction 2.3, pumice Point Raodside and Caldera Rim Picnic Area monitoring sites. The majority of these higher sound levels were caused by old technology snowcoaches. Sounds from both visitor and administrative oversnow vehicles were included in this study.

Although on average snowmobiles were audible more than snowcoaches, snowcoaches often had higher sound levels, especially at higher speeds. Consistent with acoustic data collected during the previous eight winter seasons, the sound level and the percent time oversnow vehicles were audible remained substantially lower than during the 2002-2003 winter use season. The reduced sound and audibility levels were largely explained by fewer snowmobiles, the change from two to four-stroke engine technology, and the guided group requirements. The value of this monitoring study increases with each additional year as trends emerge in addition to detailed information about specific winters and locations.

2. **Natural Soundscape Monitoring in Yellowstone National Park December 2009 – March 2010.** Burson, S. (2010) National Park Service – Grand Teton National Park, Division of Science and Resource Management. http://www.nps.gov/yell/parkmgmt/upload/soundscape_monitoring-2009-2010.pdf

Abstract: Sounds associated with oversnow vehicles (snowmobiles and snowcoaches) are an important management concern at Yellowstone National Park. Acoustical standards and thresholds have been defined in park planning documents for the winter use season. The primary purpose of this study was to monitor the impact of oversnow vehicles on the natural soundscape. Acoustical data were collected at two winter-long sites and one shorter-term site (near a plowed road used by wheeled vehicles) in Yellowstone National Park during the winter use season, 15 December 2009-15 March 2010.

Oversnow vehicles were audible in the most heavily used developed area, Old Faithful, an average of 55% of the day between 8 am and 4 pm. Oversnow vehicles were audible for an average of 54% of the day near Madison Junction along the corridor between Old Faithful and the West Entrance. At Madison Junction oversnow vehicles were audible over 50% for 18 (60%) of 30 days analyzed. The average noise-free interval between 8 am and 4 pm at Madison Junction was four minutes and 24 seconds. Wheeled vehicles were monitored in Lamar Valley at 140 feet (43m) from the plowed road between Tower and the Cooke City and were audible for 66% of the time between 8 am and 4 pm. The average noise-free interval between 8 am and 4 pm at Lamar Valley was 50 seconds. The maximum sound levels of oversnow vehicles sometimes exceeded 70 A-weighted decibels (dBA) along the groomed travel corridor between Madison Junction and the West Yellowstone entrance (Madison Junction 2.3). The majority of these higher sound levels were caused by old technology snowcoaches. Sounds from both visitor and administrative oversnow vehicles were included in this study.

Although snowmobiles were audible more than snowcoaches, snowcoaches in general had higher sound levels, especially at higher speeds. Consistent with acoustic data collected during the previous seven winter seasons, the sound level and the percent time oversnow vehicles were audible remained substantially lower than during the 2002-2003 winter use season. The reduced sound and audibility levels were largely explained by fewer snowmobiles, the change from two to four-stroke engine technology, and the guided group requirements. The value of this monitoring study increases with each additional year as trends emerge with the addition of detailed information about specific winters and locations.

3. **Natural Soundscape Monitoring in Yellowstone National Park December 2008 – March 2009.** Burson, S. (2009) National Park Service – Grand Teton National Park, Division of Science and Resource Management. http://www.nps.gov/yell/parkmgmt/upload/soundscape_monitoring-2008-2009.pdf

Abstract: Sounds associated with oversnow vehicles (snowmobiles and snowcoaches) are an important management concern at Yellowstone National Park. Acoustical standards and thresholds have been defined in park planning documents for the winter use season. The primary purpose of this study was to monitor the impact of oversnow vehicles on the natural soundscape. Acoustical data were collected at two winter-long sites and three shorter-term sites (two near a plowed road used by wheeled vehicles) in Yellowstone National Park during the winter use season, 15 December 2008- 15 March 2009.

Oversnow vehicles were audible in the most heavily used developed area, Old Faithful, an average of 55% of the day between 8 am and 4 pm. Oversnow vehicles were audible for an average of 45% of the day at the two travel corridor monitoring sites; 47% of the day near Madison Junction along the busiest corridor between Old Faithful and the West Entrance, and for 26% adjacent to the road at North Twin Lake between Norris and Mammoth. At Madison Junction oversnow vehicles were audible over 50% for 8 (33%) of 24 days analyzed and 0 (0%) of 7 days analyzed at the North Twin Lake site. Wheeled vehicles were monitored and were audible at one roadside and one backcountry monitoring site; 26% at Blacktail Roadside (100 feet (30m) from the plowed road between Mammoth and Tower), and 16% at Blacktail Backcountry (one and one half mile [2.4 km] from the same section of road as the Blacktail Roadside monitor. The maximum sound levels of oversnow vehicles sometimes exceeded 70 A-weighted decibels (dBA) along the groomed travel corridor between Madison Junction and the West Yellowstone entrance (Madison Junction 2.3) and between Norris and Mammoth (North Twin Lake). The majority of these higher sound levels were caused by old technology snowcoaches. Sounds from both visitor and administrative oversnow vehicles were included in this study.

