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Noise Modeling to Determine Soundscape Benefits to Berm Implementation along US Highway I-80

Herbert Hoover National Historic Site

Background

In 2018, the Natural Sounds and Night Skies Division (NSNSD) received a technical assistance request to examine the spread of noise from vehicle traffic along US Interstate 80 at Herbert Hoover National Historic Site (HEHO). Excavation of a water detention basin will yield a large quantity of earth that will be more economical to distribute on site than to haul elsewhere. Installation of a noise berm between I-80 and the park boundary project has been proposed to realize another long-term benefit from the earthmoving project. To evaluate the noise reduction benefits a berm would provide, NSNSD simulated daily average traffic along US I-80. Results from this study will help park managers and planners understand the benefits a berm could provide to park ecosystems and visitor experience.

Noise is of concern to park visitors. It detracts from their natural and cultural resource experiences (NPS 2000) and can interrupt interpretive programs. *Noise* refers to sound which is unnecessary or unwanted either because of its effects on humans and wildlife, its interference with the perception or detection of other sounds, or both. The acoustic environment also is a natural resource that is integral to wildlife communication, behavior, and many other ecological processes (Shannon et al. 2016). Exposure to relatively high noise levels – like those experienced near I-80 – can produce potentially harmful physiological responses in humans and other animals including elevated stress hormone levels and increased blood pressure levels (Goines & Hagler 2007). Repeated noise can cause chronic stress to animals, affecting their energy stores, reproductive success, and long-term survival (Radle 2007). Even low levels of noise can interfere with ecological processes in surprising and complex ways (Shannon et al. 2016).

Noise scenarios

Three scenarios were modeled to determine the potential noise reduction the park would experience if berms were built between US I-80 and the park boundary.

Existing scenario: annual average daily traffic on US I-80, with no berm.

6 foot berm scenario: annual average daily traffic on US I-80, with a 6ft (1.8m) tall berm set 12 meters from the edge of US I-80.

9 foot berm scenario: annual average daily traffic on US I-80, with a 9ft (2.7m) tall berm set at 15.7 meters out from the edge of US I-80.

Noise Model

NSNSD used a noise propagation model called CadnaA to model the three scenarios. CadnaA (Computer Aided Noise Abatement) is a noise modeling software program that calculates noise propagation and noise mitigation benefits. CadnaA is developed in C/C++ and produces spatial outputs that are easily ingested into GIS databases. When modeling vehicle traffic, CadnaA uses the noise propagation calculations described by the Traffic Noise Model, version 2.5. The scenario output files were imported into ArcGIS (version 10.5.1) for further data analysis.

Noise Model Inputs

Traffic: annual average daily traffic of 39,600 vehicles during 24 hour day in 2016. Data received from IDOT online maps found at https://iowadot.gov/maps/msp/traffic/2014/counties/CEDAR.pdf.

Average traffic counts contain unspecified mix of cars, motorcycles, trucks, and buses.

Traffic speeds modeled at 70 miles per hour.

Road: 0% road gradient, “average” type of pavement, “main road” type of road

Weather: temperature = 20ºC (options are 0, 10, or 20 ºC), humidity = 70%

Berm: absorption coefficient of berm material set to 1, which defines the sides of the berm as soft, loamy ground. The berm was represented as a wall, with a vertical slope.

6ft Berm scenario: Maximum height of berm is 1.8 meters (6 feet) tall, the peak of the berm is located 12 meters out from the edge of the road. The berm slope was calculated using a 4:1 slope ratio (safe for mowing operations).

9ft Berm scenario: Maximum height of berm is 2.7 meters (9 feet) tall, the peak of the berm is located 15.7 meters out from the edge of the road. The berm slope was calculated using a 4:1 slope ratio (safe for mowing operations).

Calculations: Traffic Noise Model used to calculate road noise propagation, zero night or evening penalties assigned, height of sound receivers (park visitors) set at 1.2 meters.

Result Maps: 30 meter by 30 meter result raster cell size.

