Mammal Parameter Specifications for the Area 5 and Area 3 RWMS Models

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Prepared by

Michele Wolf, Tom Stockton, and John Tauxe

Neptune and Company, Inc.

1. Title: Mammal Parameter Specifications for the Area 5 and Area 3 RWMS Models			
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3. Describe Use: This documents the statistical development of parameters used to define mammals in the Area 5 RWMS model.			
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6. Remarks:

This document was rebuilt using the OOoW template, and incorporates the mammal model used in the Area 5 RWMS Model v3.0 et seq. The editing log starts at this point, even though Tom Stockton is the original author. The data contained in this report were used as the basis for the Area 5 RWMS Model v3.0.

Several automation features were added, in particular all figures (these use the Illustration style in this document), equations, and tables were given automated cross-references, and references in the Summary section to specific parts in the text (e.g. to the discussion of a distribution derivation) are linked to reference codes in the text in order to simplify QA.

Some references, such as parameter values in the Summary cross-referenced to text passages, are inserted near where the value is mentioned. These are inserted using the command Insert | Cross-reference | tab: References | item: Set Reference. Very handy.

Note that since OOo Writer does not use font formatting in the tables contents, figures, or tables, a bit of touching up (italics, subscripts, etc.) might be necessary after any of these tables is updated.

CONTENTS

FIGURES

TABLES

1.0 Area 5 Summary

Listed below are the mammal fate and transport model parameter distributions for version 3.1 of the Area 5 Radioactive Waste Management Site model summarized in this document:

- Rodent volume excavated per mound:
  \TransportProcesses\AnimalTransport\Mammal1Data\MoundVolume

  ~ N(0.092, 0.0064, min = 0, max = arbitrarily large) m^3/yr (see Figure 3 and page 8)
- Other mammal volume excavated per mound:
  \TransportProcesses\AnimalTransport\Mammal2Data\MoundVolume

  ~ N(0.14, 0.041, min = 0, max = arbitrarily large) m^3/yr (see Figure 4 and page 8)
- Rodent mound density:
  \TransportProcesses\AnimalTransport\Mammal1Data\MoundDensity

  ~ N(192, 13.86, min = 0, max = arbitrarily large) mounds/ha (see Figure 6 and page 13)
- Other mammal mound density:
  \TransportProcesses\AnimalTransport\Mammal2Data\MoundDensity

  ~ N(2, 1.41, min = 0, max = arbitrarily large) mounds/ha (see Figure 7 and page 13)
- Rodent maximum burrow depth:
  \TransportProcesses\AnimalTransport\Mammal1Data\MaxDepth = 200 cm (see page 19)
- Other mammal maximum burrow depth:
  \TransportProcesses\AnimalTransport\Mammal2Data\MaxDepth = 250 cm (see page 20)
- Rodent *b* parameter for burrow density as function of depth:
  \TransportProcesses\AnimalTransport\Mammal1Data\b

  ~ N(4.5, 0.84, min = 1, max = arbitrarily large) (see Figure 10 and page 21)
- Other mammal *b* parameter for burrow density as function of depth:
  \TransportProcesses\AnimalTransport\Mammal2Data\b

  ~ N(4.7, 0.69, min = 1, max = arbitrarily large) (see Figure 11 and page 22)

2.0 Area 3 Summary

Listed below are the mammal fate and transport model parameter distributions for the version 3.1 of the Area 3 Radioactive Waste Management Site model summarized in this document:

- Rodent volume excavated per mound:
  \TransportProcesses\AnimalTransport\Mammal1Data\MoundVolume

  ~ N(0.11, 0.0074, min = 0, max = arbitrarily large) m^3/yr (see Figure 5 and page 8)
- Other mammal volume excavated per mound:
  \TransportProcesses\AnimalTransport\Mammal2Data\MoundVolume

  ~ N(0.14, 0.041, min = 0, max = arbitrarily large) m^3/yr (see Figure 4 and page 8)
- Rodent mound density:
  \TransportProcesses\AnimalTransport\Mammal1Data\MoundDensity

  ~ N(660, 200, min = 0, max = arbitrarily large) mounds/ha (see Figure 8 and page 16)
- Other mammal mound density:
  \TransportProcesses\AnimalTransport\Mammal2Data\MoundDensity

  ~ N(13, 6.6, min = 0, max = arbitrarily large) mounds/ha (see Figure 9 and page 16)
- Rodent maximum burrow depth:
  \TransportProcesses\AnimalTransport\Mammal1Data\MaxDepth = 200 cm (see page 19)
- Other mammal maximum burrow depth:
  \TransportProcesses\AnimalTransport\Mammal2Data\MaxDepth = 250 cm (see page 20)
- Rodent *b* parameter for burrow density as function of depth:
  \TransportProcesses\AnimalTransport\Mammal1Data\b

  ~ N(4.5, 0.84, min = 1, max = arbitrarily large) (see Figure 10 and page 21)
- Other mammal *b* parameter for burrow density as function of depth:
  \TransportProcesses\AnimalTransport\Mammal2Data\b

  ~ N(4.7, 0.69, min = 1, max = arbitrarily large) (see Figure 11 and page 22)

3.0 Introduction

Burrowing mammals can have a profound impact on the distribution of soil and its contents near the soil surface. The degree to which mammals influence soil structure is dependent on the behavioral habits of individual species. While some species account for a large volume of soil displacement, others are less influential. Needless to say, as a whole, mammals impact near surface mixing more than any other group on the NTS. In this manuscript, we present the mammalian contribution to soil rearrangement and the functional factors used to parameterize both the Area 5 and Area 3 GoldSim models. Factors such as burrowing depth, burrow depth distributions, percent burrow by depth, tunnel cross-section dimension, tunnel lengths, soil displacement by weight, soil displacement by volume and animal density per hectare play a critical role in determining the final soil constituent mass by depth within the soil.

Modeling soil and contaminant transport by mammal species within both the Area 5 and Area 3 models assumes animals move materials from lower cells to those cells above while excavating burrows. Furthermore, burrows are assumed to collapse over time and return soil from upper cells back to lower cells (Figure 1). Thus through time the balance of materials is preserved. Calculating soil and contaminant movement from one cell to another is straightforward. Within each layer, the fraction of burrow volume for each animal type and the fraction of contaminants contained within the burrowed volume are determined. The fraction of contaminants within the burrowed volume is based on the ratio of burrow volume to total volume of each layer and is assumed to be distributed homogeneously within the layer. Secondly, the sum of contaminants from each layer associated with burrow excavation by all animal types are calculated with the assumption that all excavations from layers below are deposited in the uppermost layer. Finally, downward movement of contaminants associated with burrow collapse from each layer to the layer below is calculated and the net movement of contaminants into each layer is determined. The amount of contaminants in each layer is then used to adjust contaminant inventory in each layer for the next time step.

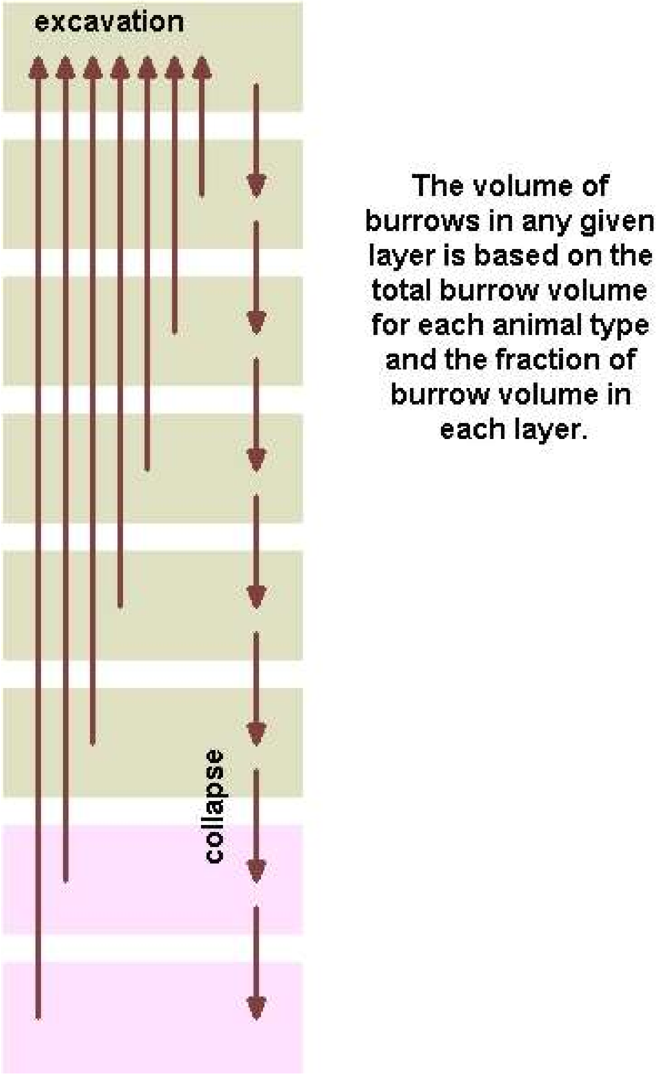

Figure 1. Diagram illustrating burrow excavation and burrow collapse, maintaining a balance of materials within the system.

The basic algorithm involves the following considerations:

1. Identify the data sets that pertain to the construction of mammalian biomass transport. Moreover, evaluate whether those data pertain to the Area 5 or Area 3 RWMS on the NTS and where they are lacking.
2. Identify which of the mammal species overwhelmingly contribute to the rearrangement of soils near the surface. Furthermore, group those species into functionally similar categories for modeling as “rodents” and “others.”

3. Determine the excavated volume for the entire population of rodents and other larger mammals.
4. Calculate burrow density as a function of depth for rodents and other larger mammals.
5. Determine the distribution of the burrow depth fitting parameter *b* for both modeling categories: rodents and larger mammals.

Each of these steps in the algorithm is discussed in detail in the following section.

4.0 Parameter Distributions

4.1 Relevant Data Sets

There are several sets of data that contain the majority of the information needed to parameterize the mammal component of the Area 5 and Area 3 models. Hooten et al. (2004, Table 10) list 33 mammal species that are likely to contribute to soil mixing on the NTS. Including all 33 species in either the Area 5 or Area 3 models is unwieldy, therefore the table was narrowed to those species that burrow deeply into soils and are considered the major contributors to soil mixing. The original species from Table 10 in Hooten et al. is reproduced in this document as Table 4. This more narrow list of species used for parameterization can be found in Table 5 along with plants affiliated for each species and the relationship of those affiliations to the alliances/affiliations described by Ostler et al. (2000). This smaller list had previously been complied (Hooten et al., 2004 Table 11) and was reproduced directly from that work.

Table 12 from Hooten et al. (2004) also was an important source of information during the modeling process and so its two parts are reproduced in this document as Tables 6 and 7. These tables present burrowing parameters such as maximum burrowing depth, burrow depth distributions, percent burrow by depth, tunnel cross-section dimension, tunnel lengths, soil displacement by weight, soil displacement by volume and animal density per hectare. Table 8 contains data recently collected on the NTS and describes X-Y-Z coordinates for mammal and badger mounds as well as mound volumes for these two groups. Finally, Tables 9 and 10 contain various pieces from Table 6 in a condensed version useful for bootstrapping and running simulations.

4.2 Relevant Mammalian Fauna

There are anywhere from 46 (O'Farrell and Emery, 1976) to 49 (Rundel and Gibson, 1996) species of mammals found on the NTS depending on the reference cited. Many of the mammals included in these lists are those that do not make burrows (Hooten et al., 2004). Moreover, there are species on those lists that simply modify existing burrows and do not construct new tunnels themselves. For those reasons, these two categories of mammals were not included in the model.

Table 6 lists the species that are major contributors to burrow formation, excavating massive quantities of soils to the surface and producing extensive tunnel systems. A vast number of these mammals are rodents, thus rodents were grouped together to form a functionally similar grouping called the "rodent" component of the model. Other mammals also contribute to soil redistribution but encompass a wide variety of species other than rodents. These mammals were grouped together as an all encompassing "other" category within the model. There is limited data available for some of the mammal species, therefore those species with sufficient data were included in the model and the specific data used during modeling are summarized in Tables 8, 9, and 10.

4.3 Excavated Mammal Burrow Volumes

Calculating Excavated Mound Volume

Estimated mound volume was calculated for rodent and badger mounds based on X-Y-Z measurements (*i.e.* length, width and height of the mound) recorded in the field on six quadrats from the NTS. The raw data and calculated volumes are in Table 8. Estimated mound volume was calculated using the equation for an elliptical cone, i.e. (X/2)(Y/2)(Z/2)pi. This calculation was then multiplied by 10,000 to convert X-Y-Z measurements from cm^3 to m^3. These estimated volumes are roughly equivalent to the dirt placed above the surface of the ground by mammal activity that occurs in a 1 to 10 year span of excavating and maintaining mammal dwellings. It is difficult to determine the actual rate at which such volumes of dirt are moved to the ground surface. It is clear, however, from observations made over the last 3 years that such mounds are readily maintained annually by mammals and that without such maintenance, they would fully collapse back into the soil (on a level with the surrounding ground) within a matter of 2-10 years. The rate of collapse depends on the size of the mound, annual precipitation, exposure to wind and the presence of plants to stabilize the mound dirt. Therefore, since these measurements are assumed to be for the amount of soil placed above the surface in a years time, mound volumes are measured as m^3/yr.

Quadrat 2 was surveyed in its entirety while measurements on quadrats Q3, Q4, Q5, Q8 and Q9 were made only on one quarter of the quadrat. Two field teams were formed with two individuals on each team to take measurements and make observations. The six quadrats were divided in half and each team collected measurements from mammal mounds on their half of the quadrat recording whether each was a small rodent mound, badger mound or both. Efforts were made to instruct each team regarding how to measure mammal mounds so that measuring techniques were consistent between the two teams. Only data from four of the six quadrats were used for analysis. Data from quadrats 8 and 9 were not included since these two quadrats were established to model climate change on the NTS. Moreover these plant communities are very different from those on the other four quadrats, so they would not be appropriate for modeling either Area 5 or Area 3. Finally, two other data points were excluded from the analysis because each represented a mound containing both small rodent and badger excavations. Since the two mounds could not be distinguished, these data were removed. Side-by-side plots of excavated mound volume for rodents and badgers from the four quadrats are shown in Figure 2.

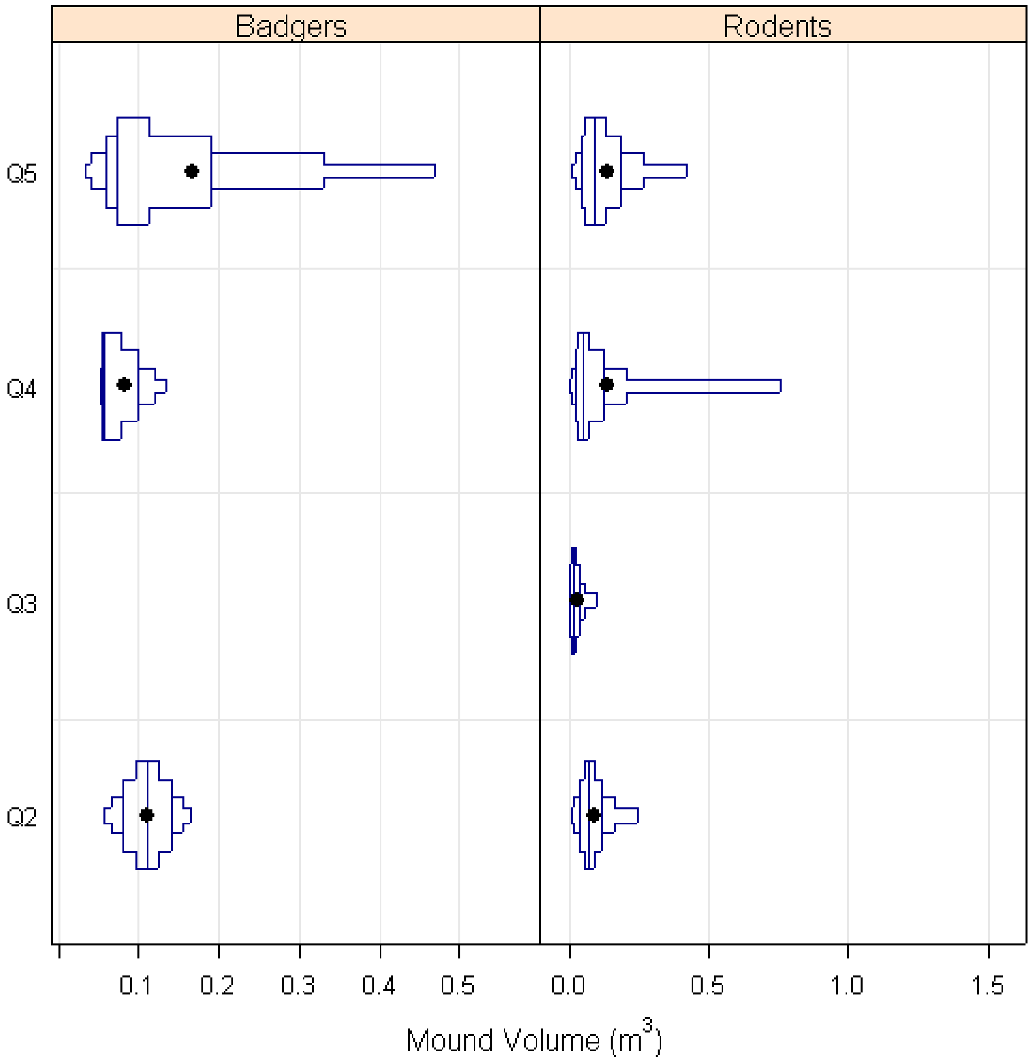

Figure 2. Side-by-side comparison of excavated mound volume for small mammals and badgers from 4 quadrats on the NTS. The data for this plot are in Table 4.

