APPENDIX A

Summary of Population Modeling of Wild Horses

Population Model Overview

WinEquus is a computer software program designed to simulate population dynamics based on various management alternatives concerning wild horses. It was developed by Stephen H. Jenkins of the Department of Biology, University of Nevada at Reno. For further information about the model, please contact Stephen H. Jenkins at the Department of Biology/314, University of Nevada, Reno, NV 89557.

The following data was summarized from the information provided within the WinEquus program. It will provide background about the use of the model, the management options that may be used, interpretation of modeling results, and the types of output that may be generated.

The population model for wild horses was designed to help wild horse and burro specialists evaluate various management strategies that might be considered for a particular area. The model uses data on average survival probabilities and foaling rates of horses to project population growth for up to 20 years. The model accounts for year-to-year variation in these demographic parameters by using a randomization process to select survival probabilities and foaling rates for each age class from a distribution of values based on these averages. This aspect of population dynamics is called environmental stochasticity, and reflects the fact that future environmental conditions that may affect a wild horse population's demographics can not be established in advance. Therefore, each trial will give a different pattern of population growth. Some trials may include mostly "good" years, when the population grows rapidly; other trials may include a series of several "bad" years in succession. The stochastic approach to population modeling uses repeated trials to project a range of possible population trajectories over a period of years, which is more realistic than predicting a single specific trajectory.

The model incorporates both selective removal and fertility treatment as management strategies. A simulation may include no management, selective removal, fertility treatment, or both removal and fertility treatment. Wild horse and burro specialists can specify many different options for these management strategies such as the schedule of gathers for removal or fertility treatment, the threshold population size which triggers a gather, the target population size following a removal, the ages and sexes of horses to be removed, and the effectiveness of fertility treatment.

To run the program, one must supply an initial age distribution (or have the program calculate one), annual survival probabilities for each age-sex class of horses, foaling rates for each age class of females, and the sex ratio at birth. Sample data are available for all of these parameters. Basic management options must also be specified.

Population Data: Age-Sex Distribution

An important point about the initial age-sex distribution is that it is NOT necessarily the starting population for each of the trials in a simulation. This is because the program assumes that the initial age-sex distribution supplied on this form or calculated from a population size that the user enters is not an exact and complete count of the population. For example, if the user enters an initial population size of 100 based on an aerial survey, this is really an estimate of the population and not a census. Furthermore, it is likely to be an underestimate because some horses will be missed in the survey. Therefore, the program uses an average sighting probability of approximately 90% (Garrott et al. 1991) to "scale-up" the initial population estimate to a starting population size for use in each trial. This is done by a random process, so the starting population sizes are different for all trials. An option does exist to consider the initial population size to be exact and bypass this scaling-up process.

Population Data: Survival Probabilities

A fundamental requirement for a population model are data on annual survival probabilities of each age class. The program contains files of existing sets of survival or it is possible to enter a new set of data in the table. In most cases, Wild Horse and Burro Specialists do not have data on survival probabilities for their herd populations, so the sample data files provided with WinEquus are used and assume that average survival probabilities in the populations are similar. These data are more difficult to get than is often assumed, because they require keeping track of known individuals over time. A "snapshot" of a population, providing information on the age distribution at a single gather, can NOT be used to estimate survival probabilities without assuming a particular growth rate for the population (Jenkins, 1989). More data from long-term studies of marked horses are needed to develop estimates of survival in various habitats.

Population Data: Foaling Rates

Foaling rates are the proportions of females in each age class that produce a foal at that age. Files are available within the program that set foaling rates or the user may enter a new set of data in the table. The user may also enter the sex ratio at birth, another necessary parameter for population simulation.

Environmental Stochasticity

For any natural population, mortality and reproduction vary from year to year due to unpredictable variation in weather and other environmental factors. This model mimics such environmental stochasticity by using a random process to increase or decrease survival probabilities and foaling rates from average values for each year of a simulation trial. Each trial uses a different sequence of random values to give different results for population growth. Looking at the range of final population sizes in many such trials will give the user an indication of the range of possible outcomes of population growth in an uncertain environment.