Noise metrics

All noise metrics are reported as average daily sound energy ($LA_{eq,\ 24h}$) and reflect modeled vehicle noise added to the landscape averaged across 24 hours. The average noise metrics were not added to the natural ambient sound level. Acoustic metrics, including those presented in this report, are on a logarithmic scale and reported as decibels (dB) relative to 20 µPa. The decibel scale is the standard way to express the wide range of sound pressure levels. For example, the threshold of human hearing is nominally 0 dB, and the sound level that crosses the threshold of pain is 120 dB. This represents twelve orders of magnitude, a trillion-fold change in sound level.

The noise metrics presented in this report are also A-weighted. The A-weighting function is applied to sound pressure levels in order to resemble the response of the human ear (Harris, 1998, p. 116). A-weighting discounts sounds below 1 kHz and above 6 kHz to approximate human hearing sensitivity. Human hearing sensitivity serves as a protective threshold for wildlife hearing, as human hearing of low-frequency noise is similar to or better than many terrestrial wildlife species (Dooling & Popper 2007). For comparative purposes, Table 1 provides examples of A-weighted sound levels measured in national parks, as the sounds might be perceived by a park visitor. The unit is $LA_{eq,\ 1s}$, or the sound level averaged over one second. Though the notation may seem complex, It is important to specify details like A-weighting and the duration of sound level averaging when reporting sound levels. Later in this report, differences in sound levels are reported. As these differences involve identical noise metrics, details like A-weighting and 24 hour averaging effectively “cancel out,” so changes in sound level are reported in dB. For example, if adding the berm changed the noise level from 60dB $LA_{eq,\ 24hr}$ to 55dB $LA_{eq,\ 24hr}$, the report will state that the park received a noise reduction of 5dB.

Table 1. Sound level examples.

Park Sound Sources	**Common Sound Sources**	**Sound Level (dBA)**
Volcano crater (HALE)	Human breathing at 3m	10
Leaves rustling (CANY)	Whispering	20
Crickets at 5m (ZION)	Residential area at night	40
Conversation at 5m (WHMI)	Busy restaurant	60
Cruiser motorcycle at 15m (BLRI)	Curbside of busy street	80
Thunder (ARCH)	Jackhammer at 2m	100
Military jet at 100m AGL (YUCH)	Train horn at 1m	120