Although snowmobiles were audible more than snowcoaches, snowcoaches in general had higher sound levels, especially at higher speeds. The overall impact on the natural soundscape from oversnow vehicles was lower than the past five seasons, likely due to the decrease in daily average number of oversnow vehicles that entered the park; an average decrease of about 95 oversnow vehicles/day from last season. Consistent with acoustic data collected during the previous five winter seasons, the sound level and the percent time oversnow vehicles were audible remained substantially lower than during the 2002-2003 winter use season. The reduced sound and audibility levels were largely explained by fewer snowmobiles, the change from two to four-stroke engine technology, and the guided group requirements. The value of this monitoring study increases with each additional year because trends can emerge in addition to detailed information about specific winters and locations.

4. **Exterior Sound Level Measurements of Over-Snow Vehicles at Yellowstone National Park** (2008) U.S. Department of Transportation – Research and Innovative Technology Administration, John A. Volpe National Transportation Systems Center – Environmental Measurement and Modeling Division, RTV-4F Cambridge, MA http://www.nps.gov/yell/parkmgmt/upload/dot_vntsc_08-03.pdf

Executive Summary: Sounds associated with Oversnow Vehicles (OSVs), such as snowmobiles and snowcoaches, are an important management concern at Yellowstone and Grand Teton National Parks. The John A. Volpe National Transportation Systems Center's Environmental Measurement and Modeling Division (Volpe Center) is supporting the National Park Service (NPS) with implementation of the Winter Use Planning program (Ref. 1, 2, 3, 4) and supporting National Environmental Policy Act (NEPA) documents, including the 2007 Winter Use Planning / Environmental Impact Statement. As part of this support, the Volpe Center, in cooperation with the NPS, performed acoustic measurements of ten snowcoaches and six snowmobiles at the southern entrance of Yellowstone National Park from the 26th through the 28th of February 2008. The measurement site location is indicated in Figure 2.

These measurements were made with three primary objectives in mind:

1) Help determine what sound testing protocols should be used to determine if *snowcoaches* meet the Best Available Technology (BAT) with respect to noise emissions.
2) Determine which *snowcoaches* meet BAT standards with respect to noise emissions.
3) Determine if there was a significant difference between *snowmobile* sound levels when tested using two different methodologies.

The measurement site was an open section of snow packed road at the south entrance of Yellowstone National Park, at the same location as was used in October 2002 for snowcoach measurements. There was a 2 to 3 foot buildup of snow in the measurement area adjacent to the road which was not ideal, however, analysis of the data indicated that this snow berm did not substantially influence the measurements.

Three microphones were setup along a line perpendicular to the road. Two were set 50 feet from the center of the over-snow vehicle travel path, one 4 feet above the snow and a second 15 feet above the snow. One microphone was set 200 feet from the center of the travel path, 4 feet above the snow. Sound levels were measured as the over-snow vehicle traveled along the roadway.

The snowcoaches tested are indicated in Table 1. Testing of the snowcoaches was guided by specifications given in SAE J1161 (Ref. 11). On the first day of testing, vehicles were measured at idle, 15 mph and 30 mph, however, due to degraded road conditions, only idle and 15 mph measurements were made on the second day. Results from these measurements are shown in Figure 1.

Snowmobiles tested are shown in Table 2. These vehicles were evaluated in order to determine if two different revisions of SAE J192 (Ref. 12) would produce different sound level results. The 1985 revision required snowmobiles to start from rest and then travel along the road at full throttle while measuring the sound level using a fast time response. The 2003 revision required snowmobiles to approach the measurement zone at 15 mph and then travel along the road at full throttle while measuring the sound level using a slow time response. On average, the 1985 revision produced results about 2 dB greater than the 2003 revision.

Based on experiences during this study, the following recommendations are suggested for future measurement of snowcoach sound levels for the purpose of testing BAT conformance. The measurements should adhere to SAE J1161 with the following modifications and considerations:

- Because of the altitude, barometric pressure specifications should be expanded to include typical pressures in the parks during the winter season. The sound level variation due to the lower barometric pressure could be corrected in a manner similar to the methods described in References 5 and 6.
- If a snow berm is present, all practical efforts to remove it should be implemented.
- If a snow berm greater than 3 feet tall cannot be removed, another site should be sought.
- Testing should be conducted for three conditions
    - Idle
    - 15 mph

  - A high speed to be determined by the park based on local speed limits, e.g., 30 mph, road speed limit, or a typical cruising speed.
- A road groomer should be kept on hand in order to ensure that the road conditions do not deteriorate over the course of the testing.
- If vehicles fail to meet BAT requirements at the high speed, consideration should be given to restrictions which would still allow the snowcoach to operate in the parks, but at a reduced speed.

