COMPARATIVE COST ANALYSIS OF ALTERNATIVE ANIMAL TRACING STRATEGIES DIRECTED TOWARD FOOT AND MOUTH DISEASE OUTBREAKS IN THE TEXAS HIGH PLAINS

A Thesis

by

JOHN CHRISTOPHER LOONEY

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2009

Major Subject: Agricultural Economic

COMPARATIVE COST ANALYSIS OF ALTERNATIVE ANIMAL TRACING STRATEGIES DIRECTED TOWARD FOOT AND MOUTH DISEASE OUTBREAKS IN THE TEXAS HIGH PLAINS

A Thesis

by

JOHN CHRISTOPHER LOONEY

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Approved by:

Chair of Committee,	Bruce A. McCarl
Committee Members,	David P. Anderson
	David A. Bessler
	Gale Wagner
Head of Department,	John Nichols

December 2009

Major Subject: Agricultural Economics

ABSTRACT

Comparative Cost Analysis of Alternative Animal Tracing Strategies Directed Toward Foot and Mouth Disease Outbreaks in the Texas High Plains.

John Christopher Looney, B.S., University of Arkansas

Chair of Advisory Committee: Dr. Bruce A. McCarl

The primary objective of this study is to evaluate the industry impact of a hypothetical Foot and Mouth Disease (FMD) outbreak in the Texas High Plains using alternative animal tracing levels. To accomplish this objective, an epidemiological disease spread model, AUSSPREAD, is used to simulate the FMD outbreak and an economic model is used to examine the impacts of different animal identification levels in cattle. The different levels of animal identification relate to the model's ability to trace back the subsequent infected and/or dangerous contacts with which the initial outbreak herd has been in contact. The study examines direct disease management costs (slaughter, euthanasia, disposal, surveillance, and cleaning disinfection), forgone income, and other indirect costs (indemnity payments and welfare slaughter) for outbreaks originating from a large beef operation, a feedlot, and a saleyard across subsequent tracing periods from 1 to 10 days. Welfare slaughter and quarantine costs were estimated for the best and worst outbreaks from the feedlot operation. It is noteworthy that total direct costs of a FMD outbreak would be more extensive than the current study's calculations, which only analyzed the direct disease management costs.

The increased days to trace dangerous contacts presented overall increases in outbreak losses over each outbreak scenario. Although outcome averages appear insensitive at times under the assumptions applied, the epidemiological model presented the possibility that traceability could reduce the risk of extreme outcomes in respect to the overall distribution of losses. For each cattle operation, the outbreaks stayed consistent or marginally increased with their respective average costs, but their maximum losses rose steadily, across the trace periods examined. The impact of increased traceability and decreased outbreak length can be justified in affecting FMD outbreak costs in a positive manner. The results provide the industry with estimations of different outbreak scenarios which can be used to inform the decision on the NAIS system. Longer tracing periods, larger simulations (by iteration), and further study of the model is necessary in order to more accurately imitate FMD outbreaks within the Texas High Plains and its detrimental effects.

DEDICATION

I would like to dedicate the time and effort put into this study to my mother, Cathryn Cannon Looney, and father, Charles Richard Looney, for their continuous love and support.

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to Amy Hagerman, for her tremendous patience, guidance, valuable suggestions, and encouragement throughout all stages of this thesis. Without her support and assistance, I would not have completed this thesis nor gained the knowledge that I acquired through the process.

I would also like to thank Dr. McCarl, the chair of my advisory committee, for the opportunity to research under the USDA National Needs Fellowship. The freedom and financial assistance allowed me to pursue my masters and my research without the added pressure of affording tuition and related expenses. I also like to thank him for the idea and direction of my thesis and its ongoing obstacles.

Finally, I would like to thank the remaining committee members, Dr. David Anderson, my co-chair, and Dr. David Bessler, for their support throughout my tenure at Texas A&M University and guidance through the masters program. For this, I will be forever indebted. Also, I would like to acknowledge Dr. Wagner, from the Texas A&M Veterinary School, for his suggestions, opinions, and time taken away from his department to aid in this study, as it is greatly appreciated. Lastly, I would like to thank Dr. David Leatham for giving me the initial opportunity to further my education at Texas A&M University and pursue my Master's degree.

TABLE OF CONTENTS

CHAPTER Page

LIST OF FIGURES

Page

LIST OF TABLES

CHAPTER I

INTRODUCTION

I.1 Objective

The primary objective of this study was to evaluate the industry impact of a hypothetical Foot and Mouth Disease (FMD) outbreak in the Texas High Plains with alternative animal tracing levels. To accomplish this objective, an epidemiological disease spread model (AUSSPREAD, Garner and Beckett, 2005) is used to simulate the FMD outbreak and an economic model (Elbakidze, 2008) to examine the impacts for different animal identification levels in cattle. The different levels of animal identification relate to the model's ability to trace back the subsequent infected and or dangerous contacts with which the initial outbreak herd has been in contact. By changing the tracing levels of these dangerous contacts, the model results indicate the benefits of added traceability of subsequent FMD infected herds in the context of the U.S. beef industry and agricultural industry. The costs of the added traceability will be represented and compared to a functional National Animal Identification System (NAIS).

I.2 Motivation

Currently, the U.S. has depended primarily on the word of the producers and livestock owners to find all other animals possibly infected with an animal disease.

This thesis follows the style of the *American Journal of Agricultural Economics.*

Some paper trail exists with health papers, transfer documents, and bills of sale to help with animal searches, but there can still be gaps of information which can allow for missed animals and further spread of the animal disease. Animal identification and tracking will allow the most effective way to find all the subsequent infected animals or herds quickly in the event of an outbreak in order to minimize the impact of the disease. Tracking animal movements will also help in finding potentially infected herds that would be otherwise missed, overlooked, or "forgotten" about.   The countries that have had animal disease outbreaks in the past have suffered staggering economic losses which have in turn crippled the associated industries and producers for an extended period of time, if not, forever. The problem of potential disease outbreaks is a serious concern for any country, especially for those who have nothing in place to restrain the disease from becoming endemic.

Whether the animal identification system for the United States is the NAIS or something else, it is important to prepare response plans for diseases such as FMD. The objective of such a plan would be to quickly isolate the disease before it becomes uncontrollable. If a highly infectious animal disease such as FMD was introduced in the U.S. without a response system such as NAIS, animal health officials would be unable to locate many of the potential infected premises. Epidemiologists could spend days interviewing herd owners, veterinarians, county agents, and others to gather names and addresses of potential producers in the area. This process alone may take several days, weeks, or possibly months to complete depending on existing resources. As each day passes, the disease would spread further, and more animals or herds would be exposed.

As the number of exposed animals increased, more producers would be directly impacted by the outbreak. The cost of mitigation efforts could increase by hundreds of thousands of dollars per day and the producer's loss of livestock and their own livelihoods would grow exponentially as each day passes (USDA, 2007). If the same scenario occurred in the U.S. with a functional and effective NAIS, animal health officials could use the system's databases on day one of the response to identify all the potentially infected premises and exposed animals in the surrounding area. During the same day, epidemiologists would be able to contact the owners of the premises and begin taking steps to prevent the outbreak from spreading further. Also, combined efforts of private and state animal tracking databases would provide information on animals that have moved from infected zones (USDA, 2007). NAIS' ability to trace infected and potentially infected animals would allow the U.S. to rapidly respond to a foreign animal disease outbreak and neutralize its spreading quickly and efficiently. The identification system's capabilities present how important animal traceability can be in the event of an outbreak.

The focus of this study will be the benefits of minimizing economic losses from a disease outbreak. By quantifying the potential costs of a hypothetical FMD outbreak in one area, we will be able to estimate how much of an impact the disease might have on the national industry as a whole. The research should show that rapid disease response will reduce the detrimental costs of a FMD outbreak or any other animal disease epidemic. Decreasing the amount of time it takes to find any animal that has had contact with the initial infected herd will help in the reduction of the economic strain of the disease, whether it is for the producers or the industry. The results should illustrate the significance of having such a program in place and why the NAIS could be successful if the majority of producers participated. With less producers affected by the disease, fewer hardships would occur, such as losing irreplaceable breeding stock and bloodlines, as well as animal distress and losses incurred by the eradication efforts. An animal identification system will also aid in reducing the economic strain that a disease could cause including the loss of jobs or decreased incomes for families and individuals, the loss of animals, and the loss towards the livelihoods in affected communities.

With an implementation of an animal tracking system, producers will be able prove that their animals were not affected by an outbreak and can avoid unnecessary slaughter of their animals. This can be done with the system's ability to quickly define which regions of the country are and are not affected by an animal disease. It may be true that borders, at least initially, will close if an outbreak was found. Yet, if a system was able to quickly identify all animals that could possibility be infected, perhaps fewer markets and trade borders would close and the time it would take to reopen those markets would be quicker. A tracking system, such as the NAIS, will also improve the marketability of U.S. products and can help maintain and protect prices for domestic commodities in order to keep international markets open. The research done in this study hopes to demonstrate through simulated disease outbreaks and control strategies that the economic losses minimized by having animal tracing would prevent the vast financial losses that could incur without having such response capabilities.

CHAPTER II

BACKGROUND ON FOOT AND MOUTH DISEASE AND ANIMAL TRACEABILITY

II.1 Foot and Mouth Disease

Foot and Mouth Disease, more correctly referred to as Hoof and Mouth Disease, is a highly contagious viral disease affecting cloven hoof species, including cattle, swine, sheep, and goats. Signs of the disease include blisters followed by erosions in the mouth or on the feet. The resulting excessive salivation and/or lameness are the best known signs of the disease. It can leave the animal debilitated and cause serious losses in milk and meat yields. FMD does not affect humans.

The last outbreak of FMD in the U.S. was in 1929. However, it is still considered the most dangerous foreign animal disease that could be introduced into the country. The estimated costs of disease outbreaks have been large in other countries. For example, the cost of the FMD outbreak in Taiwan in 1997 was $1.6 billion; and in 2001, a research study estimated the potential economic impact of a hypothetical outbreak in Australia to be $1.5 to $10 billion (Ward et al., 2007). Recent outbreaks in countries such as Japan, South Korea, France, the Netherlands, and the U.K. have shown the importance of a well planned response strategy.

The U.K. has experienced FMD outbreaks in 2001 and in 2007. By the time the first case of FMD had been confirmed in 2001, close to 60 premises were already infected. More than seven months later (221 days), when the outbreak was eradicated, “2,026 cases of FMD had been confirmed, approximately 6.5 million animals were destroyed, and the disease had spread to Ireland, France, and the Netherlands” (Pendell, 2008). It took another four months for the U.K. to regain “FMD free” status by the Organization of International Epizootics (OIE). The most recent outbreak (August 2008) was declared eradicated in September 2008. Although serious, the outbreak was less severe than the 2001 outbreak,” …because there were systems in place” (Pendell, 2008).

As a current protection policy, countries with endemic FMD are not allowed to export products that may transfer the disease. The USDA strategy to protect the U.S. from the risk of FMD includes monitoring the occurrence of FMD outside the country, regulating, inspecting, and intercepting products at the U.S. borders, maintaining a strong animal health infrastructure inside the U.S., and finally, establishing and maintaining a strong emergency response system to quickly control and/or eradicate the disease (NCBA, 2008). One way the USDA has improved its response system is through the National Animal identification System (NAIS).

Increased animal traceability will aid in combating the spread of contagious diseases such as FMD by determining where an animal has been in order to isolate, trace, and prevent the spread of the disease. Although the U.S. is developing an animal traceability system, it is still behind many other countries in doing so. There were efforts to develop and implement animal tracing systems in the U.S. prior to the discovery of one cow that tested positive for BSE in the state of Washington in 2003. Those efforts gained substantial momentum in subsequent years (Pendell, 2008).

II.2 Animal Traceability

The current status of the National Animal Identification System (NAIS) is not where it was projected to be by Mike Johanns, the U.S. Secretary of Agriculture, in 2005. The strategic plan for the system proposed that all premises be registered and all animals be identified in accordance to NAIS standards by January 2008. These developments clearly did not occur within that time frame, with premise registration and animal identification still in its infancy. The National Animal Identification System's current participation is voluntary.

The three parts or steps for participating in the NAIS are as follows. (USDA, 2008) First, each registered livestock premise is given a Premise Identification Number (PIN). Second, all food animals are to be identified either with a group/lot identification number (GIN) or an animal identification number (AIN). Participation in animal identification is not required but if an owner decides to participate with animal ID, then there are specific manufacturers that produce AIN devices including visual tags, RFID tags, and injectable transponders. The last step for NAIS is animal tracing. Animal tracking databases (ATD) that are maintained by the states and private industry can be selected by producers. There are several ATDs collecting animal movements that can be found online. ATDs are beneficial for animal tracing because they can provide timely, accurate records, which will show where your animals have been and what other animals have come into contact with them (USDA, 2008).

The NAIS is supposed to help producers and animal health officials respond quickly and effectively to animal disease events in the United States. If a disease outbreak were to occur, rapid tracking and detection of associated animals through a system, such as the NAIS, would minimize the detrimental effects and costs of the disease on the producers as well as the industry as a whole. The long term goal of NAIS is to provide animal health officials with the capability to identify all livestock and premises that have had direct contact with a reportable disease of concern within 48 hours after discovery of the disease (USDA, 2007).

The NAIS program was initially introduced as a mandatory program, which met a good deal of resistance from some producers and industry groups. Now, as a voluntary program, this may be one of the biggest stumbling blocks it has towards getting to the necessary level of participation needed to become useful in preventing large-scale disease outbreaks. As of now, participation and premise registration has been erratic at best. The USDA currently estimates that almost 33% of the nation’s 1.4 million livestock farms have been registered (Foster, 2008). The most successful areas of the country with participation in the NAIS are those states that have made it mandatory. Wisconsin has led the way by making the system mandatory through a state statue in 2006. Michigan’s Department of Agriculture made a mandatory requirement in November 2006, which required all animals that are moved off the farm premises to have electronic identification (Foster, 2008). To further push its development, the USDA has purchased a total of 1.5 million “840” radio frequency animal identification tags to support the disease control programs (Foster, 2008). Beyond animal identification, the third component of the NAIS, establishing a cohesive system to track animal movements, seems to pose the biggest challenge for the program. From recent reports, USDA officials have noted that there is still a great deal of infrastructure left to complete in order to coordinate this final aspect of the NAIS (Foster, 2008). It seems as long as the process is voluntary for the NAIS, it will be a long time before the system is functional and can make a significant impact in controlling disease outbreaks.

CHAPTER III

LITERATURE REVIEW

"The efficient and rapid tracking of physical product and traits from and to critical points of origin or destination in the food chain necessary to achieve specific food safety and or assurance goals" is the definition of traceability in American Agriculture according to Farm Foundation (2004). There have been many studies and publications on animal identification and the related benefits and costs of animal traceability. Although the research area of NAIS is deep, there have not been many studies involving animal identification and its impact on the industry. However, studies on the epidemiology of diseases, such as FMD and BSE are many and provide a means to support the rationale for studies on animal identification. There have been many investigations of a possible Foot and Mouth disease outbreak in the U.S. and its consequences.

Different control options for FMD were examined for their effectiveness (Garner and Lack, 1995). Their study focused on three regions in Australia: i) Northern New South Wales; ii) Northern Victoria; and iii) the Midlands region of Western Australia. The different control responses included: slaughter of infected animals only, slaughter of infected and potentially infected animals, slaughter of infected animals with implementing early ring vaccination, and finally slaughter of infected animals plus late vaccination. Garner and Lack used a stochastic epidemiological model that included using Monte-Carlo methods. Their input-output analysis estimated that if the FMD outbreak was likely to spread quickly then the best way to reduce the economic impact of the outbreak was to slaughter all the infected animals as well as all the potentially infected animals. The research also concluded that “zoning” had potential to lessen the detrimental effects of an outbreak. Finally, early ring vaccination was not economically justifiable when compared to stamping out even though it did reduce the size and duration of the outbreaks (Garner and Lack, 1995).

Ekboir (1999) performed a similar study with a hypothetical FMD outbreak which showed the potential losses in California’s South Valley (Fresno, Kerns, Kings, and Tulane counties) could amount to an estimated $13.5 billion. A state-transition model developed from a Markov chain similar to Garner and Lack (1995) was used to carry out the research. Five health states were installed in the model including susceptible, latent, infected, immune, and depopulated. The economic model connected to the disease spread model was comprised of three sections. The first dealt with the direct costs of depopulation, disinfection, and enforcing the quarantine zone. The second of the economic model used an input-output model to calculate the direct, indirect, and induced losses for California. The final part computed the losses from restricted trade. Ekboir’s study evaluated different mitigation strategies including: i) partial stamping out with and without ring vaccination; ii) complete stamping out with ring vaccination; and iii) vaccination only. The results concluded that the control strategies involving vaccination were more expensive compared to the non-vaccination strategies since export markets were lost and control costs increased (Ekboir, 1999).

A study done at the University of Tennessee projected economic impacts of a FMD outbreak inside the state. The study estimated the economic effects of the FMD outbreak by examining depopulation rate scenarios of 50%, 35%, and 10%. They used TN-AIM (an IMPLAN-based input-output model for the Tennessee economy) to decrease the industry output for the sectors of dairy farm products, ranch fed cattle, range fed cattle, and hogs to simulate the depopulation rate scenarios. The model estimated the industry output losses, disposal costs, labor costs to enforce quarantine zones, tourism losses, and etc. The results of the study presented estimated direct effects of 136 million in losses to industry output and over 6,000 jobs lost for the 10% outbreak. The 50% outbreak resulted in 357 million in direct losses to the industry and when considering all other effects, amounted to over 690 million in total losses. The 50% outbreak also estimated that over 25,000 jobs would be lost through the outbreaks' impact. They also predicted a 10% percent decrease in tourism in the state of Tennessee. It is clear the effects multiplied as the outbreaks got larger. These results influenced the current study of how to minimize the outbreak length in order to minimize its total effects (Jensen et al., 2003).

Another state study for potential impact of FMD was analyzed by Ekboir, Jarvis, and Bervejillo (2003) for California. They again used an epidemiological model which was a state transition model developed from a Markov chain. They estimated direct costs of the outbreak, production losses, indirect and induced losses, and finally trade losses from the entire U.S. They considered seven scenarios with high and low dissemination rates, and altered the percent of depopulation per week, as well as the particular week when eradication was initiated. The analysis "…indicated that the time that is required to diagnose FMD and initiate the stamping out policy was the most important factor in determining the outbreaks ultimate effect" (Ekboir, 2001). The simulation results defended that the effectiveness of the eradication process depended on when it was started. A week delay in initiating "depopulation increased the proportion of infected premises from 18% to 90%" (Ekboir, 2001). The results also found it profitable for California to invest in supplementary resources to watch for, and respond to, an FMD outbreak. If the resources could minimize the outbreak by 5 billion, the research found that California could spend up to $700,000 a year in preventative methods for a FMD outbreak (Ekboir, 2001).