Results

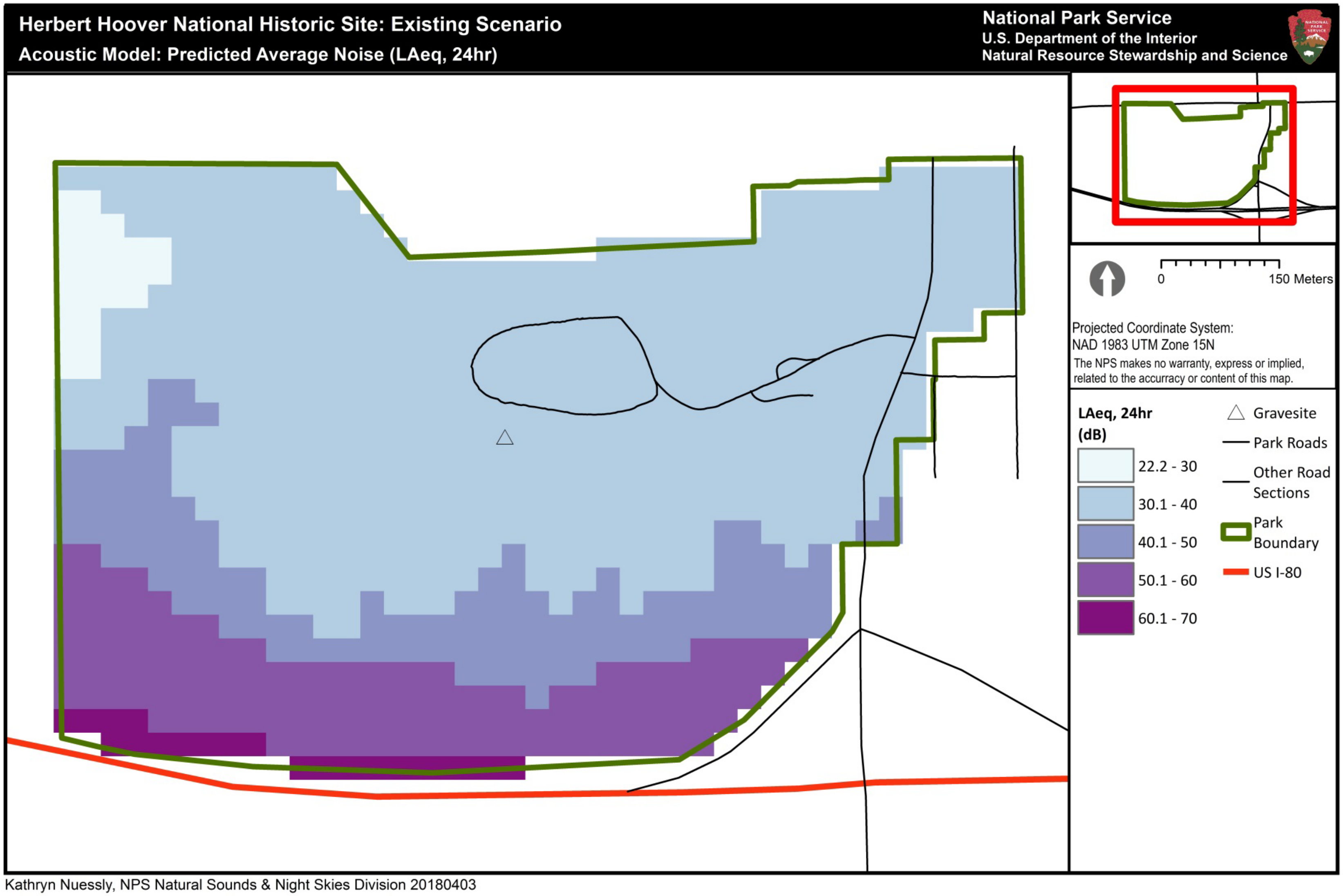

Figure 1: Existing average noise levels (LAeq, 24hr) resulting from 24 hour traffic on US I-80. The purple raster cells ranging from 50 to 70 $LA_{eq,\ 24hr}$ represent locations where noise is predicted to elevate blood pressure and stress hormone levels (Haralabidis et al., 2008).