How variable are annual survival probabilities and foaling rates for wild horses? The longest study reporting such data was done at Pryor Mountain, Montana by Garrott and Taylor (1990).

Based on 11 years of data at this site, survival probability of foals and adults combined was greater than 98% in 6 years, between 90 and 98% in 3 years, 87% in 1 year, and only 49% in 1 year of severe winter weather. These values clearly are not normally distributed, but can be approximated by a logistic distribution. This pattern of low mortality in most years but markedly higher mortality in occasional years of bad weather was also reported by Berger (1986) for a site in northwestern Nevada. Therefore, environmental stochasticity in this model is simulated by drawing random values from logistic distributions. If desired, different values can be entered to change the scaling factors for environmental stochasticity.

Because year-to-year variation in weather is likely to affect foals and adults similarly, this model makes foal and adult survival perfectly correlated. This means that when survival probability of foals is high so is the survival probability of adults, and vice versa. By contrast, the correlation between survival probabilities and foaling rates can be adjusted to any value between -1 and +1. The default correlation is 0 based on the Pryor Mountain data and the assumption that most mortality occurs in winter and winter weather is not highly correlated with foaling-season weather.

The model includes another form of random variation called demographic stochasticity. This means that mortality and reproduction are random processes even in a constant environment (i.e., a foaling rate of 40% means that each female has a 40% chance of having a foal). Because of demographic stochasticity, even if scaling factors for both survival probabilities and foaling rates were set equal to 0, different runs of the simulation would produce different results. However, variation in population growth due to demographic stochasticity will be small except at low population sizes.

Gathering Schedule

There are three choices for the gather schedule: gather at a regular interval, gather at a minimum interval (the default), or gather in specific years. Gathering at a minimum interval means that gathers will be conducted no more frequently than a prescribed interval (e.g., 3 years), but will not be conducted if the time interval has passed unless the population is above a threshold size that triggers a gather.

Gather Interval

This is the number of years between gathers.

Gather for fertility treatment regardless of population size?

If this option is selected (the default), then gathers occur according to the gathering schedule specified regardless of whether or not the population exceeds a threshold population size. One effect of this is that a minimum-interval schedule really functions as a regular interval.

Continue gather after reduction to treat females?

Continuing a gather after a reduction to treat females (with fertility control management options) means that, if a gather for a removal has been triggered because the population has exceeded a threshold population size, then horses will continue to be processed even after enough have been removed to reduce the population to the target population size. As additional horses are processed, females to be released back will be treated with an immunocontraceptive according to the information specified in the Contraceptive Parameters form.

Threshold for Gather

The threshold population size for triggering a gather is the actual population size in a particular year estimated by the program. This is NOT the same as the number of horses counted in an aerial census, but closer to an estimate of population size taking into account the fact that an aerial census typically underestimates population size.

Target Population Size

This is the goal for the population size following a gather and removal. Horses will be removed until this target is reached, although it may not be possible to achieve this goal, depending on the removal parameters (percentages of each age-sex class to be removed) and gathering efficiency.

Are foals included in AML?

In most field offices, foals are counted as part of the appropriate management level (AML).

Gathering Efficiency

Typically, some horses will successfully resist being gathered, either by hiding in habitats where they can not be seen or moved by a helicopter, or by following escape routes that make it dangerous or un-economical for them to be herded from the air. These horses are not available for removals or fertility treatment. The default gathering efficiency is 80%, meaning that the program assumes that 20% of the population will successfully resist being gathered. This value may be changed.

Note that the program assumes that horses of all age-sex classes are equally likely to be gathered. This is an unrealistic assumption because bachelor males, for example, may be more likely to successfully avoid being gathered than females or foals or band stallions.