Schoenbaum and Disney (2003) also looked at the effectiveness of slaughter and vaccination strategies under different conditions of herd sizes and disease spread rates in the U.S. Three different geographically circular regions that contained different livestock populations were considered: South Central U.S., North-Central U.S., and Western U.S. The varying options for slaughter were: slaughter only infected herds, slaughter herds with direct contact with the initial herd within two weeks prior to the first detection of the outbreak, slaughter herds within three kilometers distance of the initial infected herd, and slaughter herds with both indirect and direct contact with the initial infected herd. Vaccination strategies included no vaccination, vaccinating all herds within 10 km of the infected herds after 2 detections were made, and then vaccinating all herds within 10 km of the initial infected herds after 50 infected animals were detected. The materials included a stochastic simulation model for FMD which was based on previous designed state transition model by Garner and Lack (1995). They installed direct, indirect, and airborne spread mechanisms and evaluated both direct (by animal) and indirect (by people) movements to quantify the spread rate. They chose 14 days as the time it took to trace direct and indirect herds. Detection of the disease was determined by two probability charts and all infected herds were found by day 25 or sooner. Median governmental costs for the outbreaks ranged from $300,000 to $2.8 billion depending on the scenario. The study also found that changes in consumer and producer surpluses could amount to an annual $789.9 million dollar loss (Schoenbaum and Disney, 2003). The best mitigation tactic depended on herd demographics and on the contact rate between the herds. The most expensive slaughter strategy was ring slaughter while slaughtering infected (direct contacts) and dangerous (indirect contacts) herds decreased the control costs of FMD compared to only slaughtering infected herds. Also, ring vaccination was more costly than slaughter strategies, but early vaccination was an effective strategy to shorten the FMD outbreaks (Schoenbaum and Disney, 2003).

Bates, Carpenter, and Thurmond (2003b) performed a benefit-cost analysis of vaccination and preemptive slaughter as a means to eradicate FMD where the sample population examined was 2,238 herds and 5 saleyards located in Fresno, Kings, and Tulane counties of California. They used a spatial stochastic epidemic simulation model and applied direct costs associated with indemnity, slaughter, disinfection, and vaccination for different eradication strategies. They also estimated additional cost, total program cost, net benefit, and benefit costs for each strategy. Four alternate control strategies were simulated: i) slaughter all infected herds and quarantining FMD infected areas; ii) ring vaccinate all uninfected herds within 1 to 5 km of infected herds; iii) slaughtering all herds within 1 to 5 km of infected herds; and iv) slaughter the "highest risk" herds. Mean vaccination costs were calculated to be $2,960/herd, and total eradication costs ranged from $61 million to $551 million (Bates et al., 2003b). They found that "all of their supplemental strategies involving use of vaccination were economically efficient and feasible; whereas, supplemental strategies involving preemptive slaughter were not found to be economically efficient or feasible" (Bates et al., 2003b). This study concluded that vaccination with an efficacious vaccine may be cost effective for control of FMD, but only if vaccinated animals were not afterward slaughtered and if there were no negative economic impacts such as closing of export markets and trade restrictions. The study did however find that the current U.S. eradication policy was preferred over other selective preemptive slaughter strategies (Bates et al., 2003b). Bates found that vaccines could be useful, but the current US stockpile of FMD vaccines and labor needed to perform such vaccination tasks may be unreasonable. Also, it is likely that trade restrictions would occur regardless of whether vaccination was used or not.

One study, in southwest Kansas, described the consequences of an FMD outbreak stemming from a single cow-calf operation, a single medium size feedlot, and simultaneous introduction at five large feedlots. The regional economic impact study used an epidemiological model for FMD and the results obtained indicated that as the size of the index herd infected with FMD increased, the outbreak duration, number of animals destroyed, and associated costs would also increase. The input-output analysis indicated the losses from the FMD outbreaks originating in a cow calf operation, medium size feedlot, and 5 large feedlots were estimated to be $32 million, $193 million, and $942 million respectively. The overall impact for Kansas for the same scenarios were estimated to be total losses of $51 million, $284 million, and $1.3 billion, respectively (Pendell and Schroeder, 2007).

In an investigation that also used the High Plains data, Elbakidze (2008) used the Reed Frost model along with an economic modeling framework to study the effectiveness of several strategies to control FMD under 4 different scenarios of disease introduction into the High Plains of Texas. The model was used to simulate the disease outbreak and the different control responses. The economic part presented the costs of the disease outbreak for the livestock industry in terms of lost animal values and lost gross revenue due to the epidemic. The costs incurred also included disease management costs such as euthanasia, disposal, disinfection, vaccination, and surveillance. The results found that of the scenarios that were under investigation, the most effective ones for reducing the economic losses of a FMD outbreak in the High Plains were to have detection as early as possible. In some of the scenarios, enhanced surveillance provided a benefit but not always, and the ability to have more vaccine available seemed to increase the costs instead of reduce the overall cost of the outbreak. The simulations suggested that an FMD outbreak could cost up to $1 billion in the High Plains industry losses alone. Based on other assumptions and the results of the epidemiologic disease spread simulations, the analysis indicated that early detection was the most economically effective control option of those considered in the study. The results found that early detection reduced the median epidemic costs by approximately $150 million (68%), $40 million (69%), $5 million (74%), and 3 million (97%) for Large Feedlot, Backgrounder Feedlot, Large Grazing, and Backyard introductions, respectively (Elbakidze, 2008).

Even though there have not been many studies with animal identification, more are being published with the fear that animal disease outbreaks could increase. Various analyses consider the benefits and costs associated with animal identification in cattle.

The current U.S. response strategy mainly relies on quarantine and depopulation of infected herds, identified based on "sound epidemiological evidence" and largely relying on the recognition of clinical signs by a producer, an animal caretaker, a meat inspector, or a veterinarian to detect animal diseases such as FMD (Bates et al., 2003a). The problem with this approach is that detection is solely based on visual observation which can be problematic, especially when the clinical signs of one disease may be similar to other diseases.

Some studies have dealt with animal diseases and traceability (Pendell, 2006, 2008; Pendell and Schroeder, 2007; Pendell et al., 2007), particularly, the effect of traceability success rates and the subsequent impact it would have on a hypothetical FMD outbreak. The authors used a simulated outbreak in southwest Kansas, and used the North American Animal Disease Spread Model (NAADSM) for the epidemiological model. The model was designed by APHIS and has also been used by Disney et al. (2001) and Schoenbaum and Disney (2003). The model was based on previous work done by Garner and Lack (1995), and with stochastic simulation and temporal and spatial spread of the FMD virus at the herd level (Pendell, 2006). The model allowed for

5 different health/disease states: latently infected, susceptible, infectious and sub-clinically infected, infectious and clinically infected, and immune (Pendell and Schroeder, 2007). Pendell evaluated outbreaks initiated from three different premises: feedlot, farm, and swine operation, and estimated appraisal, cleaning and disinfection, euthanizing, indemnity payments, and disposal costs for each outbreak (Pendell, 2006).

Animal traceability was added by changing the success rate of finding the direct and indirect trace back animals that may be infected with FMD. Pendell used tracing levels of 90% (high), 60% (medium), and 30% (low) in order to determine the impact that animal tracing can have after an outbreak is found. The model (NAADSM) contained limitations that restricted any other changes in animal tracing. The model also assumed all disease spread and trace backs occurred within 24 hours of first detection. The model confined itself to minimize tracing forward only one level, which prevents itself from finding herds beyond one level and does not find the potential infected herds that infected the detected premise (Pendell, 2006). Although the animal tracing was conservative, the results depicted increasing mean, minimum, and maximum depopulation, and costs across the decreasing traceability success rates. The average cost expenditures for a feedlot outbreak expanded from $196 million (high level) to $402 million (medium level) to 560 million (low level). The maximum cost expenditures for the feedlot outbreak ranged from 742 million (high) to 1,231 million (medium) to 1,435 million (low). The farm operation outbreaks costs ranged from 1.7 million (high) to near 11 million (low), and for the maximum costs, ranged from only 5.4 million (high) to 23 million (low) (Pendell, 2006). Pendell concluded that as the extent of animal identification in cattle increased, the number of animals culled was reduced as were the associated costs, and the length of the outbreak (by nearly two weeks). As the surveillance was increased, costs of consumer/producer welfare decreased. Producer and consumer surplus figures decreased approximately 60% (Pendell, 2006).

Another study used similar animal tracing levels and the epidemiological disease spread model to simulate a hypothetical FMD outbreak in southwest Kansas (Pendell, 2008). The study also involved simulating the outbreak with three different levels of animal identification, referred to as high, medium, and low. The high level system had a 90% success rate of both direct and indirect trace back within 24 hours. The medium and low level systems had 60% and 30% success rates, respectively. The study found that the total number of infected livestock and the length of the epidemic were among the factors that most affect economic impact (Pendell, 2008). The loss of animals in this study ranged from 790,000 head for the low level ID system to 265,000 for the high level ID system. The producer losses for the meat industry (i.e. beef, pork, and poultry) were also calculated and ranged from $535 million for the low level system to $399 million for the high level ID system. The study also presented the importance of animal tracing and trace-back, and showed the difference success rates that trace back sensitivity could have on a model of disease spread. Regardless of differences, the study suggested that as animal tracing intensifies, the number of livestock lost to a FMD outbreak will decrease along with the FMD related costs (Pendell, 2008).

Elbakidze (2007) also evaluated the effect of an animal identification system on traceability and subsequent isolation of potentially infected herds. He found two main drawbacks of the NAIS. First, producers do not want any additional costs to their program to implement and operate an animal tracking system. Second, producers are concerned about potential liability that could arise due to the information available through the NAIS. In addition, some producers may be uncomfortable with the possibility of NAIS data becoming available to the Internal Revenue Service. Elbakidze also investigated the benefits of the NAIS, especially in minimizing expected losses to cattle producers, including the costs of lost production, suppressed demand in the cattle industry, lost export markets, indirect losses in related industries, and the costs of preventing and responding to an outbreak. The model was used to conduct sensitivity analyses of the benefits of investing in an animal tracking system. The results showed that if the tracking process was efficient, then contact rates decreased, and the number of cattle lost also decreased. For instance, reducing the tracking time from four days to two days generated enough benefits to exceed the costs of an infectious disease outbreak (Elbakidze, 2007).

The costs of implementing an animal tacking system such as the NAIS continue to be one of the biggest obstacles for producers to participate in the system. Before 2003, full implementation costs of the U.S. Animal Identification Plan were estimated to total over $500 million for the first six years of the program (Bailey, 2004). Another cost study completed by Sparks Companies Inc. (2002) estimated that the capital investment required to implement a source verification system for cattle would only be approx-imately $140 million with an additional annual variable cost of about $108 million. Buhr (2002) estimated the costs of implementing a farm to fork traceability system for a single supply chain in Europe to be between $10-12 million. Costs were also calculated by Blasi et al. (2003) for the NAIS for Texas Producers. The latter study estimated the annual costs of implementing the animal ID system at the producer level for cow/calf operators and feedlots. Their calculations included the costs of transponder tags, electronic readers, computer hardware, computer software, internet access, required upgrades, and labor. These estimations were combined with Texas cattle inventory numbers to derive an approximation of the NAIS costs based on Texas cattle herd composition according to size and type of operation. The annual NAIS costs according to Blasi's estimations were $112 million dollars a year (Blasi et al., 2003).

The main issues with animal identification, according to Bailey and Slade (2004), relate to how the liability will be shared in a system such as the NAIS and how the costs of implementing animal ID will be allocated. One question is which technology or technologies will be used and how those technologies will interface in transferring information to a national database. But despite these problems, animal ID and the NAIS "offers opportunities for controlling animal diseases, standardizing beef trade in world markets, and expanding niche market opportunities to beef producers" (Bailey, 2004). The most important reason to implement NAIS among the supporters and non supporters of animal identification is the maintenance of our international markets; both parties agree on this issue (Bailey and Slade, 2004).

Maintaining open trade markets has become significant because the value of U.S. cattle exports reached about $200 million in live animals and over $3 billion in animal products in 2000 (Disney et al., 2001). However, since the discovery of BSE infected cattle in 2003, the 2007 value of the U.S. beef industry has declined to 74 billion dollars, and the number of cattle slaughtered per year is approximately 34 million. The 2007 value of U.S beef exports was $2.175 billion dollars, up from 631 million in 2004. Beef exports peaked in 2003, with a value near 3.2 billion dollars. Although most export markets have reopened and recovered, 2007 numbers for U.S. meat and livestock import/export values were near $900 million, and a decline of about $600 million in Japan and South Korea since 2003. These differences clearly show the importance of maintaining our foreign markets and how imperative it is to keep our animals healthy and accounted for. Although traceability systems will not prevent markets from closing, they do minimize the time that markets are shut down. These export values can also be used as additional potential losses in the current study if we assume that markets will close after a FMD outbreak is announced (USDA, 2009b).

A benefit and cost analysis of animal identification for disease control was examined by the Center for Animal Disease and Information and the Center for Epidemiology and Animal Health. The reports clearly stated the benefits of an identification system are "limiting the spread of a foreign animal disease (FAD), enabling faster traceback of infected animals, limiting production losses due to disease presence, reducing the cost of governmental control, intervention, and eradication, and ultimately minimizing potential trade losses" (Disney et al., 2001). Other potential benefits included: reducing the economic consequences of endemic animal diseases that are already under eradication, promoting consumer confidence in the national livestock industry, and contributing to producer gains from improved genetics, carcass quality, herd certification, and premium prices for specific products. The research estimated benefit cost ratios stochastically to show the uncertainty and variability involved with disease outbreaks. The benefits were based on the assumption that a single primary disease outbreak would occur in the U.S. over a 50 year time frame. Professional surveys were used to estimate the level of identification present, the time required to trace, and the probability of correctly identifying the index case. These were coupled with different scenarios of tracking cattle and swine from one location to another using only paper trail tracking first; and then improved tracking using back tags and ear tags plus the paper trail. The analysis suggested that for cattle, the enhanced level of identifications could provide sufficient economic benefits in terms of reduced FAD consequences, but for the swine scenarios, the improved systems did not show significant benefits. They concluded that when effective, recording systems could make possible rapid disease control and disposal (Disney et al., 2001).

Disney et al. (2001) also presented cost figures that were useful in this current study. Their premise was that if an identification and tracking system was in place, the labor and costs to run the system should be considered. They assumed each data entry of livestock movement cost $ US 0.10, considering a clerk earning approximately $20,000 per year. They also assumed that a maximum of 11 data entry actions per animal could occur, so the maximum data entry costs of an animal would be $1.10. With these figures, the research involving cattle estimated that there would be a $48 million dollar difference between a paper trail system compared to a system using back and ear tags.

The back and ear tag system was found to cost $72 and $84 million dollars respectively to track cattle to the former places of ownership (Disney et al., 2001).

In April, 2009, The USDA and APHIS made available a benefit cost analysis of the National Animal Identification System. APHIS along with numerous universities (led by Kansas State University) conducted the study. The analysis showed that not implementing some aspects of NAIS could result in considerable losses, as much as $1.32 billion on average per year over a 10 year period, due mostly to restricted export trading. The cattle industry costs for the NAIS were 91.5% percent of the total costs for the major food animal species (sheep, swine, poultry, and cattle). Most (75%) of the cattle sectors yearly implementation cost consisted of identification tags and the act of tagging the animals. The tagging costs varied across producers. Tagging costs included the labor, chute, tag applicator, and economic impact of cattle shrink and potential injury for cattle and people during tagging. The cost per cow ranged from a low $2.53 per animal for the largest operation, to a high of $5.84 per head for the smallest operation. The RFID tags represented about 46% of the total costs to the industry (USDA, 2009a).

The overall costs for 90% participation level NAIS, the minimal level deemed effective by APHIS would be $192.22 million dollars annually for all four primary animal species (cattle, swine, sheep, and poultry). A 100% participation level for all species would cost about $228.27 million annually. The cattle sector (beef and dairy) would account for 92% of those costs. For 90% and 100% participation levels, a traceable NAIS system would cost $175.87 and $209.07 million annually. Some of the average costs within the beef sector included $4.91 per head for beef cattle operation,

$.71 per head for backgrounder operation, $.51 per head for a feedlot, $.23 for an auction market, and $.10 per head for packers. The average cost per animal marketed throughout the cattle sector would be $5.97, with dairy cows averaging the highest at $6.21. The benefits consisted of reducing animal disease testing times and the associated costs “aid” to ensure that markets maintain at the current levels or better, and the ability of NAIS animal identification methods to be used in other value added and certification programs. The general benefits discussed included better disease management and surveillance, reduction of economic impact of animal disease events, and the ability of NAIS to prove U.S. origin for other programs, such as COOL (country of origin labeling) (USDA, 2009a).

These costs of the NAIS will be compared to the FMD outbreak results to determine if a “complete” traceback system would benefit the producers and the U.S. agricultural industry.

Other research that directly relates to this study includes the work done by Beckett and Garner, the creators of the original model used in this study, AUSSPREAD. The Australian Government Department of Agriculture, Fisheries and Forestry developed AUSSPREAD, a sophisticated spatial model for FMD. The outputs include “a range of maps and tabulated outbreak statistics describing the outbreak, and its duration, the numbers of affected, slaughtered and as relevant, vaccinated herds or flocks, and the cost of control and eradication” (Garner and Beckett, 2005). AUSSPREAD is written in MapBasic (MapInfo Corporation, Troy, NY, USA) and simulates the spread of FMD in daily time steps in order to allow farm interaction between different animal species and different production types.

Tracing will be the control measure that will be altered in this study. AUSSPREAD uses probabilities to find farms with which the infected farm has had direct or indirect contact (“Trace forward”) and the source of infection (“trace back”). Traced farms that are considered to have had a high chance of exposure to FMD are specified as dangerous contacts (dc) and are subject to active surveillance (Garner and Beckett, 2005). Sensitivity within the tracing procedure is defined as the proportion of source or contacted farms that will be correctly identified as infected herds. Specificity allows the model to simulate farms that have been incorrectly found as infected premises. The default farm types used will be beef cattle, dairy cattle, sheep, pigs, small holders and feedlots. These will be added to and diversified for our study in the Texas High Plains. AUSSPREAD will also allow variables such as the rate of disease spread through the population, the time period from infection until the initial detection of disease, and the ability and extent of resources for performing mitigations (Garner and Beckett, 2005).

Welfare slaughter is a relatively new concept in foreign animal disease (FAD) eradication. A short welfare slaughter study is planned in the current study to see its added effect on the costs of an FMD outbreak. The welfare slaughter refers to the slaughter of animals that are not known to be infected by the FAD but have to be eliminated because of overcrowding or other deteriorating animal husbandry conditions on farms placed under movement restrictions; for example, when animals are in excess of market demands, when proper management can no longer be assured, or both (Whiting, 2003). With Welfare slaughter, animals are destroyed and do not enter the food chain as is also seen with pre-emptive slaughter and stamping out (Miranda, 1999). The meat from the animal carcasses under movement restriction cannot be salvaged for human food under EC regulations; therefore, it is usually sent to rendering or otherwise destroyed. One lesson to be learned from the experience of recent disease eradication efforts is that the number of welfare slaughter animals rises rapidly during the course of an expanding animal disease. In recent incursions of FAD into member countries of the Office International des Epizootics (OIE) whose national policy is stamping out, the scale of welfare slaughter was such that its cost was one half to 10 times that of eradicating the disease on infected farms (Whiting, 2003). Welfare slaughter is a direct cost of FAD eradication and often far exceeds the cost of dealing with infected farms.

CHAPTER IV

CONCEPTUAL MODEL AND PROCEDURE

IV.1 Model

This project will expand on work previously done with the model AUSSPREAD. The simulation will involve FMD outbreaks in the Texas High Plains area. Although there is good data from actual outbreaks of FMD, such that occurring in the UK in 2001, all of the research done with modern day FMD outbreaks in the U.S. are simulations performed under hypothetical situations. These studies along with data from actual outbreaks are used to examine the potential impact that an FMD outbreak might have on a society. Simulation is used to examine how an animal identification tracking system, such as the NAIS, could help reduce society's vulnerability to FMD. The primary data collection involved in this study comes from the High Plains Project (Ward et al., 2007). That study included herd characteristics and animal movements in the Texas Panhandle area in order to examine vulnerability as well as to improve the epidemiologic engine of AUSSPREAD. A High Plains specific version of AUSSPREAD was developed and used to simulate scenarios for policy planning and decision making related to intensive agricultural settings such as found in the High Plains (Ward et al., 2009). An economic analysis of the modeling results was conducted in order to evaluate the economic impact of various outbreak scenarios and mitigation strategies.