4.4 Area 5 Excavated Mound Volume

Data from quadrat 2 were bootstrapped to determine the distribution of excavated soil for small mammals. A random normal distribution was simulated using the mean and standard deviation from the bootstrapped distribution as input parameters. The cumulative distribution functions for both distributions were plotted (Figure 3) and the fit of the normal distribution to the bootstrapped data was deemed adequate. Thus, the total volume excavated by an individual small rodent was modeled using a normal distribution with a mean of 0.092 m^3/yr and a standard deviation of 0.0065 m^3/yr.

Excavated mound volume for the "other" category is based on all data arising from X-Y-Z measurements made on badger mounds. The badger mound volume data are presented in Table 8. Bootstrap sampling was used on the data set to determine the excavated badger mound distribution of the sample mean. A random normal distribution was simulated using the mean and standard deviation from the bootstrapped distribution as input parameters. The CDFs for the bootstrapped and normal distribution were plotted (Figure 4) and the normal distribution was found to be an adequate fit to the bootstrapped data. Thus, the volume excavated by badgers, the "other" category in the model, was modeled using a normal distribution with a mean of 0.14 m^3/yr and a standard deviation of 0.041 m^3/yr per burrow.

Since volume excavated must be a positive number, both of the normal distributions for rodents and badgers are truncated at 0. If either tail of the distribution is truncated, then GoldSim requires both tails to be truncated. Therefore, the right-tails of the normal distributions are truncated at 1.0E+20 so as to not affect the simulation.

4.5 Area 3 Excavated Mound Volume

Data from quadrats Q3, Q4, and Q5 were bootstrapped to determine the distribution of excavated mound volume for small mammals. The bootstrapped data is shown in Table 8. A random normal distribution was simulated using the mean and standard deviation of the bootstrapped data set. The cumulative distribution functions for both the bootstrapped and normal distributions were plotted (Figure 5) and the fit of the normal distribution to the bootstrapped data was deemed adequate. Thus, the total volume excavated by an individual small rodent was modeled using a normal distribution with a mean of 0.11 m^3/yr and a standard deviation of 0.0074 m^3/yr.

Since there are limited data available on badger volumes, the data used to model badger mound volume for Area 5 also is used to model badger mound volume in Area 3. Therefore, the same distribution developed for Area 5 is used for Area 3. The bootstrapped data and normal fit to the data can be seen in Figure 4. Therefore a normal distribution with a mean of 0.14 m^3/yr and a standard deviation of 0.041 m^3/yr per burrow will be used in the Area 3 model for excavated badger mound volume.

Distributions developed for Area 3 are truncated at zero and 1.0E+20. Distributions are truncated at zero to ensure excavated volumes be a positive number. The upper tail of the distribution also is truncated because in GoldSim if either tail of a distribution is truncated, the other tail also must be truncated. These measures were taken so as to not affect the GoldSim simulation.

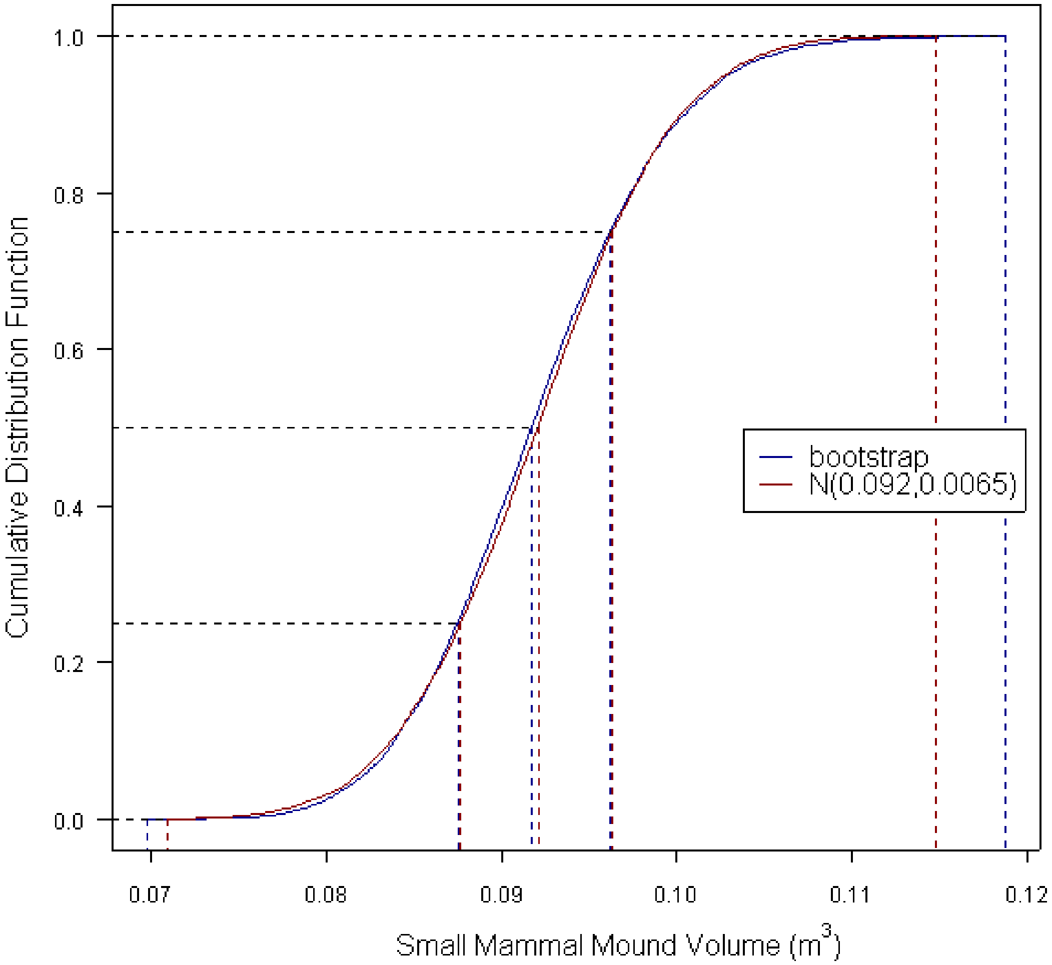

Figure 3. Comparison of the CDF of the bootstrapped distribution of excavated mound volume for small mammals versus the CDF of the normal distribution. These CDF's were constructed using data found in Table 8. This distribution was used in the Area 5 GoldSim model.

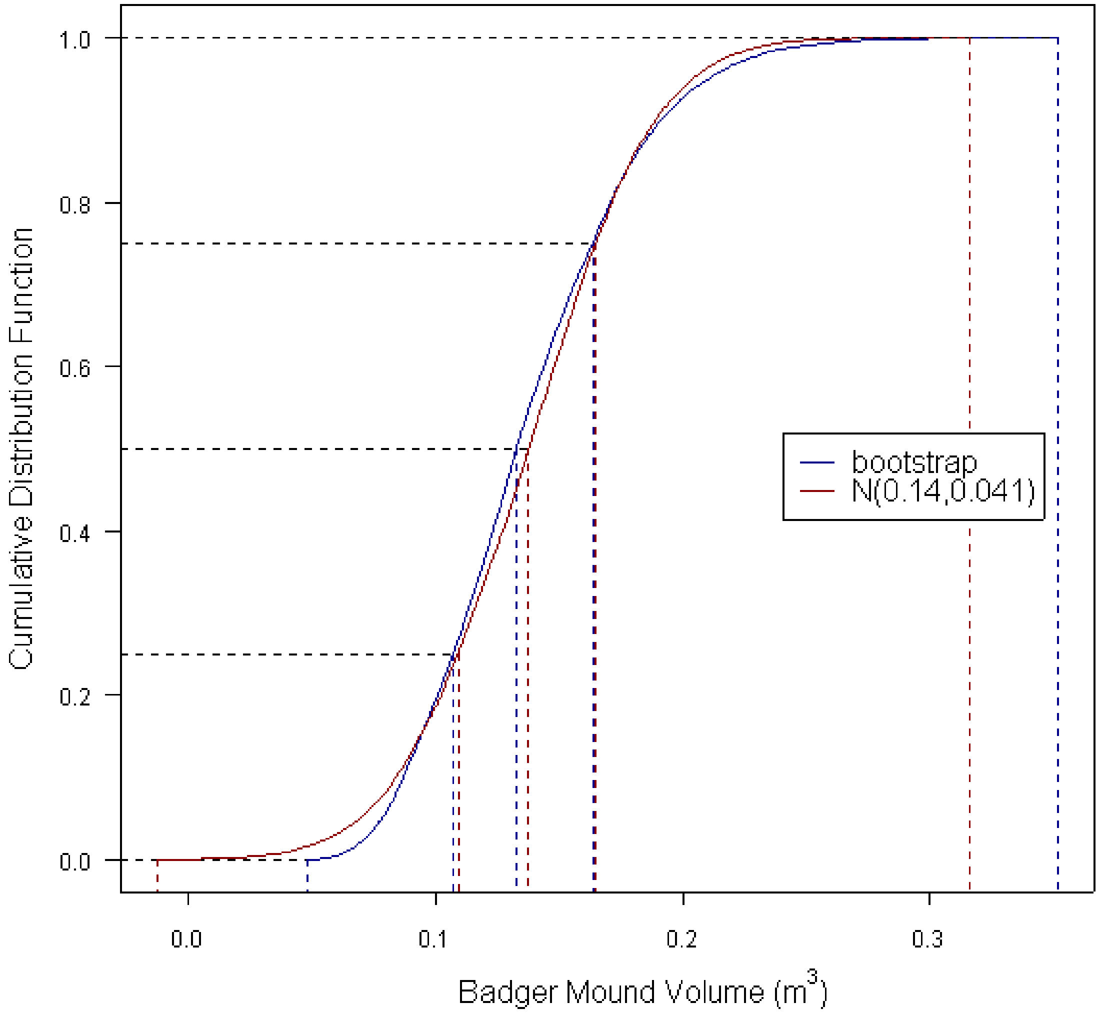

Figure 4. Comparison of the CDF of the bootstrapped distribution of excavated mound volume for badgers versus the CDF of the random normal distribution. These CDF's were constructed using data found in Table 8. This distribution was used in both the Area 5 and Area 3 GoldSim models.

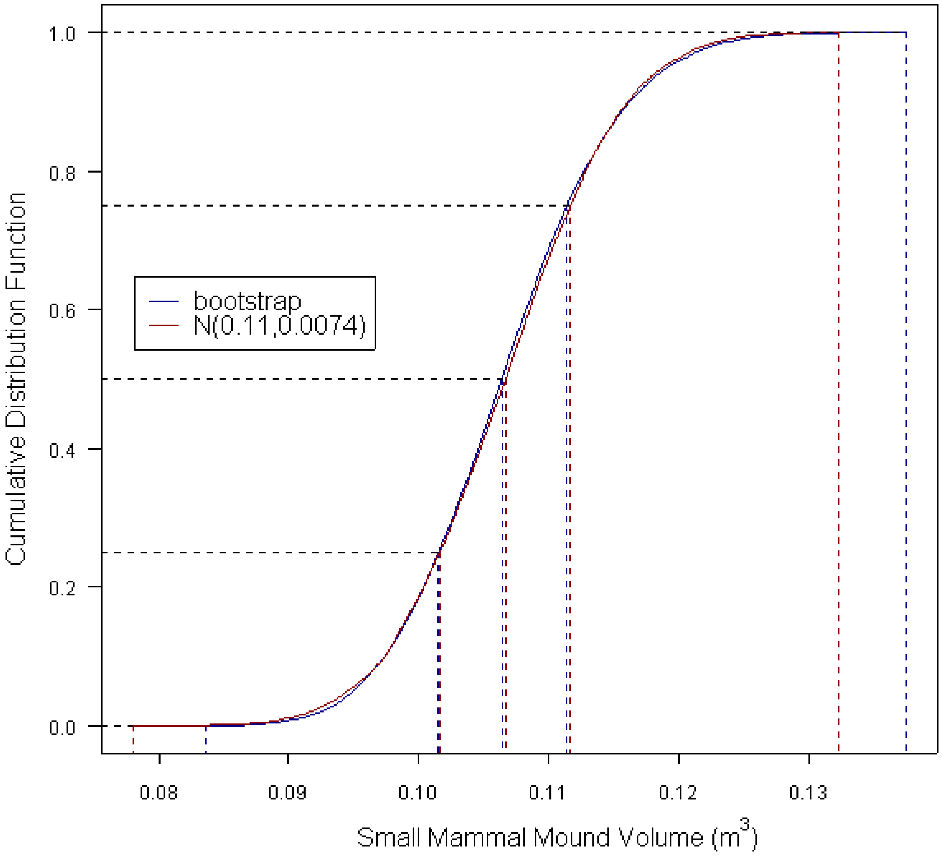

Figure 5. Comparison of the CDF of the bootstrapped distribution of excavated mound volume for small mammals versus the CDF of the normal distribution. These CDF's were constructed using data found in Table 8. This distribution was used in the Area 3 GoldSim model.

4.6 Density of Mammal Mounds on the RWMS

The animal model requires specification of a distribution for the density (number of animal burrows per hectare) of small mammals for both categories, rodents and badgers. Density data were collected from 5 quadrats during the summer 2003 field trip (Hooten et al., 2004) to the Nevada Test Site. Each of the five quadrats is 100m×100m and hence constitute 1 hectare each. All small mammal mounds on quadrat 2 were measured in their entirety, whereas the other quadrats were measured for mammal mound density only in one 50m×50m quarter (hence, ¼ hectare). The data are in Table 1, with the data for quadrats 3, 4, 5 and 8 multiplied by 4 for a hectare-based result.

Table 1. Numbers of small mammal mounds per hectare on five quadrats from the NTS. Field observations from the Summer 2003 field trip.

Quadrat	**2**	**3**	**4**	**5**	**8**
Small Rodents	192	544	304	1140	500
Badgers	2	0	12	28	0

4.7 Area 5 Mammal Mound Density

The data for the small rodents show that the mound density is lower in quadrat 2 than in any of the other quadrats. This is of interest because quadrat 2 is the only one of these quadrats that is in Frenchman Flat and hence currently associated with the Area 5 RWMS. That is, the density of small rodent mounds in Frenchman Flat appears less than their density in Yucca Flat and elsewhere (quadrat 8 is in the Great Basin desert). Consequently, only the data for quadrat 2 were considered for specification of the density of small rodent mounds for the Area 5 RWMS.

It is not possible to reach a similar conclusion for badgers based on the available data. Nevertheless, the same approach was taken more for consistency than for any other data-based reason. Consequently, the density of 192 mounds per hectare for small rodents and 2 mounds per hectare for badgers were used as the starting point for specifying probability distributions.

An approach based on the binomial distribution was taken for specifying distributions using the limited amount of available mound density information. In implementing the binomial distribution, three parameters must be established, the probability of a success (p), the probability of failure ($1-p$) and the total number of samples (n). For rodent mound density, each reported mound was considered a "binomial success." To create "binomial failures," conceptually the quadrat was divided into many small areas. The size of each quadrat was initially based on the areal dimension of the burrows. Since small rodent burrows were generally less than 3 m across, one possibility is to consider consecutive 3 m squares within the hectare. This suggests 1089 subunits (approximately) in a hectare, from which there are 192 successes (192 subunits containing a mound) and 897 failures (897 subunits that did not contain a mound). Following from these arguments, the parameters of interest are $p = 192/1089$, $1-p = 1-(192/1089)$ and $n = 1089$. Since these parameters are based on the binomial distribution, the mean and variance may be calculated based on the mean (np) and variance ($np(1-p)$) formulas from the binomial distribution. Therefore, the variance for rodent mounds is calculated as 159.44 and the standard deviation is then 12.6.