Sanctuary-bound Horses

Age-selective removals typically target younger age classes such as 0 to 5 year-olds or 0 to 9 year-olds because these horses are more easily adopted. However, it may not be possible to reduce the population to a target size by restricting removals to these younger age classes, especially if age-selective removals have been conducted in the past. In this case, an option is available to remove older animals as well, who may be destined for permanent residence in a long term holding facility rather than for adoption. The minimum age of these long term holding facility horses is specified for this element. When older age classes as well as younger age classes are identified for removal on the Removal Parameters form, horses of these older age classes are selected along with younger age class horses as the population is reduced to the target value. If a minimum age for long term holding facility horses is specified, then older animals are only removed if the population can not be reduced to the target population size by removing the younger ones.

Percent Effectiveness of Fertility Control

These percentages represent the percentage of treated females that are in fact sterile for one year, two years, etc. (i.e., the efficacy or effectiveness of fertility treatment). The default values are 90% efficacy for one year. However, the user may specify the effectiveness year by year for up to five years.

Removal Parameters

This allows the user to determine the percentages of horses in each sex and age class to be removed during a gather. The program uses these percentages to determine the probabilities of removing each horse that is processed during a gather. If the percentage for an age-sex class is 100%, then all horses of that age-sex class that are processed will be removed until the target population size is reached. If the percentage for an age-sex class is 0%, then all horses of that age-sex class will be released. If the percentage for an age-sex class is greater than 0% but less than 100%, then the proportion of horses of that age-sex class removed will be approximately equal to the specified percentage.

Contraception Parameters

This allows the user to specify the percentage of released females of each age class that will be treated with an immunocontraceptive. The default values are 100% of each age class, but any or all of these may be changed.

Most Typical Trial

This is the trial that is most similar to each of the other trials in a simulation

Population Size Table

The default is both sexes and all age classes, but summary results may also be chosen for a subset of the population. The table identifies some key numbers such as the lowest minimum in all trials, the median minimum, and the highest minimum. Thinking about the distribution of minima for example, half of the trials have a minimum less than the median of the minima and half have a minimum greater than the median of the minima. If the user was concerned about applying a management strategy that kept the population above some level because the population might be at risk of losing genetic diversity if it were below this level, then one might look at the 10th percentile of the minima, and argue that there was only a 10% probability that the population would fall below this size in x years, given the assumptions about population data, environmental stochasticity, and management that were used in the simulation.

Gather Table

The default is both sexes and all age classes, but summary results may be for a subset of the population. The table shows key values from the distribution of the minimum total number of horses gathered, removed, and (if one elected to display data for both sexes or just for females) treated with a contraceptive across all trials. This output is probably the most important representation of the results of the program in terms of assessing the effects of your management strategy because it shows not only expected average results but also extreme results that might be possible. For example, only 10% of the trials would have entailed gathering fewer animals than shown in the row of the table labeled "10th percentile", while 10% of the trials would have entailed gathering more than shown in the row labeled "90th percentile". In other words, 80% of the time one could expect to gather a number of horses between these 2 values, given the assumptions about survival probabilities, foaling rates, initial age-sex distribution, and management options made for a particular simulation

Growth Rate

This table shows the distribution of the average population growth rate. The direct effects of removals are not counted in computing average annual growth rates, although a selective removal may change the average foaling rate or survival rate of individuals in the population (e.g., because the age structure of the population includes a higher percentage of older animals), which may indirectly affect the population growth rate. Fertility control clearly should be reflected in a reduction of population growth rate.

Results - Population Modeling of the High Rock HMA

Objectives of Population Modeling

To complete the population modeling for the High Rock HMA, version 1.40 of the WinEquus program, created April 2, 2002, was utilized. Review of the data output for each of the simulations provided many useful comparisons of the possible outcomes for each Alternative. The developer, Stephen Jenkins, recommends thinking about the range of possible outcomes and not just focusing on one average or typical trial. Some of the questions that need to be answered through the modeling include:

- Do any of the Alternatives "crash" the population?
- What effect does fertility control have on population growth rate?
- What effect do the different Alternatives have on the average population size?
- What effect do the different Alternatives have the number of horses handled and/or removed from the HMA?