The High Plains study region includes an 8 county area in the panhandle of Texas. The area covers over 7,900 square miles and in 2002, consisted of 118 feedlots, 29 dairies, 88 swine farms, and 1,058 beef cattle premises according to the National Agricultural Statistics Service (NASS) Census of Agriculture (USDA, 2003). This region was chosen for its dominant concentration of cattle. Texas is the largest cattle production state in the U.S. and the states' largest agriculture revenue stems from the sale of beef cattle. The panhandle region has the most feedlot operations, and with nearly 6 million cattle on feed (Ward et al., 2007).

The AUSSPREAD model is a stochastic, state transition susceptible-latent-infected-recovered (SLIR) model, which operates within a geographic information system (GIS) framework. AUSSPREAD uses spatial distributions of livestock species and their predicted contact structure to model the spread of FMD over space. Direct and indirect contact pathways can also be used to model disease spread. Lastly, the model also incorporates disease spread due to sale barns, order buyers, and windborne spread from large feedlots and swine facilities.

The High Plains Study was comprised of three components: data collection and survey analysis, epidemic modeling, and economic analysis. The data collection and survey analysis component was led by Dr. Bo Norby at Texas A&M University. Dr. Norby used in person interviews to collect data from feedlots, beef herds, dairies, swine operations, and auction barns. The data collection included the size of the operation, animal movements, contacts between different herd types, and seasonal variation in contacts and movements. The data were used in the epidemic modeling component of the study, which focused on modeling the potential spread of FMD in the High Plains region for various introduction and mitigation scenarios. Predictions from the results of the epidemic model were used to design the economic analysis of the study, led by Dr. Bruce McCarl.

The study showed the impact of early vs. late detection, adequate vs. inadequate vaccines, and enhanced vs. regular surveillance. Different slaughter strategies were also performed where strategies examined the impact of only slaughtering infected animals vs. slaughtering infected animals and slaughter of dangerous contacts (dc). These comparisons as well as others were done along with 13 different herd types to make a total of 64 different scenarios. Tables 4.1 provides all of the default herd types included in the High Plains version of AUSSPREAD, where disease spread could reach or initiate at (Ward et al., 2009). Table 4.2 shows which herd types were chosen as initial outbreak herds for the High Plains Report and all of the 64 different mitigation strategies possible. Finally, the comparisons were evaluated to determine which had the most impact on reducing the epidemic length and minimizing the financial losses.

In this study, we will adapt and modify the High Plains version of AUSSPREAD to simulate a situation that would assume rapid quicker animal traceback (Ward et al., 2009).

Thirteen herd types were decided based on discussion with TCFA, WTAMU and collaborators at TAMU and are summarized in Table 4.1 below:

Table 4.1. Herd Type Summarization

Herd Type	Name	Size or Description
1	Company Owned Feedlot	greater than 50,000 head
2	Stockholder Feedlot	more than 20,000 but less than 50,000
3	Custom Feedlot	more than 5,000 but less than 20,000
4	Backgrounder Feedlot	located from a previously compiled list*
5	Yearling-pasture feedlot	less than 5,000 head
6	Dairy Calf-raiser feedlot	only one in study area-10,000 head herd
7	Small Beef	less than 100 cattle
8	Large Beef	more than 100 cattle
9	Small Dairy	less than 1000 dairy cows
10	Large Dairy	more than 1000 dairy cows
11	Backyard	less than 10 animals
12	Small Ruminant	sheep and goats
13	Swine	pig concentrated animal feeding operations

*description given in the High Plains Report (Ward et al., 2007).

Table 4.2. Mitigation Strategies by Index Herd Type

	Index Outbreak Herd Type			
Strategy	Feedlot Type 1	Feedlot Type 4	Large Beef	Backyard
Ring slaughter, regular surveillance, slaughter of infected, slaughter of dc's, early detection	1	2	3	4
Ring slaughter, regular surveillance, slaughter of infected, slaughter of dc's, late detection	5	6	7	8
Ring slaughter, regular surveillance, slaughter of infected, slaughter of dc's, late detection, targeted vaccination, adequate vaccine	9	10	11	12
Ring slaughter, regular surveillance, slaughter of infected, slaughter of dc's, late detection, targeted vaccination, inadequate vaccine	13	14	15	16
Enhanced surveillance, slaughter of infected, slaughter of dc's, early detection	17	18	19	20
Enhanced surveillance, slaughter of infected, slaughter of dc's, late detection	21	22	23	24
Enhanced surveillance, slaughter of infected, slaughter of dc's, late detection, targeted vaccination, adequate vaccine	25	26	27	28
Enhanced surveillance, slaughter of infected, slaughter of dc's, late detection, targeted vaccination, inadequate vaccine	29	30	31	32
Slaughter of infected, slaughter of dc's, regular surveillance, ring vaccination, early detection, inadequate vaccine	33	34	35	36
Slaughter of infected, slaughter of dc's, regular surveillance, early detection	37	38	39	40
Slaughter of infected, slaughter of dc's, regular surveillance, late detection, ring vaccination, adequate vaccine	41	42	43	44
Slaughter of infected, slaughter of dc's, regular surveillance, ring vaccination, late detection, inadequate vaccine	45	46	47	48
Slaughter of infected, slaughter of dc's, regular surveillance, early detection, targeted vaccination, adequate vaccine	49	50	51	52
Slaughter of infected, slaughter of dc's, regular surveillance, late detection	53	54	55	56
Slaughter of infected, slaughter of dc's, regular surveillance, late detection, targeted vaccination, adequate vaccine	57	58	59	60
Slaughter of infected, slaughter of dc's, regular surveillance, early detection, ring vaccination, adequate vaccine	61	62	63	64

*table from The High Plains Report (Ward et al., 2007).

IV.2 Procedure

The study included changing current model parameters reflecting the tracing of subsequent herds that may have been in direct contact with the initial outbreak and/or herd. In the High Plains modified AUSSPREAD model, there are two probability variables that could be changed to affect animal tracing: (1) tracing sensitivity, and (2) tracing specificity (Ward et al., 2009). A sensitivity/specificity change in the model determines whether these accuracy probabilities have an impact in minimizing the losses of a disease outbreak. Tracing sensitivity, set by the user, is a measurement of how accurately the model will identify the truly infected herds. Since tracing is unlikely to be 100% effective, it is also likely to incorrectly assign dangerous contact premise (infected herd) status to some contacts that did not get infected (i. e. false positives). Before any changes, the current High Plains /AUSSPREAD model has the probability for tracing sensitivity and specificity for direct (dangerous) contacts at 85% and 95% respectively. The current study performed a parallel shift in the probability variables for the best and worst of the saleyard day simulations. The variables for sensitivity and specificity were set to 45% and 55% to see any impact on economic “costing” of the outbreaks.

During any simulation, the AUSSPREAD model keeps track of all the indirect and direct contacts, a proportion of which result in new infections. These contacts are stored in an 'exposures' file (which records day, source, recipient, type of contact, infected?). This forms the basis of tracing. The user can specify how far back to set the tracing period. The model will both trace forward and trace back contacts of each infected herd when that herd is “found”. The tracing period (days_til_dc) is the time taken to collect and analyze information from the infected premises and identify high risk contacts. In other words, days_til_dc are the days until dangerous contacts (dc) are found. As a default this is assumed to take between 1 and 3 days after an infected herd is identified. Using Australian emergency response terminology, such a trace is classified as a 'dangerous contact premise' (DCP). As stated above, the days_til_dc variable is set to randomly select between 1, 2, and 3 days to find all the subsequent infected or dangerous contacts.

By changing the parameters on the coded variable, days_til_dc, this study depicts faster tracing and portrays outbreaks in a confined time frame. The variable was changed to portray outbreaks of FMD where it took 1 day, 2 days, 3 days, 4 days, 6 days, 8 days, and 10 days to find all the dangerous contacts in each of these outbreaks. The initial code for days_til_dc consisted of:

*days_til_dc=round((rnd(1)*2+1),1).*

This set the time until traced to be between 1 and 3 days. After altering the AUSSPREAD model code, the constrained outbreaks were set by changing the variable as thus:

1 day:	days_til_dc=round((1-rnd(1)*.01),1)
2 days:	days_til_dc=round((2-rnd(1)*.01),1)
3 days:	days_til_dc=round((3-rnd (1)*.01),1)
4 days:	days_til_dc=round((4-rnd(1)*.01),1)
6 days:	days_til_dc=round((6-rnd(1)*.01),1)
8 days:	days_til_dc=round((8-rnd(1)*.01,1)
10 days:	days_til_dc=round((10-rnd(1)*.01,1)

This set the time until traced to be constrained to the 24th hour of the day before the day depicted in order to get the model to trace the subsequent herds as close as possible to the desired day.

Seven runs were simulated through the modified AUSSPREAD and the results were used to compare if the range of animal tracing had any effect on the industry impact from an outbreak of FMD. The High Plains modified AUSSPREAD model was not run for all 64 scenarios as earlier mentioned and listed in Table 4.2. The scenario exercised for all of this study's simulations consisted of:

- Slaughtering Infected Herds, Slaughtering Dangerous Contacts, Sustaining Regular Surveillance, Late Detection (finding the initial outbreak herd/animal at 14 days compared to 7 days for early detection).

These scenarios were numbered 53 through 56 depending on the initial herd type. This study will use #53 for Feedlot Type 1 and #55 for Large Beef index herd type. It will also use these settings for its Saleyard runs. The scenario was selected in the attempt to depict the largest potential impact for subsequent animal tracing. The scenario does not include vaccination strategies, as they were deemed more costly than beneficiary in the previous High Plains Report (Ward et al., 2007). As noted above, the simulated outbreaks were run from three different initial herd types to determine possible differences in responses and spreading of the disease. The model was run where the outbreaks began at the initial herds and places: Company-owned Feedlot (>50,000 head), Large Beef Operation (>100 cattle) and a saleyard located in the study area.

The large beef operation was run through the model for tracing periods lasting only 1, 2 and, 3 days to see if the difference in tracing periods had any increasing cost effects. This large beef herd type was not chosen for any specific reason, but the totals for all the costs were calculated in the same manner as the saleyard and feedlot runs. After the large beef herd runs were completed, seven model runs were performed using the company-owned feedlot (type 1) as the initial herd. A proiri expectations were to see large beginning losses, but a smaller percentage increase as the tracing period progressed since the operation does not have the ability that a large beef operation or a saleyard does in spreading the disease outward. The Feedlot was run for all seven different tracing periods and was followed by all the calculations to gather the different costs of the outbreak. A short welfare study was completed on the least costly and most costly tracing periods to see another effect of the animal traceability on the outbreak. After all the feedlot runs were finished, the saleyard runs were run through the High Plains version of AUSSPREAD, again including all seven trace periods. The saleyard runs were undertaken to determine the highest disease incidence, and the most exponential losses as the tracing period increased from 1 day to 10 days. In addition to the first seven runs, two more runs were completed with the saleyard’s least costly and most costly tracing periods. These runs are those discussed above in the context of the tracing sensitivity and specificity probabilities. With all of the different herd types and tracing period strategies, the High Plains modified AUSSPREAD was run a total of 19 times to collect the necessary results for the simulated Foot and Mouth Disease outbreaks.

The data was used to create an economic cost analysis for each model run in order to present the effectiveness of animal tracing in the event of a purposeful introduction of FMD. For each Herd Type and trace period costs were tabulated for slaughter, euthanasia, disposal, cleaning/disinfection, and disposal. These costs were totaled for each simulation and then the average, minimum, and maximum were figured to get values that can be compared across the increasing trace periods. The feedlot and saleyard runs were performed for a total of 100 simulations and the large beef operation for 50 simulations. Considering the AUSSPREAD model has been underutilized for animal tracing analysis, more accurate values were anticipated when completing all seven trace periods for the feedlot and saleyard runs. The above mentioned costs were figured in the same manner as was done in the High Plains Report and were as follows:

- *The cost of appraisal for slaughter* for small (<100 head), medium (100-500 head) and large (>500 head) herds was assumed to be $300, $400, and $500 per herd, respectively.
- *Euthanasia costs* were assumed to be $5 per head, regardless of herd type.
- *The cost of disposal* of a culled herd was assumed to be $11 per head in small (<100) and medium (100-500) herds, and $12 per head in large (>500) herds.
- *The cost of cleaning and disinfection* for small (<100), medium (100-500) and large (>500) herds was assumed to be $5000, $7000, and $10000 per herd, respectively.
- *Fixed surveillance costs* were assumed to be $150, $200, and $400, for small (<100 head), medium (100-500) and large (>500) herds (Ward et al., 2007).

For each of these costs, the infected animals which would have to be disposed of had to be separated from those unaffected animals. These calculations and actions were performed through Microsoft Excel, as were all the other calculations for the economic costs of the outbreaks.

Forgone Income and Indemnity Payments set up by the government were calculated along with the other costs to see the impact of animal traceability. The High Plains report provided the 2004 market dollar values and daily revenues given by the USDA (Table 4.3), along with a composition table of herds by animal type proportions (Table 4.4), to find the indemnity payments and forgone income for each AUSSPREAD model run. The total infected/dead livestock had to be separated into their different herd types. From there, they were multiplied by their composition and either the indemnity payment dollar value or the forgone income daily revenue. Forgone income represented the stream of future income that was no longer available and represented the time from when the herd was depopulated until the premise was allowed to repopulate and regain its normal production. The future stream of income was a rough estimation and could include the weight gained in a feedlot, lost milk production in a dairy, or the gain from birthing a calf. The future income did not include the loss of capital assets such as breeding genetics. The forgone daily income values were multiplied by 60, since the High Plains report estimated that producers whose cattle were culled due to infection were kept out of business for at least 60 days (Ward et al. 2007). Finally, the values were separated and totaled in their respective simulations. Minimum and maximum averages were determined in order to compare the values across the different tracing periods to again see the impact of traceability.

As stated before a small welfare analysis with the least and most costly feedlot trace periods was performed. The AUSSPREAD model was developed with the capability to calculate losses associated with quarantine with and without provisions to move feed into the quarantined areas. Quarantine associated welfare slaughter losses only applied to herds which had a status of “susceptible” and fell within a movement restriction zone. These animals were not deemed as infected or a dangerous contact. The losses did not apply to grazing operations, backyard operations, and herds of less than fifty animals since they were assumed to be self sufficient and not requiring any outside food source. In the cases where movement of feed was allowed, the assumption used was that feed was delivered to the quarantined herds at a cost of $1.25 per animal per day. This cost was to cover disinfection of feed trucks that would enter and exit the premises. If feed was not allowed, then after 8 days the herd was assumed to be culled and there was no salvage value. 8 days was chosen as an optimistic view of how long the cattle operation could operate normally with feed on hand. The quarantine feed costs were done to a maximum of 60 days as that was the model’s assumption for how long a producer would be kept out of business. The welfare slaughter animals were destroyed because of restricted movement and were slaughtered since it was assumed that the

Table 4.3. Values and Daily Revenues for Herd Types

Herd Types	Indemnity Payments	Forgone Income	
	Dollar Value	Daily Revenue	Revenue for 60 days
Heifer under 600 lbs	-$411/head	.$33/head	$19.8/head
Steer under 600 lbs	-$411/head	.$33/head	$19.8/head
Heifer under 800 lbs	-$693/head	.$33/head	$19.8/head
Steer under 800 lbs	-$693/head	.$33/head	$19.8/head
Heifer under 1000 lbs	-$900/head	.$33/head	$19.8/head
Steer under 1000 lbs	-$900/head	.$33/head	$19.8/head
Heifer under 1200 lbs	-$1138/head	.$33/head	$19.8/head
Steer under 1200 lbs	-$1138/head	.$33/head	$19.8/head
Heifer under 1400 lbs	-$1250/head	.$33/head	$19.8/head
Steer under 1400 lbs	-$1250/head	.$33/head	$19.8/head
Milk Cow	-$1850/head	$8.6/head	$516/head
Ewes (adult female sheep) under 160 lbs	-$90/head	$.10/head	$6/head
Rams (adult male sheep) under 230 lbs	-$128/head	$.10/head	$6/head
Male lamb (young male sheep) 90 lbs	-$105/head	$.10/head	$6/head
Female lamb (young female sheep) 80 lbs	-$93/head	$.10/head	$6/head
Male Yearling (baby male sheep) 60 lbs	-$70/head	$.10/head	$6/head
Female Yearling baby female sheep) 50 lbs	-$58/head	$.10/head	$6/head
Boar (adult male pig) 200-250 lbs	-$96/head	$.18/head	$10.8.head
Sow (adult female pig) 180-250 lbs	-$85/head	$.18/head	$10.8.head
Male piglet 100-180 lbs	-$60/head	$.18/head	$10.8.head
Female piglet 100-180 lbs	-$60/head	$.18/head	$10.8.head
Male piglet	-$50/head	$.18/head	$10.8.head
Female piglet 100-180 lbs	-$60/head	$.18/head	$10.8.head

Notes: Types of animals and associated dollar values and corresponding daily revenues were assumed to be as above.

*table values and revenues provided in The High Plains Report (Ward et al., 2007).

Table 4.4. Composition of Herds by Animal Type

	Herd Types												
Animal Types	Yearling-pasture	Large dairy	Small Dairy	Swine	Backyard	Company Feedlot	Stockholder Feedlot	Custom Feedlot	Backgrounder feedlot	Small ruminant	Dairy calf raiser	Large Beef herd	Small Beef herd
Steer 600	0.17				0.24	0.11	0.11	0.11	0.25		0.2	0.17	0.17
Heifer 600	0.17	0.06	0.15		0.24	0.07	0.07	0.07	0.15		0.2	0.17	0.17
Steer 800	0.11				0.1	0.24	0.24	0.24	0.35		0.1	0.11	0.11
Heifer 800	0.11	0.06	0.18		0.1	0.16	0.16	0.16	0.25		0.2	0.11	0.11
Steer 1000	0.21				0.3	0.2	0.2	0.2			0.1	0.21	0.21
Heifer 1000	0.21	0.06	0.17		0.01	0.11	0.11	0.11			0.2	0.21	0.21
Steer 1200	0.01				0.01	0.05	0.05	0.05				0.01	0.01
Heifer 1200	0.01					0.03	0.03	0.03				0.01	0.01
Steer 1400						0.02	0.02	0.02					
Heifer 1400						0.01	0.01	0.01					
Milk cow		0.82	0.5										
Ewes										0.31			
Rams										0.1			
Male lambs										0.13			
Female lambs										0.12			
Male yearling				0.1						0.23			
Female yearling				0.01						0.11			
Boar				0.3									
Sow				0.3									
Male piglet				0.07									
Female piglet				0.08									
Baby Male piglet				0.08									
Baby Female piglet				0.06									

*table presented in The High Plains Report (Ward et al., 2007).

producer either did not see future returns for keeping the animals alive; or could not continue feeding his animals due to unattainable funds to pay for the feed if movement was allowed, or if not allowed, on the farm feed was vacant.

According to the High Plains FMD costing model created by Levan Elbakidze (2008), welfare slaughter losses include slaughter costs, forgone income, and indemnity payments for the animals destroyed. All of these costs were evaluated the exact same way as with the dangerous and infected herds. In the AUSSPREAD model, there are variables identified as *restricted* and *When_res*. The restricted variable was used as a dummy variable (either 0 or 1) to classify a herd as within a quarantine zone or not. The When_res simulation variable was defined as a number of days a farm had been restricted and listed any number of days as its output. If this variable listed a number of or over 8 days, then the herd was assumed to be culled without any salvage value or slaughter gain.