As it turns out, the choice of *n* is somewhat arbitrary since the standard deviation reaches an asymptote as *n* increases (here labeling the binomial variable *X*):

$$Var(X) = np(1-p) = \frac{\sum X_i\left(n - \sum X_i\right)}{n}$$

and

$$max\left(Var(X)\right) = \sum X_i \ . \qquad \text{(Equation 1)}$$

That is, the maximum possible standard deviation is the square root of the number of successes ($\sqrt{(192)}$ = 13.86). Given the sparseness of the available information, this approach was taken to maximize the standard deviation. Conceptually this corresponds to infinitesimal subunits, but the result is not very different than that obtained by using a large finite number of subunits, and it standardizes the approach without choosing an arbitrary finite number of subunits. Note also that the sample size is considered sufficiently large that the mean and standard deviation calculated this way are considered ultimately as parameters of the normal distribution.

Hence for small rodents, the mound density distribution is specified as N(192, 13.86) in units of small mammal mounds per hectare. The same approach was taken for badgers, resulting in a mound density distribution of N(2, 1.41), again in units of badger mounds per hectare. The badger specification is further supported by information from Lindzey (1982). Lindzey reports a study of badger density in Idaho in which the number of badgers per hectare averaged 1.6. This value is consistent with the distribution that is proposed here. Finally, since the density of mammal mounds per hectare (small mammal or badger mounds) must be a positive number, the normal distributions are truncated at 0. In GoldSim, if either tail of the distribution is to be truncated, then both tails must be truncated. Therefore, the right-tails of the normal distributions are truncated at 1.0E+20 so as to not affect the simulation.

More generally, the information content could be improved in upcoming field trips. Counting small rodent mounds across entire hectares might prove exhausting, but an approach that counts small rodent mounds in smaller areas (e.g., 1% of a hectare) and badger mounds in entire hectares might yield better information on which to base these distributions. For now, we recognize some of the limitations of the approach that has been taken to distribution specification, but also recognize that what has been constructed should be thought of as prior distributions that are subject to updating as more information is collected. For example, the data come from a single quadrat, so variation between sub-areas of Frenchman Flat is not included, and variation between plant communities is not included (e.g., no data are available from quadrat 6). To compensate, the asymptotic standard deviations were used, but we recognize that collection of more data would yield more defensible distributions. The distributions specified are considered reasonable as prior distributions until more data are collected.

Total excavated soil volumes for Area 5 were therefore obtained by directly multiplying excavated volume by mound density to obtain total excavated volume per hectare per year.

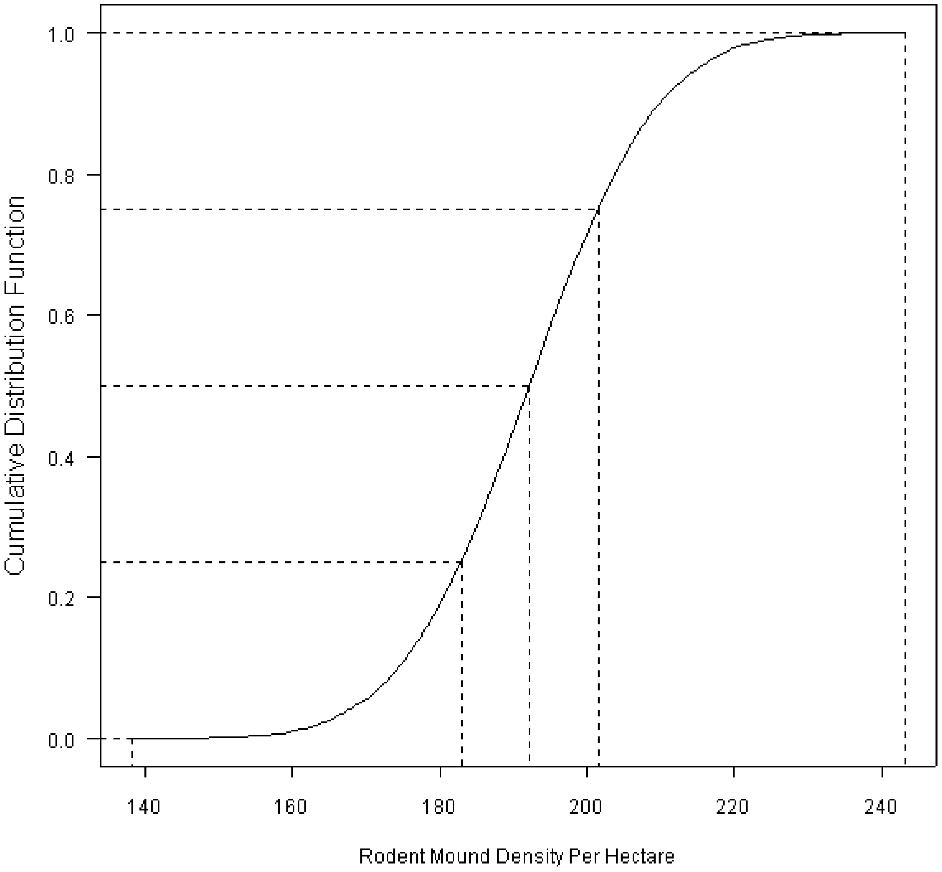

Figure 6. The Area 5 CDF of the random normal distribution of rodent mound density on the RWMS. This CDF was constructed using data found in Table 1.

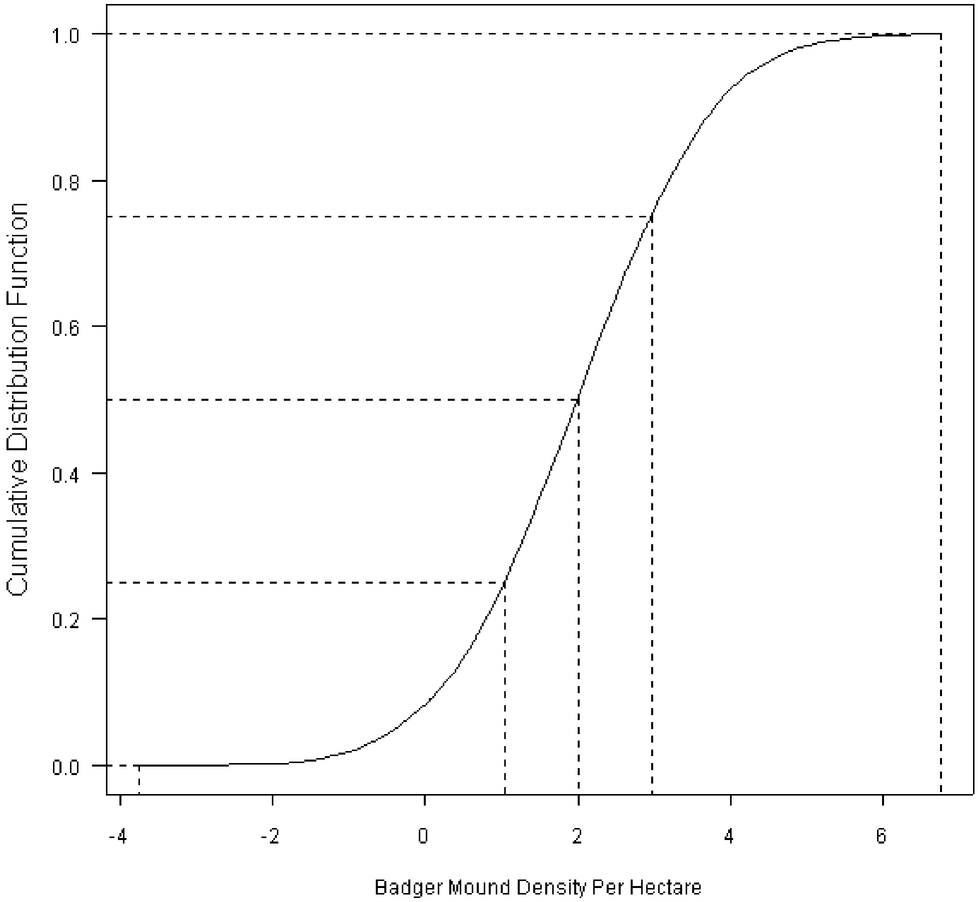

Figure 7. The Area 5 CDF of the random normal distribution of badger mound density on the RWMS. This CDF was constructed using data found in Table 1.

4.8 Area 3 Mammal Mound Density

Three quadrats (Q3, Q4 and Q5) were established in Yucca Flat and are currently associated with Area 3 of the RWMS. Data from these quadrats are shown in Table 1. These data were used to develop small mammal and badger mound density distributions for the Area 3 GoldSim model.

Although the data were sparse, small mammal mound densities from all three quadrats were bootstrapped to determine the distribution of the mean mound density. A random normal distribution was also simulated using the mean and standard deviation from the bootstrapped distribution as input parameters. The cumulative distribution functions for both distributions were plotted (Figure 8) and the fit of the normal distribution to the bootstrapped data was deemed adequate. Thus, mean mound density for small rodents was modeled using a normal distribution with a mean of 660 mounds/hectare and a standard deviation of 200 mounds/hectare.

A similar approach was used to determine the mean mound density for badgers in Area 3. Data shown in Table 1 were bootstrapped, plotted and a normal distribution fit to the bootstrapped data (Figure 9). The fit was appropriate, therefore badger mound density was modeled using a normal distribution with a mean of 13 mounds/hectare and a standard deviation of 6.6 mounds/hectare.

Finally, total excavated soil volumes for Area 3 were obtained by directly multiplying excavated volume by mound density to obtain total excavated volume per hectare per year for each mammal category.

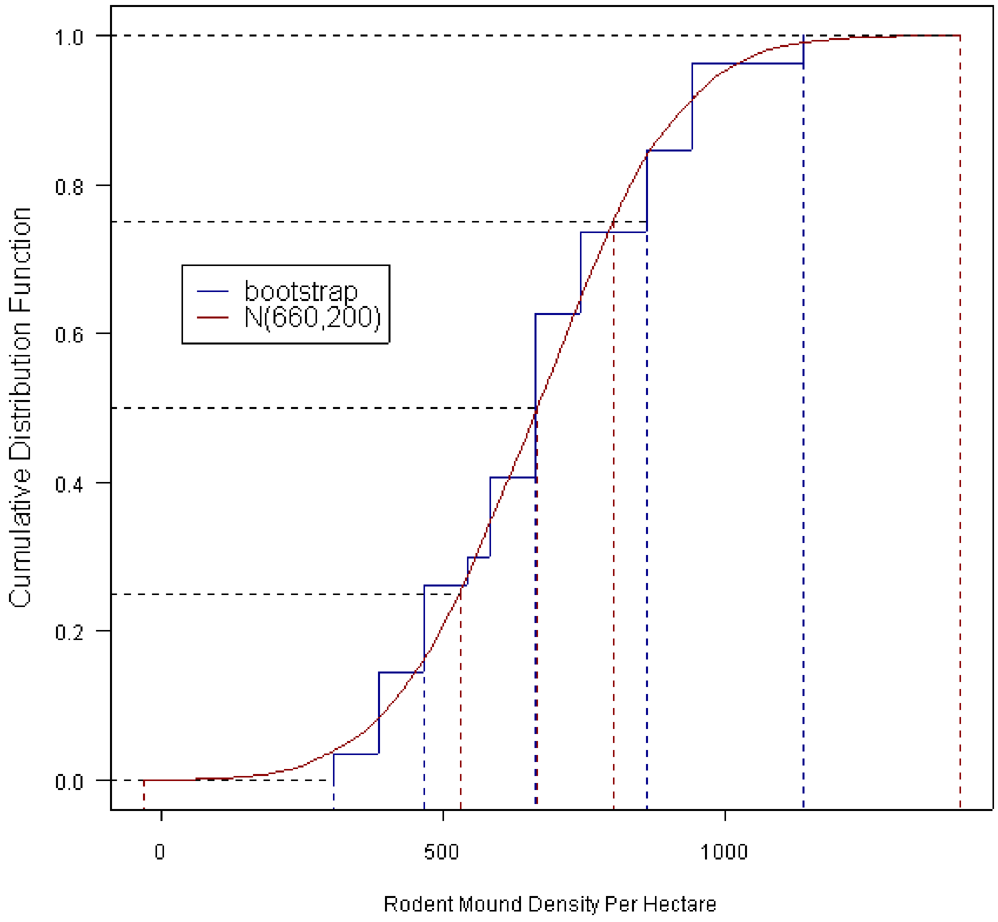

Figure 8. Area 3 comparison of the CDF of the bootstrapped distribution of mound density for small mammals versus the CDF of the normal distribution. These CDF's were constructed using data found in Table 1.

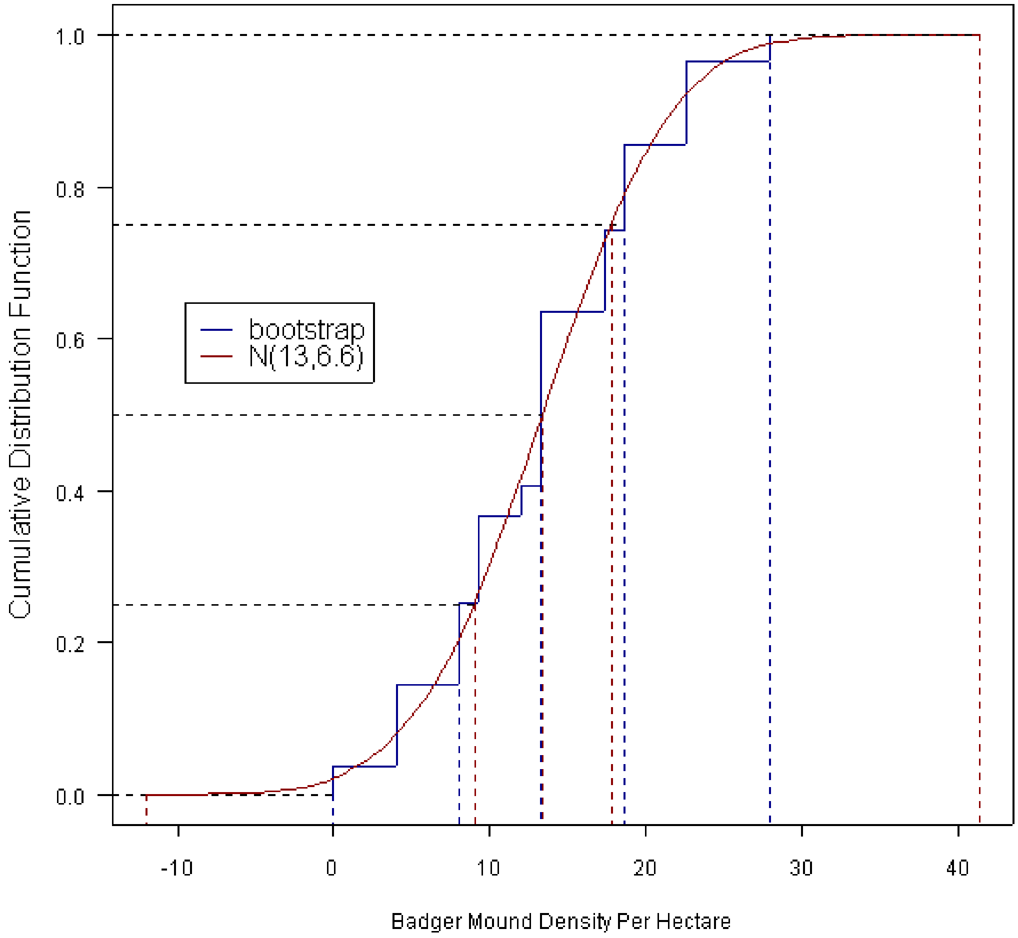

Figure 9. Area 3 comparison of the CDF of the bootstrapped distribution of mound density for badgers versus the CDF of the normal distribution. These CDF's were constructed using data found in Table 1.

4.9 Burrow Volume as a Function of Depth

Burrow density as a function of depth depends on two quantities for its calculation, the maximum burrowing depth (z_{max}) and the fitting parameter *b*. These two values are used in equation (Equation 2) for determining the fraction of the burrow above any given depth.

$$F(z)=1-\left(1-\frac{z}{z_{max}}\right)^b, \quad 0<z<z_{max}, \quad b\geq 1 \qquad \text{(Equation 2)}$$

Maximum Burrow Depth

Field data for small mammal burrowing depths on the RWMS do not exist. Therefore the current literature pertaining to maximum burrowing depths for small mammals was searched to better understand the data that would be appropriate for the RWMS. A summary of those efforts (Hooten et al., 2004) can be found in Table 2. Based on the literature maximum burrow depths for small mammals range from 50cm to 200cm. Therefore the maximum burrow depth for the population of small mammals is set at 200 cm based on a combination of literature values and best professional judgment. Since these are the only data available for maximum burrow depth, this value will be used for both the Area 5 and Area 3 GoldSim models.

Table 2. Maximum burrow depths for several species of small mammals obtained through a literature review of available data.