Population Data, Criteria, and Parameters utilized for Population Modeling

The initial age structure for the 2006 herds was developed from age structure data collected during the 2000 and 2001 gathers of the High Rock HMA. The age distribution of the horses that were returned to the HMA, coupled with assumptions (based on the 2000 and 2001 age distributions) from the HMA that were made about the animals that were not captured, result in the following estimate of herd structure as of 2001:

Initial Age Structure 2001 – High Rock HMA

Age Class	**Horses remaining in the HMA, following the 2001 gather (not captured or returned)**		
	Females	Males	Total
Foals	15	14	29
1	17	7	24
2	11	7	18
3	8	5	13
4	9	3	12
5	2	1	3
6	6	5	11
7	12	10	22
8	5	6	11
9	2	3	5
10-14	10	16	26
15-19	4	7	11
20+	3	6	9
Total	**104**	**90**	**194**

A simulation, using the estimated 2001 population as the initial age structure was then run for the years 2001 to 2006 under the "no management" management option. The most typical trial obtained from this simulation was used to represent the 2006 age structure of the herd. This model was used to represent the current age structure of the High Rock HMA for all of the Alternatives.

Initial Age Structure 2006 – High Rock HMA

Age Class	Females	Males	Total
Foals	60	65	125
1	38	43	81
2	32	28	60
3	21	18	39
4	29	27	56
5	13	9	22
6	13	7	20
7	12	4	16
8	6	4	10
9	5	1	6
10-14	20	21	41
15-19	6	11	17
20+	3	12	15
Total	**258**	**250**	**508**

All simulations used the survival probabilities and foaling rates supplied with the WinEquus population model for the Granite Range HMA. Survival and foaling rate data were extracted from, *Wild Horses of the Great Basin*, by J. Berger (1986, University of Chicago Press, Chicago, IL, xxi + 326 pp.). Rates are based on Joel Berger's 6 year study in the Granite Range HMA in northwestern Nevada.

Survival probabilities and foaling rates utilized in the population model for each Alternative are as follows:

Survival Probabilities and Foaling Rates

Age Class	Survival Probabilities		Foaling Rates
	Females	Males	
Foals	.917	.917	--
1	.969	.969	--
2	.951	.951	.35
3	.951	.951	.40
4	.951	.951	.65
5	.951	.951	.75
6	.951	.951	.85
7	.951	.951	.90
8	.951	.951	.90
9	.951	.951	.90
10-14	.951	.951	.85
15-19	.951	.951	.70
20+	.951	.951	.70

Removal criteria utilized in the population model for Alternatives #1 and #2:

Removal Criteria - Standard

	Percentages for Removals			Percentages for Removals	
Age	Females	Males	**Age**	Females	Males
Foal	100%	100%	**7**	100%	100%
1	100%	100%	**8**	100%	100%
2	100%	100%	**9**	100%	100%
3	100%	100%	**10-14**	100%	100%
4	100%	100%	**15-19**	100%	100%
5	100%	100%	**20+**	100%	100%
6	100%	100%			

Population Modeling Criteria

The following summarizes the population modeling criteria that are common to all of the Alternatives (as applicable):

- Starting Year: 2006
- Sex ratio at birth: 50% male, 50% female
- Foals are included in the AML
- Simulations were run for five, ten and fifteen years with 100 trials each
- Initial gather year: 2006
- Gather interval: minimum interval of three years
- Gathers to be triggered by the population reaching maximum AML's (120 for the High Rock HMA).
- Estimated percent of the population that can be gathered: 90%
- Target population size following gathers is the minimum AML's (78 for the High Rock HMA). Target may not be reached at each gather, depending upon the Alternative.
- For Alternative #1, fertility control effectiveness for treated mares is assumed to be 94% the first year, 82% the second year, and 68% the third year after treatment.