Since welfare slaughter only affected those producers who could not sustain their herds with grazing pastures, the model affected the herd types: company owned feedlot, stockholder feedlot, custom feedlot, backgrounder feedlot, yearling-pasture feedlot, dairy calf raiser feedlot, small dairy, large dairy, and swine. The resulting data from using the High Plains version of AUSSPREAD would be examined to find all the animals that would have to be culled, and from those numbers and the herd composition table, the model's user could calculate the slaughter costs, forgone income, and indemnity payments (Ward et al., 2009). This procedure will be performed in this study to see the impact welfare slaughter can have in the event of a FMD outbreak.

All of the cost results were compared across the range of tracing period (1 to 10 days) for all the outbreaks to determine the total economic impact. As is with most research in this field, the total economic costs will be incomplete due to factors such as the inability to predict closing export markets and how much prices may change after an outbreak. It is difficult to simulate every cost that will develop after an outbreak, but this research demonstrates a good portion of the industry impact, and how traceability can affect that impact. After the comparison of results, previous research done on animal tracking systems will be compared with our results to see if such a system is feasible and can be economically justified. The implementation costs as well as the potential costs for employees who do the animal tracking, slaughter, and etc will be examined and figured to compare to our outbreak scenarios. The cost analysis and the financial costs of an outbreak under animal tracing constraints will be compared to see if such control responses can make a difference in reducing the harmful effects of a FMD outbreak.

The research was done in this way to see if an animal identification and tracking system is worth implementation. The initial hypothesis was that an outbreak constrained over different period of days will show how effective an animal identification and tracking system such as NAIS could be in controlling the outbreak. The thought was that the system could pay for itself in one outbreak with the economic losses it would prevent. Although the model is unable to account for markets closing and price volatility, nor determining the money saved if markets do not close.

CHAPTER V

RESULTS

The results from the alternative tracing periods in the AUSSPREAD model are presented, along with the costs of each individual FMD outbreak in the Texas High Plains. The cost analyses included slaughter of infected herds, disinfection of dangerous locations, euthanasia of infected herds, surveillance of the infected and surrounding areas, and disposal of the dead livestock. Forgone income, indemnity payments, quarantine costs, and welfare slaughter figures were also compared. The difference in the tracing periods as they increased from 1 day up to 10 days were scrutinized as far as percentage change, probability distribution of infected herd types, and overall impact to the U.S. Beef and Agricultural Industry.

V.1 Large Beef Operation Results

The results from the Large Beef Operation runs, presented in Table 5.1, indicated that animal tracing does have an effect on the economic costs of an outbreak. Although they did not jump tremendously, all costs increased on average from 1 day to 3 days, except for forgone income from the 2 day trace period to the 3 day trace period. The average infected and culled livestock increased from 5,493 (1 day) to 6,291 (2 days) to 6,825 (3 days). This was a percentage increase of 14.5% from 1 to 2 days and an 8.5% increase from 2 to 3 days. The euthanasia costs had the same percentage increase that the dead livestock had, which reflects the costs of euthanasia ($5 per head).

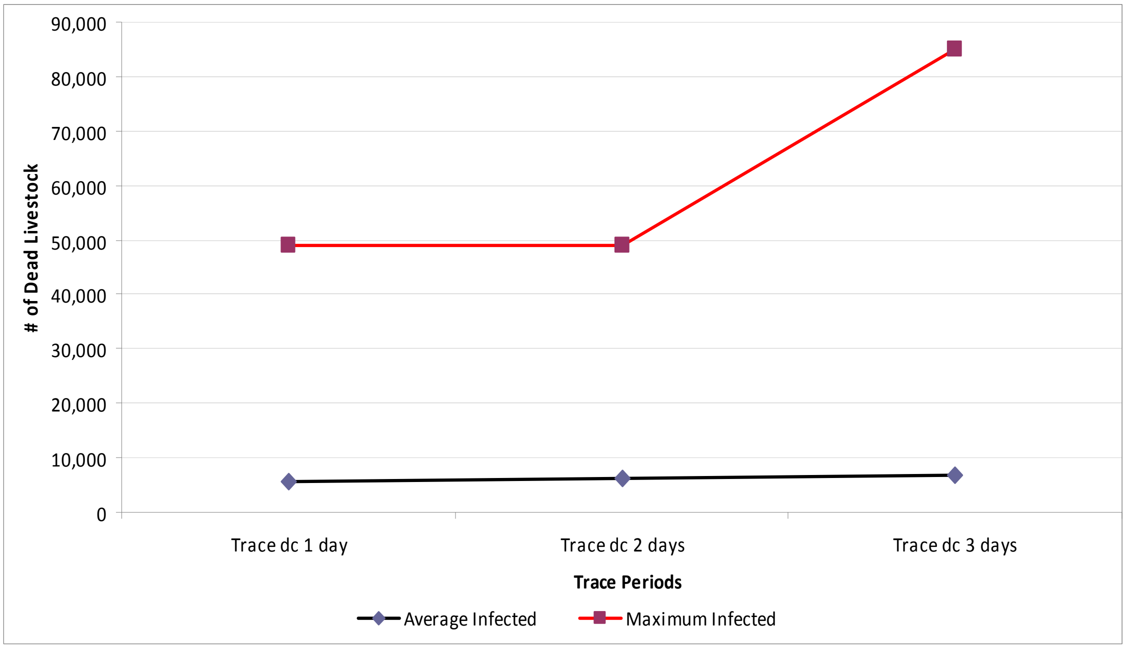
Table 5.1. Large Beef Operation FMD Outbreak Costs

Costs	Trace Periods		
	Trace dc 1 day	Trace dc 2 days	Trace dc 3 days
Dead Livestock			
Minimum	947	947	947
Maximum	49,036	49,036	84,982
Average	5,493	6,291	6,825
Euthanasia Costs			
Minimum	$4,735	$4,735	$4,735
Maximum	$245,180	$245,180	$424,910
Average	$27,464	$31,457	$34,125
Slaughter Costs			
Minimum	$800	$800	$800
Maximum	$9,200	$9,700	$11,200
Average	$3,066	$3,166	$3,316
Cleaning/Disinfection Costs			
Minimum	$15,000	$15,000	$15,000
Maximum	$162,000	$174,000	$196,000
Average	$54,800	$56,720	$59,120
Surveillance Costs			
Minimum	$550	$550	$550
Maximum	$5,200	$5,750	$6,200
Average	$1,815	$1,886	$1,946
Disposal Costs			
Minimum	$11,351	$11,351	$11,351
Maximum	$588,330	$588,330	$1,017,015
Average	$65,422	$74,960	$81,298
Forgone Income			
Minimum	$18,751	$18,751	$18,751
Maximum	$970,913	$1,773,541	$1,682,644
Average	$107,925	$156,298	$134,312
Indemnity Payments			
Minimum	$656,233	$656,233	$656,233
Maximum	$37,136,467	$37,136,467	$64,149,927
Average	$3,885,004	$4,564,914	$4,903,179
Total			
Minimum	$707,420	$707,420	$707,420
Maximum	$39,117,289	$39,932,968	$67,487,895
Average	$4,145,496	$4,889,402	$5,217,296

*Cattle numbers and dollar amounts are estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009).

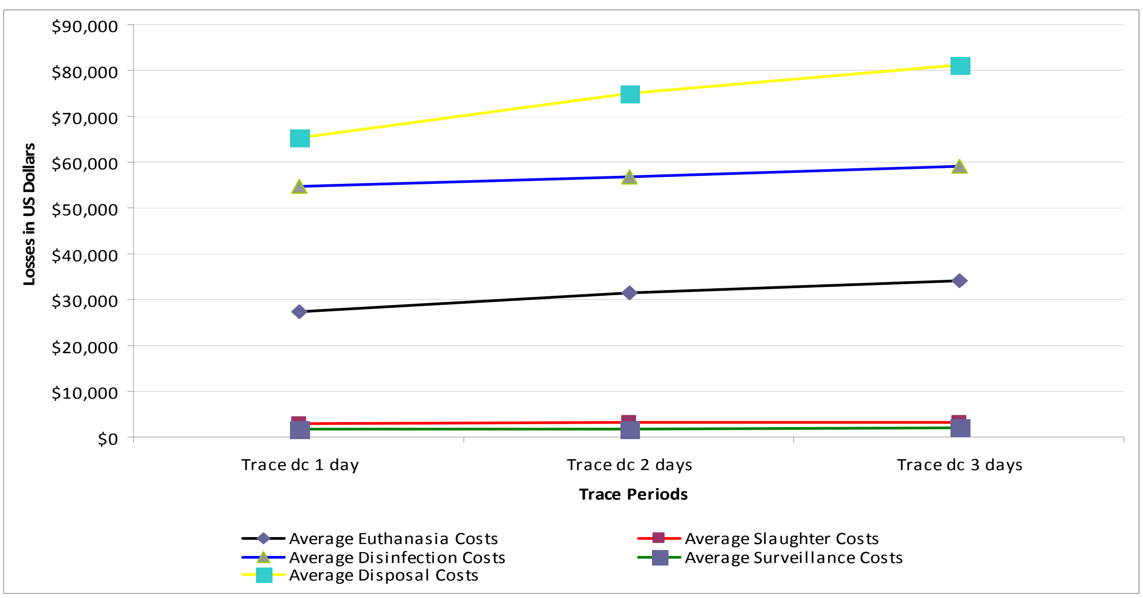
The euthanasia costs went from $27,464 US dollars to $31,457 to $34,125 for each of the trace periods. Disposal costs ranged from $65,422 to $81,298. Cleaning and disinfection costs ranged from $54,800 to $59,120 for the three different outbreaks. The percentage increases between outbreaks for disposal was 14.6% and 8.5% and for cleaning and disinfection, 3.5% and 4.2%, respectively. Other than slaughter costs, cleaning and disinfection costs were the only other cost figure to go up in percentage increase from the 2 day trace period to the 3 day trace period. Slaughter costs had a percentage increase of 3.3% (3,066 to 3,166) to 4.7% (3,166 to 3,316). Surveillance costs had the least amount of impact of the outbreak and its costs ranged from $1,815 to $1,946 with percentage increases of 3.9% and 3.2%. Graphical representations of these increases in the dead livestock numbers and average economic costs are presented in Figures 5.1-5.3.

Forgone income and indemnity payments had the most impact of the economic costs for all the different FMD outbreak simulations. In the large beef operation runs, the forgone income average went from $107,925 to $156,298 for a percentage increase of 44.8%, but then went down to $134,312 for a percentage decrease of -14.1%.. The percentage decrease had more to do with what types of animals were infected and where they came from then any other factor. In this instance, the “trace dc 2 days” simulation had the outbreak reach a large dairy which created substantial forgone income losses. The other outbreaks (Trace dc 1, 3 days) did not reach any dairies, but did reach different feedlots which still provided substantial forgone income.



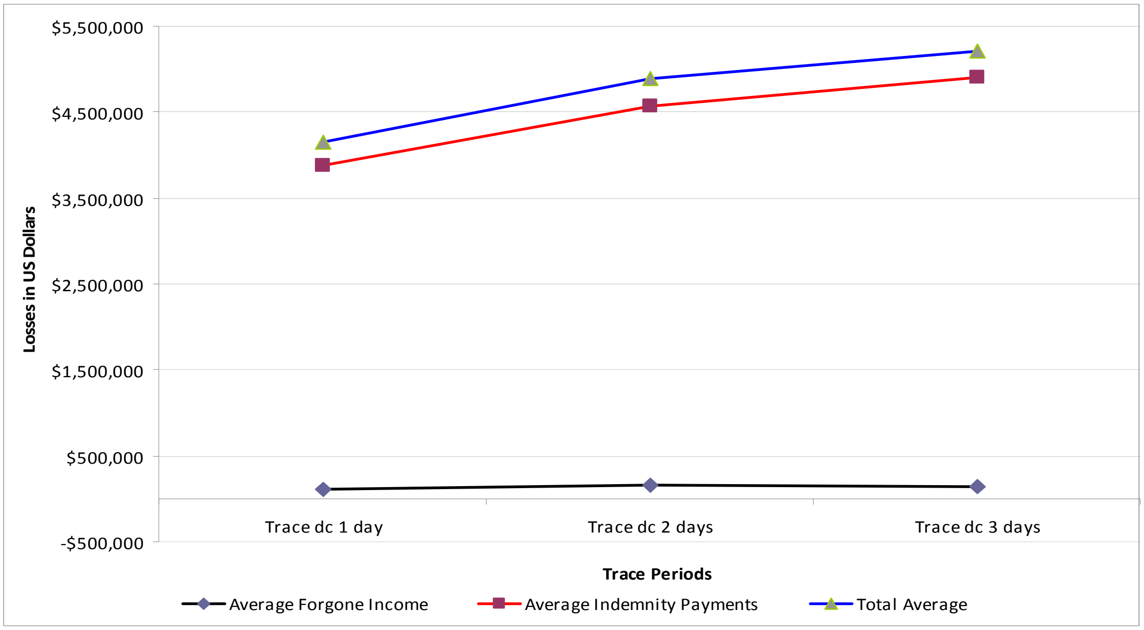
*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.1. Dead Livestock from Large Beef Operation FMD Outbreaks



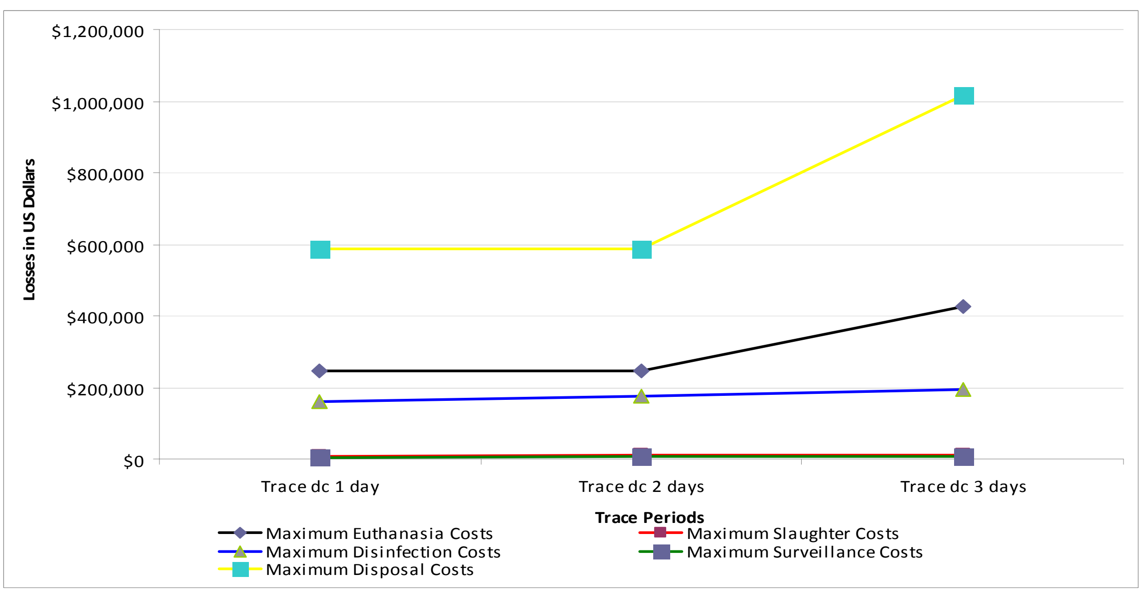
*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.2. Average Economic Costs from Large Beef Operation FMD Outbreaks: Part A



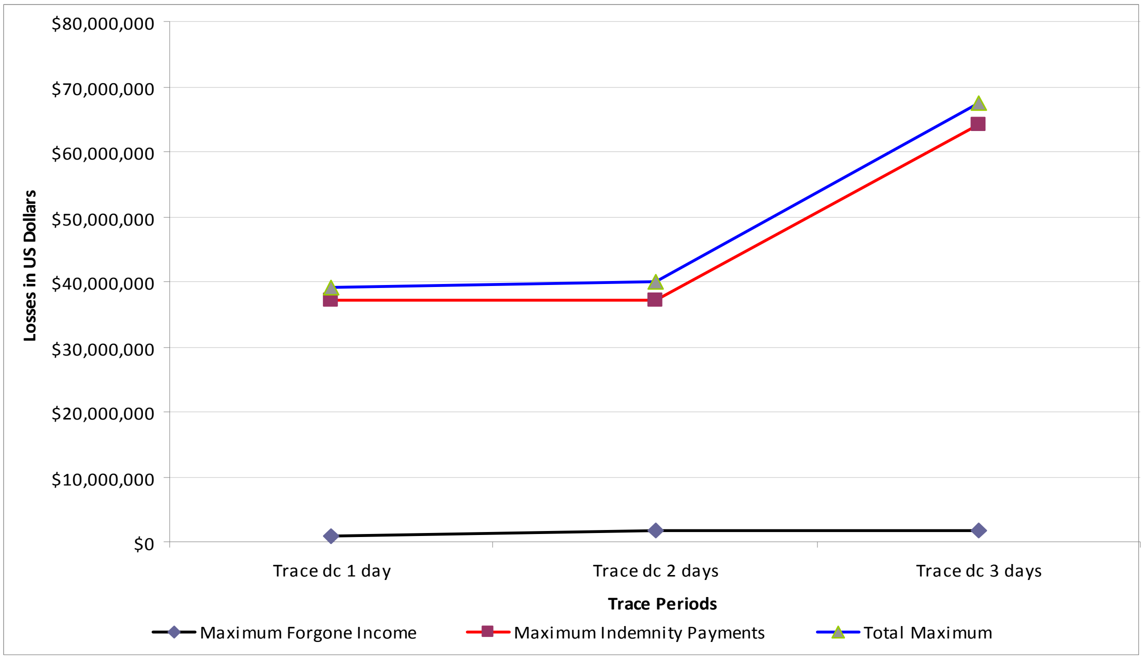
*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.3. Average Economic Costs from Large Beef Operation FMD Outbreaks: Part B



*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.4. Maximum Economic Costs from Large Beef Operation FMD Outbreaks: Part A



*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.5. Maximum Economic Costs from Large Beef Operation FMD Outbreaks: Part B