5. **Natural Soundscape Monitoring in Yellowstone National Park December 2007 – March 2008.** Burson, S. (2008) National Park Service – Grand Teton National Park, Division of Science and Resource Management. http://www.nps.gov/yell/parkmgmt/upload/soundscape_monitoring-2007-2008.pdf

Abstract: Sounds associated with oversnow vehicles (snowmobiles and snowcoaches) are an important management concern at Yellowstone National Park. Acoustical standards and thresholds have been defined in park planning documents for the winter use season. The primary purpose of this study was to monitor the impact of oversnow vehicles on the natural soundscape. These data were then compared to the adaptive management thresholds in the 2007 Yellowstone and Grand Teton National Park Winter Use Plans Environmental Impact Statement. Acoustical data were collected at three winter-long sites and three short-term sites in Yellowstone National Park during the winter use season, 19 December 2007- 9 March 2008.

Oversnow vehicles were audible in the most heavily used developed area, Old Faithful, an average of 68% of the day between 8 am and 4 pm. At Old Faithful, oversnow vehicles were audible over 75% for 2 (7%) of 27 days analyzed. Oversnow vehicles were audible for an average of 45% of the day at the two travel corridor monitoring sites. Oversnow vehicles were audible for 53% of the day near Madison Junction along the busiest corridor between Old Faithful and the West Entrance, and for 37% adjacent to the road between Grant Village and Lewis Lake along the route to the South Entrance. At Madison Junction oversnow vehicles were audible over 50% for 15 (56%) of 27 days analyzed and 3 (14%) of 22 days analyzed at Grant Village/Lewis Lake site. Oversnow vehicles were audible at one transition zone and two backcountry short-term monitoring sites; 20% at Delacy Creek Trail (one mile [1.6 km] from the groomed road), 26% at Mary Mountain 8K (one and one half mile [2.4 km] from the groomed road), and 18% at Shoshone Geyser Basin (five miles [8 km] from the groomed road). The maximum sound levels of oversnow vehicles exceeded 70 A-weighted decibels (dBA) along the groomed travel corridor between Madison Junction and the West Yellowstone entrance (Madison Junction 2.3) and between West Thumb and the South Entrance (Grant Village/Lewis Lake). The majority of these higher sound levels were caused by old technology snowcoaches. Sounds from both visitor and administrative oversnow vehicles were included in this study.

Although on average snowmobiles were audible for more time than snowcoaches, snowcoaches in general had higher sound levels, especially at higher speeds. The overall impact on the natural soundscape from oversnow vehicles was similar to the past four seasons, although there was a slight decrease in oversnow vehicle audibility at Madison Junction 2.3. The daily average number of oversnow vehicles that entered the park decreased about 2% from last season. Consistent with acoustic data collected during the previous four winter seasons, the sound level and the percent time oversnow vehicles were audible remained substantially lower than during the 2002-2003 winter use season. The reduced sound and audibility levels were largely explained by fewer snowmobiles, the change from two to four-stroke engine technology, and the guided group requirements. The value of this monitoring study increases with each additional year because trends can begin to emerge in addition to detailed information about specific winters and locations.

6. **Natural Soundscape Monitoring in Yellowstone National Park December 2006 – March 2007.** Burson, S. (2007) National Park Service – Grand Teton National Park, Division of Science and Resource Management. http://www.nps.gov/yell/parkmgmt/upload/final_natural_soundscape_monitoring2007.pdf

Abstract: Sounds associated with oversnow vehicles (snowmobiles and snowcoaches) are an important management concern at Yellowstone National Park. Acoustical standards and thresholds have been defined in park planning documents for the winter use season. The primary purpose of this study was to monitor the impact of oversnow vehicles on the natural soundscape. These data were then compared to the impact definition thresholds in the 2004 Yellowstone and Grand Teton National Park Temporary Winter Use Plans Environmental Assessment. Acoustical data were collected at five sites in Yellowstone National Park during the winter use season, 20 December 2006-11 March 2007.

Oversnow vehicles were audible in the Old Faithful developed area an average of 68% of the day between 8 am and 4 pm. At Old Faithful, oversnow vehicles were audible over the threshold of 75% for developed area for 9 of 35 days (26%) analyzed. Oversnow vehicles were audible 26% of the day adjacent to the road near Mud Volcano and 44% at Spring Creek 2. At Madison Junction 2.3 oversnow vehicles were audible for 59% of the day, exceeding the travel corridor threshold average of 50%. The maximum sound levels for oversnow vehicles exceeded 70 dBA at Old Faithful, along the groomed travel corridor between Madison Junction and the West Yellowstone entrance (Madison Junction 2.3) and between West Thumb and Old Faithful (Spring Creek 2). Sounds from both visitor and administrative oversnow vehicles were included in this study.

Although on average snowmobiles were audible for more time than snowcoaches, snowcoaches in general had higher sound levels, especially at higher speeds. The overall impact on the natural soundscape from oversnow vehicles was similar to the past two seasons, although there was increased audibility at two locations. The daily average number of oversnow vehicles that entered the park increased about 20% from last season. Consistent with acoustic data collected during the previous three winter seasons, the sound level and the percent time oversnow vehicles were audible remained substantially lower than during the 2002-2003 winter use season. The reduced sound and audibility levels were largely explained by fewer snowmobiles, the change from two to four-stroke engine technology, and the guided group requirements. The value of this monitoring study increases with each additional year because trends can begin to emerge in addition to detailed information about specific winters and locations.