Population Modeling Results

Population size in five, ten, and fifteen years

Out of 100 trials in each simulation, the model tabulated minimum, average, and maximum population sizes. The model was run for five, ten, and fifteen years to determine what the potential effects would be on population size for all Alternatives (I-III). These numbers are useful to make relative comparisons of the different Alternatives and of the potential outcomes under different management options. The data displayed within the tables are broken down into different levels. The lowest trial, highest trial, and several percentile trials are displayed for each simulation completed. According to the model developer, this output is probably the most important representation of the results in terms of assessing the effects of proposed management. The trials show not only the expected average results, but also extreme high and low results of the modeling scenario.

High Rock HMA

Population sizes in 6 years

Trial	Alternative #1			Alternative #2			Alternative #3		
	min	med	max	min	med	max	min	med	max
Lowest	**47**	151	508	**42**	150	510	**411**	598	842
10%	76	170	522	70	170	520	520	752	1010
25%	80	175	532	79	174	528	530	793	1112
Median	**85**	**178**	**552**	**86**	**178**	**544**	**558**	**876**	**1278**
75%	90	184	574	91	187	582	586	940	1388
90%	93	191	614	96	194	634	607	1026	1476
Highest	108	204	**689**	104	209	**710**	771	1264	**1887**
Gather years	06,10			06,09			n/a		

Population sizes in 11 years

Trial	Alternative #1			Alternative #2			Alternative #3		
	min	med	max	min	med	max	min	med	max
Lowest	**51**	121	512	**57**	126	509	**349**	613	993
10%	64	134	522	75	141	518	516	*1107*	1793
25%	77	140	535	80	144	536	532	1252	2312
Median	**83**	**145**	**555**	**84**	**150**	**554**	**555**	**1417**	**2820**
75%	87	147	586	87	153	576	584	1562	3142
90%	91	153	635	90	156	606	625	*1730*	3680
Highest	97	161	**748**	93	167	**722**	761	2128	**4559**
Gather years	06,10,15			06,09,12,15			n/a		

Population sizes in 16 years

Trial	Alternative #1			Alternative #2			Alternative #3		
	min	med	max	min	med	max	min	med	max
Lowest	**43**	109	510	**46**	116	509	**411**	1234	2565
10%	67	124	522	68	129	518	518	1618	3622
25%	72	127	536	74	132	530	530	1830	4252
Median	**79**	**131**	**555**	**80**	**136**	**550**	**555**	**2237**	**5342**
75%	84	134	584	84	139	577	581	2643	6737
90%	88	138	646	87	141	631	618	2983	7829
Highest	95	146	**744**	90	155	**753**	830	3864	**10236**
Gather years	06,10,15,20			06,09,12,15,18			n/a		

Average Growth Rates

Average Growth Rate (%) in 5 years

Trial	High Rock HMA		
	Alt. #1	Alt. #2	Alt. #3
Lowest	0.3	-3.1	6.8
10%	7.8	9.4	12.5
25%	11.2	12.9	15.1
Median	**13.0**	**15.9**	**17.3**
75%	15.4	18.4	19.4
90%	16.8	21.0	21.6
Highest	20.1	24.7	23.4

Average Growth Rate (%) in 10 years

Trial	High Rock HMA		
	Alt. #1	Alt. #2	Alt. #3
Lowest	1.2	7.1	6,5
10%	6.7	11.5	12.1
25%	9.4	13.7	14.9
Median	**11.2**	**15.8**	**17.4**
75%	13.1	18.5	18.7
90%	14.3	19.6	20.1
Highest	15.6	23.3	23.4

Average Growth Rate (%) in 15 years

Trial	High Rock HMA		
	Alt. #1	Alt. #2	Alt. #3
Lowest	3.2	7.5	10.0
10%	7.9	11.7	13.2
25%	9.5	13.7	14.6
Median	**10.8**	**15.7**	**16.3**
75%	12.3	17.9	17.8
90%	13.1	19.0	18.9
Highest	14.5	22.1	20.5

Historic Reproductive Rates

Gather/Census	High Rock HMA		
	Adult	Foal	Rate (%)
1994	97	25	20.5
1997	242	64	20.9
2001	452	104	18.7