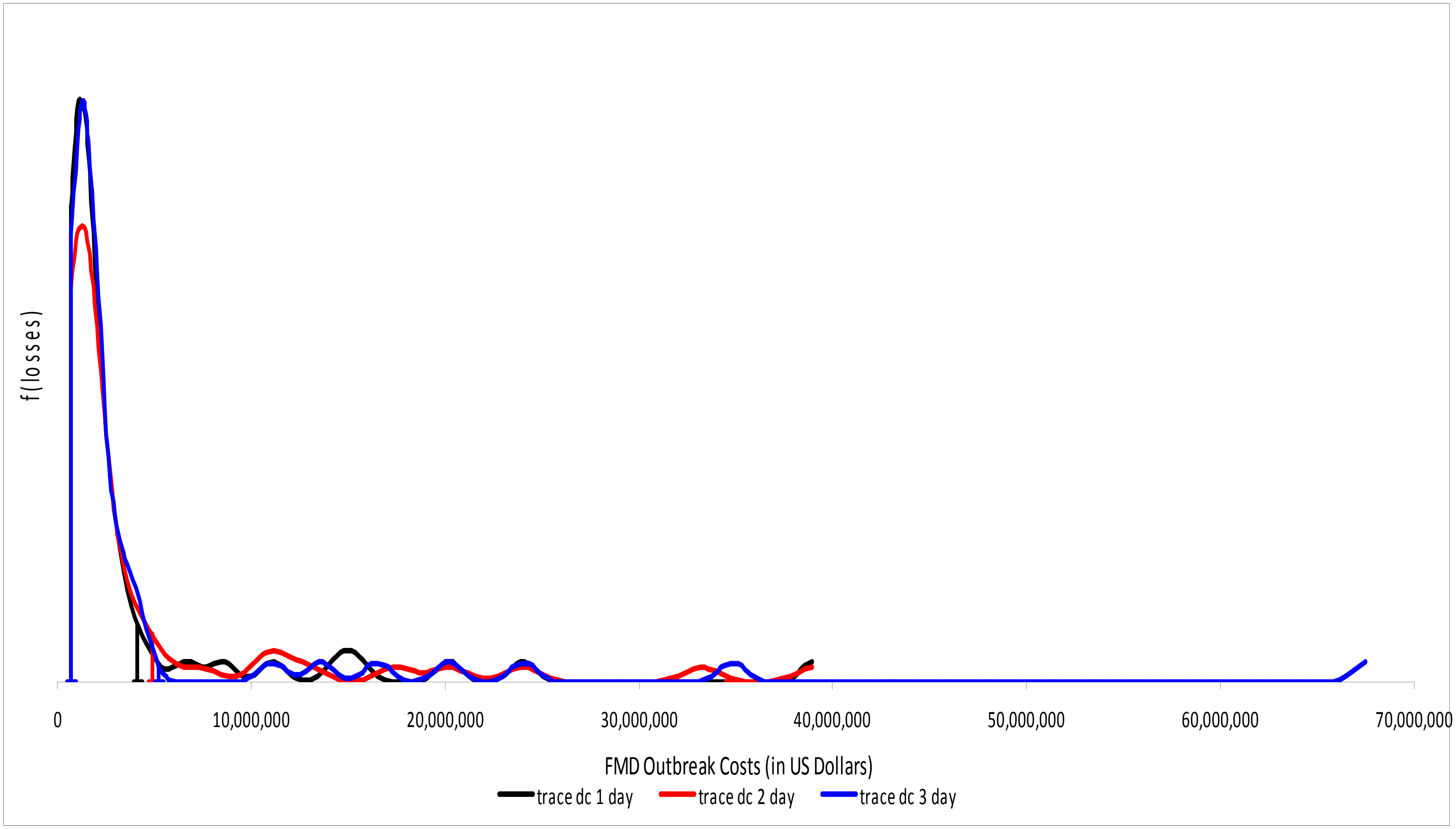
Although, the producers lost income in these simulated outbreaks, the largest loss would be for the government and industry due to indemnity payments. The payments for the three outbreaks averaged $4,451,032. The indemnity payment average went from $3,885,004 to $4,564,914 for a percentage increase of nearly 18%, and then increased again to $4,903,179 for another percentage increase of 7.4%. Although the average total costs of the three different trace period outbreaks ranged from $4,145,496 to $5,217,296, the worst case scenarios (maximum costs) suggest how detrimental an outbreak can be. The maximum economic costs for the large beef operation FMD outbreaks are shown in Figures 5.4 and 5.5. In the worst case scenarios, the difference between the tracing days

1 and 2 was $815,679. This figure may not be significant when considering how large the difference was ($27,554,927) between the tracing days 2 and 3. The percent increase in costs between the tracing day 1 and 3 is significant (73%). The fact that the maximum loss of infected/dead livestock was the same in trace days 1 and 2 can account for how similar the total worst case losses were for both of those trace days.

For the average totals, the differences between the tracing changes are not as large as the worst case scenarios, but they are still significant. There is still more than a million dollars difference (actual $1,160,292) between the changes from setting the subsequent herd tracing from 1 to 3 days. This is the equivalent of a 24% increase in costs, which shows the benefits of the increased tracing maybe more than the actual financial difference. The average number of dead livestock from the simulated FMD outbreaks increased along with the increased days until the subsequent herds was found. The differences in the averages were not large, but the difference between the maximum dead from the Trace dc 3 days outbreak to the 1 day and 2 days outbreak was considerable (35,946 animals).

The AUSSPREAD model showed in these runs, where an outbreak started at Large Beef Operation, that as it takes longer to find the subsequent infected herds of an outbreak, then the more animals will likely be infected and will accordingly make the outbreak losses increase substantially. Although the averages of the results did not show huge changes in the amount of dead livestock and financial losses for the industry, there were increases in every cost, except one, for all the simulation runs. The small changes could have been accounted by the model, with the probability for tracing sensitivity

(85%) being so high. Later test results show the effect of the tracing sensitivity/ specificity probability values. One interesting fact was that for most of these costs, the percent increase in costs went down from the outbreaks of trace dc 1 day and trace dc 2 days to the outbreaks of trace dc 2 days and trace dc 3 days. One important result from the data collected was visible in probability distribution graphs of the total costs from the large beef FMD outbreaks, shown in Figure 5.6. The distribution figure demonstrated that the outbreaks' averages stay close throughout the different tracing periods, but the tail ends of the costs go further, much further, in the trace dc 3 days outbreak compared to the trace dc 1 and 2 day outbreaks. Although it is hard to tell with only 3 different trace period outbreaks, the PDF graphs imply that maximum costs or worst case scenarios occur more as the trace periods get larger. If anything else, it would seem that controlled traceability could reduce the extreme outcomes or maximum costs of an FMD outbreak. Further study of the probability distributions with other FMD simulated outbreaks will be analyzed in this study to deem if the above statements could be valid.



*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.6. Probability Distribution Function Approximations of Large Beef Operation FMD Outbreaks

Through these three runs, traceability appeared to have some effect on the costs of an FMD outbreak. Since the AUSSPREAD model worked as the user assumed, other FMD simulations were chosen to hopefully see larger losses and larger disease spread through the different premises, i.e., Company Owned Feedlot and a Saleyard. These simulations are discussed in the next sections.

V.2 Company Owned Feedlot Results

The largest feedlot of the 6 different types of feedlots in the modified Texas High Plains AUSSPREAD model was Type 1, the company owned feedlot, which holds at a minimum 50,000 animals. If an outbreak of FMD started at a feedlot then, presumably a large group of animals would be immediately infected and euthanized. The hypothesis was that the costs would be large in the beginning with minimal increase in costs as it took longer to find all the subsequent infected animals. Although the results shown in Table 5.2 below seemed to concur at times, the costs did not always increase from trace period 1 day to trace period 10 days:

Table 5.2. Company Owned Feedlot FMD Outbreak Costs

	Trace Periods						
Costs	Trace dc 1 day	Trace dc 2 days	Trace dc 3 days	Trace dc 4 days	Trace dc 6 days	Trace dc 8 days	Trace dc 10 days
Dead Livestock							
Minimum	67,061	67,785	67,942	66,896	67,883	66,294	67,306
Maximum	228,029	206,565	247,929	240,277	267,676	271,758	361,611
Average	105,165	99,873	101,744	100,108	105,446	102,134	108,784
Euthanasia Costs							
Minimum	$335,305	$338,925	$339,710	$334,480	$339,415	$331,470	$336,530
Maximum	$1,140,145	$1,032,825	$1,239,645	$1,201,385	$1,338,380	$1,358,790	$1,808,055
Average	$525,826	$499,363	$508,719	$500,541	$527,232	$510,668	$543,921
Slaughter Costs							
Minimum	$5,400	$6,500	$6,800	$6,900	$7,500	$7,300	$7,800
Maximum	$46,500	$60,200	$51,400	$40,100	$47,300	$41,600	$61,700
Average	$19,710	$18,111	$17,846	$19,205	$18,898	$19,900	$21,406
Cleaning/Disinfection Costs							
Minimum	$98,000	$116,000	$131,000	$133,000	$133,000	$133,000	$142,000
Maximum	$822,000	$1,050,000	$930,000	$735,000	$818,000	$732,000	$1,086,000
Average	$347,120	$319,140	$322,040	$345,210	$332,590	$350,160	$376,640
Surveillance Costs							
Minimum	$3,300	$6,500	$4,300	$4,550	$4,350	$4,550	$4,650
Maximum	$26,700	$60,200	$30,800	$23,900	$25,750	$23,500	$34,900
Average	$11,195	$18,111	$10,401	$11,119	$10,721	$11,279	$12,110
Disposal Costs							
Minimum	$803,415	$811,826	$814,490	$799,856	$812,811	$793,234	$806,179
Maximum	$2,730,685	$2,469,058	$2,968,517	$2,877,911	$3,206,121	$3,256,469	$4,328,047
Average	$1,258,411	$1,195,180	$1,217,610	$1,197,793	$1,261,976	$1,222,053	$1,301,495
Forgone Income							
Minimum	$1,327,808	$1,337,935	$1,332,183	$1,324,541	$1,348,921	$1,312,621	$1,318,624
Maximum	$15,717,605	$17,580,600	$17,506,825	$18,702,536	$14,213,246	$15,131,111	$12,962,919
Average	$3,002,298	$2,854,800	$2,814,976	$2,782,517	$2,687,762	$2,535,060	$3,030,334

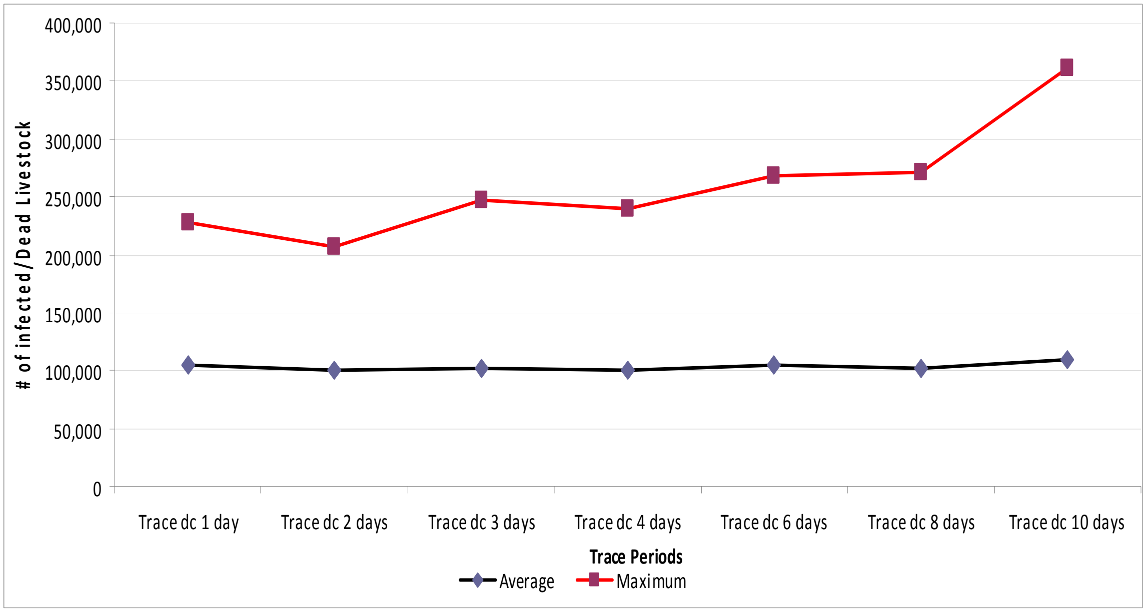
Table 5.2. Continued

	Trace Periods						
Costs	Trace dc 1 day	Trace dc 2 days	Trace dc 3 days	Trace dc 4 days	Trace dc 6 days	Trace dc 8 days	Trace dc 10 days
Indemnity Payments							
Minimum	$50,679,231	$51,128,449	$50,715,421	$50,564,292	$51,234,058	$50,147,130	$50,233,618
Maximum	$187,499,805	$170,875,002	$186,814,614	$209,863,217	$201,892,871	$225,258,690	$281,626,777
Average	$80,410,600	$77,289,257	$77,627,119	$76,368,954	$79,965,746	$77,156,903	$82,953,937
Total							
Minimum	$53,252,458	$53,746,136	$53,343,904	$53,167,619	$53,880,055	$52,729,305	$52,849,401
Maximum	$207,983,440	$193,127,885	$209,541,801	$233,444,049	$221,541,669	$245,802,160	$301,908,398
Average	$85,575,159	$82,193,962	$82,518,710	$81,225,338	$84,804,925	$81,806,023	$88,239,842

*Cattle numbers and dollar amounts are estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009).

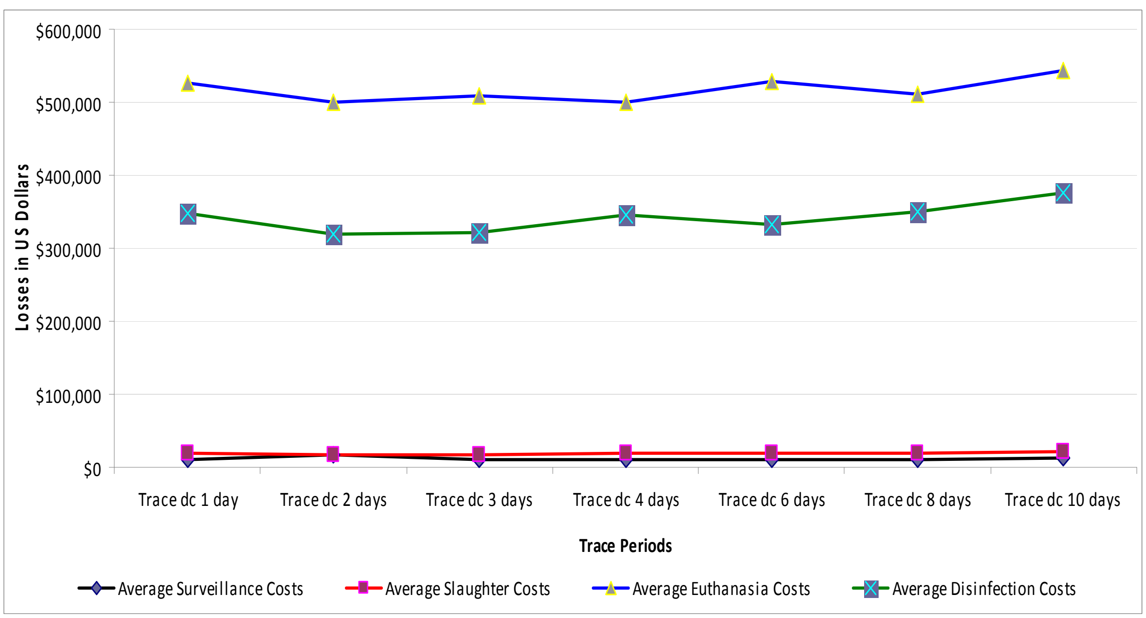
There were many times that the average costs and maximum costs fluctuated over the increased number of days. A surprising occurrence was how high the trace period 1 day costs were compared to the simulations for the other trace periods.

Although there seemed to be a slight upward trend in the charted data for all the costs, presented in Figures 5.7 - 5.13, the AUSSPREAD model's results seemed curious compared to practical thought when considering traceability and increased outbreak length. One clear result was how much more the total outbreak losses were compared to the simulated runs for the outbreaks initiated from a large beef operation. The total losses from the feedlot simulations ranged from $81,223,338 to $88,239,842 for the average costs and $193,127,885 to $301,908,398 for the maximum costs. The indemnity payments accounted for most of these applied costs, ranging between 88% to 95% of the total costs. The original High Plains report estimated the average range of costs for a type 1 outbreak was $66.7 to $538.6 million, and the maximum costs were $128.7 to $981.7 million dollars (Ward et al., 2007).



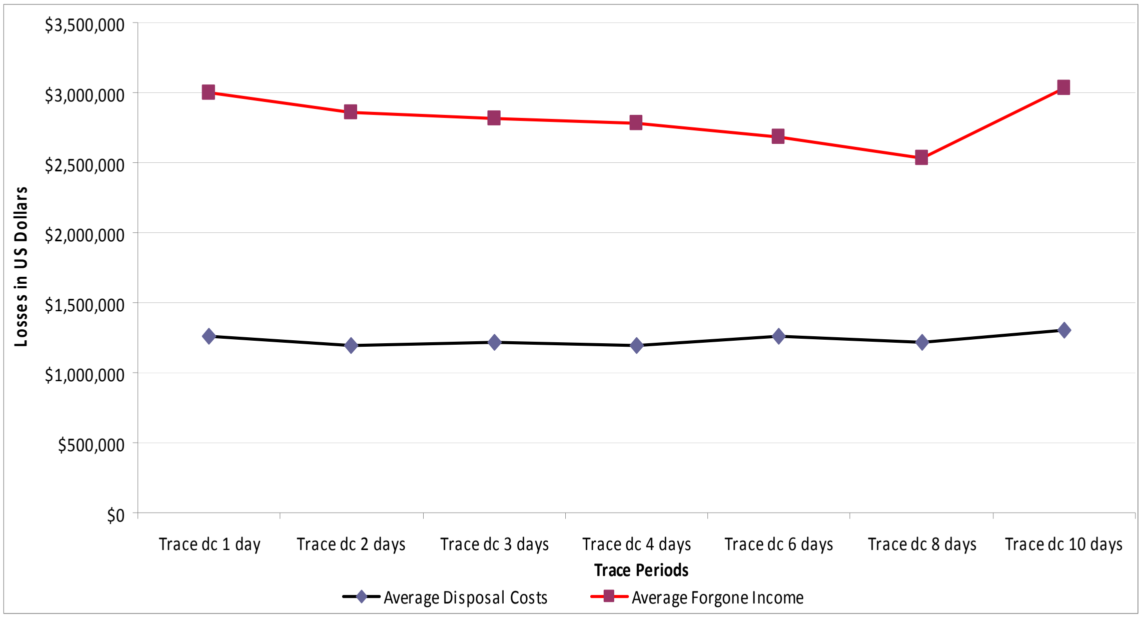
*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.7. Dead Livestock from Feedlot Type 1 FMD Outbreaks



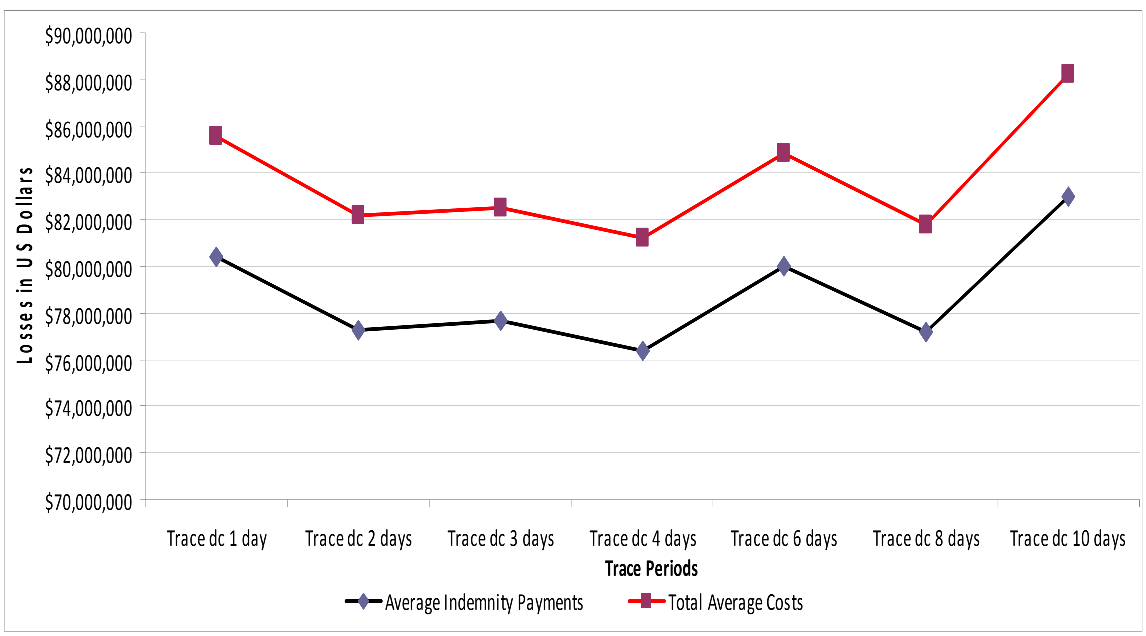
*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