7. **Natural Soundscape Monitoring in Yellowstone National Park December 2005 – March 2006.** Burson, S. (2006) National Park Service – Grand Teton National Park, Division of Science and Resource Management. http://www.nps.gov/yell/parkmgmt/upload/final_soundscape.pdf

Abstract: Sounds associated with oversnow vehicles (snowmobiles and snowcoaches) are an important management concern at Yellowstone National Park. Acoustical standards and thresholds have been defined in park planning documents for the winter use season. The primary purpose of this study was to monitor the impact of oversnow vehicles on the natural soundscape. These data were then compared to the impact definition thresholds in the 2004 Yellowstone and Grand Teton National Park Temporary Winter Use Plans Environmental Assessment. Acoustical data were collected at five primary sites in Yellowstone National Park during the winter use season, 21 December 2005-12 March 2006.

Oversnow vehicles were audible in the Old Faithful developed area an average of 67% of the day between 8 am and 4 pm. Oversnow vehicles were audible 35% (Old Faithful Upper Basin) and 62% (West Thumb Geyser Basin) of the day within geyser basins adjacent to developed areas. Along travel corridors the percent time audible was 34% (Spring Creek) and 55% (Madison Junction 2.3). The maximum sound levels for oversnow vehicles exceeded 70 dB(A) at Old Faithful, along the groomed travel corridor between Madison Junction and the West Yellowstone entrance (Madison Junction 2.3) and between West Thumb and Old Faithful (Spring Creek). Sounds from both visitor and administrative oversnow vehicles were included in this study. Acoustic data from previous years is included for comparison.

Although on average snowmobiles were audible for more time than snowcoaches, snowcoaches in general had higher sound levels, especially at higher speeds. The overall impact on the natural soundscape from oversnow vehicles was similar to the past two seasons, although there was increased audibility at two locations. The number of oversnow vehicles that entered the park increased slightly. Consistent with acoustic data collected during the previous three winter seasons, the sound level and the percent time oversnow vehicles were audible remained substantially lower than during the 2002-2003 winter use season. The reduced sound and audibility levels were largely explained by fewer snowmobiles, the change from two to four-stroke engine technology, and the guided group requirements. The value of this monitoring study increases with each additional year because trends can begin to emerge in addition to detailed information about specific winters and locations.

8. **Modeling Sound Due to Over-Snow Vehicles in Yellowstone and Grand Teton National Parks** Hastings, A.L., Fleming, G.G., Lee, C.S.Y. (2006) Research and Innovative Technology Administration, John A. Volpe National Transportation Systems Center – Environmental Measurement and Modeling

Division, RTV-4F Acoustics Facility, Cambridge, MA
http://www.nps.gov/yell/parkmgmt/upload/finalsound%20_modelingreport.pdf

Executive Summary: The National Park Service (NPS) is developing Winter Use Plans for Yellowstone and Grand Teton National Parks to help manage the use of Over-Snow Vehicles (OSV) in the parks. The use of snowmobiles in the parks is a concern because of increased use and legal actions by environmental, recreational, and commercial groups. Several modeling alternatives are being considered for the NPS Winter Use Plans. These alternatives affect the number of OSVs that are allowed to operate in the parks and where they are allowed to travel. Some modeling alternatives allow standard OSVs while others require the use of Best Available Technology (BAT) OSVs. Some modeling alternatives represent a reduction or cessation of activity while others consider increased operations. The U.S. Department of Transportation, Research and Innovative Technology Administration, John A. Volpe National Transportation Systems Center (Volpe Center) is supporting the NPS by modeling the acoustical environment in the parks associated with each modeling alternative as well as current and historical conditions.

Acoustical modeling was performed by using the Federal Aviation Administration's (FAA) Integrated Noise Model (INM) Version 6.2, adapted for use with OSVs. Model adaptation included the development of ground-to-ground sound propagation models to better account for propagation over snow-covered terrain. Ambient sound levels were provided by the NPS and a set of acoustic zones were developed in order to generate natural ambient maps for the parks. See Figure 1 and Figure 2. The Volpe Center developed Noise-Speed-Distance (NSD) relationships for OSVs based on previously published OSV acoustical studies and winter 2005-2006 measurements. Vehicle types modeled included two- and four-stroke snowmobiles, purpose built snowcoaches, and snowcoaches based on modified conversion vans with either two or four tracks.