Maximum Burrowing Depth (cm)	Mammal Species	Literature Source
50	*Peromyscus maniculatus*	Suter et al. 1993
50	*Peromyscus maniculatus*	Reynolds and Wakkinen 1987
58	*S. townsendii*	Bowerman and Redente 1998
65	*Perognathus longimembris*	Kenagy 1973
69	*D. microps*	Reynolds and Wakkinen 1987
70	*D. microps*	Suter et al. 1993
75	*Perognathus longimembris*	Kenagy 1973
92	*Burrows of pocket mice*	Bowerman and Redente 1998
105	*Perognathus parvus*	Bowerman and Redente 1998
140	*Perognathus parvus*	Suter et al. 1993
140	*S. townsendii*	Suter et al. 1993
150	*S. townsendii*	Reynolds and Laundrj 1988
150	*Thomomys bottae*	Felthauser and McInroy 1983
160	*Thomomys bottae*	Reichman et al. 1982
175	*D. merriami*	Kenagy 1973
200	Several species of pocket mice and kangaroo rats	Kennedy et al. 1985
200	Several species of ground squirrels	Kennedy et al. 1985

The North American badger (Carnivora: *Taxidea taxus*) burrows after prey and also for the purpose of reproduction. In the seminal text *Wild Mammals of North America* (Chapman and Feldhamer 1982), Lindzey (1982) summarizes the following for the function of the badger den:

> "Dens display a central role in the ecology of the badger, functioning as sites for diurnal activity, food storage, and parturition, and as foci for foraging. Dens are variable in characteristics because most are dug in

> pursuit of prey. Generally, they have only a single, often elliptical entrance. Soil excavated during the formation of the den is piled at the entrance."

Speaking specifically of natal dens, Lindzey (1982) remarks:

> "In Utah, natal dens had the following characteristics in common: (1) a main tunnel that branched into two secondary tunnels that later rejoined; (2) dead-end side tunnels that projected from the main tunnel, secondary tunnels and chambers; (3) pockets of less than 15 cm in length in the sides of tunnels and chambers; (4) shallow excavations in the floors of tunnels; and (5) chambers."

Kennedy et al. (1985) summarize that badger tunneling can be to depths of over 2 m from the ground surface and that the majority (about 85 percent) of badger excavations occur in the top meter of soil. Table 3 (Kennedy et al. 1985) summarizes percent badger burrow by depth, with no reported measure of variability.

Table 3. Percent badger burrow by depth.

Percent burrow volume by depth	
Depth (cm)	**% burrow**
0–50	70
51–100	15
101–150	5
151–200	5
200	5

In light of Lindsay's (1982) statement "Dens are variable in characteristics because most are dug in pursuit of prey," one may interpret Kennedy et al.'s distribution to mean that approximately 70 percent of badger digs are confined to the top 50 cm of soil, while 85 percent are in the top meter, etc. This makes biological sense for the sake that most shallow burrows are after rodents that live primarily in the top meter of soils, while deep burrows (over 1 m) are energetically expensive and only dug when truly necessary, especially to escape harsh weather or temperature conditions (including hibernation), escape predation, or for the sake of natality and rearing young. Thus, few badger digs are deep, per se, and the maximum depth is likely between 200 and 250 cm, given the distribution of Kennedy et al. (1985). A reasonable statement based on this sparse information would be that the majority, i.e. 95 percent, of badger digs will be less than 200 cm depth, while a likely maximum depth will be 250 cm.

A maximum depth of 250 cm for a badger dig in the area of the Area 5 RWMS is a reasonable expectation. Anecdotally, in the course of 14 excavations of ant mounds at the RWMS, we found that few mammal burrows exceeded 1 meter with maximum observations at about 1.5 meters. Given that badgers will dig primarily in pursuit of prey, observations of mammal burrows confined mostly to the top meter of soil at the RWMS would support the interpretations (made above) of Kennedy et al. (1985) in concert with Lindzey (1982). Given that these are the only available data pertaining to maximum burrow depths for badgers, these data will be used for both the Area 5 and Area 3 GoldSim models.

Estimation of *b*

The *b* parameter in Equation 2 alters the form and volume of the excavated burrow. As the value of *b* increases, the fraction of burrow excavated at each depth moves from being evenly distributed to a highly skewed distribution with most of the excavation occurring near the soil surface.

For rodents, the form of excavated burrows can take on a variety of shapes. Data for small mammals are given in Table 12 in Hooten et al., 2004 (Table 6 in this document). Estimates of *b* for each burrow were found using non-linear least squares. For the estimation, the overall maximum depth was used for z_{max} rather than maximum depth for the individual burrow. This selection of z_{max} was made because it is the maximum likelihood estimate of maximum burrow depth and if z_{max} does not fall at a GoldSim depth interval, then only a negligible percentage of the predicted burrow volume will fall below z_{max}. The 5 fitted *b* values were bootstrapped to find the distribution of the mean of *b*. A plot of the bootstrap distribution and a normal distribution with mean 4.5 and standard deviation 0.84 is given in Figure 10. The figure indicates that the normal distribution provides a good fit to the distribution of the average of the *b* parameter.

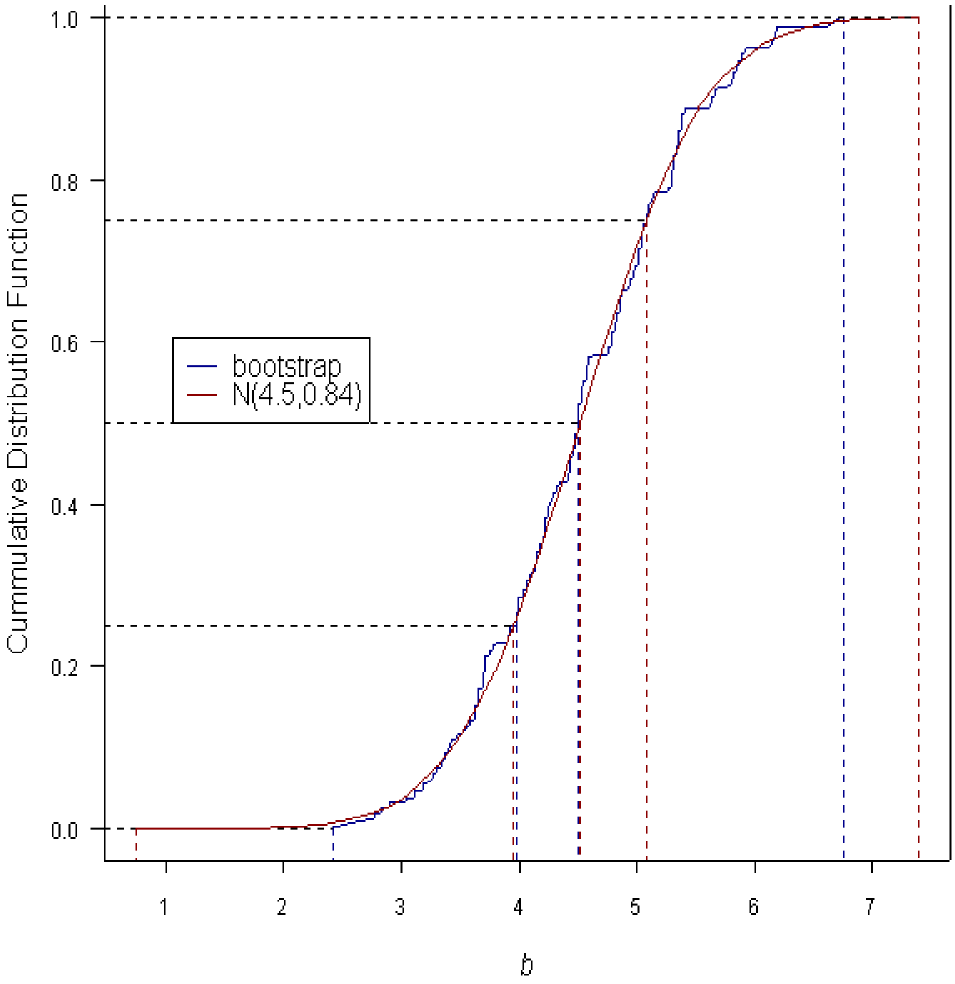

Figure 10. Comparison of bootstrap and normal distributions for the average of the small mammals burrow volume with depth parameter *b*. This distribution is used for both the Area 5 and Area 3 models.

The only available data for badger burrow volume with depth are given in Table 3. These data are from a single badger burrow identified through a literature search. The data from this burrow was used in Equation 1 to fit beta. The resulting estimate of b and the standard error of b was 4.7 and 0.69, respectively. Since there was little information regarding the distribution for the average b, a normal distribution is chosen with a mean of 4.7 and a standard deviation of 0.69 (Figure 11) to describe both the Area 5 and Area 3 b distributions for badgers.

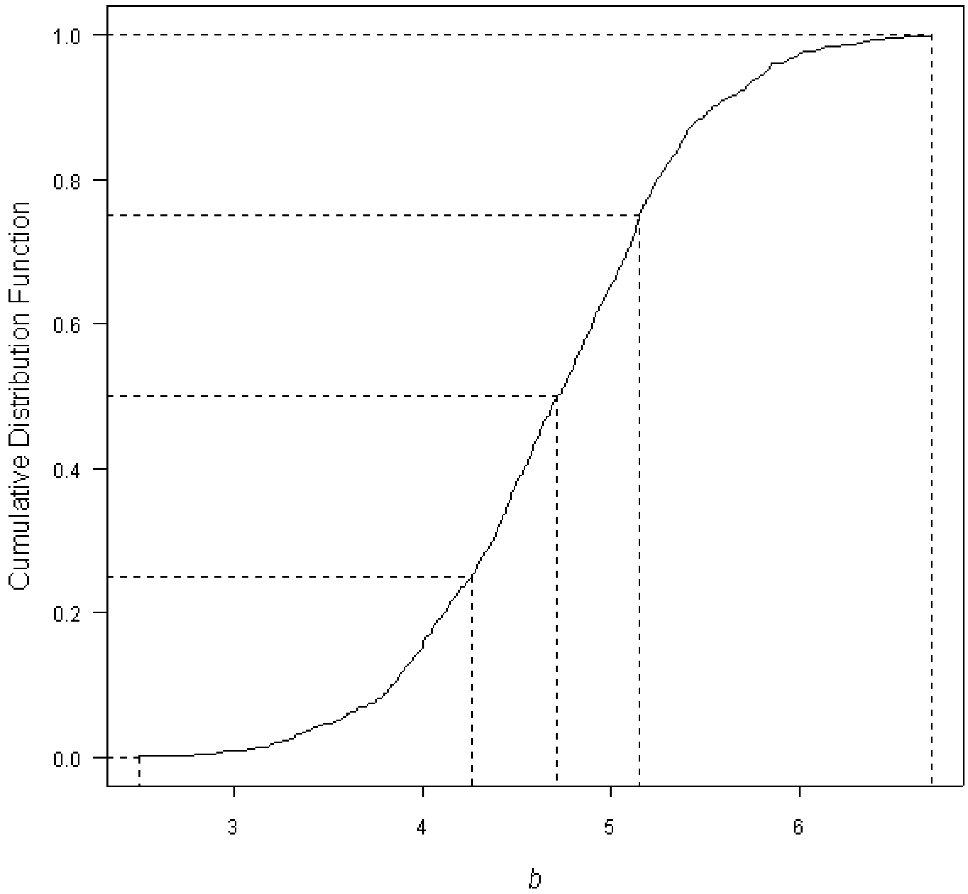

Figure 11. Cumulative distribution function for the *b* parameter in the badger burrow volume with depth function (Equation 1). This distribution is used for both the Area 5 and Area 3 models.

The parameter *b* defines the shape of the burrow. If *b* is greater than 1, then the burrow volume for a given layer decreases with depth. If *b* is less then 1, then the burrow volume for a given layer increases with depth. Therefore, to achieve the desired burrow shape the parameter *b* must be at least one, and so the distributions are truncated at 1. If either tail of the distribution is to be truncated, then GoldSim requires both tails to be truncated. Therefore, the right-tails of the distributions are truncated at 1.0E+20 so as to not affect the simulation.

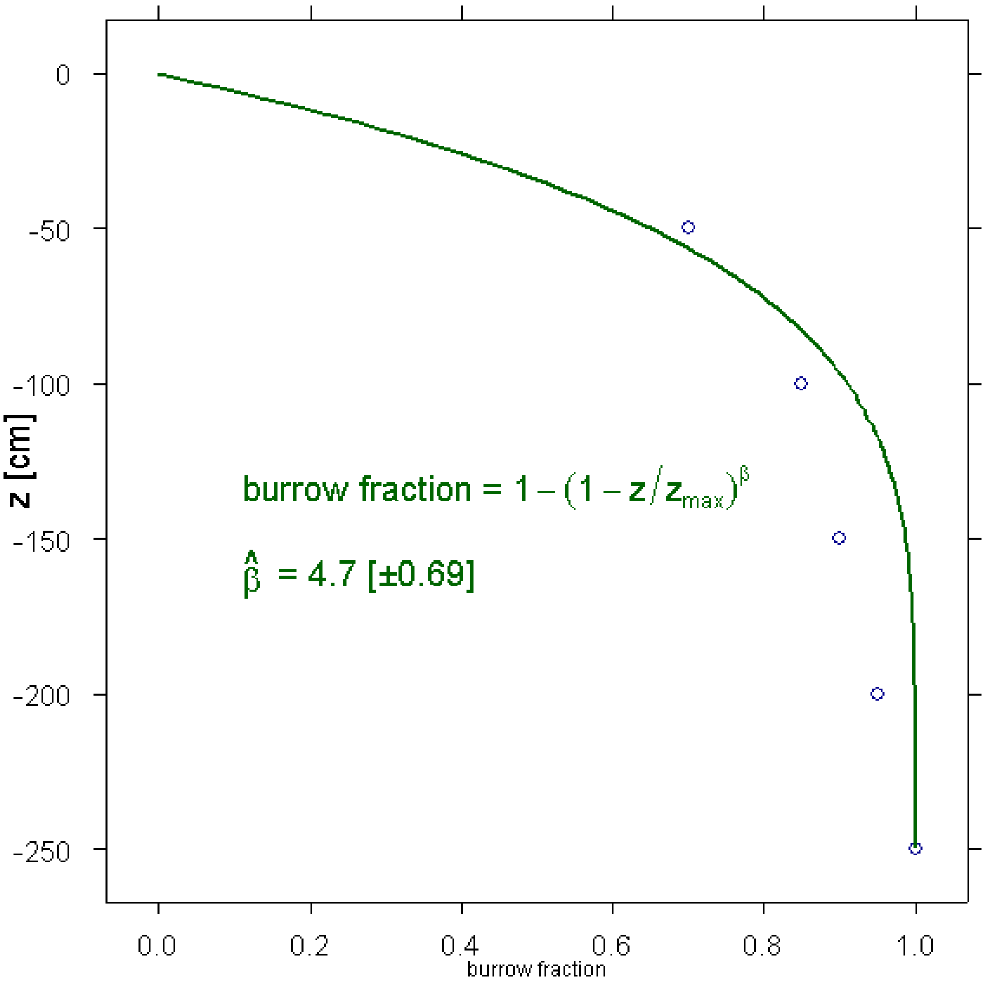

Figure 12. Model of badger burrow volume fraction with depth.

Table 4. Burrowing mammals of the NTS. Source: Hooten et al. (2004) Table 10.

Family	Species/Author	Common Name	Burrow Type (Aboveground, Shallow, Deep, Opportunistic*)	Primary Biome Affiliation	Topo-graphic Preference
Arvicolidae	*Lagurus curtatus* Cope	sagebrush vole	shallow	Great Basin	montane
Canidae	*Canis latrans* Say	coyote	deep	All	All
	Vulpes macrotis Merriam	kit fox	deep	Mojave/ Transition	flats/hilly
Cricetidae	*Neotoma lepida* Thomas	desert woodrat	aboveground	Mojave/ Transition	flats/hilly
	Onychomys torridus Coues	southern grasshopper mouse	opportunistic	Mojave	flats
	Peromyscus crinitus Merriam	canyon mouse	aboveground/ shallow	Great Basin/ Transition	hilly/ montane
	P. eremicus Baird	cactus mouse	shallow	Mojave/ Transition	flats/hilly
	P. maniculatus Wagner	deer mouse	shallow/deep	All	All
	P. true Shufeldt	piñon mouse	aboveground	Great Basin	montane
	Reithrodontomys megalotis Baird	western harvest mouse	aboveground	Mojave/ Transition	flats
Geomyidae	*Thomomys bottae* Eydoux and Gervais	Botta's pocket gopher	deep	All	flats
Heteromyidae	*Dipodomys deserti* Stephens	desert kangaroo rat	deep	Mojave	flats
	D. merriami Mearns	Merriam's kangaroo rat	deep	Mojave	flats
	D. microps Merriam	Great Basin kangaroo rat	deep	Great Basin	flats
	D. ordii Woodhouse	Ord's kangaroo rat	deep	All	flats
	Microdipodops megacephalus Merriam	dark kangaroo mouse	shallow/deep	Great Basin	flats

Table 5. Plant affiliations[1], desert regions, plant associations and alliances[2] for deep-burrowing mammals of the bajadas of the NTS. Reproduced from Hooten et al., 2004 Table 11.