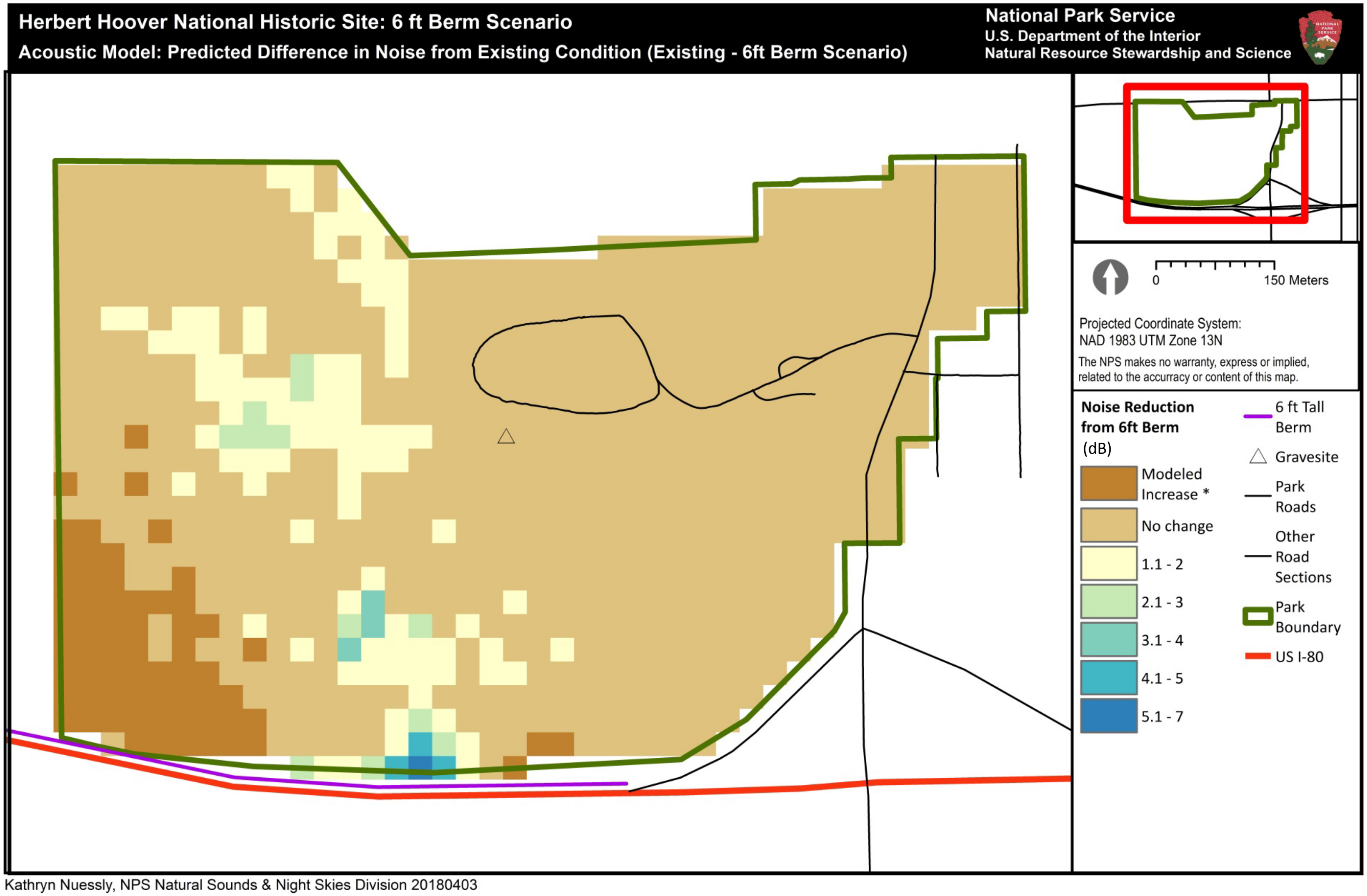

Figure 2: Noise reduction resulting from 6ft berm placed between US I-80 and the park boundary. This map shows the difference between the existing scenario and the 6ft berm scenario. *See Conclusion section below for further explanation.