Each modeling alternative was evaluated for an 8-hour day with temperature, relative humidity, and snow cover representative of an average day during the winter season in the parks. In order to account for increased usage during peak hours, the 8-hour day was divided into 1-hour intervals and vehicle operations were assigned based on scheduling provided by the National Park Service. Modeling alternatives are labeled 1 to 6. Each modeling alternative was designed to model a particular management alternative:

- Modeling Alternative 1 (*Continue Temporary Plan*): This alternative continues the current Temporary Plan into the future with some modifications. This alternative limits the number of snowmobiles and snowcoaches according to NPS specifications found in "Preliminary Draft Alternatives – Winter Use Plans"1, and requires that all vehicles be guided and of Best Available Technology (BAT). This alternative includes several options as follows:
    - Option A: East entrance to Yellowstone open. (Daily Entrance Limit: 720 snowmobiles / 78 snowcoaches)
    - Option B: East entrance to Yellowstone closed for avalanche control. (Daily Entrance Limit: 720 snowmobiles / 78 snowcoaches)
    - Option C: Was not modeled because the operations were adequately modeled by Option D and Ea.
    - Option D: East entrance to Yellowstone closed and reduced over-snow vehicle use. (Daily Entrance Limit: 680 snowmobiles / 78 snowcoaches)
    - Option E: East entrance to Yellowstone and Gibbon Canyon closed, reduced over-snow vehicle use. (Daily Entrance Limit: 680 snowmobiles / 78 snowcoaches)
- Modeling Alternative 2 (*Snowcoaches Only*): This alternative limits over-snow vehicles to BAT snowcoaches only and would also close the East entrance to Yellowstone. Since snowcoaches do not operate in Grand Teton, no modeling was necessary for Grand Teton. (Daily Entrance Limit: 0 snowmobiles / 120 snowcoaches)
- Modeling Alternative 3 (*Eliminate Most Road Grooming*): This alternative eliminates grooming of most roads in Yellowstone and Grand Teton. The exceptions would be the road segment from the South Entrance to Old Faithful and the Grassy Lake Road. These two roads would continue to be groomed. (Daily Entrance Limit: 250 snowmobiles / 20 snowcoaches)
- Modeling Alternative 4 (*Expand Recreational Use*): This alternative would expand the recreational use of the parks during the winter season. For Yellowstone, BAT requirements would remain in place and about 25% of all snowmobiles would be unguided. For Grand Teton, a portion of the snowmobiles on the road segment from Moran to Flagg Ranch would be allowed to be non-BAT. (Daily Entrance Limit: 1025 snowmobiles / 115 snowcoaches)

- Modeling Alternative 5 (*Provide for Unguided Access*): For Yellowstone, BAT requirements would remain in place and about 20% of all snowmobiles would be unguided. This alternative does not increase the number of over-snow vehicles in operation, in contrast to Modeling Alternative 4. (Daily Entrance Limit: 625 snowmobiles / 100 snowcoaches)
- Modeling Alternative 6 (*Mixed Use*): This alternative allows for the use of both oversnow vehicles as well as wheeled vehicles, namely Busses and Vans. The wheeled vehicles would travel on plowed roads on the west side of Yellowstone, whereas the other road sections would be groomed for over-snow vehicle use. (Daily Entrance Limit: 350 snowmobiles / 40 snowcoaches / 100 wheeled vehicles)
- Current Condition: The Current Condition evaluates the level of *use* during the most recent winter seasons. This includes BAT requirements for snowmobiles but not for snowcoaches. The Current Condition also requires guides for all vehicles in Yellowstone, but not for Grand Teton. (Average Daily Entrance: 260 snowmobiles / 29 snowcoaches)
- Historical Condition: The Historical Condition considers a return to the 1983 Regulations guiding winter use in the parks. This would remove limits to visitor use and eliminate Best Available Technology requirements. (Average Daily Entrance: 1400 snowmobiles / 40 snowcoaches)

Percent time audible (%TAUD) contours and time above A-weighted level in seconds (TALA) were calculated for the modeling alternatives, as well as for current and historical conditions. The percent time audible contours had highest levels near the OSV travel corridors. Increases in operations increased the highest percent time audible up to a maximum of 100%. Increases in group size and the inclusion of snowcoaches that do not meet Best Available Technology (BAT) specifications increased the park area with “any audibility”. Although not intuitive, inclusion of snowmobiles that do not meet BAT specifications did not increase the park area with “any audibility”. Although these results were initially thought to be erroneous, further investigation indicated them to be correct and to be a result of the spectra associated with BAT and non-BAT snowmobiles. Specifically, the sound levels from non-BAT snowmobiles attenuated faster with increasing distance than the sound levels from BAT snowmobiles, which had greater sound energy at low frequencies. However, non-BAT snowmobile sound levels near the travel corridor were higher than BAT snowmobiles. Similar trends were found from the results of the TALA calculations.

The modeling alternatives, as well as current and historical conditions, were rank ordered based on park area associated with the Integrated Noise Model’s calculated percent time audible contours. Yellowstone rankings are shown in Figure 3 and Grand Teton rankings are shown in Figure 4 for the case of any audible events. Figure 5 shows the Yellowstone ranking for the case of audibility 50 percent of the time, i.e., these values represent the percent of park area in which OSVs are audible at least 50 percent of the 8-hour study period. The percent TAUD was generally bellow 20%. Because of these lower percentages, an analysis of 50% time audible was not conducted for Grand Teton.