Species	Common Name	Known Plant Affiliations	Desert Region	Plant Alliance	Plant Association
Canis latrans	coyote	*Larrea-Ambrosia/* All	Mojave/ Transition/ Great Basin	All	All
Vulpes macrotis	kit fox	*Larrea-Ambrosia*	Mojave/ Transition	*Lycium spp.* Shrubland. *Larrea tridentata-Ambrosia dumosa* Shrubland. *Atriplex confertifolia-Ambrosia dumosa* Shrubland. *Hymenoclea-Lycium* Shrubland. *Ephedra nevadensis* Shrubland. *Coleogyne ramosissima* Shrubland	*Lycium shockleyi- Lycium pallidum* Shrubland *Larrea tridentata-Ambrosia dumosa* Shrubland *Atriplex confertifolia-Ambrosia dumosa* Shrubland *Lycium andersonii-Hymenoclea salsola* Shrubland *Hymenoclea salsola-Ephedra nevadensis* Shrubland *Menodora spinescens-Ephedra nevadensis* Shrubland *Krascheninnikovia lanata-Ephedra nevadensis* Shrubland *Eriogonum fasciculatum-Ephedra nevadensis* Shrubland *Ephedra nevadensis-Grayia spinosa* Shrubland *Coleogyne ramosissima-Ephedra nevadensis* Shrubland
P. maniculatus	deer mouse	*Atriplex-Kochia, Coleogyne, Grayia-Lycium*	Mojave/ Transition/ Great Basin	All	All
Thomomys bottae	Botta's pocket gopher	*Ephedra*	Mojave/ Transition/ Great Basin	All	All
Dipodomys deserti	desert kangaroo rat	*Larrea-Ambrosia*	Mojave	*Lycium spp.* Shrubland, *Larrea tridentata-Ambrosia dumosa* Shrubland, *Atriplex confertifolia-Ambrosia dumosa* Shrubland	*Lycium shockleyi- Lycium pallidum* Shrubland *Larrea tridentata-Ambrosia dumosa* Shrubland *Atriplex confertifolia-Ambrosia dumosa* Shrubland
D. merriami	Merriam's kangaroo rat	*Larrea, Lycium, Atriplex-Kochia, Coleogyne, Grayia-Lycium*	Mojave	See above (*Dipodomys deserti)*	See above (*Dipodomys deserti)*

Species	Common Name	Known Plant Affiliations	Desert Region	Plant Alliance	Plant Association
D. microps	Great Basin kangaroo rat	*Larrea, Lycium, Atriplex-Kochia, Coleogyne, Grayia-Lycium, Artemisia*	Great Basin (uncommon or rare elsewhere)	*Atriplex spp.* Shrubland *Chrysothamnus-Ericameria* Shrubland *Artemisia spp.* Shrubland *Pinus monophylla-Artemisia spp.* Woodland	*Atriplex confertifolia-Kochia americana* Shrubland *Atriplex canescens-Krascheninnikovia lanata* Shrubland *Chrysothamnus viscidiflorus-Ephedra nevadensis* Shrubland *Ericameria nauseosa-Ephedra nevadensis* Shrubland *Ephedra viridis-Artemisia tridentata* Shrubland *Artemisia tridentata-Chrysothamnus viscidiflorus* Shrubland *Artemisia nova-Chrysothamnus viscidiflorus* Shrubland *Artemisia nova-Artemisia tridentata* Shrubland *Pinus monophylla-Artemisia nova* Woodland *Pinus monophylla-Artemisia tridentata* Woodland
D. ordii	Ord's kangaroo rat	*Atriplex confertifolia*	Great Basin	See above *(Dipodomys microps)*	See above *(Dipodomys microps)*
Microdipodops megacephalus	dark kangaroo mouse	*Atriplex confertifolia*	Great Basin	See above *(Dipodomys microps)*	See above *(Dipodomys microps)*
M. pallidus	pale kangaroo mouse	*Atriplex confertifolia*	Transition	*Hymenoclea-Lycium* Shrubland, *Ephedra nevadensis* Shrubland, *Coleogyne ramosissima* Shrubland	*Lycium andersonii-Hymenoclea salsola* Shrubland *Hymenoclea salsola-Ephedra nevadensis* Shrubland *Menodora spinescens-Ephedra nevadensis* Shrubland *Krascheninnikovia lanata-Ephedra nevadensis* Shrubland *Eriogonum fasciculatum-Ephedra nevadensis* Shrubland *Ephedra nevadensis-Grayia spinosa* Shrubland *Coleogyne ramosissima-Ephedra nevadensis* Shrubland

Species	**Common Name**	**Known Plant Affiliations**	**Desert Region**	**Plant Alliance**	**Plant Association**
Perognathus longimembris	little pocket mouse	*Larrea,* *Lycium,* *Atriplex confertifolia,* *Atriplex-Kochia,* *Coleogyne,* *Grayia-Lycium*	Mojave/ Transition	See above *(Vulpes macrotis)*	See above *(Vulpes macrotis)*
Lepus californicus	black-tailed jackrabbit	All	Mojave/ Transition/ Great Basin	All	All
Sylvilagus audubonii	desert cottontail	All	Mojave/ Transition/ Great Basin	All	All
Taxidea taxus	badger	*Larrea-Ambrosia,* *Atriplex confertifolia,* *Coleogyne,* *Artemisia*	Mojave/ Transition/ Great Basin	All	All
Spermophilus tereticaudus	round-tailed ground squirrel	*Larrea-Ambrosia*	Mojave	See above (*Dipodomys deserti)*	See above (*Dipodomys deserti)*
S. townsendii	Townsend's ground squirrel	*Artemisia*	Great Basin	See above *(Dipodomys microps)*	See above *(Dipodomys microps)*
S. variegates	rock squirrel		Mojave/ Transition	See above *(Vulpes macrotis)*	See above *(Vulpes macrotis)*

[1] Ascertained from Allred and Beck (1963), O'Farrell and Emery (1976), Rundel and Gibson (1996).

[2] Following Ostler et al. (2000).

Table 6. Characteristic burrowing parameters for potentially deep-burrowing mammals of the bajadas of the NTS[1]: Burrow characteristics with depth. (Reproduced from Hooten et al., 2004 Table 12, part 1.)

Species	**Max burrow depth (cm)**	**Burrow depth distributions (cm)**	**Percent burrow by depth (% per cm ± s.d.)**	**References**
		Depth Range Mean ± s.d.	**Depth % burrow ± s.d.**	
Coyote*, Canis latrans*	Similar to badger, but rarely of their own excavation			Bekoff 1982
Kit fox, *Vulpes macrotis*	300			O'Farrell 1987
Deer Mouse, *Peromyscus maniculatus*	50			Suter et al. 1993
	50	13–50 24 ± 11 (n = 26)		Reynolds and Wakkinen 1987
		19.2 ± 8.7 (n = 26)		Laundré and Reynolds 1993
Botta's pocket gopher, *Thomomys bottae*		13.1 ± 5.7 (n = 41)		Best 1973
		10–46		Andelt and Case 1995
		30–70		Davis and Schmidly 1994
	150			Felthauser and McInroy 1983
	160			Reichman et al. 1982
"Several species" of pocket gophers			0–50 85 51—100 15 >100 0	Kennedy et al. 1985
Desert kangaroo rat, *Dipodomys deserti*				No available information.
Merriam's kangaroo rat, *D. merriami*	175	26–175 98		Kenagy 1973
Great Basin kangaroo rat, *D. microps*				No available information.
Ord's kangaroo rat, *D. ordii*	69	20–69 34 ± 12 (n = 19)		Reynolds and Wakkinen 1987
		40.9 ± 19.6 (n = 17)		Laundré and Reynolds 1993
	70			Suter et al. 1993
Dark kangaroo mouse, *Microdipodops megacephalus*				No available information.
Pale kangaroo mouse, *M. pallidus*				No available information.

Species	**Max burrow depth (cm)**	**Burrow depth distributions (cm)**	**Percent burrow by depth (% per cm ± s.d.)**	**References**
		Depth Range Mean ± s.d.	**Depth % burrow ± s.d.**	
Little pocket mouse, *Perognathus longimembris*	65 (undisturbed) 75 (disturbed)	52–65 (undisturbed) 40–75 (disturbed) 69 (mean; n = 6)		Kenagy 1973
Great Basin pocket mouse, *Perognathus parvus*	105			Bowerman and Redente 1998
	140			Suter et al. 1993
Burrows of pocket mice	92			Bowerman and Redente 1998
"Several species" of pocket mice and kangaroo rats			0–50 50 51–100 40 101–150 5 151–200 5 >201 0	Kennedy et al. 1985
Black-tailed jackrabbit *Lepus californicus*				No available information.
Desert cottontail, *Sylvilagus audubonii*	25	15–25		Ingles 1941
Badger, *Taxidea taxus*	>200		0–50 70 51–100 15 101–150 5 151–200 5 >200 5	Kennedy et al. 1985
Round-tailed ground squirrel, *Spermophilus tereticaudus*				No available information.
Townsend's ground squirrel, *S. townsendii*	From reference [1] 150 (approx.)	From reference [1]: "Shallow burrow system" 14–55 29 ± 12 "Deep burrow system" 121–138 128 ± 9 Overall: 14–138 46 ± 38	n = 20, reference [2] 0–10 12.8 ± 1.1 11–20 37.4 ± 27.8 21–30 27.7 ± 23.5 31–40 7.5 ± 9.4 41–50 3.1 ± 6.7 51–60 0.8 ± 2.3 61–70 0.5 ± 1.3 71–80 0.4 ± 1.1 81–90 0.3 ± 0.7 91–100 0.4 ± 1.1 101–110 0.8 ± 2.0 111–120 1.2 ± 3.0 121–130 6.9 ± 18.2 131–140 0.3 ± 1.5	[1] Reynolds and Wakkinen 1987 [2] Reynolds and Laundré 1988, Table 2. Percent distribution from undisturbed sites.

Species	Max burrow depth (cm)	Burrow depth distributions (cm)	Percent burrow by depth (% per cm ± s.d.)	References
		Depth Range Mean ± s.d.	Depth % burrow ± s.d.	
Townsend's ground squirrel, *S. townsendii* (continued)			n = 10, reference [2] 0–10 11.0 ± 16.0 11–20 28.3 ± 31.2 21–30 15.7 ± 16.1 31–40 7.0 ± 10.0 41–50 5.6 ± 7.9 51–60 7.7 ± 8.2 61–70 5.2 ± 5.5 71–80 3.8 ± 7.5 81–90 3.9 ± 7.8 91–100 5.3 ± 10.8 101–110 2.7 ± 8.6 111–120 3.0 ± 9.6 121–130 0.6 ± 1.9 131–140 zero	[2] Reynolds and Laundré 1988, Table 2. Percent distribution from disturbed sites.
	140			Suter et al. 1993
	58			Bowerman and Redente 1998
		55.4 ± 36.6 (n = 19)		Laundré and Reynolds 1993
Rock squirrel *S. variegates*				No available information.
"Several species" of ground squirrels			0–50 50 51–100 30 101–150 15 151–200 5 >200 0	Kennedy et al. 1985

[1] Listed species may include congeners or similar species if information is supplemental. Deep-burrowing species for which no information is available are noted "N/A."

Table 7. Characteristic burrowing parameters for potentially deep-burrowing mammals of the bajadas of the NTS[1]: Tunnel dimensions and volumes. (Reproduced from Hooten et al., 2004 Table 12, part 2.)

Species	Tunnel cross-sectional dimensions (cm)[2]	Observed tunnel lengths (cm)	Volume (m^3)	References
	Height Width ± s.d.	Range Mean ± s.d.	Range Mean ± s.d.	
Coyote, *Canis latrans*	30	750		Bekoff 1982
Kit fox, *Vulpes macrotis*		600		McGrew 1979
Deer Mouse, *Peromyscus maniculatus*	1.5–5.2 1.9–10.5			Laundré 1989
		70 ± 50 (n = 26)	0.013 ± 0.009 (n = 26)	Laundré and Reynolds 1993
		30–470 132 ± 107 (n = 26)	0.003–0.077 0.017 ± 0.018 (n = 26)	Reynolds and Wakkinen 1987
Botta's pocket gopher, *Thomomys bottae*	7.0 ± 0.66 (n = 41)			Best 1973
		1500		Felthauser and McInroy 1983
	5.28 ± 0.63 (n = 20)			Cox 1990
		6320 ± 3018 (n = 17) 3160 ± 2514 (n = 27)		Reichman et al. 1982
	5–8.9	18,300 (total linear dimension)		Andelt and Case 1995
		3000–15000		Davis and Schmidly 1994
Desert kangaroo rat, *Dipodomys deserti*				No available information.
Merriam's kangaroo rat, *D. merriami*	3.5–6 (diameter)			Kenagy 1973
	3	457	0.01	Reynolds 1958
Great Basin kangaroo rat, *D. microps*				No available information.
Ord's kangaroo rat *D. ordii*		50–890 253 ± 233 (n = 19)	0.01-0.263 0.072 ± 0.07 (n = 19)	Reynolds and Wakkinen 1987
		270 ± 230 (n = 17)	0.083 ± 0.087 (n = 17)	Laundré and Reynolds 1993
Dark kangaroo mouse, *Microdipodops megacephalus*				No available information.
Pale kangaroo mouse, *M. pallidus*				No available information.
Little pocket mouse, *Perognathus longimembris*	1.5–2			Kenagy 1973

	Tunnel cross-sectional dimensions (cm)[2]	**Observed tunnel lengths (cm)**	**Volume (m^3)**	
Species	**Height ± s.d. Width**	**Range Mean ± s.d.**	**Range Mean ± s.d.**	**References**
“Several species” of pocket mice and kangaroo rats			0.014	Kennedy et al. 1985
Black-tailed jackrabbit *Lepus californicus*				No available information.
Desert cottontail, *Sylvilagus audubonii*				No available information.
Badger, *Taxidea taxus*			0.170	Kennedy et al. 1985
Round-tailed ground squirrel, *Spermophilus tereticaudus*				No available information.
Townsend’s ground squirrel, *Spermophilus townsendii*	4.3–6.3 6.5–9.6			Laundré 1989
		260 ± 250 (n = 19)	0.0102 ± 0.092 (n = 19)	Laundré and Reynolds 1993
		“Shallow burrow system” 222 ± 284 (n = 17) “Deep burrow system” 813 ± 43 (n = 3) Overall: 30–890 404 ± 349 (n = 20)	0.012-0.164 0.082 ± 0.097 (n = 17) 0.228-0.299 0.0279 ± 0.018 (n = 3)	Reynolds and Wakkinen 1987
Rock squirrel *S. variegates*				No available information.
“Several species” of ground squirrels			0.02	Kennedy et al. 1985

[1] Listed species may include congeners or similar species if information is supplemental. Deep-burrowing species for which no information is available are noted “N/A.”

[2] If only one value or range of values is reported, it is the reported “diameter” of the tunnel.

Table 8. Data set for calculating excavated mound volume for small mammals (R) and badgers (B). The values *x*, *y*, and *z* record the elliptical cone dimensions of the mounds used to estimate the mound volume.