5.8. Average Economic Costs from Feedlot Type 1 FMD Outbreaks: Part A



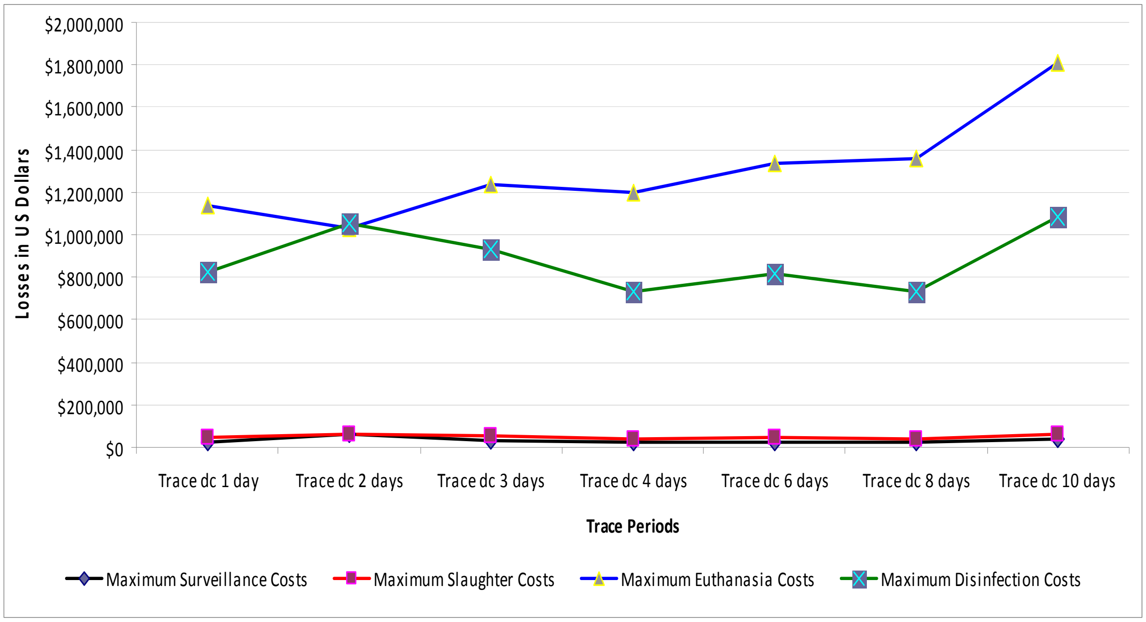
*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.9. Average Economic Costs from Feedlot Type 1 FMD Outbreaks: Part B



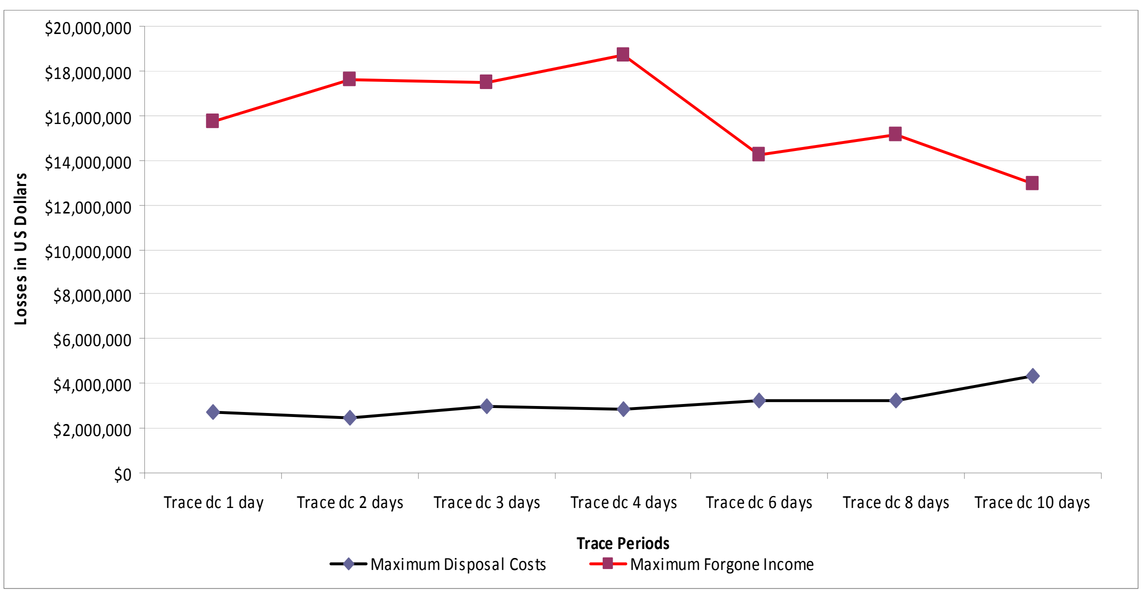
*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.10. Average Economic Costs from Feedlot Type FMD Outbreaks: Part C



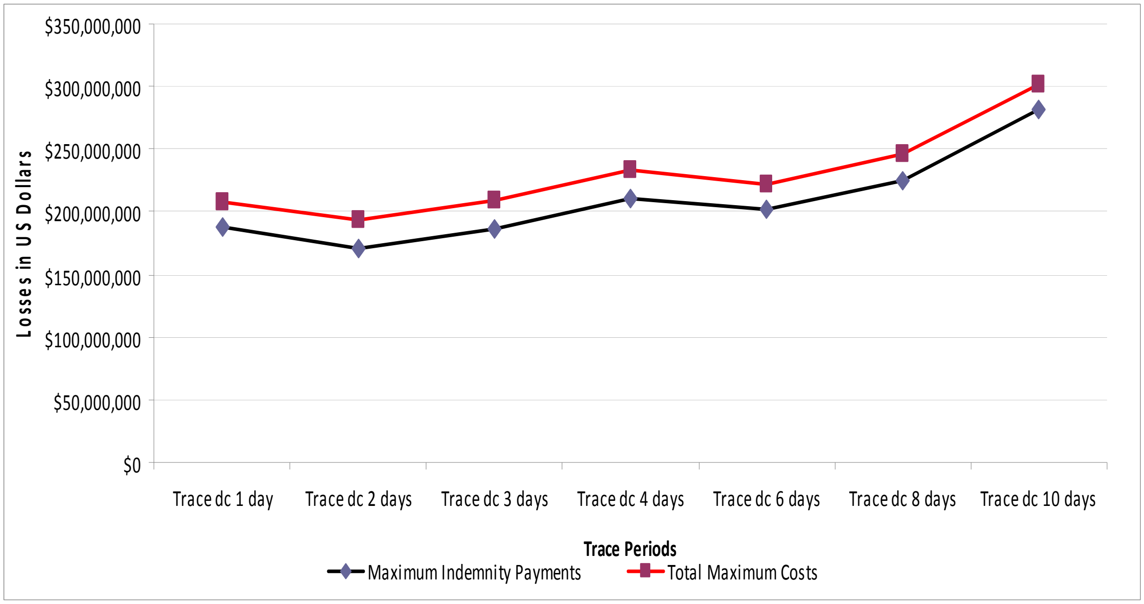
*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.11. Maximum Economic Costs from Feedlot Type 1 FMD Outbreaks: Part A



*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.12. Maximum Economic Costs from Feedlot Type 1 FMD Outbreaks: Part B



*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.13. Maximum Economic Costs from Feedlot Type 1 FMD Outbreaks: Part C

The High Plains report gave the same cost figures for outbreaks simulated from a large beef operation (Table 5.3). The range of economic costs given in Table 5.3, include other cost figures not analyzed on every run performed for this research. For example, welfare costs, quarantine costs, and cost of vaccination were not included. It is also important to note that each scenario was used in the High Plains Report. However, this research only used one set of scenarios for the simulations. Of all the costs that were examined, forgone income and disposal costs were the other noteworthy costs that had a sizable amount of impact on the entire outbreak. Disposal costs were the smaller of the two and ranged from $1,195,180 to $1,301,495 for its average costs and ranged from $2,469,058 to $4,328,047 for maximum costs. Forgone income consisted from 3% to 8% of the outbreak total costs and ranged from $2,535,060 to $3,030,334 for average costs, and ranged from $12,962,919 to $18,702,536 for maximum costs. One item that was evident in the feedlot simulations was that almost every average and maximum was the highest on the trace period, trace dc 10 days. The two outliers were the average surveillance costs for trace dc 2 days and the maximum forgone income values for trace dc 4 days. These differences may be due to the costs' structure since the average infected (108.784) and maximum infected (361,611) livestock were higher within the trace dc 10 days outbreak than any other. The two figures that seemed to stand out the most were trace dc 2 days and trace dc 10 days. These two outbreaks consistently had lower losses (2 days) or higher losses (10 days) than any of the outbreaks. These data confirm previous animal traceability research.

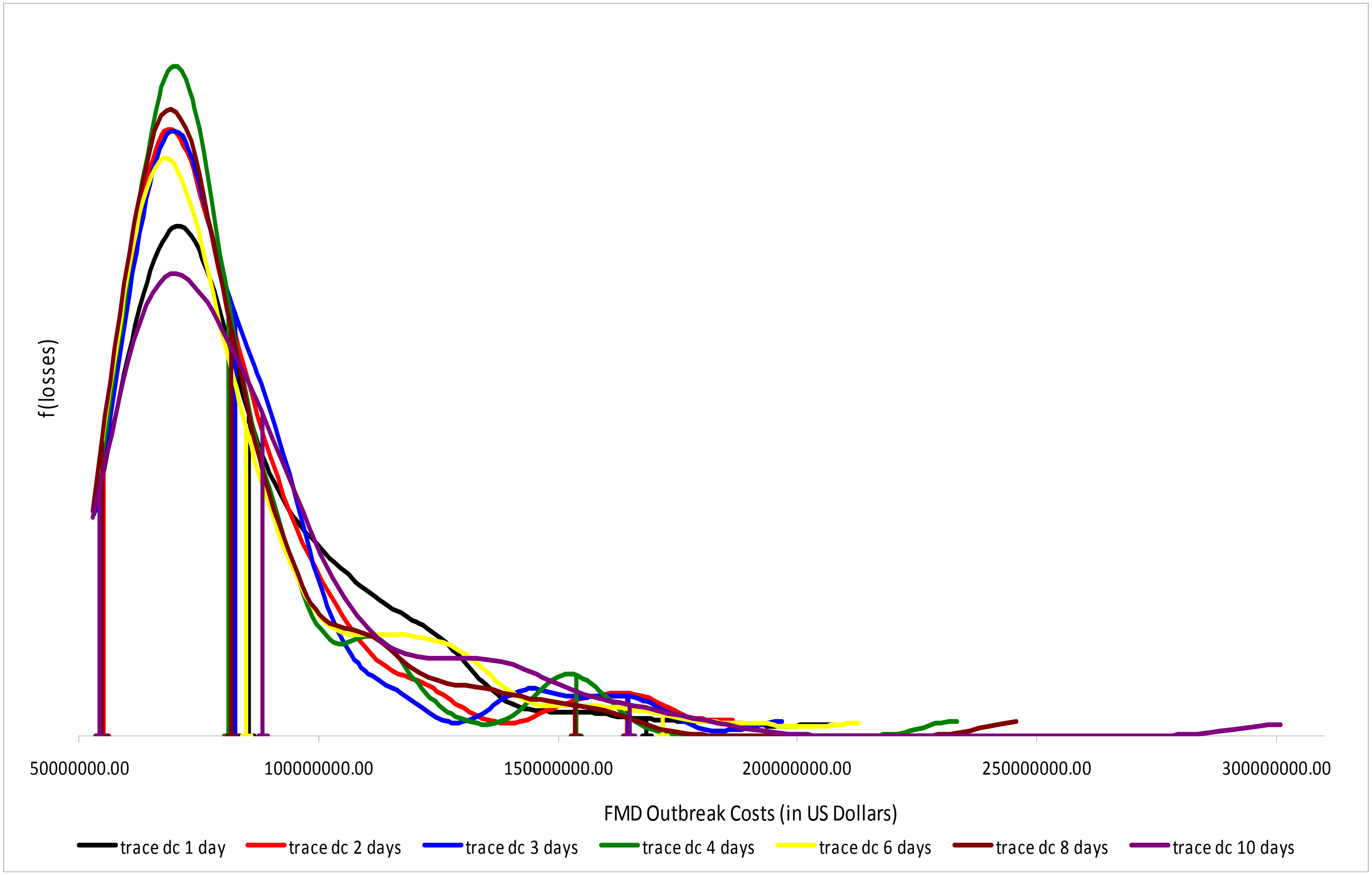
Table 5.3. Range of Economic Costs for the High Plains Report

Type of Herds	Range of Economic Costs Using Different Mitigation Strategies in $1 millions			
	Minimum Values	Maximum Values	Average Values	Median Values
Within Feedlot Type 1	55.5-246.8	128.7-981.7	66.7-538.6	62.9-546
Within Large Beef	0.77-3.8	42-597.8	3.5-159.1	1.1-79.3

*(Ward et al., 2007)

Another outlier was the cost of the trace dc 1 day outbreak since it was not the least costly. The anticipated result that it would be the least costly of the outbreaks could be explained by AUSSPREAD's random simulations and how close all the feedlot outbreaks were in regards to economic costs. Since practical thought is that disease spread might not move far out of a feedlot because of lack of livestock transported outward, the similarity of the outbreaks costs can be rationalized. It is important to note that trace dc 1 day was the second least costly of the outbreaks in regards to maximum infected livestock. The percentage change for the shortest time to find all the subsequent herds, trace dc 1 day, to the longest time, trace dc 10 days, can be considered when looking at the impact of traceability. Losses in terms of infected livestock and euthanasia costs were an increase of 3.5% for the averages, and an increase of 59% for the maximums. Slaughter average costs went up 8.6% on average and increased 32.6% for the maximum costs. Cleaning and Disinfection costs also increased on average, 8.5%, and increased 32% for the maximum cost. Surveillance costs had the least amount of total impact, but increased 8% for its average and increased to 30% for the maximum cost. Disposal costs percentage change was 3.4% for the average costs and 59% for the maximum cost. Forgone income and indemnity payments accounted for most of the total costs of the outbreak and for forgone income, the percentage change was a small 1% increase for the average costs and a negative 18% decrease for the maximum costs. This decrease was more than likely due to the first outbreak spreading to a dairy(s) where although the animals might be fewer, they are worth more income on a daily basis. Lastly, the Indemnity Payment percentage change was a 3% increase for the average costs and a substantial 50% increase for the maximum costs.

Since probability distribution function approximations were used in the large beef FMD outbreaks to show traceability’s effectiveness in minimizing the occurrences of extreme outcomes or losses from a FMD outbreak, a similar analysis was completed with the total cost data from the feedlot outbreaks. In the large beef operation outbreaks, only three trace periods were used, thus limiting our analysis of the PDF graphs. For the feedlot outbreaks, PDFs of all the applied trace periods (trace dc 1 day to trace dc 10 days), presented in Figure 5.14, allowed for a more complete analysis. Whereas before, calculations and cost results from the feedlot outbreaks gave few conclusions on how impactful traceability can be in minimizing the effect of an FMD outbreak, the PDF figures presented consistent results with the large beef operation outbreak simulations. The PDFs for all the trace periods presented that the most probable of the total costs to occur were in the range of 66 to 70 million dollars. This is well below the average calculations for all the different trace periods. Yet, the markers for 50% of the cost observations ended close to the average cost calculations. The PDFs also show that the longest trace period, trace dc 10 days, has the longest PDF tail or the worst possible outcome from an outbreak. The trace dc 10 days outbreak also had the largest range of total costs before 50% of the simulations were figured (lowest PDF arc line in figure), which depicts it having the widest range of total costs across all the simulations. The PDFs again defend that traceability can reduce the instances where the maximum losses can be incurred from an FMD outbreak. The PDF figure shows that the two largest trace periods have the longest tails, which show that those outbreaks contain the highest cost observations. It is also important, although hard to tell in Figure 5.14, that the three smallest trace periods (trace dc 1 day, 2 days, and 3 days) have the smallest PDF tails among all the different outbreaks. The PDF figures show similar results as far as their cost observations being in a similar range of dollars, and all show a long tail of higher costs at a smaller number of observations. This describes how animal traceability may not show large decreases in costs as it is intensified, but it supports how animal tracing reduces the number of potential extreme or worst case outcomes in a FMD outbreak. It also helps that the PDF tails (worst case observations) seem to decrease as the trace periods of subsequent infected animal tracing is increased.



*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.14. Probability Distribution Function Approximations of Company Owned Feedlot FMD Outbreaks

Since the trace dc 2 days and trace dc 10 days outbreaks were the best and worst of all the outbreaks for total costs, a small welfare study was performed to see how traceability may affect those costs. It is noteworthy that the percentage changes from the trace dc 2 days to trace dc 10 days outbreaks would be greater than the changes presented above since the trace dc 10 days showed fewer total costs.

V.3 Welfare Slaughter Study Results

The AUSSPREAD model had the capability to tabulate the quarantine costs with and without provisions to move feed into the quarantined areas. The associated welfare losses only dealt with those susceptible to infection and within a restricted movement area. To demonstrate further the relationship between animal traceability and economic losses due to an animal disease outbreak, the best and worst simulated feedlot outbreaks were used to calculate the disinfection costs to allow feed movement to the herds and also the welfare slaughter losses that would occur without feed allowed to the herds.