Recommendations for further work include:

- Collect additional source data.
  - Include a greater range of vehicles and speeds to better represent the Park’s OSV fleet. This should include any vehicles that make up a significant portion of the operations to be modeled, especially if no vehicles with similar acoustic characteristics have already been included.
  - Include a greater number of repetitions to provide more statistical confidence in the mean levels.
- Run controlled operations for validation, e.g. measure LAmax at several locations simultaneously for a single snowmobile.
- Run modeling alternatives for cold and warm days and humid and dry days to determine sensitivity to weather extremes.
- Run alternatives for different types of snow cover, e.g., freshly fallen snow versus ice. This will require further modeling of ground effects.
- Use park fleet distributions to weight source data for each vehicle model when estimating the mean level for each source type. For example if there are 200 Snowbuster snowcoaches and 100 Bombardier snowcoaches in the park fleet, then the Snowbusters could be counted twice and the Bombardiers could be counted once when averaging source levels.
- Conduct surveys to determine visitor responses to alternatives that can be modeled. Averaged response ratings could be correlated to acoustic metrics such as percent time audible. This would provide an understanding of what metric levels are acceptable to park visitors.

It is understood that these tasks represent a large investment of several groups' time and resources. Further discussion needs to be conducted in order to prioritize these and to determine which items are actionable for an updated version of this study.

9. **Natural Soundscape Monitoring in Yellowstone National Park December 2004 – March 2005.** Burson, S. (2005) National Park Service – Grand Teton National Park, Division of Science and Resource Management. http://www.nps.gov/yell/parkmgmt/upload/soundscape_monitoring_2005_final.pdf

Abstract: Sounds associated with oversnow vehicles (snowmobiles and snowcoaches) are an important management concern at Yellowstone National Park. Acoustical standards and thresholds have been defined in park planning documents for the winter use season. The primary purpose of this study was to determine the impact of oversnow vehicles on the natural soundscape. These data were then compared to the impact definition thresholds in the 2004 Yellowstone and Grand Teton National Park Temporary Winter Use Plans Environmental Assessment. Acoustical data were collected at seven sites in Yellowstone National Park during the winter use season 15 December 2004 – 13 March 2005.

Oversnow vehicles were audible in the Old Faithful developed area an average of 69% of the day between 8 am and 4 pm. Oversnow vehicles were audible 29% (Old Faithful Upper Basin) and 47% (West Thumb Geyser Basin) of the day within geyser basins adjacent to developed areas. Along travel corridors the percent time audible ranged from 55% (West Yellowstone 3.1) to 61% during Presidents Day weekend (Madison Junction 2.3). The percent time audible in backcountry areas ranged from 4% (Lone Star Geyser) to 26% (Mary Mountain 8K). Sounds from oversnow vehicles were audible at least one mile adjacent to the main motorized routes at Mary Mountain 8K and Lone Star Geyser. Oversnow vehicles operating in the Gallatin National Forest on the west boundary of Yellowstone National Park were often audible at the West Yellowstone 3.1 monitoring site, three miles away. The maximum sound levels for oversnow vehicles exceeded 70 dB(A) at Old Faithful, along the groomed travel corridor between Madison Junction and the West Yellowstone entrance (Madison Junction 2.3 and West Yellowstone 3.1).

Oversnow vehicle use was restricted on some road segments due to inadequate snowcover early and late in the winter use season. Consistent with acoustic data collected the previous winter season, the sound level and percent time oversnow vehicles were audible remained substantially lower than oversnow vehicle sounds from the 2002-2003 winter use season. The reduced sound and audibility levels were largely explained by the fewer numbers of snowmobiles used, the change from two to four-stroke engine technology, and the guided group requirement.

10. **Comparing Sound Emissions of Snowmobiles to those of Road Vehicles.** Davis, G. & Marietta, N. (2005) Michigan Technological University.

Abstract, Conclusion and Table: The focus of this paper was to examine and compare sound emissions of production trail-ridden snowmobiles to that of other everyday vehicles that travel by road such as passenger cars, motorcycles, and semi tractor/trailers. The paper outlines the standard test used by the Society of Automotive Engineers (SAE) that all production snowmobiles must pass before they can be sold to the public, and compares these numbers to actual test data of noise emissions produced by standard road vehicles.

Conclusion: It is clearly seen that snowmobiles in fact do not make a great deal more noise than standard road vehicles. In many cases, snowmobiles are noticeably quieter. A snowmobile under full throttle emits the same sound level as a truck pulling a camper or an off-road Jeep traveling at constant highway speeds applying very little throttle. So if you refer to a worst-case scenario, a snowmobile leaving a stop sign and applying full throttle, the noise produced is still about the same as a very common vehicle simply cruising down the road.

Now if we look at the worst-case scenario in the opposite sense, a Harley Davidson motorcycle accelerating and applying nearly full throttle produces nearly six times the noise to your ear that a snowmobile driving the same way produces. In a more common example, a logging truck pulling a loaded trailer down the highway traveling at 45 mph will produce twice the noise of a snowmobile applying full throttle.