X	Y	Z	Volume	Date	Quadrat	Mammal Category
220	170	11	0.1077	May 28, 2003	Q2	R
60	40	6	0.0038	May 28, 2003	Q2	R
260	140	13	0.1239	May 28, 2003	Q2	R
260	150	21	0.2144	May 28, 2003	Q2	R
200	140	14	0.1026	May 28, 2003	Q2	R
40	35	6	0.0022	May 28, 2003	Q2	R
310	180	17	0.2483	May 28, 2003	Q2	R
200	160	13	0.1089	May 28, 2003	Q2	R
180	140	15	0.0990	May 28, 2003	Q2	R
200	110	14	0.0806	May 28, 2003	Q2	R
300	200	10	0.1571	May 28, 2003	Q2	R
190	190	12	0.1134	May 28, 2003	Q2	R
200	170	15	0.1335	May 28, 2003	Q2	R
230	130	11	0.0861	May 28, 2003	Q2	R
280	270	30	0.5938	May 28, 2003	Q2	R
240	110	14	0.0968	May 28, 2003	Q2	R
170	100	14	0.0623	May 28, 2003	Q2	R
130	80	10	0.0272	May 28, 2003	Q2	R
240	130	9	0.0735	May 28, 2003	Q2	R
290	150	14	0.1594	May 28, 2003	Q2	R
70	70	3	0.0038	May 28, 2003	Q2	R
190	120	11	0.0657	May 28, 2003	Q2	R
150	90	7	0.0247	May 28, 2003	Q2	R
130	110	16	0.0599	May 28, 2003	Q2	R
240	170	12	0.1282	May 28, 2003	Q2	R
140	150	10	0.0550	May 28, 2003	Q2	R
170	80	12	0.0427	May 28, 2003	Q2	R
140	130	12	0.0572	May 28, 2003	Q2	R

160	130	11	0.0599	May 28, 2003	Q2	R
170	160	12	0.0855	May 28, 2003	Q2	R
110	100	10	0.0288	May 28, 2003	Q2	R
120	100	13	0.0408	May 28, 2003	Q2	R
90	80	13	0.0245	May 28, 2003	Q2	R
260	210	10	0.1429	May 28, 2003	Q2	R
130	110	16	0.0599	May 28, 2003	Q2	R
160	100	8	0.0335	May 28, 2003	Q2	R
270	230	15	0.2439	May 28, 2003	Q2	R
100	60	8	0.0126	May 28, 2003	Q2	R
110	110	5	0.0158	May 28, 2003	Q2	R
160	130	15	0.0817	May 28, 2003	Q2	R
160	100	17	0.0712	May 28, 2003	Q2	R
160	90	11	0.0415	May 28, 2003	Q2	R
140	130	6	0.0286	May 28, 2003	Q2	R
130	120	13	0.0531	May 28, 2003	Q2	R
190	80	9	0.0358	May 28, 2003	Q2	R
250	130	9	0.0766	May 28, 2003	Q2	R
100	90	6	0.0141	May 28, 2003	Q2	R
170	150	15	0.1001	May 28, 2003	Q2	R
110	80	8	0.0184	May 28, 2003	Q2	R
90	90	10	0.0212	May 28, 2003	Q2	R
130	120	9	0.0368	May 28, 2003	Q2	R
120	90	10	0.0283	May 28, 2003	Q2	R
220	190	10	0.1094	May 28, 2003	Q2	R
90	60	7	0.0099	May 28, 2003	Q2	R
180	110	8	0.0415	May 28, 2003	Q2	R
250	180	15	0.1767	May 28, 2003	Q2	R
170	120	11	0.0587	May 28, 2003	Q2	R
220	170	12	0.1175	May 28, 2003	Q2	R
200	160	12	0.1005	May 28, 2003	Q2	R
90	70	8	0.0132	May 28, 2003	Q2	R

300	200	14	0.2199	May 28, 2003	Q2	R
90	70	10	0.0165	May 28, 2003	Q2	R
240	170	16	0.1709	May 28, 2003	Q2	R
160	150	10	0.0628	May 28, 2003	Q2	R
170	150	18	0.1202	May 28, 2003	Q2	R
230	160	12	0.1156	May 28, 2003	Q2	R
230	130	15	0.1174	May 28, 2003	Q2	R
130	80	13	0.0354	May 28, 2003	Q2	R
190	100	9	0.0448	May 28, 2003	Q2	R
140	120	13	0.0572	May 28, 2003	Q2	R
170	160	13	0.0926	May 28, 2003	Q2	R
100	100	12	0.0314	May 28, 2003	Q2	R
180	130	10	0.0613	May 28, 2003	Q2	R
160	100	9	0.0377	May 28, 2003	Q2	R
240	160	12	0.1206	May 28, 2003	Q2	R
80	80	8	0.0134	May 28, 2003	Q2	R
220	120	14	0.0968	May 28, 2003	Q2	R
140	120	10	0.0440	May 28, 2003	Q2	R
90	60	10	0.0141	May 28, 2003	Q2	R
140	110	16	0.0645	May 28, 2003	Q2	R
190	120	8	0.0478	May 28, 2003	Q2	R
160	130	16	0.0871	May 28, 2003	Q2	R
50	40	4	0.0021	May 28, 2003	Q2	R
220	170	20	0.1958	May 28, 2003	Q2	R
110	90	9	0.0233	May 28, 2003	Q2	R
200	130	18	0.1225	May 28, 2003	Q2	R
210	140	15	0.1155	May 28, 2003	Q2	R
70	60	4	0.0044	May 28, 2003	Q2	R
170	90	6	0.0240	May 28, 2003	Q2	R
190	110	7	0.0383	May 28, 2003	Q2	R
130	130	15	0.0664	May 28, 2003	Q2	R
180	130	16	0.0980	May 28, 2003	Q2	R

230	190	12	0.1373	May 28, 2003	Q2	R
240	170	13	0.1389	May 28, 2003	Q2	R
188	174	10	0.0856	May 28, 2003	Q2	R
317	256	22	0.4674	May 28, 2003	Q2	R
208	138	10	0.0751	May 28, 2003	Q2	R
305	184	17	0.2498	May 28, 2003	Q2	R
292	163	13	0.1620	May 28, 2003	Q2	R
146	90	19	0.0654	May 28, 2003	Q2	R
120	96	9	0.0271	May 28, 2003	Q2	R
212	200	13	0.1443	May 28, 2003	Q2	R
92	84	9	0.0182	May 28, 2003	Q2	R
125	117	11	0.0421	May 28, 2003	Q2	R
170	118	12	0.0630	May 28, 2003	Q2	R
85	77	7	0.0120	May 28, 2003	Q2	R
198	122	14	0.0885	May 28, 2003	Q2	R
162	128	16	0.0869	May 28, 2003	Q2	R
160	130	17	0.0926	May 28, 2003	Q2	R
179	130	14	0.0853	May 28, 2003	Q2	R
185	165	9	0.0719	May 28, 2003	Q2	R
261	136	12	0.1115	May 28, 2003	Q2	R
187	156	11	0.0840	May 28, 2003	Q2	R
243	114	15	0.1088	May 28, 2003	Q2	R
238	184	10	0.1146	May 28, 2003	Q2	R
188	144	13	0.0921	May 28, 2003	Q2	R
110	75	6	0.0130	May 28, 2003	Q2	R
330	214	17	0.3143	May 28, 2003	Q2	R
275	202	17	0.2472	May 28, 2003	Q2	R
294	195	8	0.1201	May 28, 2003	Q2	R
125	92	14	0.0421	May 28, 2003	Q2	R
148	117	13	0.0589	May 28, 2003	Q2	R
206	160	15	0.1294	May 28, 2003	Q2	R
170	155	10	0.0690	May 28, 2003	Q2	R

262	201	13	0.1792	May 28, 2003	Q2	R
156	150	13	0.0796	May 28, 2003	Q2	R
165	105	11	0.0499	May 28, 2003	Q2	R
157	134	10	0.0551	May 28, 2003	Q2	R
110	110	10	0.0317	May 28, 2003	Q2	R
106	76	9	0.0190	May 28, 2003	Q2	R
198	132	9	0.0616	May 28, 2003	Q2	R
220	209	8	0.0963	May 28, 2003	Q2	R
280	215	16	0.2522	May 28, 2003	Q2	R
188	106	6	0.0313	May 28, 2003	Q2	R
178	156	7	0.0509	May 28, 2003	Q2	R
186	176	12	0.1028	May 28, 2003	Q2	R
229	159	13	0.1239	May 28, 2003	Q2	R
132	130	12	0.0539	May 28, 2003	Q2	R
215	168	15	0.1418	May 28, 2003	Q2	R
121	106	17	0.0571	May 28, 2003	Q2	R
227	176	18	0.1883	May 28, 2003	Q2	R
114	105	13	0.0407	May 28, 2003	Q2	R
173	116	14	0.0736	May 28, 2003	Q2	R
307	234	15	0.2821	May 28, 2003	Q2	R
213	187	14	0.1460	May 28, 2003	Q2	R
96	80	6	0.0121	May 28, 2003	Q2	R
127	60	9	0.0180	May 28, 2003	Q2	R
146	133	7	0.0356	May 28, 2003	Q2	R
144	138	16	0.0832	May 28, 2003	Q2	R
147	143	16	0.0881	May 28, 2003	Q2	R
204	155	5	0.0414	May 28, 2003	Q2	R
107	93	5	0.0130	May 28, 2003	Q2	R
215	165	11	0.1022	May 28, 2003	Q2	R
305	198	10	0.1581	May 28, 2003	Q2	R
91	78	7	0.0130	May 28, 2003	Q2	R
130	106	8	0.0289	May 28, 2003	Q2	R

150	148	10	0.0581	May 28, 2003	Q2	R
84	48	8	0.0084	May 28, 2003	Q2	R
96	96	11	0.0265	May 28, 2003	Q2	R
96	94	8	0.0189	May 28, 2003	Q2	R
208	146	10	0.0795	May 28, 2003	Q2	R
166	122	9	0.0477	May 28, 2003	Q2	R
124	113	5	0.0183	May 28, 2003	Q2	R
86	82	15	0.0277	May 28, 2003	Q2	R
289	260	19	0.3738	May 28, 2003	Q2	R
153	150	12	0.0721	May 28, 2003	Q2	R
69	42	9	0.0068	May 28, 2003	Q2	R
153	145	13	0.0755	May 28, 2003	Q2	R
374	142	16	0.2225	May 28, 2003	Q2	R
287	190	12	0.1713	May 28, 2003	Q2	R
194	190	17	0.1640	May 28, 2003	Q2	R
391	300	20	0.6142	May 28, 2003	Q2	R
107	77	5	0.0108	May 28, 2003	Q2	R
218	177	16	0.1616	May 28, 2003	Q2	R
185	154	11	0.0820	May 28, 2003	Q2	R
132	97	10	0.0335	May 28, 2003	Q2	R
120	97	6	0.0183	May 28, 2003	Q2	R
182	139	15	0.0993	May 28, 2003	Q2	R
169	130	13	0.0748	May 28, 2003	Q2	R
94	94	12	0.0278	May 28, 2003	Q2	R
194	175	8	0.0711	May 28, 2003	Q2	R
254	173	12	0.1380	May 28, 2003	Q2	R
268	232	15	0.2442	May 28, 2003	Q2	R
170	102	19	0.0863	May 28, 2003	Q2	R
83	81	12	0.0211	May 28, 2003	Q2	R
138	136	11	0.0540	May 28, 2003	Q2	R
282	161	15	0.1783	May 28, 2003	Q2	R
101	89	11	0.0259	May 28, 2003	Q2	R

187	187	18	0.1648	May 28, 2003	Q2	R
255	214	21	0.3000	May 28, 2003	Q2	R
120	116	8	0.0292	May 28, 2003	Q2	R
351	159	12	0.1753	May 28, 2003	Q2	R
60	50	5	0.0039	May 28, 2003	Q3	R
70	60	6	0.0066	May 28, 2003	Q3	R
60	40	7	0.0044	May 28, 2003	Q3	R
160	110	9	0.0415	May 28, 2003	Q3	R
120	70	6	0.0132	May 28, 2003	Q3	R
50	40	8	0.0042	May 28, 2003	Q3	R
110	40	6	0.0069	May 28, 2003	Q3	R
70	70	9	0.0115	May 28, 2003	Q3	R
120	80	14	0.0352	May 28, 2003	Q3	R
60	50	9	0.0071	May 28, 2003	Q3	R
100	70	8	0.0147	May 28, 2003	Q3	R
50	40	9	0.0047	May 28, 2003	Q3	R
160	70	3	0.0088	May 28, 2003	Q3	R
50	50	4	0.0026	May 28, 2003	Q3	R
100	40	5	0.0052	May 28, 2003	Q3	R
110	70	13	0.0262	May 28, 2003	Q3	R
200	100	12	0.0628	May 28, 2003	Q3	R
70	50	6	0.0055	May 28, 2003	Q3	R
80	40	8	0.0067	May 28, 2003	Q3	R
100	60	15	0.0236	May 28, 2003	Q3	R
90	40	6	0.0057	May 28, 2003	Q3	R
180	120	13	0.0735	May 28, 2003	Q3	R
150	80	12	0.0377	May 28, 2003	Q3	R
150	80	7	0.0220	May 28, 2003	Q3	R
120	60	7	0.0132	May 28, 2003	Q3	R
70	50	8	0.0073	May 28, 2003	Q3	R
120	70	5	0.0110	May 28, 2003	Q3	R
130	80	12	0.0327	May 28, 2003	Q3	R

30	20	5	0.0008	May 28, 2003	Q3	R
80	80	6	0.0101	May 28, 2003	Q3	R
40	20	5	0.0010	May 28, 2003	Q3	R
110	50	10	0.0144	May 28, 2003	Q3	R
40	20	6	0.0013	May 28, 2003	Q3	R
60	40	9	0.0057	May 28, 2003	Q3	R
120	80	8	0.0201	May 28, 2003	Q3	R
60	40	10	0.0063	May 28, 2003	Q3	R
100	60	14	0.0220	May 28, 2003	Q3	R
80	70	7	0.0103	May 28, 2003	Q3	R
150	80	5	0.0157	May 28, 2003	Q3	R
130	90	15	0.0459	May 28, 2003	Q3	R
150	50	5	0.0098	May 28, 2003	Q3	R
30	20	3	0.0005	May 28, 2003	Q3	R
150	70	7	0.0192	May 28, 2003	Q3	R
40	30	4	0.0013	May 28, 2003	Q3	R
170	100	9	0.0401	May 28, 2003	Q3	R
160	60	6	0.0151	May 28, 2003	Q3	R
110	60	7	0.0121	May 28, 2003	Q3	R
60	40	5	0.0031	May 28, 2003	Q3	R
150	80	9	0.0283	May 28, 2003	Q3	R
70	40	4	0.0029	May 28, 2003	Q3	R
80	80	10	0.0168	May 28, 2003	Q3	R
30	20	5	0.0008	May 28, 2003	Q3	R
60	25	12	0.0047	May 28, 2003	Q3	R
130	60	8	0.0163	May 28, 2003	Q3	R
110	70	5	0.0101	May 28, 2003	Q3	R
150	70	9	0.0247	May 28, 2003	Q3	R
90	70	6	0.0099	May 28, 2003	Q3	R
10	10	1	0.0000	May 28, 2003	Q3	R
90	40	4	0.0038	May 28, 2003	Q3	R
70	60	5	0.0055	May 28, 2003	Q3	R

80	50	6	0.0063	May 28, 2003	Q3	R
120	80	6	0.0151	May 28, 2003	Q3	R
140	100	7	0.0257	May 28, 2003	Q3	R
30	15	7	0.0008	May 28, 2003	Q3	R
70	30	8	0.0044	May 28, 2003	Q3	R
70	30	8	0.0044	May 28, 2003	Q3	R
130	120	11	0.0449	May 28, 2003	Q3	R
110	100	9	0.0259	May 28, 2003	Q3	R
110	50	6	0.0086	May 28, 2003	Q3	R
30	20	6	0.0009	May 28, 2003	Q3	R
60	40	9	0.0057	May 28, 2003	Q3	R
60	40	8	0.0050	May 28, 2003	Q3	R
120	100	13	0.0408	May 28, 2003	Q3	R
100	70	12	0.0220	May 28, 2003	Q3	R
280	110	11	0.0887	May 28, 2003	Q3	R
100	90	14	0.0330	May 28, 2003	Q3	R
120	90	12	0.0339	May 28, 2003	Q3	R
90	70	13	0.0214	May 28, 2003	Q3	R
80	60	13	0.0163	May 28, 2003	Q3	R
140	140	19	0.0975	May 28, 2003	Q3	R
80	50	12	0.0126	May 28, 2003	Q3	R
90	60	14	0.0198	May 28, 2003	Q3	R
90	80	16	0.0302	May 28, 2003	Q3	R
150	100	14	0.0550	May 28, 2003	Q3	R
40	40	7	0.0029	May 28, 2003	Q3	R
170	150	16	0.1068	May 28, 2003	Q3	R
140	80	12	0.0352	May 28, 2003	Q3	R
170	120	11	0.0587	May 28, 2003	Q3	R
140	100	14	0.0513	May 28, 2003	Q3	R
140	120	15	0.0660	May 28, 2003	Q3	R
90	70	17	0.0280	May 28, 2003	Q3	R
120	60	10	0.0188	May 28, 2003	Q3	R

110	70	11	0.0222	May 28, 2003	Q3	R
140	100	15	0.0550	May 28, 2003	Q3	R
60	50	9	0.0071	May 28, 2003	Q3	R
40	30	5	0.0016	May 28, 2003	Q3	R
210	160	14	0.1232	May 28, 2003	Q3	R
210	130	22	0.1572	May 28, 2003	Q3	R
40	40	10	0.0042	May 28, 2003	Q3	R
110	90	16	0.0415	May 28, 2003	Q3	R
140	100	15	0.0550	May 28, 2003	Q3	R
160	130	12	0.0653	May 28, 2003	Q3	R
120	70	4	0.0088	May 28, 2003	Q3	R
50	40	7	0.0037	May 28, 2003	Q3	R
60	40	12	0.0075	May 28, 2003	Q3	R
80	60	10	0.0126	May 28, 2003	Q3	R
70	40	12	0.0088	May 28, 2003	Q3	R
170	160	27	0.1923	May 28, 2003	Q3	R
30	20	4	0.0006	May 28, 2003	Q3	R
100	90	12	0.0283	May 28, 2003	Q3	R
100	90	13	0.0306	May 28, 2003	Q3	R
220	100	20	0.1152	May 28, 2003	Q3	R
80	120	12	0.0302	May 28, 2003	Q3	R
50	40	12	0.0063	May 28, 2003	Q3	R
40	40	10	0.0042	May 28, 2003	Q3	R
110	110	21	0.0665	May 28, 2003	Q3	R
40	20	6	0.0013	May 28, 2003	Q3	R
140	100	20	0.0733	May 28, 2003	Q3	R
120	90	21	0.0594	May 28, 2003	Q3	R
70	50	15	0.0137	May 28, 2003	Q3	R
50	60	2	0.0016	May 28, 2003	Q3	R
80	80	13	0.0218	May 28, 2003	Q3	R
150	150	10	0.0589	May 28, 2003	Q3	R
40	20	8	0.0017	May 28, 2003	Q3	R