The welfare losses include the slaughter costs, forgone income of the lost animals, and the indemnity payments given to the producers. The quarantine costs, the disinfection costs of the feed trucks, for the trace dc 2 days outbreak was on average $3,042,971, but had a maximum of $20,700,000. These costs do not include the actual cost of feed or any labor costs. The worst outbreak, trace dc 10 days, averaged $4,622,412 for quarantine costs with feed movement and had a maximum of $23,561,625. The percentage change for the averages was a 52% increase and the maximum was a 14% increase. The slaughter costs of the two simulated model runs had

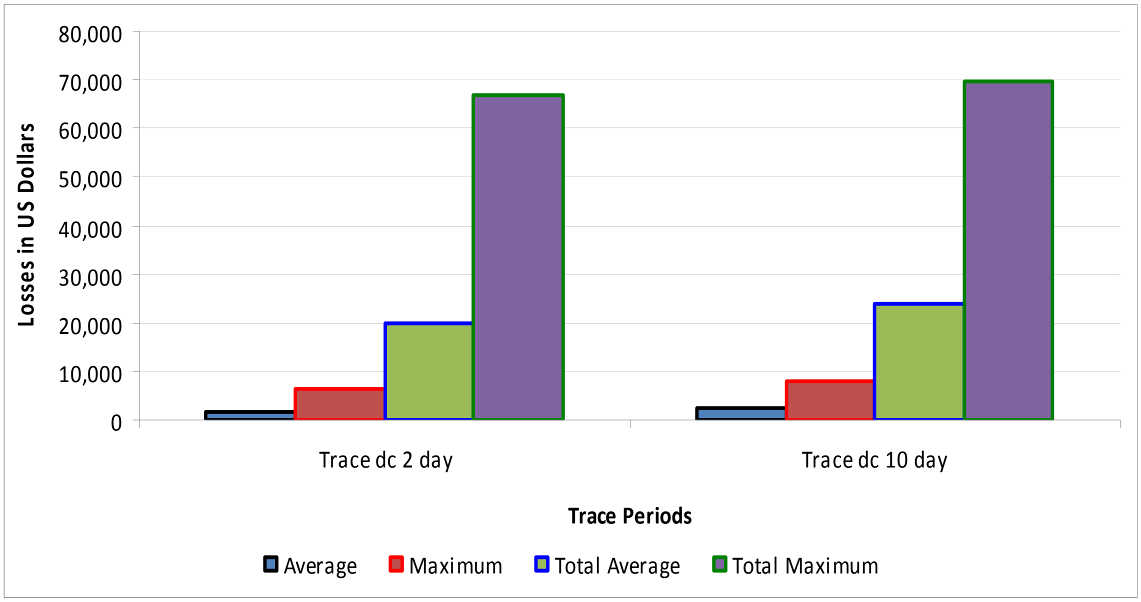
Table 5.4. Welfare Slaughter Costs

	Trace Periods	
Costs	Trace dc 2 day	Trace dc 10 day
Quarantine Costs		
Average	$3,042,971	$4,622,412
Maximum	$20,700,000	$23,561,625
Slaughter Costs		
Average	$1,700	$2,470
Maximum	$6,500	$8,000
Forgone Income		
Average	$3,847,693	$5,635,891
Maximum	$23,367,696	$27,786,446
Indemnity Payments		
Average	$37,048,342	$55,927,434
Maximum	$248,061,600	$256,277,762
Total Welfare Slaughter Losses		
Average	$40,897,735	$61,565,794
Maximum	$271,435,796	$284,072,208
Total Economic Losses*		
Average	$123,091,697	$149,805,637
Maximum	$464,563,681	$585,980,606

*Cattle numbers and dollar amounts are estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

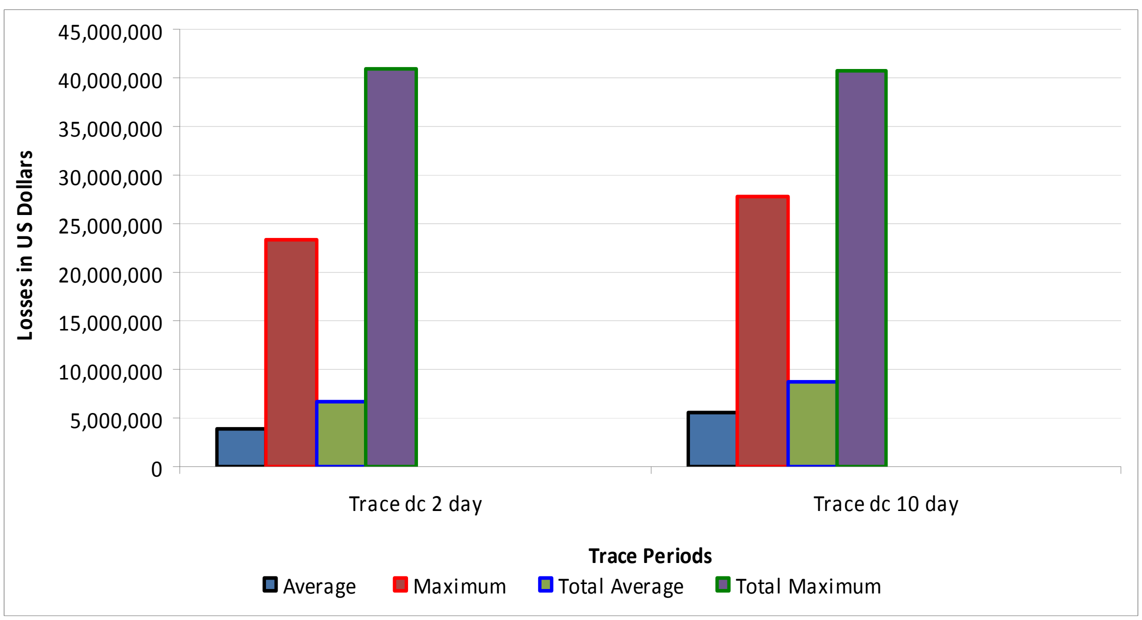
*Total Economic Losses calculated with assumption that quarantine costs were too expensive and welfare slaughter losses were accounted for in their place.

a 45% increase in their average losses and a 23% increase in the maximum losses. The actual values as well as all the other cost figures for the welfare analysis are shown in Table 5.4 and Figures 5.15-5.18. The forgone income losses were slightly larger than those of the quarantine costs. For trace dc 2 days, forgone income averaged $3,847,693, but could have cost up to $23,367,696. For trace dc 10 days, the average costs were $5,635,891, but could cost the producer up to $27,786,446. Between the two, the averages increased 46% and the maximum losses increased 19%. The dilemma for the producer is that he may not have the income to feed the animals and the disinfection costs for the trucks, but the losses seem lower than with the quarantine costs with feed movement than with the losses from forgone income. The dilemma is that since these animals were not infected, the producers also will not be given the indemnity payments provided by the government. The total indemnity payments not received averaged $37,048,342 for trace dc 2 days outbreak and up to $55,927,434 for the trace dc 10 days, a 51% increase. The maximum losses from indemnity payments reached up to $248,061,600 for the trace dc 2 days outbreak and up to $256,277,762 for the trace 10 days outbreak. This was also a percentage increase of 3.3%. Under the current U.S. policy on quarantine zones, these payments may be enticing enough so that producers are induced to transport their animals TO infected areas in hopes of receiving the payments. This creates a moral hazard problem. Those actions would be high risk to spread the disease further and possibly make the disease difficult to control. The total welfare losses averaged $40,897,735 for trace dc 2 days outbreak and $61,565,795 for the trace dc 10 days outbreak. With these changes in animal tracing, there



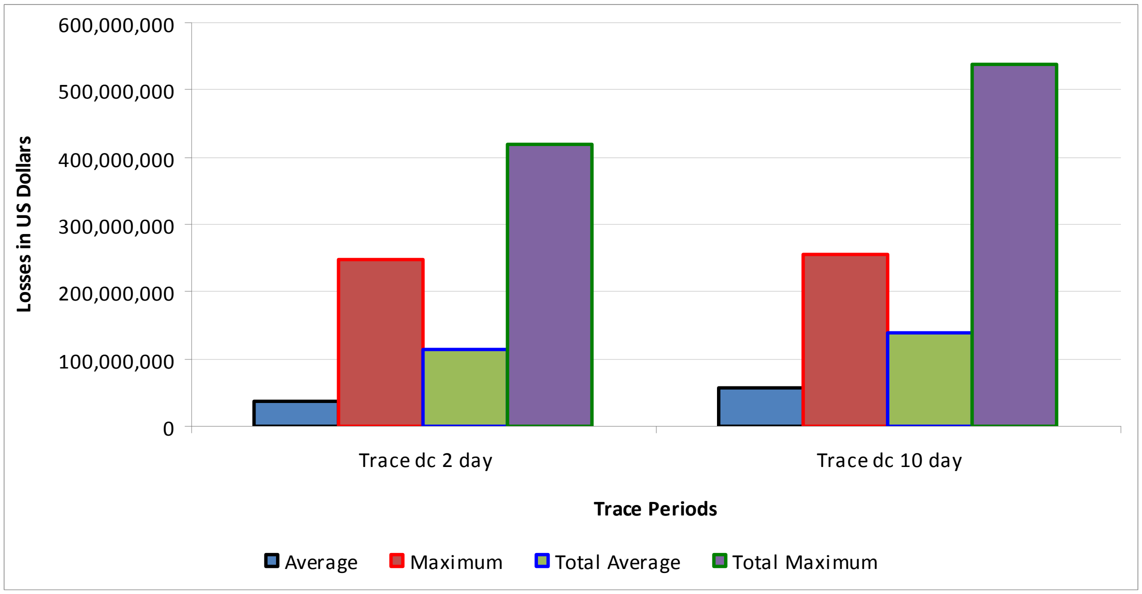
*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.15. Welfare Slaughter Analysis-Slaughter Costs



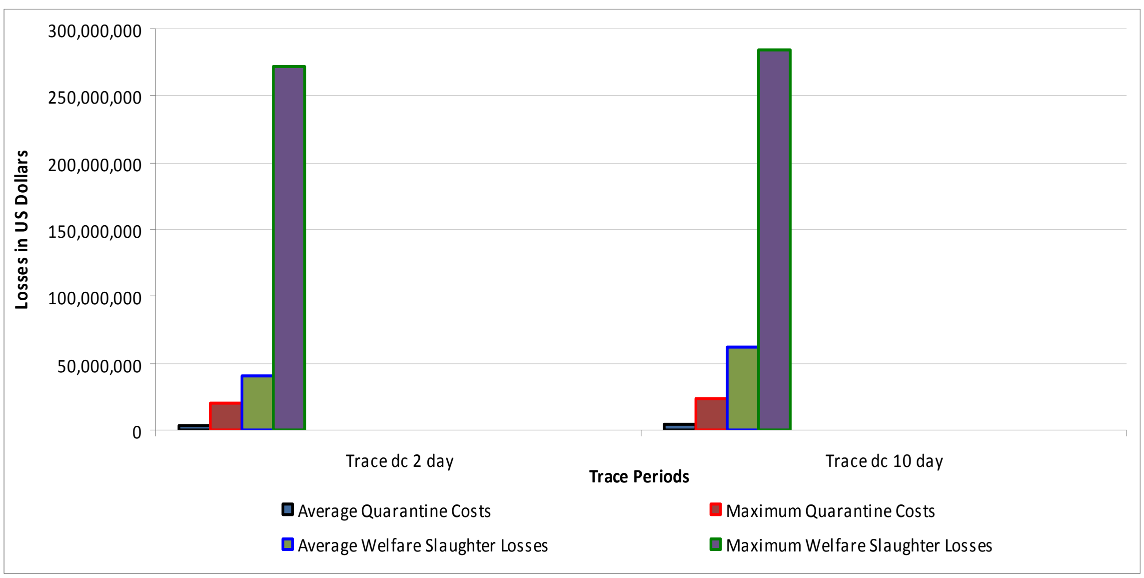
*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.16. Welfare Slaughter Analysis-Forgone Income



*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.17. Welfare Slaughter Analysis-Indemnity Payments



*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.18. Welfare Slaughter Analysis-Quarantine and Total Welfare Slaughter Losses

was a 51% increase in average welfare slaughter losses. There was only a 5% increase in losses from the maximum welfare slaughter costs. Yet, the difference in the losses from the average to the maximum was vast. The trace dc 2 days outbreak losses were $271,435,796 and the trace dc 10 days outbreak was $284,072,208. The quarantine costs suggest a benefit if the producer can still gain off other production such as milk from dairy cows, but it may be hard to afford those costs when the producer is unable to receive income from production elsewhere. The producer may also consider the costs of transporting feed into the quarantine zone compared to the indemnity payments he or she would receive if they slaughtered their animals. Even if the indemnity payments were substantial, the producer would lose his entire herd, breeding stock/genetic pool, and more than likely his annual income which would certainly be a difficult decision, especially if there are limited options. If the producer could not afford the quarantine costs to move in feed to their premise, the welfare slaughter losses would make the average cost of the feedlot outbreaks to total $123,091,697 (for trace dc 2 days) and $149,805,637 for (trace dc 10 days). The difference in animal traceability accounted for a difference of $26,713,940 and a 22% increase in total losses. The maximum total losses went up a similar 26% percent and made the losses $464,563,681 (for trace dc 2 days) and $585,980,606 (for trace dc 10 days). These losses look different than those in Table 5.3, but are within the ranges, so one can figure the differences rely in the scenarios and eliminated vaccination costs, which according to AUSSPREAD were calculated based on per animal costs and fixed per herd costs.

V.4 Saleyard Results

Two saleyards were involved in this High Plains /AUSSPREAD model. The estimated number of buyers per sale was assumed to be 100. It was assumed that 90% of sales were in-region, with 10% being out of region. The probability of sending livestock to the sale was 20% and only herd types 7 and 8 (small and large beef) were assumed to sell livestock at sales. The probability of buying livestock from a sale was assumed to be 20%. The saleyard was assumed to be infected if animals from an infected herd were sent to the sale. The saleyard was reset to uninfected status after each sale. All saleyards were assumed to be shut down 1 day post detection of FMD, in this case, day 15. In the model runs, a random herd was infected at the one saleyard resulting in late detection. The assumption was that the FMD would quickly spread before any response was initiated. However, the results from the saleyard runs did not come out as expected. The results over the trace period range fluctuated and remained flat without any distinct pattern. The total losses did differ from the large beef outbreak runs but did not come close to the impact that the feedlots reached.

Table 5.5. Saleyard FMD Outbreak Costs

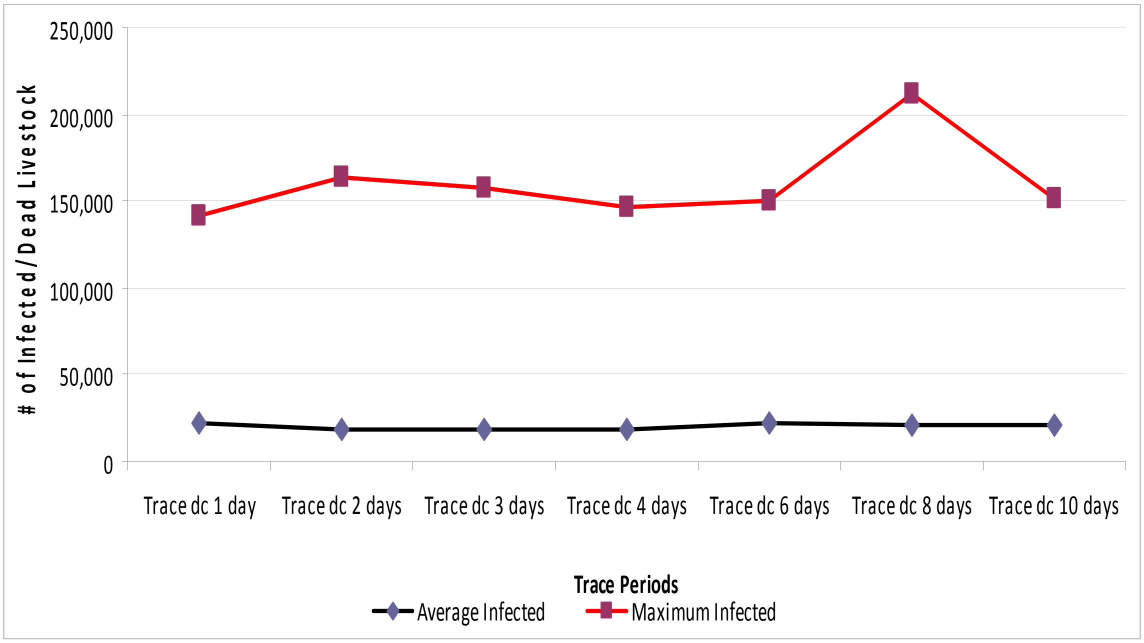
Costs	Trace Periods						
	Trace dc 1 day	Trace dc 2 days	Trace dc 3 days	Trace dc 4 days	Trace dc 6 days	Trace dc 8 days	Trace dc 10 days
Dead Livestock							
Minimum	180	35	35	49	189	69	58
Maximum	141,820	163,881	157,038	147,059	150,156	211,535	150,995
Average	22,499	18,924	19,065	18,975	22,536	20,912	21,180
Euthanasia Costs							
Minimum	$900	$175	$175	$245	$945	$345	$290
Maximum	$709,100	$819,405	$785,190	$735,295	$750,780	$1,057,675	$754,975
Average	$112,497	$94,620	$95,324	$94,874	$112,678	$104,559	$105,902
Slaughter Costs							
Minimum	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500
Maximum	$40,500	$38,300	$40,300	$38,900	$43,400	$37,800	$40,700
Average	$12,117	$12,460	$11,810	$12,235	$13,328	$12,820	$12,869
Cleaning/Disinfection Costs							
Minimum	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000
Maximum	$707,000	$669,000	$708,000	$679,000	$737,000	$659,000	$708,000
Average	$209,888	$214,990	$204,214	$211,490	$230,724	$221,796	$222,551
Surveillance Costs							
Minimum	$750	$750	$750	$750	$750	$750	$750
Maximum	$22,500	$21,250	$22,700	$21,400	$23,050	$21,000	$22,450
Average	$6,578	$6,698	$6,384	$6,599	$7,227	$6,941	$6,961
Disposal Costs							
Minimum	$1,980	$385	$385	$539	$2,079	$759	$638
Maximum	$1,697,368	$1,959,785	$1,878,132	$1,759,786	$1,793,957	$2,533,545	$1,806,460
Average	$267,898	$224,985	$226,754	$225,563	$268,164	$248,744	$251,929

Table 5.5. Continued

	Trace Periods						
Costs	Trace dc 1 day	Trace dc 2 days	Trace dc 3 days	Trace dc 4 days	Trace dc 6 days	Trace dc 8 days	Trace dc 10 days
Forgone Income							
Minimum	$3,564	$624	$624	$901	$3,742	$1,297	$1,079
Maximum	$3,866,852	$3,133,067	$3,109,270	$4,066,666	$7,849,713	$5,652,679	$2,989,701
Average	$510,434	$358,668	$423,744	$514,281	$598,888	$518,794	$465,540
Indemnity Payments							
Minimum	$122,932	$19,228	$19,228	$27,995	$128,568	$40,521	$33,632
Maximum	$106,902,694	$117,284,556	$117,390,326	$110,038,132	$111,078,007	$161,543,973	$113,234,570
Average	$16,511,093	$12,372,178	$13,903,971	$14,080,229	$16,634,389	$15,350,404	$15,814,202
Total							
Total Minimum	$156,626	$47,662	$47,662	$56,931	$162,584	$70,172	$62,889
Total Maximum	$113,946,015	$123,925,363	$123,933,917	$117,339,179	$122,275,907	$171,505,672	$119,556,856
Total Average	$17,630,505	$13,284,600	$14,872,202	$15,145,272	$17,865,398	$16,464,059	$16,879,955

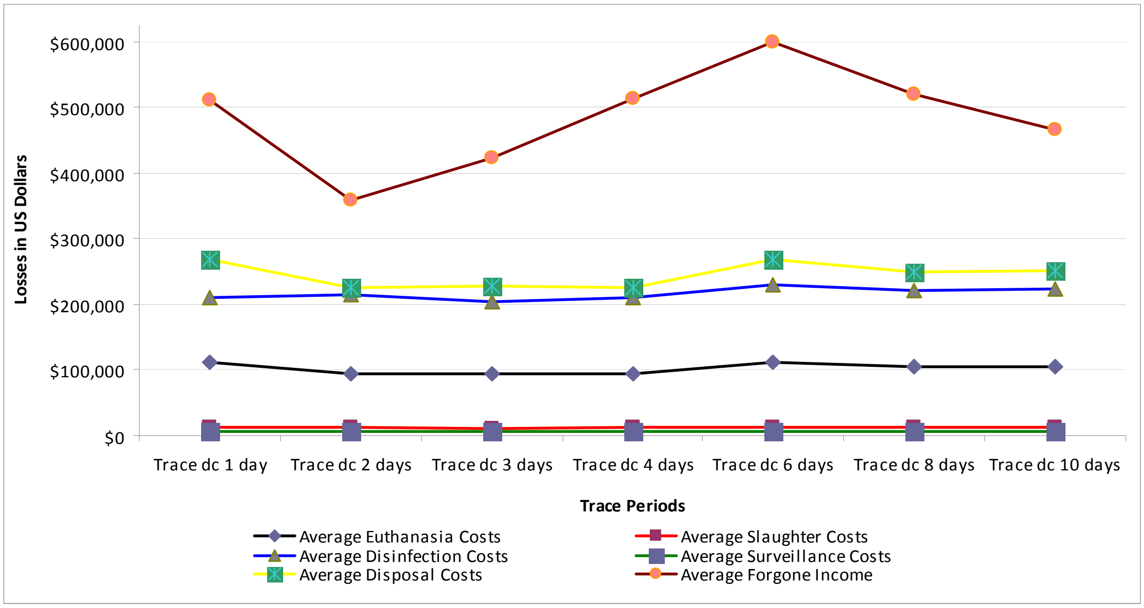
*Cattle numbers and dollar amounts are estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009).