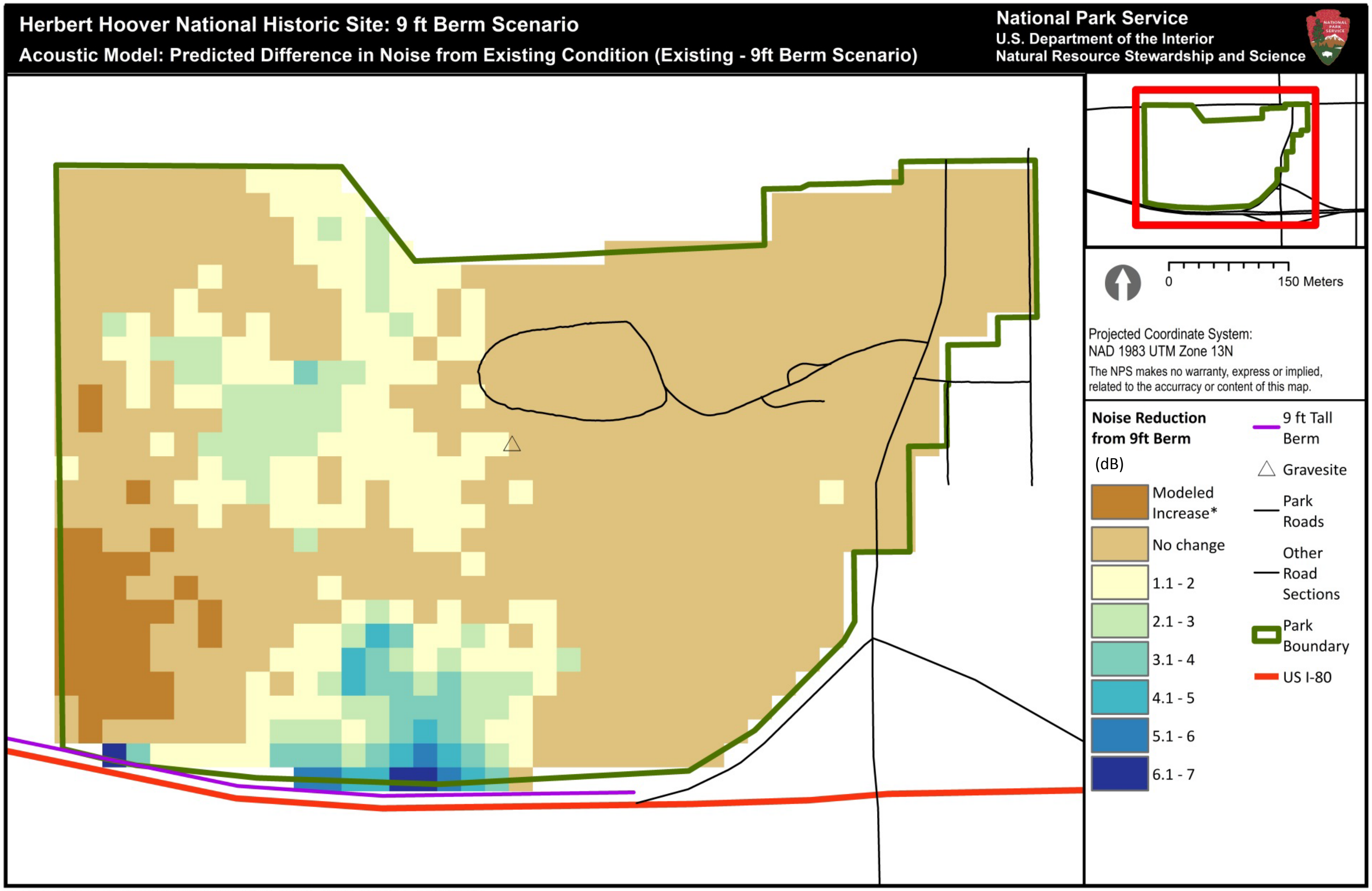

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Figure 3: Noise reduction results from 9ft berm placed between US I-80 and the park boundary. This map shows the difference between the existing scenario and the 9ft berm scenario. *See Conclusion section below for further explanation.