40	30	8	0.0025	May 28, 2003	Q3	R
40	40	8	0.0034	May 28, 2003	Q3	R
110	100	20	0.0576	May 28, 2003	Q3	R
100	100	14	0.0367	May 28, 2003	Q3	R
40	30	7	0.0022	May 28, 2003	Q3	R
200	170	26	0.2314	May 28, 2003	Q3	R
60	60	14	0.0132	May 28, 2003	Q3	R
140	70	5	0.0128	May 28, 2003	Q3	R
220	120	15	0.1037	May 28, 2003	Q3	R
120	100	15	0.0471	May 28, 2003	Q3	R
130	60	15	0.0306	May 28, 2003	Q3	R
90	60	13	0.0184	May 28, 2003	Q3	R
200	200	13	0.1361	May 28, 2003	Q4	R
780	190	20	0.7760	May 28, 2003	Q4	R
290	230	13	0.2270	May 28, 2003	Q4	R
100	40	3	0.0031	May 28, 2003	Q4	R
40	30	8	0.0025	May 28, 2003	Q4	R
170	110	15	0.0734	May 28, 2003	Q4	R
100	80	15	0.0314	May 28, 2003	Q4	R
130	70	6	0.0143	May 28, 2003	Q4	R
180	130	7	0.0429	May 28, 2003	Q4	R
90	80	6	0.0113	May 28, 2003	Q4	R
180	140	30	0.1979	May 28, 2003	Q4	R
60	50	4	0.0031	May 28, 2003	Q4	R
180	110	14	0.0726	May 28, 2003	Q4	R
160	70	14	0.0411	May 28, 2003	Q4	R
130	120	14	0.0572	May 28, 2003	Q4	R
70	60	6	0.0066	May 28, 2003	Q4	R
90	60	6	0.0085	May 28, 2003	Q4	R
140	100	9	0.0330	May 28, 2003	Q4	R
50	40	4	0.0021	May 28, 2003	Q4	R
70	60	5	0.0055	May 28, 2003	Q4	R

150	90	7	0.0247	May 28, 2003	Q4	R
90	80	8	0.0151	May 28, 2003	Q4	R
210	140	9	0.0693	May 28, 2003	Q4	R
150	130	13	0.0664	May 28, 2003	Q4	R
190	170	24	0.2029	May 28, 2003	Q4	R
210	140	4	0.0308	May 28, 2003	Q4	R
90	70	5	0.0082	May 28, 2003	Q4	R
360	180	20	0.3393	May 28, 2003	Q4	R
210	130	12	0.0858	May 28, 2003	Q4	R
170	90	9	0.0360	May 28, 2003	Q4	R
170	120	15	0.0801	May 28, 2003	Q4	R
90	90	15	0.0318	May 28, 2003	Q4	R
140	80	7	0.0205	May 28, 2003	Q4	R
220	130	8	0.0599	May 28, 2003	Q4	R
120	90	8	0.0226	May 28, 2003	Q4	R
320	190	13	0.2069	May 28, 2003	Q4	R
130	100	16	0.0545	May 28, 2003	Q4	R
250	170	11	0.1224	May 28, 2003	Q4	R
100	60	15	0.0236	May 28, 2003	Q4	R
180	90	10	0.0424	May 28, 2003	Q4	R
150	90	5	0.0177	May 28, 2003	Q4	R
80	40	9	0.0075	May 28, 2003	Q4	R
110	80	4	0.0092	May 28, 2003	Q4	R
50	50	6	0.0039	May 28, 2003	Q4	R
160	120	5	0.0251	May 28, 2003	Q4	R
200	110	10	0.0576	May 28, 2003	Q4	R
110	100	14	0.0403	May 28, 2003	Q4	R
240	180	12	0.1357	May 28, 2003	Q4	R
120	100	7	0.0220	May 28, 2003	Q4	R
170	140	13	0.0810	May 28, 2003	Q4	R
40	20	13	0.0027	May 28, 2003	Q4	R
25	30	14	0.0027	May 28, 2003	Q4	R

170	90	12	0.0481	May 28, 2003	Q4	R
120	100	10	0.0314	May 28, 2003	Q4	R
780	360	16	1.1762	May 28, 2003	Q4	R
180	120	10	0.0565	May 28, 2003	Q4	R
200	140	12	0.0880	May 28, 2003	Q4	R
650	500	18	1.5315	May 28, 2003	Q4	R
160	120	12	0.0603	May 28, 2003	Q4	R
150	150	8	0.0471	May 28, 2003	Q4	R
680	400	16	1.1394	May 28, 2003	Q4	R
250	240	12	0.1885	May 28, 2003	Q4	R
80	60	11	0.0138	May 28, 2003	Q4	R
170	150	9	0.0601	May 28, 2003	Q4	R
170	160	16	0.1139	May 28, 2003	Q4	R
15	15	7	0.0004	May 28, 2003	Q4	R
160	150	8	0.0503	May 28, 2003	Q4	R
390	220	9	0.2022	May 28, 2003	Q4	R
270	250	7	0.1237	May 28, 2003	Q4	R
430	200	14	0.3152	May 28, 2003	Q4	R
250	240	16	0.2513	May 28, 2003	Q4	R
400	310	23	0.7467	May 28, 2003	Q4	R
210	110	18	0.1089	May 28, 2003	Q4	R
160	140	9	0.0528	May 28, 2003	Q4	R
210	170	17	0.1589	May 28, 2003	Q4	R
250	240	10	0.1571	May 28, 2003	Q4	R
180	120	15	0.0848	May 28, 2003	Q5	R
130	80	9	0.0245	May 28, 2003	Q5	R
170	80	14	0.0498	May 28, 2003	Q5	R
150	130	15	0.0766	May 28, 2003	Q5	R
160	100	10	0.0419	May 28, 2003	Q5	R
190	110	11	0.0602	May 28, 2003	Q5	R
190	150	13	0.0970	May 28, 2003	Q5	R
210	70	15	0.0577	May 28, 2003	Q5	R

230	220	19	0.2517	May 28, 2003	Q5	R
160	150	15	0.0942	May 28, 2003	Q5	R
450	170	22	0.4406	May 28, 2003	Q5	R
240	170	18	0.1923	May 28, 2003	Q5	R
430	150	19	0.3208	May 28, 2003	Q5	R
350	90	7	0.0577	May 28, 2003	Q5	R
210	70	10	0.0385	May 28, 2003	Q5	R
420	160	15	0.2639	May 28, 2003	Q5	R
150	140	12	0.0660	May 28, 2003	Q5	R
110	50	14	0.0202	May 28, 2003	Q5	R
190	120	13	0.0776	May 28, 2003	Q5	R
220	130	13	0.0973	May 28, 2003	Q5	R
190	110	20	0.1094	May 28, 2003	Q5	R
130	120	13	0.0531	May 28, 2003	Q5	R
440	90	11	0.1140	May 28, 2003	Q5	R
140	100	9	0.0330	May 28, 2003	Q5	R
190	140	15	0.1045	May 28, 2003	Q5	R
270	250	13	0.2297	May 28, 2003	Q5	R
190	190	29	0.2741	May 28, 2003	Q5	R
250	240	18	0.2827	May 28, 2003	Q5	R
210	210	13	0.1501	May 28, 2003	Q5	R
150	110	12	0.0518	May 28, 2003	Q5	R
200	120	19	0.1194	May 28, 2003	Q5	R
150	100	13	0.0511	May 28, 2003	Q5	R
230	140	17	0.1433	May 28, 2003	Q5	R
300	150	18	0.2121	May 28, 2003	Q5	R
110	100	12	0.0346	May 28, 2003	Q5	R
370	170	14	0.2305	May 28, 2003	Q5	R
130	80	11	0.0299	May 28, 2003	Q5	R
170	160	19	0.1353	May 28, 2003	Q5	R
100	80	6	0.0126	May 28, 2003	Q5	R
400	200	20	0.4189	May 28, 2003	Q5	R

170	150	4	0.0267	May 28, 2003	Q5	R
280	120	18	0.1583	May 28, 2003	Q5	R
460	150	10	0.1806	May 28, 2003	Q5	R
260	210	28	0.4002	May 28, 2003	Q5	R
190	160	19	0.1512	May 28, 2003	Q5	R
440	150	12	0.2073	May 28, 2003	Q5	R
200	190	11	0.1094	May 28, 2003	Q5	R
60	50	4	0.0031	May 28, 2003	Q5	R
850	160	14	0.4985	May 28, 2003	Q5	R
320	110	12	0.1106	May 28, 2003	Q5	R
410	210	15	0.3381	May 28, 2003	Q5	R
350	130	17	0.2025	May 28, 2003	Q5	R
260	140	14	0.1334	May 28, 2003	Q5	R
450	180	21	0.4453	May 28, 2003	Q5	R
270	130	20	0.1838	May 28, 2003	Q5	R
320	140	19	0.2228	May 28, 2003	Q5	R
270	180	20	0.2545	May 28, 2003	Q5	B
280	90	14	0.0924	May 28, 2003	Q5	R
230	130	13	0.1018	May 28, 2003	Q5	R
380	80	10	0.0796	May 28, 2003	Q5	R
350	120	21	0.2309	May 28, 2003	Q5	R
190	100	13	0.0647	May 28, 2003	Q5	R
250	200	18	0.2356	May 28, 2003	Q5	R
360	140	12	0.1583	May 28, 2003	Q5	R
220	110	16	0.1014	May 28, 2003	Q5	R
350	150	12	0.1649	May 28, 2003	Q5	R
480	170	18	0.3845	May 28, 2003	Q5	R
400	120	10	0.1257	May 28, 2003	Q5	R
120	110	14	0.0484	May 28, 2003	Q5	R
440	260	19	0.5690	May 28, 2003	Q5	R
120	70	2	0.0044	May 28, 2003	Q5	R
110	90	7	0.0181	May 28, 2003	Q5	R

210	100	12	0.0660	May 28, 2003	Q5	R
240	140	17	0.1495	May 28, 2003	Q5	R
180	70	13	0.0429	May 28, 2003	Q5	R
190	110	10	0.0547	May 28, 2003	Q5	R
140	130	11	0.0524	May 28, 2003	Q5	R
230	130	12	0.0939	May 28, 2003	Q5	R
120	60	6	0.0113	May 28, 2003	Q5	R
220	210	13	0.1572	May 28, 2003	Q5	R
410	120	20	0.2576	May 28, 2003	Q5	R
140	90	8	0.0264	May 28, 2003	Q5	R
160	70	8	0.0235	May 28, 2003	Q5	R
140	120	7	0.0308	May 28, 2003	Q5	R
290	160	8	0.0972	May 28, 2003	Q5	R
80	50	5	0.0052	May 28, 2003	Q5	R
200	80	10	0.0419	May 28, 2003	Q5	R
160	100	7	0.0293	May 28, 2003	Q5	B
160	90	8	0.0302	May 28, 2003	Q5	R
100	70	8	0.0147	May 28, 2003	Q5	R
390	130	7	0.0929	May 28, 2003	Q5	R
130	90	11	0.0337	May 28, 2003	Q5	R
180	150	12	0.0848	May 28, 2003	Q5	R
110	90	11	0.0285	May 28, 2003	Q5	R
460	190	33	0.7551	May 28, 2003	Q5	R
130	80	10	0.0272	May 28, 2003	Q5	R
250	160	13	0.1361	May 28, 2003	Q5	R
90	80	8	0.0151	May 28, 2003	Q5	R
250	200	9	0.1178	May 28, 2003	Q5	R
120	70	12	0.0264	May 28, 2003	Q5	R
150	140	12	0.0660	May 28, 2003	Q5	R
70	70	4	0.0051	May 28, 2003	Q5	R
150	110	13	0.0562	May 28, 2003	Q5	R
250	240	10	0.1571	May 28, 2003	Q5	R

410	190	17	0.3467	May 28, 2003	Q5	R
240	120	9	0.0679	May 28, 2003	Q5	R
210	100	8	0.0440	May 28, 2003	Q5	R
280	110	9	0.0726	May 28, 2003	Q5	B
370	290	20	0.5618	May 28, 2003	Q5	B
100	80	4	0.0084	May 28, 2003	Q5	R
160	120	7	0.0352	May 28, 2003	Q5	R
130	100	8	0.0272	May 28, 2003	Q5	R
220	140	18	0.1451	May 28, 2003	Q5	R
160	120	7	0.0352	May 28, 2003	Q5	R
380	190	30	0.5671	May 28, 2003	Q5	R
190	280	17	0.2368	May 28, 2003	Q5	R
290	150	23	0.2619	May 28, 2003	Q5	R
210	120	18	0.1188	May 28, 2003	Q5	R
140	100	11	0.0403	May 28, 2003	Q5	R
280	120	12	0.1056	May 28, 2003	Q5	R
190	100	10	0.0497	May 28, 2003	Q5	R
210	110	8	0.0484	May 28, 2003	Q5	R
240	130	8	0.0653	May 28, 2003	Q5	R
150	130	9	0.0459	May 28, 2003	Q5	B
450	140	8	0.1319	May 28, 2003	Q5	R
260	140	12	0.1144	May 28, 2003	Q5	R
440	160	29	0.5345	May 28, 2003	Q5	R
230	80	10	0.0482	May 28, 2003	Q5	R
280	170	15	0.1869	May 28, 2003	Q5	R
110	100	14	0.0403	May 28, 2003	Q5	R
200	150	14	0.1100	May 28, 2003	Q5	R
180	120	10	0.0565	May 28, 2003	Q5	R
180	110	20	0.1037	May 28, 2003	Q5	R
290	160	14	0.1701	May 28, 2003	Q5	R
240	170	12	0.1282	May 28, 2003	Q5	B
240	170	17	0.1816	May 28, 2003	Q5	R

60	60	7	0.0066	May 28, 2003	Q5	R
310	160	12	0.1558	May 28, 2003	Q5	R
190	160	14	0.1114	May 28, 2003	Q5	R
160	130	7	0.0381	May 28, 2003	Q5	R
280	100	10	0.0733	May 28, 2003	Q5	R
130	100	6	0.0204	May 28, 2003	Q5	R
190	140	13	0.0905	May 28, 2003	Q5	R
300	200	15	0.2356	May 28, 2003	Q5	R
140	130	11	0.0524	May 28, 2003	Q5	R
200	110	5	0.0288	May 28, 2003	Q5	R
190	80	7	0.0279	May 28, 2003	Q5	R
70	50	7	0.0064	May 28, 2003	Q5	R
120	120	13	0.0490	May 28, 2003	Q5	R
100	90	6	0.0141	May 28, 2003	Q5	R
160	120	11	0.0553	May 28, 2003	Q5	R
80	60	9	0.0113	May 28, 2003	Q5	R
100	90	6	0.0141	May 28, 2003	Q5	R
180	140	14	0.0924	May 28, 2003	Q5	R
110	110	7	0.0222	May 28, 2003	Q5	R
110	100	7	0.0202	May 28, 2003	Q5	R
90	60	10	0.0141	May 28, 2003	Q5	R
240	230	16	0.2312	May 28, 2003	Q5	R
180	130	10	0.0613	May 28, 2003	Q5	R
190	160	11	0.0875	May 28, 2003	Q5	R
200	170	14	0.1246	May 28, 2003	Q5	R
75	70	5	0.0069	May 28, 2003	Q5	R
300	280	8	0.1759	May 28, 2003	Q5	R
290	160	11	0.1336	May 28, 2003	Q5	R
320	220	10	0.1843	May 28, 2003	Q5	R
170	120	15	0.0801	May 28, 2003	Q5	R
270	210	16	0.2375	May 28, 2003	Q5	R
160	120	15	0.0754	May 28, 2003	Q5	R