It has been demonstrated here that the common snowmobile is simply not allowed under law to produce the sound levels, under any type of driving conditions, that common road vehicles produce every day. It is illegal for a snowmobile being driven under full throttle to be as loud as a semi tractor/trailer cruising down the highway each and every day.

Table 1: Examples of Every Day Sound Levels

Sound Source	Sound Level dB(A)
75-piece orchestra	130
Car horn, snow blower	110
Blow dryer, diesel truck	100
Electric shaver, lawn mower	85
Garbage disposal, vacuum cleaner	80
Snowmobile (full throttle at 50 feet; maximum allowed by law)	78
Alarm clock, city traffic	70
Dishwasher	60
Leaves rustling, refrigerator	40

11. **Supplemental Over-Snow Vehicle Sound Level Measurements.** Daily, J.G. and Raap, K. (February 2002) Jackson Hole Scientific Investigations and Wyoming Department of State Parks and Cultural Resources. SAE Technical Paper Number 2002-01-2766. http://wyotrails.state.wy.us/Research/SoundLevel.aspx

Abstract: This study of over-snow vehicle sound levels was conducted to provide supplemental and additional information for preparation of the Winter Use Plan Supplemental Environmental Impact Statement (SEIS) for Yellowstone and Grand Teton National Parks and the John D. Rockefeller, Jr., Memorial Parkway. The tests conducted in this study resulted from the analysis of previous tests conducted in September 2001. The September tests were done on a grass surface, which is permissible under SAE standards. In order to get the best data possible, these February tests were done on snow under typical winter trail conditions.

The pass-by sound level of a variety of over-snow vehicles was measured at operational speeds that would be experienced under normal use of the vehicles while in the national park units. The pass-by testing included three different types of snow coaches, two commercially available four-stroke snowmobile models, a groomer, and various two-stroke snowmobiles. All testing was conducted on the same day in the same location with the same terrain and background conditions.

Conclusion: The loudest stock over-snow vehicle at a steady state speed was a Bombardier snow coach with high exhaust, which generated 78.4 dB(A) at 30 mph. The loudest stock snowmobile was a Polaris two-stroke 500cc Wide Track, which had a peak reading of 76.8 dB(A) at 45 mph. A modified Polaris RMK 800 was the loudest vehicle tested overall, with a peak average reading of 79.7 dB(A) at 45 mph. It recorded 84.9 dB(A) under full throttle acceleration.

The quietest over-snow vehicle tested was the Polaris Frontier touring snowmobile at 20 mph. Its lowest average reading at this speed was 65.0 dB(A). Four-stroke snowmobiles averaged 65.8 dB(A) at 20 mph, while the two-stroke snowmobiles averaged 70.7 dB(A) at 20 mph. The snow coaches averaged 69.6 dB(A) at 20 mph. The Ford two-track conversion van snow coach had a low average reading at 20 mph of 65.4 dB(A), making it the quietest of the snow coaches at this speed.

These data show the sound levels of many late model snowmobiles overlap or are quieter than snow coaches under the same or similar testing conditions. The quietest snowmobile at 20 mph produced less sound than any of the snow coaches at the same speed.

The lowest average reading for a snowmobile at 35 mph was the Polaris Frontier four-stroke, with a sound level of 70.3 dB(A). The lowest average reading for a snowmobile at 45 mph was 71.6 dB(A) by both the Polaris Frontier and the Arctic Cat Four-Stroke.

The lowest average reading for a snow coach at a nominal 30 mph was 69.5 dB(A) by the Ford two-track conversion van.

For comparison, the Kettering University entry in the Clean Snowmobile Challenge (CSC) 2001 competition recorded a sound level of 72 dB(A) during the maximum acceleration event. This is on par with the levels generated by the production four-stroke snowmobiles in this testing.

Quiet snowmobiles already exist, as shown by these data. The technology is improving to make these machines even quieter than they are now. Work will need to be done not only with engine sound levels, but also with the mechanical sound generated by the track and skis, regardless of whether the over-snow vehicle is a snowmobile or a snow coach. This work is going forward with the CSC as well as by the various snowmobile manufacturers. The production sleds tested in this evaluation are showing major improvements in the control of sound emissions compared to snowmobiles of just a few years ago.

The technology appears to exist to require that over-snow vehicles meet reasonable sound regulations. However, any regulations written should reasonably consider that over-snow vehicle sound levels are not attributable to just engine sounds must also must factor in the other mechanical sounds associated with tracked vehicles. These data show clearly the best available technology for reducing sound emissions from over-snow vehicles lie with the new technology four-stroke snowmobiles. The average sound emission from the production four-stroke snowmobiles at 45 mph is 72.5 dB(A), while the average sound emission at 30 mph of the snow coaches is 74 dB(A).

12. **Over-Snow Vehicle Sound Level Measurements.** Daily, J.G. and Raap, K. (September 2001) Jackson Hole Scientific Investigations and Wyoming Department of State Parks and Cultural Resources. SAE Technical Paper Number 2002-01-1656.