Number of Horses Gathered, Removed, and Treated

High Rock HMA

Number of horses Gathered (G), Removed (R), and Treated (T) in 6 years

Trial	Alternative #1			Alternative #2			Alternative #3		
	G	R	T	G	R	T	G	R	T
Lowest	446	403	7	408	391	0	0	0	0
10%	534	442	14	464	443	0	0	0	0
25%	562	456	35	475	454	0	0	0	0
Median	**578**	**474**	**39**	**492**	**470**	**0**	**0**	**0**	**0**
75%	600	493	44	531	508	0	0	0	0
90%	635	532	46	576	552	0	0	0	0
Highest	716	621	54	653	627	0	0	0	0

Number of horses Gathered (G), Removed (R), and Treated (T) in 11 years

Trial	Alternative #1			Alternative #2			Alternative #3		
	G	R	T	G	R	T	G	R	T
Lowest	548	443	26	465	443	0	0	0	0
10%	574	470	35	520	500	0	0	0	0
25%	607	488	39	554	529	0	0	0	0
Median	**682**	**518**	**64**	**585**	**560**	**0**	**0**	**0**	**0**
75%	719	553	70	619	590	0	0	0	0
90%	758	592	76	648	621	0	0	0	0
Highest	856	699	108	759	732	0	0	0	0

Number of horses Gathered (G), Removed (R), and Treated (T) in 16 years

Trial	Alternative #1			Alternative #2			Alternative #3		
	G	R	T	G	R	T	G	R	T
Lowest	568	466	35	505	481	0	0	0	0
10%	684	*510*	62	580	*553*	0	0	0	0
25%	710	533	72	616	588	0	0	0	0
Median	**800**	**569**	**94**	**650**	**624**	0	**0**	**0**	**0**
75%	822	591	100	698	668	0	0	0	0
90%	874	*648*	105	724	*696*	0	0	0	0
Highest	982	753	121	926	885	0	0	0	0

Population Modeling Summary

To summarize the results obtained by simulating the range of Alternatives for the High Rock HMA wild horse gather, the original questions can be addressed.

- Do any of the Alternatives "crash" the population?

None of the Action Alternatives indicate that a crash is likely to occur in the High Rock HMA population. The minimum population level was 42 horses in the High Rock HMA under the extreme lowest trial. Median growth rates are all within reasonable levels, and adverse impacts to the population are not likely. The No Action Alternative #3 could result in a crash. If no horses are removed from the HMA, the population would have an 80% chance of ranging from 1107 head to 1730 head by 2016. By that time, horses would be causing serious impacts on soil stability, vegetation, water sources (springs and creeks), wildlife habitat, and livestock operations. Horses would begin running out of forage and water, and would be in poor shape going into winter. At some point the populations would crash, probably during an unusually cold or snowy winter.

- What effect does fertility control have on population growth rate?

The alternative implementing fertility control along with gate-cut gathers (Alternative #1, Proposed Action) reflects the lowest overall growth rates. Median growth rates for Alternative #1 ranged from 10.8 to 13.0, as compared to Alternative #2 which ranged from 15.7 to 15.9. The highest expected growth rates (16.6 to 17.4) occurred under the no action Alternative, or Alternative #3.

- What effect do the different Alternatives have on the median population size?

Implementation of Alternative #1 or #2 would result in stable median population numbers that are close to AML's over the long term. The impacts of these two Alternatives on long term populations are virtually identical. Implementation of Alternative #3 would result in population sizes that would exceed the carrying capacity of the HMA within 10 years (probably by 2016).

- What effect do the different Alternatives have the number of horses handled and/or removed from the HMA's?

Of the Action Alternatives (#1 and #2), implementation of Alternative #1 would result in the fewest number of horses being removed from the HMA (80% chance of 510 to 648 head, vs. an 80% chance of 553 to 696 head under Alternative #2). In addition, Alternative #1 would require one less gather or four gathers over ther next 15 years to meet AML, versus the five gathers needed under Alternative #2.