180	110	10	0.0518	May 28, 2003	Q5	R
240	130	9	0.0735	May 28, 2003	Q5	B
300	230	16	0.2890	May 28, 2003	Q5	R
400	260	16	0.4356	May 28, 2003	Q5	R
390	230	16	0.3757	May 28, 2003	Q5	R
180	100	16	0.0754	May 28, 2003	Q5	R
110	110	11	0.0348	May 28, 2003	Q5	R
340	150	12	0.1602	May 28, 2003	Q5	R
130	120	11	0.0449	May 28, 2003	Q5	R
270	170	14	0.1682	May 28, 2003	Q5	R
340	260	14	0.3240	May 28, 2003	Q5	R
270	210	16	0.2375	May 28, 2003	Q5	R
320	220	11	0.2027	May 28, 2003	Q5	R
280	180	15	0.1979	May 28, 2003	Q5	R
240	170	19	0.2029	May 28, 2003	Q5	R
130	120	10	0.0408	May 28, 2003	Q5	R
220	170	20	0.1958	May 28, 2003	Q5	R
100	70	9	0.0165	May 28, 2003	Q5	R
190	150	14	0.1045	May 28, 2003	Q5	R
150	110	16	0.0691	May 28, 2003	Q5	R
280	210	24	0.3695	May 28, 2003	Q5	R
200	100	12	0.0628	May 28, 2003	Q5	R
130	70	10	0.0238	May 28, 2003	Q5	R
240	190	13	0.1552	May 28, 2003	Q5	R
290	170	17	0.2194	May 28, 2003	Q5	R
330	200	12	0.2073	May 28, 2003	Q5	R
440	230	11	0.2914	May 28, 2003	Q5	R
180	120	7	0.0396	May 28, 2003	Q5	R
300	180	13	0.1838	May 28, 2003	Q5	R
220	200	12	0.1382	May 28, 2003	Q5	R
170	160	14	0.0997	May 28, 2003	Q5	R
150	70	10	0.0275	May 28, 2003	Q5	R

210	170	16	0.1495	May 28, 2003	Q5	R
100	80	7	0.0147	May 28, 2003	Q5	R
70	40	5	0.0037	May 28, 2003	Q5	R
180	150	9	0.0636	May 28, 2003	Q5	R
210	210	13	0.1501	May 28, 2003	Q5	R
340	150	14	0.1869	May 28, 2003	Q5	R
380	280	25	0.6964	May 28, 2003	Q5	R
230	170	4	0.0409	May 28, 2003	Q5	R
230	130	11	0.0861	May 28, 2003	Q5	R
270	170	20	0.2403	May 28, 2003	Q5	R
200	140	15	0.1100	May 28, 2003	Q5	R
280	250	18	0.3299	May 28, 2003	Q5	R
320	260	19	0.4139	May 28, 2003	Q5	R
410	240	22	0.5667	May 28, 2003	Q5	R
420	200	12	0.2639	May 28, 2003	Q5	R
110	60	16	0.0276	May 28, 2003	Q5	R
490	150	20	0.3848	May 28, 2003	Q5	R
240	160	15	0.1508	May 28, 2003	Q5	R
120	90	5	0.0141	May 28, 2003	Q5	R
320	240	22	0.4423	May 28, 2003	Q5	R
190	170	13	0.1099	May 28, 2003	Q5	R
340	230	21	0.4299	May 28, 2003	Q5	R
140	110	11	0.0443	May 28, 2003	Q5	R
180	170	11	0.0881	May 28, 2003	Q5	R
230	90	10	0.0542	May 28, 2003	Q5	R
140	100	16	0.0586	May 28, 2003	Q5	R
240	160	13	0.1307	May 28, 2003	Q5	R
200	190	14	0.1393	May 28, 2003	Q5	R
160	110	14	0.0645	May 28, 2003	Q5	R
60	40	13	0.0082	May 28, 2003	Q5	R
120	70	8	0.0176	May 28, 2003	Q5	R
90	50	6	0.0071	May 28, 2003	Q5	R

200	150	15	0.1178	May 28, 2003	Q5	R
150	150	20	0.1178	May 28, 2003	Q5	R
210	210	21	0.2425	May 28, 2003	Q5	R
220	160	17	0.1567	May 28, 2003	Q5	R
240	170	15	0.1602	May 28, 2003	Q5	R
230	220	15	0.1987	May 28, 2003	Q5	R
390	290	23	0.6810	May 28, 2003	Q5	R
200	160	14	0.1173	May 28, 2003	Q5	R
180	120	8	0.0452	May 28, 2003	Q5	R
160	150	13	0.0817	May 28, 2003	Q5	R
150	140	12	0.0660	May 28, 2003	Q5	R
250	180	14	0.1649	May 28, 2003	Q5	R
370	170	17	0.2799	May 28, 2003	Q5	R
110	90	8	0.0207	May 28, 2003	Q5	R
60	60	5	0.0047	May 28, 2003	Q5	R
140	110	11	0.0443	May 28, 2003	Q5	R
280	160	18	0.2111	May 28, 2003	Q5	R
30	30	5	0.0012	May 28, 2003	Q5	R
90	90	5	0.0106	May 28, 2003	Q5	R
130	120	6	0.0245	May 28, 2003	Q5	R
160	120	10	0.0503	May 28, 2003	Q5	R
30	40	4	0.0013	May 28, 2003	Q5	R
70	50	4	0.0037	May 28, 2003	Q5	R
380	210	14	0.2925	May 28, 2003	Q5	R
230	170	13	0.1331	May 28, 2003	Q5	R
510	430	25	1.4353	May 28, 2003	Q5	R
110	110	11	0.0348	May 28, 2003	Q5	R
300	200	17	0.2670	May 28, 2003	Q5	R
270	230	20	0.3252	May 28, 2003	Q5	R
290	210	20	0.3189	May 28, 2003	Q5	R
230	200	14	0.1686	May 28, 2003	Q5	R
170	110	9	0.0441	May 28, 2003	Q5	R

150	80	13	0.0408	May 28, 2003	Q5	R
130	130	11	0.0487	May 28, 2003	Q5	R
130	100	7	0.0238	May 28, 2003	Q5	R
150	120	13	0.0613	May 28, 2003	Q5	R
140	140	7	0.0359	May 28, 2003	Q5	R
200	190	17	0.1691	May 28, 2003	Q5	R
320	190	23	0.3661	May 28, 2003	Q5	R
250	170	15	0.1669	May 28, 2003	Q5	R
250	180	22	0.2592	May 28, 2003	Q5	R
110	50	5	0.0072	May 28, 2003	Q5	R
130	100	12	0.0408	May 28, 2003	Q5	R
180	120	12	0.0679	May 28, 2003	Q5	R
120	90	14	0.0396	May 28, 2003	Q5	R
170	130	16	0.0926	May 28, 2003	Q5	R
160	110	10	0.0461	May 28, 2003	Q5	R
180	140	18	0.1188	May 28, 2003	Q5	R
340	160	14	0.1994	May 28, 2003	Q5	R
280	130	12	0.1144	May 28, 2003	Q5	R
120	120	16	0.0603	May 28, 2003	Q5	R
260	80	18	0.0980	May 28, 2003	Q5	R
120	70	15	0.0330	May 28, 2003	Q5	R
120	100	11	0.0346	May 28, 2003	Q5	R
190	100	14	0.0696	May 28, 2003	Q5	R
160	140	10	0.0586	May 28, 2003	Q5	R
100	90	9	0.0212	May 28, 2003	Q5	R
220	120	11	0.0760	May 28, 2003	Q5	R
190	100	10	0.0497	May 28, 2003	Q5	R
230	100	9	0.0542	May 28, 2003	Q5	R
40	25	5	0.0013	May 28, 2003	Q8	R
190	160	15	0.1194	May 28, 2003	Q8	R
120	90	9	0.0254	May 28, 2003	Q8	R
250	110	14	0.1008	May 28, 2003	Q8	R

200	140	7	0.0513	May 28, 2003	Q8	R
120	70	7	0.0154	May 28, 2003	Q8	R
200	140	21	0.1539	May 28, 2003	Q8	R
190	170	15	0.1268	May 28, 2003	Q8	R
70	40	14	0.0103	May 28, 2003	Q8	R
370	260	29	0.7304	May 28, 2003	Q8	R
70	50	9	0.0082	May 28, 2003	Q8	R
150	120	10	0.0471	May 28, 2003	Q8	R
110	80	12	0.0276	May 28, 2003	Q8	R
240	170	26	0.2777	May 28, 2003	Q8	R
160	90	9	0.0339	May 28, 2003	Q8	R
130	80	13	0.0354	May 28, 2003	Q8	R
160	120	14	0.0704	May 28, 2003	Q8	R
250	160	27	0.2827	May 28, 2003	Q8	R
290	140	20	0.2126	May 28, 2003	Q8	R
60	40	7	0.0044	May 28, 2003	Q8	R
280	120	16	0.1407	May 28, 2003	Q8	R
300	200	15	0.2356	May 28, 2003	Q8	R
80	50	10	0.0105	May 28, 2003	Q8	R
210	150	22	0.1814	May 28, 2003	Q8	R
270	210	29	0.4305	May 28, 2003	Q8	R
180	90	8	0.0339	May 28, 2003	Q8	R
40	25	7	0.0018	May 28, 2003	Q8	R
240	150	18	0.1696	May 28, 2003	Q8	R
100	90	15	0.0353	May 28, 2003	Q8	R
40	25	6	0.0016	May 28, 2003	Q8	R
240	180	22	0.2488	May 28, 2003	Q8	R
210	210	21	0.2425	May 28, 2003	Q8	R
160	130	14	0.0762	May 28, 2003	Q8	R
40	15	11	0.0017	May 28, 2003	Q8	R
300	170	23	0.3071	May 28, 2003	Q8	R
280	160	18	0.2111	May 28, 2003	Q8	R

220	160	25	0.2304	May 28, 2003	Q8	R
90	60	12	0.0170	May 28, 2003	Q8	R
240	120	13	0.0980	May 28, 2003	Q8	R
270	260	20	0.3676	May 28, 2003	Q8	R
280	140	11	0.1129	May 28, 2003	Q8	R
220	150	17	0.1469	May 28, 2003	Q8	R
90	40	10	0.0094	May 28, 2003	Q8	R
190	100	3	0.0149	May 28, 2003	Q8	R
130	110	11	0.0412	May 28, 2003	Q8	R
140	120	14	0.0616	May 28, 2003	Q8	R
180	150	22	0.1555	May 28, 2003	Q8	R
320	300	40	1.0053	May 28, 2003	Q8	R
20	10	4	0.0002	May 28, 2003	Q8	R
30	20	7	0.0011	May 28, 2003	Q8	R
420	140	23	0.3541	May 28, 2003	Q8	R
60	30	6	0.0028	May 28, 2003	Q8	R
130	90	8	0.0245	May 28, 2003	Q8	R
120	110	16	0.0553	May 28, 2003	Q8	R
210	130	25	0.1787	May 28, 2003	Q8	R
110	50	12	0.0173	May 28, 2003	Q8	R
110	40	11	0.0127	May 28, 2003	Q8	R
50	30	13	0.0051	May 28, 2003	Q8	R
100	60	9	0.0141	May 28, 2003	Q8	R
100	100	13	0.0340	May 28, 2003	Q8	R
80	60	9	0.0113	May 28, 2003	Q8	R
230	120	14	0.1012	May 28, 2003	Q8	R
150	130	7	0.0357	May 28, 2003	Q8	R
180	90	13	0.0551	May 28, 2003	Q8	R
220	100	15	0.0864	May 28, 2003	Q8	R
80	50	10	0.0105	May 28, 2003	Q8	R
50	30	8	0.0031	May 28, 2003	Q8	R
190	150	11	0.0821	May 28, 2003	Q8	R

100	80	9	0.0188	May 28, 2003	Q8	R
150	100	16	0.0628	May 28, 2003	Q8	R
220	190	24	0.2626	May 28, 2003	Q8	R
140	80	16	0.0469	May 28, 2003	Q8	R
250	100	17	0.1113	May 28, 2003	Q8	R
180	110	13	0.0674	May 28, 2003	Q8	R
70	20	6	0.0022	May 28, 2003	Q8	R
100	80	16	0.0335	May 28, 2003	Q8	R
270	260	17	0.3124	May 28, 2003	Q8	R
110	30	16	0.0138	May 28, 2003	Q8	R
180	170	20	0.1602	May 28, 2003	Q8	R
160	160	18	0.1206	May 28, 2003	Q8	R
230	150	13	0.1174	May 28, 2003	Q8	R
430	400	48	2.1614	May 28, 2003	Q8	R
160	150	15	0.0942	May 28, 2003	Q8	R
250	210	20	0.2749	May 28, 2003	Q8	R
120	90	11	0.0311	May 28, 2003	Q8	R
280	260	35	0.6671	May 28, 2003	Q8	R
170	100	18	0.0801	May 28, 2003	Q8	R
160	80	14	0.0469	May 28, 2003	Q8	R
140	120	16	0.0704	May 28, 2003	Q8	R
280	240	12	0.2111	May 28, 2003	Q8	R
240	230	30	0.4335	May 28, 2003	Q8	R
310	170	18	0.2483	May 28, 2003	Q8	R
310	230	27	0.5040	May 28, 2003	Q8	R
300	220	22	0.3801	May 28, 2003	Q8	R
290	290	27	0.5945	May 28, 2003	Q8	R
140	90	12	0.0396	May 28, 2003	Q8	R
80	70	19	0.0279	May 28, 2003	Q8	R
160	160	16	0.1072	May 28, 2003	Q8	R
180	100	20	0.0942	May 28, 2003	Q8	R
310	300	26	0.6330	May 28, 2003	Q8	R

290	240	45	0.8200	May 28, 2003	Q8	R
250	220	24	0.3456	May 28, 2003	Q8	R
350	350	41	1.3149	May 28, 2003	Q8	R
140	120	16	0.0704	May 28, 2003	Q8	R
340	340	39	1.1803	May 28, 2003	Q8	R
170	150	9	0.0601	May 28, 2003	Q8	R
360	290	28	0.7653	May 28, 2003	Q8	R
240	160	25	0.2513	May 28, 2003	Q8	R
40	40	7	0.0029	May 28, 2003	Q8	R
40	40	6	0.0025	May 28, 2003	Q8	R
230	220	19	0.2517	May 28, 2003	Q8	R
150	120	20	0.0942	May 28, 2003	Q8	R
440	200	27	0.6220	May 28, 2003	Q8	R
420	240	25	0.6597	May 28, 2003	Q8	R
220	170	16	0.1567	May 28, 2003	Q8	R
220	170	23	0.2252	May 28, 2003	Q8	R
260	250	26	0.4424	May 28, 2003	Q8	R
230	220	22	0.2914	May 28, 2003	Q8	R
320	260	23	0.5010	May 28, 2003	Q8	R
250	180	24	0.2827	May 28, 2003	Q8	R
240	190	18	0.2149	May 28, 2003	Q8	R
310	210	22	0.3749	May 28, 2003	Q8	R
340	280	27	0.6729	May 28, 2003	Q8	R
110	90	17	0.0441	May 28, 2003	Q8	R
30	40	15	0.0047	May 28, 2003	Q8	R
NA	NA	NA	0.0568	March 29, 2003	Q4	B
NA	NA	NA	0.1419	March 29, 2003	Q4	B
NA	NA	NA	0.0520	March 29, 2003	Q4	B
NA	NA	NA	0.0520	March 31, 2003	Q2	B

NA	NA	NA	0.1703	March 31, 2003	Q2	B

Table 9. Maximum burrow depths for rodents that deeply burrow on the NTS, summarized from Table 6.

Species	Max burrow depth (cm)	References
Deer Mouse, *Peromyscus maniculatus*	50	Suter et al. 1993
	50	Reynolds and Wakkinen 1987
Botta's pocket gopher, *Thomomys bottae*	150	Felthauser and McInroy 1983
Botta's pocket gopher, *Thomomys bottae*	160	Reichman et al. 1982
Merriam's kangaroo rat, *D. merriami*	175	Kenagy 1973
Ord's kangaroo rat, *D. ordii*	69	Reynolds and Wakkinen 1987
	70	Suter et al. 1993
Little pocket mouse, *Perognathus longimembris*	65 (undisturbed) 75 (disturbed)	Kenagy 1973
Great Basin pocket mouse, *Perognathus parvus*	105	Bowerman and Redente 1998
	140	Suter et al. 1993
Burrows of pocket mice	92	Bowerman and Redente 1998
"Several species" of pocket mice and kangaroo rats	200	Kennedy et al. 1985
"Several species" of ground squirrels	200	Kennedy et al. 1985
Townsend's ground squirrel, *S. townsendii*	150	Reynolds and Wakkinen 1987
Townsend's ground squirrel, *S. townsendii* (continued)	140	Suter et al. 1993
	58	Bowerman and Redente 1998

Table 10. Maximum burrow depths for mammal species other than rodents that deeply burrow on the NTS, summarized from Table 6.

Species	Max burrow depth (cm)	References
Coyote*, Canis latrans*	Similar to badger, but rarely of their own excavation	Bekoff 1982
Kit fox, *Vulpes macrotis*	300	O'Farrell 1987
Badger, *Taxidea taxus*	>200	Kennedy et al. 1985

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