Abstract: This study of over-snow vehicle sound levels was conducted to provide new and additional information for preparation of the Winter Use Plan Supplemental Environmental Impact Statement (SEIS) for Yellowstone and Grand Teton National Parks and the John D. Rockefeller, Jr., Memorial Parkway. The pass-by sound level of a variety of over-snow vehicles was measured at operational speeds that would be experienced under normal use of the vehicles while in the national park units. The pass-by testing included four different types of snow coaches and various models of snowmobiles. All testing was conducted on the same day (in September on grass due to time constraints) in the same location with the same terrain and background conditions. Two additional 4-stroke snowmobiles were tested in January 2002 in Yellowstone National Park under typical winter conditions.

Conclusion: The loudest stock over-snow vehicle was a Ford two-track conversion van, which registered an average peak of 81.3 dB(A). The loudest stock snowmobile was a Ski Doo Summit 700, which had a peak reading of 79.8 dB(A) at 45 mph. A modified Polaris RMK 800 was the loudest vehicle overall, with a peak average reading of 81.9 dB(A).

The quietest over-snow vehicle tested during September was the Arctic Cat Four-Stroke Touring snowmobile at 20 mph. Its lowest average reading at this speed was 67.3 dB(A). Several other snowmobiles were in this range of the high 60's to low 70's at the 20 mph speed. The Bombardier snow coach had a low average reading at 20 mph of 69.9 dB(A), making it the quietest of the snow coaches at this speed.

The Polaris Frontier tested during January had an average pass-by sound level at 20 mph of 66.7 dB(A), which makes it the quietest over-snow vehicle run during this series of tests.

These data show the sound levels of many late model snowmobiles overlap or are quieter than snowcoaches under the same or similar testing conditions. The quietest snowmobile at 20 mph produced less sound than any of the snow coaches at the same speed. None of the over-snow vehicles were as quiet as the wheeled road vehicles tested, although the Dodge diesel pickup was near the lower level of the snowmobile sound envelope.

The Arctic Cat Four-Stroke tested in September was subjectively considerably quieter at 20 mph than any other over-snow vehicle tested at that time. This may be due to the fewer exhaust pulses at a given RPM as well as the clutching engagement tailored to the four-cycle engine. As the testing speed increased for this snowmobile, the mechanical sound of the track and under-dampened skis overcame the engine sound level. One observation is that this higher level of track and ski noise may be generated because of: 1) the blow-molded plastic skis on this particular snowmobile model versus a thinner profile plastic ski which appeared to generate less sound on other models, and 2) more noise and vibration emanating from the track, perhaps due to track tension, lug height, or other factors associated with track noise. Because of this, the Arctic Cat Four-Stroke was not the quietest snowmobile at speeds of 35 and 45 mph.

The lowest average reading for a snowmobile at 35 mph and 45 mph was the Polaris Frontier, with average sound levels of 70.7 dB(A) and 72.1 dB(A) respectively. As an aside, the sound level recorded during normal conversation after the September testing was 78 dB(A).

For comparison, the Kettering University entry in the Clean Snowmobile Challenge (CSC) 2001 competition recorded a sound level of 72 dB(A) during the maximum acceleration event. We would expect its sound level during steady state operation to be considerably lower than this.

Quiet snowmobiles already exist, as shown by these data. However, work to reduce overall sound levels even further needs to be done. Sound comes from the engine as well as mechanical components such as the clutch, track and skis, regardless whether the over-snow vehicle is a snowmobile or a snow coach.

The technology appears to exist to require that over-snow vehicles meet reasonable sound regulations. With the advent of four-stroke technologies for snowmobiles, sound level restrictions can be more stringent, especially in environmentally sensitive areas such as Yellowstone National Park. However, any regulations written should reasonably consider that over-snow vehicle sound levels are not attributable just to engine sounds but also must factor in other mechanical sounds associated with tracked vehicles.

13. **Factors affecting response to noise in outdoor recreational environments**. Kariel, H. G. (1990). The Canadian Geographer, 34(2), 142-149.

Abstract: Analyzes the relation between various sound sources in the outdoor environment and people's evaluations of them. Concludes that sound level alone is not a good predictor of annoyance; randomness, listener's subjective associations, and inconsistencies with expected environment were far greater factors in whether noise was considered a nuisance. Paper includes an itemized list of the decibel level of approximately 60 normally encountered activities when camping or picnicking.

14. **Portraits in sound: A study comparing ambient sounds with those generated by snowmobiles.** Wurzbach, W. F., & Freund, M. (1975). http://nohvcclibrary.forestry.uga.edu/SCANNED%20FILES/SO-0007.pdf

Abstract: This study is a very technical approach to increasing the awareness of the noise environment in which we find ourselves and its impact upon our daily lives, both physically and subjectively. This study concluded that snowmobile noise is a noise source contributor but not a major contributor. Presents a method for predicting the impact of noise on outdoor recreation called the System for the Prediction of Acoustic Detectability (SPREAD). SPREAD attempts to address the phenomenon of detectable noise vs. measured ambient noise levels with a formula (and worksheets) for predicting sound levels for the purpose of deciding what is appropriate/inappropriate acoustic impact in recreation sites.