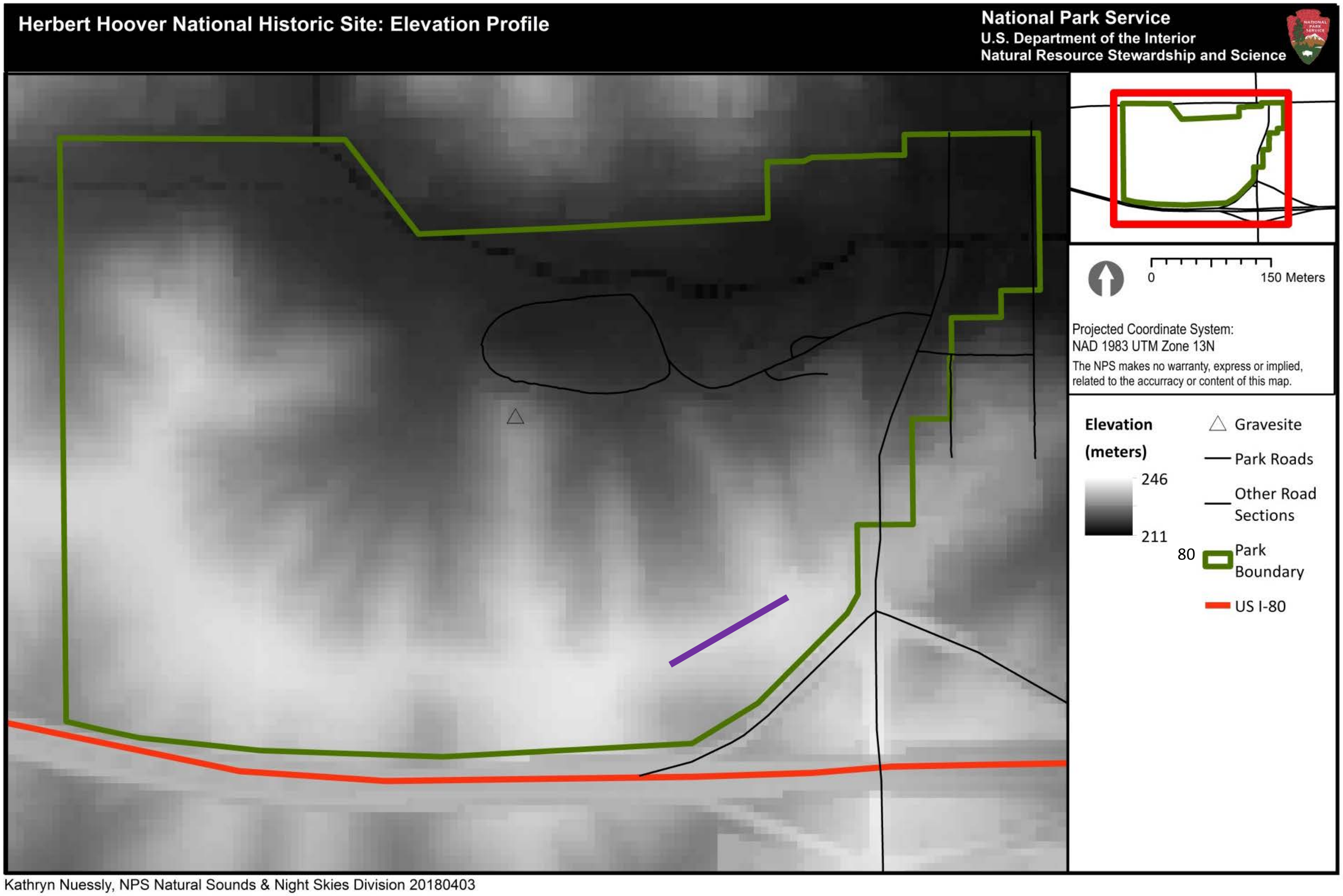

Figure 4. Elevation profile of HEHO.

Conclusions

The existing scenario predicts that average noise levels ($LA_{eq,\ 24hr}$) in the park resulting from US I-80 traffic-only ranged from 66dBA nearest to the park's southern boundary to 22dBA farthest from the southern boundary (Figure 1). The gravesite is predicted to receive daily average highway noise levels of 36dBA.

Both the 6ft berm (Figure 2) and the 9ft berm (Figure 3) are predicted to decrease the amount of highway noise that spreads into the park, and thus improve the acoustic condition for visitors and wildlife. The 9ft berm is predicted to experience greater noise reduction when compared to the 6ft berm. Areas that are closest to the noise berm will always receive the most benefit from noise mitigation. In the two scenarios, the park area that is predicted to receive the largest noise reduction benefit is the Prairie Trails trail that borders the park. On this trail, park visitors are predicted to experience a reduction in noise of 1dBA to 7dBA, which are equivalent to 20% and 80% reductions in traffic.

Overall, approximately 1/6th of the park area realizes a reduction in noise. However, the gravesite was not predicted to receive measureable noise reduction in the 6ft or 9ft berm scenarios. In order to reduce highway noise at the gravesite, the park could construct a berm south of the gravesite, paralleling the highway. Alternatively, the park could add fill on top of the natural rise of land 80 meters into the park from the south eastern boundary (marked by a purple line on Figure 4). Adding fill at this location would decrease the highway noise at the eastern farm area and possibly at the gravesite.

* The model predicts that the addition of berms will increase noise levels in the southwest portion of the park. This portion of the park's terrain is elevated relative to the nearest section of US I-80. One factor that may explain the increase in traffic noise is the way the berm was represented. For this modeling effort the berm is represented as a wall, with a vertical slope. Though we defined the absorption coefficient of the "wall" to reflect the soft, loamy soil in the berm, the berm represented in the model still lacks the sloped walls that a berm would have. Thus, the model may predict an exaggerated overflow of noise energy that spills over the top of the modeled wall, which propagates into the park with very little absorption by the ground past the wall.

Literature Cited

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