The complete results are calculated and presented in Table 5.5 and Figures 5.19-5.23. The total average economic losses ranged from $13,284,600 to $17,865,398 in US currency. The maximum potential losses ranged from $113,946,015 (trace dc 1 day) to $171,505,672 (trace dc 8 days). There was not one cost figure, (minimum, maximum, or average) that increased from the smallest trace period to the largest. The largest number of infected livestock was in the trace dc 8 days outbreak with its maximum dead totaling 211,535 livestock. The largest average infected came from the trace dc 6 days outbreak with 22,536 infected/dead livestock, but it is noteworthy that the second closest was the smallest trace period, trace dc 1 day with 22,499. Also, the trace dc 1 day simulated runs produced the smallest maximum infected livestock as well, by a large margin. As expected, the indemnity payments made up approximately 90% of the costs that were applied to this study. Forgone income and disposal costs averaged over one million dollars over the trace period range, and were the other most influential cost figures, as they were in the company owned feedlot outbreaks. The highest numbers came from outbreaks that spread to feedlot(s) or dairies(s), as they created the most forgone income and indemnity payments. The longer it would take to find these subsequent infected herds, the more likely it would spread to these types of herds. This was illustrated in the trace dc 6 and 8 days outbreaks, where many of the simulated outbreaks involved large feedlots and large dairies, and caused their averages and maximums to be higher than the other outbreaks.



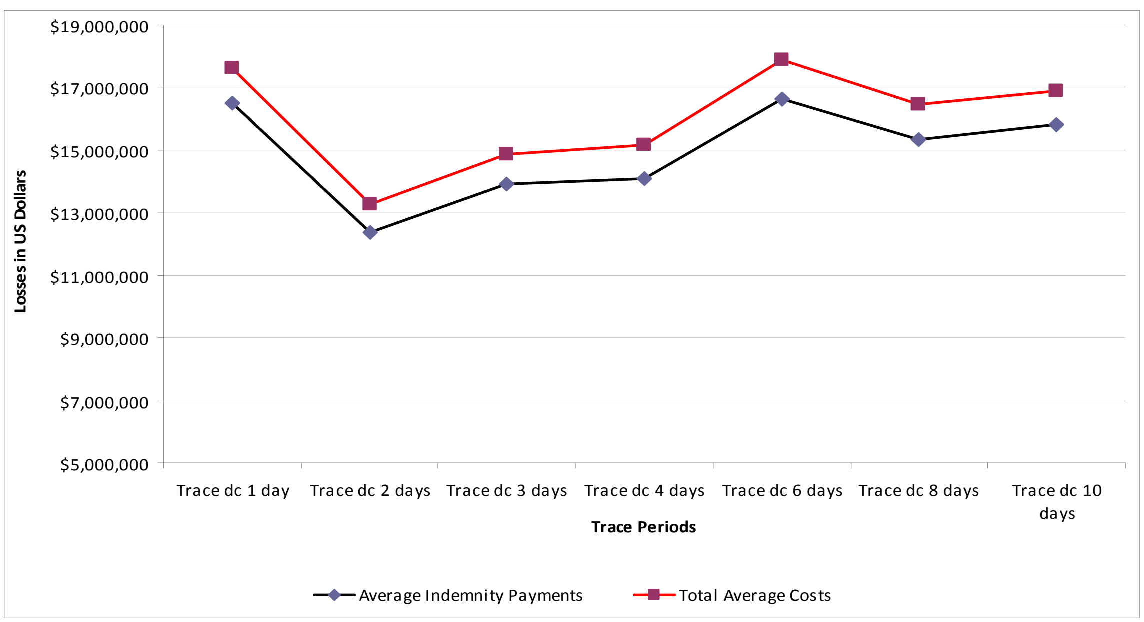
*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.19. Dead Livestock from Saleyard FMD Outbreaks



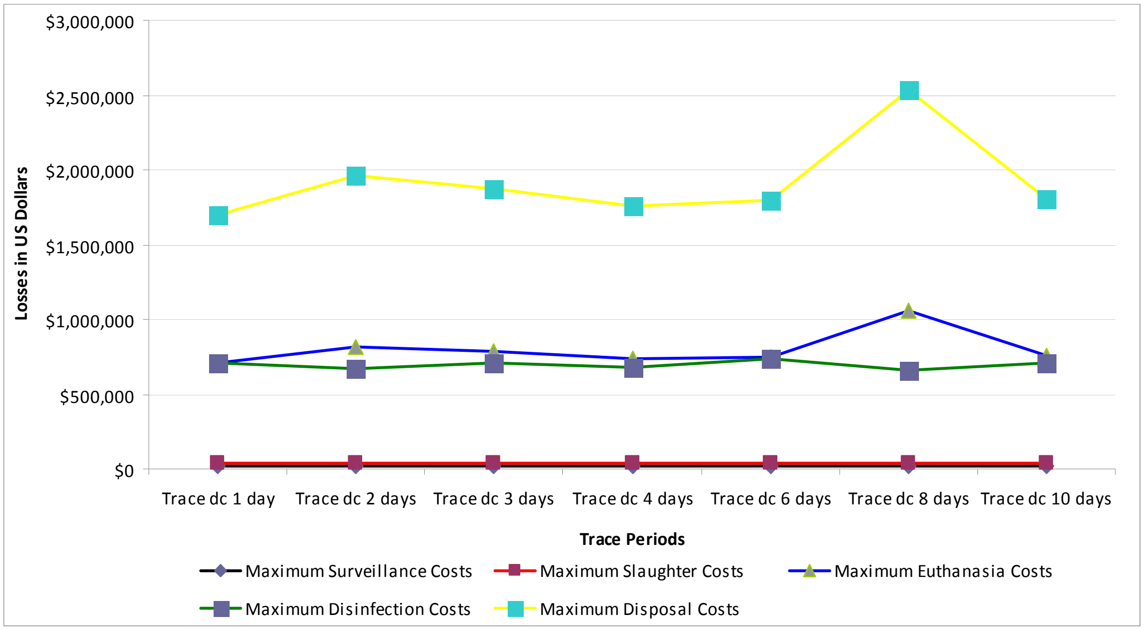
*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.20. Average Economic Costs from Saleyard FMD Outbreaks: Part A



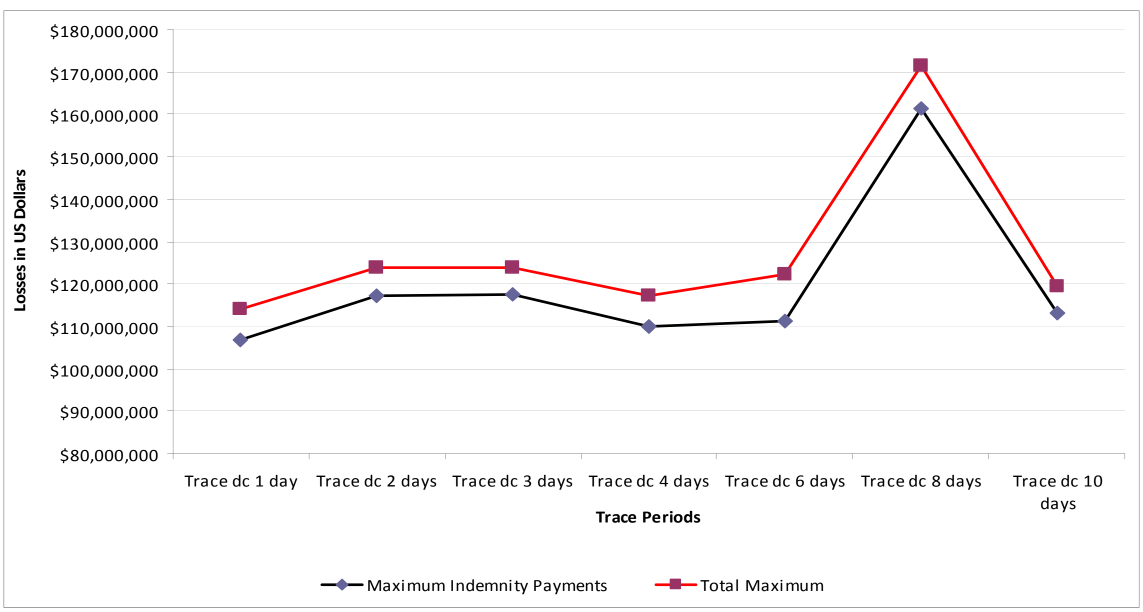
*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.21. Average Economic Costs from Saleyard FMD Outbreaks: Part B



*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.22. Maximum Economic Costs from Saleyard FMD Outbreaks: Part A

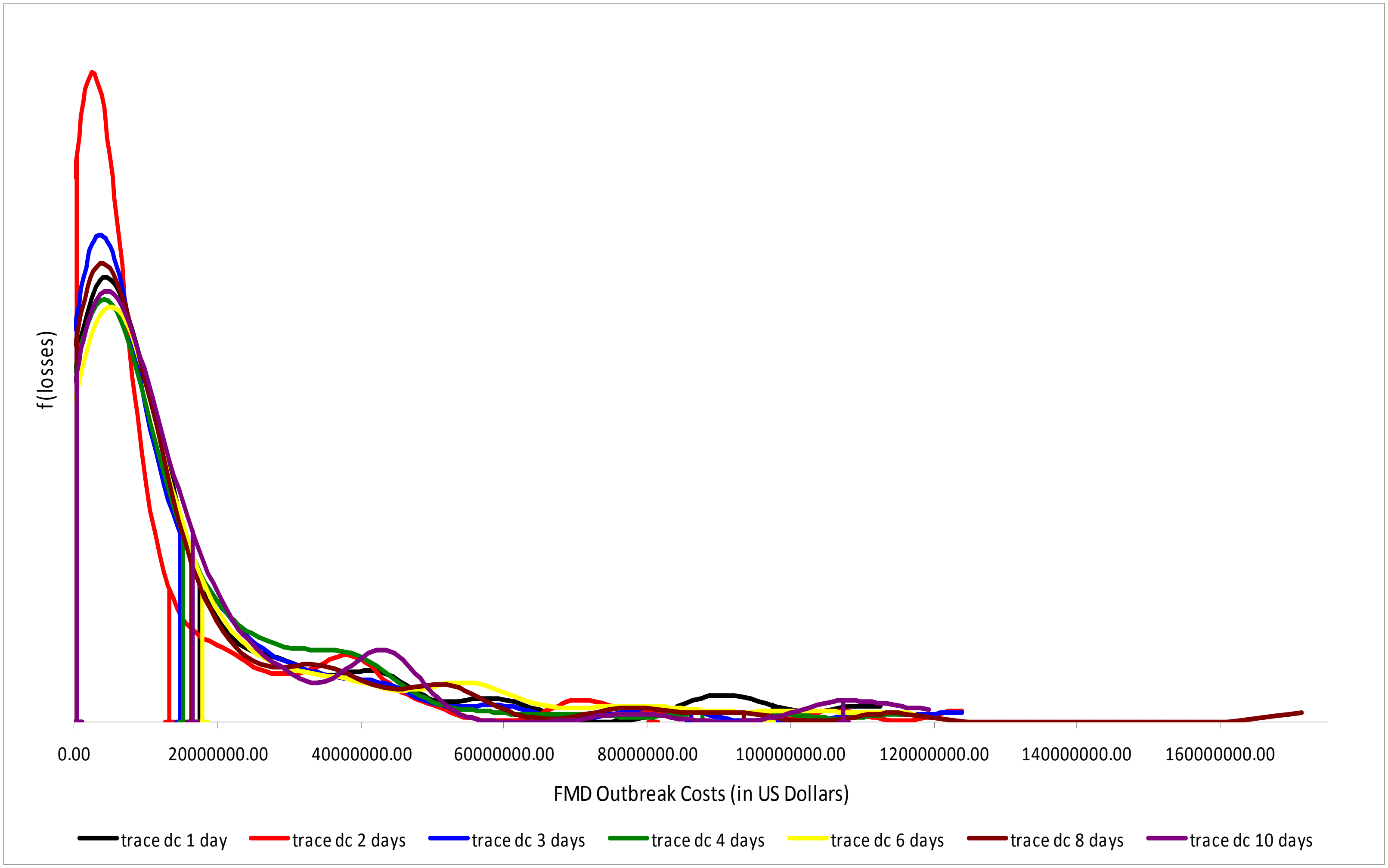


*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.23. Maximum Economic Costs from Saleyard FMD Outbreaks: Part B

There could be many reasons why the AUSSPREAD model for the Texas High Plains did not perform as expected with the saleyard FMD outbreaks. The costs were expected to exponentially rise as the trace periods got longer. The losses may not have reached their potential in this study because the probability of buying and selling at the saleyard was low. If the chances were 20% that the owner would sell and 20% that someone might buy, that translates to a 4% chance the selling and buying will actually occur. If this assumption is true, then the saleyard expectations may be very low. Also, if true, then the sellers will be identified and their cattle tested. It is doubtful that many buyers who actually received cattle will be part of the traceback. Also, the saleyard is reset in this model and cannot be a source of continuous disease spread. The saleyard has sales every Monday (weather permitting), so with late detection (14 days), there should be at least two sales before the operation is shut down and reset. This could help a disease spread, but it also may have no impact if there were not any infected animals at the second sale or if they were a small number of actual sales. If the percentage of sales was much higher, greater losses from the saleyard outbreaks would be expected. The disease outbreaks may not have cost much more as the days went on because the buyers that purchased cattle were less likely to transport the cattle after receiving them. Thus no additional spread would have occurred. If the trace-back process took longer to track the subsequent infected herds, and allowed time for those producers to move any infected animals another time, then the expected results would be seen.

It seems true that the model did not produce substantial and effective results to present how minimizing animal tracing could minimize economic losses of a FMD outbreak in these saleyard situations. Yet, probability distribution function approximations were performed as with the large beef and company owned feedlot outbreaks to see if traceability had any effect on decreasing the instances of worst case scenarios. Just as was done the company-owned feedlot FMD outbreaks, the PDFs for the saleyard outbreaks, shown in Figure 5.24, were done for all the trace periods (trace dc 1 day to trace dc 10 days). The PDFs showed promising results this time as well with



*Numbers estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009)

Figure 5.24. Probability Distribution Function Approximations of Saleyard FMD Outbreaks

traceability reducing extreme outcomes. Throughout the trace periods of subsequent tracing of herds, the PDF approximations presented that the more likely total costs appear in the range of the calculated averages and the worst cases are least likely to occur. As Table 5.5 shows, the trace dc 8 days outbreak has the largest maximum cost which is again represented in the PDF figure as the trace period with the longest PDF tail. The PDF for the trace dc 2 days outbreak shows that 50% (marked by the first line under the PDF) of the estimations were observed with lower total costs than the other outbreaks. Although hard to tell in the figure, the PDF tails are the shortest for the trace dc 1 day outbreak followed by the trace dc 2 day outbreak. Although it seems odd that the trace dc 10 day outbreak has a similar PDF tail to the other outbreaks, it is important to note that a significant portion of the total cost observations were larger than the other outbreaks. Since a larger trace period had the longest PDF tail (trace dc 8 days) and shorter trace periods had the shortest PDF tails and more estimations in lower costs (trace dc 1 day and trace dc 2 days), it can be safe to say that traceability does have an effect on minimizing extreme outcomes or maximum incurred losses from an FMD outbreak.

Although the trace periods effectiveness varied in the saleyard outbreaks, other variables that could affect the disease spread, changes to the trace sensitivity and trace specificity, were performed. This analysis will be discussed in the following section.

V.5 Trace Sensitivity/Specificity Analysis

The AUSSPREAD model allowed different ways other than changing the parameters to find the subsequent infected herds, e.g., days_til_dc. The probability variables were tracing sensitivity and trace specificity, which were determined the accuracy of subsequent herd locations, and how accurate it would indentify an infected herd and not a false positive (potential infected area but not infected herd). To test these percentage figures, we performed a large parallel shift in the values to see any changes in the total losses, as a method to evaluate their impact for animal traceability. It was assumed that by changing the values for trace sensitivity and specificity from .85 and .95 to .45 and .55 respectively, we would see an increase across the board in losses due to the lack of accuracy in finding the subsequent herds. We again used the trace dc 2 days and 10 days outbreaks as we did for the welfare slaughter study, but we looked at those simulated runs from the saleyard and not the company owned feedlot herd type. The trace dc 2 days outbreak averaged the smallest economic losses out of all the calculated outbreaks for the saleyard runs. The trace dc 10 days was the longest trace period, and again, one of the more costly outbreaks, as one would expect. When the results were returned and tabulated, the losses were not large. For both outbreaks, the costs did not always increase, nor did the costs reflect the sensitivity/specificity changes. As can be seen in Table 5.6, there were increases from the trace dc 2 days outbreaks, but the trace dc 10 days outbreaks showed very flat results. For the trace dc 2 days outbreaks, the

Table 5.6. Tracing Sensitivity and Specificity Cost Analysis

	Original		**Sensitivity/Specificity Change**	
Saleyard Costs	Trace dc 2 days	Trace dc 10 days	Trace dc 2 days	Trace dc 10 days
Dead Livestock				
Minimum	35	58	183	141
Maximum	163,881	150,995	179,556	147,962
Average	18,924	21,180	20,206	20,417
Euthanasia Costs				
Minimum	$175	$290	$915	$705
Maximum	$819,405	$754,975	$897,780	$739,810
Average	$94,620	$105,902	$101,030	$102,085
Slaughter Costs				
Minimum	$1,500	$1,500	$1,500	$1,500
Maximum	$38,300	$40,700	$41,700	$37,100
Average	$12,460	$12,869	$12,414	$13,361
Cleaning/Disinfection Costs				
Minimum	$25,000	$25,000	$25,000	$25,000
Maximum	$669,000	$708,000	$725,000	$637,000
Average	$214,990	$222,551	$214,776	$230,755
Surveillance Costs				
Minimum	$750	$750	$750	$750
Maximum	$21,250	$22,450	$22,650	$19,900
Average	$6,698	$6,961	$6,724	$7,218
Disposal Costs				
Minimum	$385	$638	$2,013	$1,551
Maximum	$1,959,785	$1,806,460	$2,144,723	$1,771,914
Average	$224,985	$251,929	$240,358	$242,807
Total				
Minimum	$27,845	$28,236	$30,361	$29,647
Maximum	$3,671,621	$3,483,580	$4,011,409	$3,353,686
Average	$572,678	$621,393	$595,508	$616,644

*Cattle numbers and dollar amounts are estimated from the High Pains version of AUSSPREAD simulation model (Ward et al., 2009) average dead livestock went from 18,924 to 20,206 and the maximum dead went from 163,881 to 179,556. This analysis did not include forgone income or indemnity payments since the initial costs resulted without the drastic changes that were expected. The total average losses, which included slaughter, disposal, disinfection, euthanasia, and surveillance, went from $572,678 to $734,837 for the trace dc 2 days outbreaks. The maximum losses for those outbreaks went from $3,671,621 to $4,011,409, a percentage increase of 9%. The total infected livestock and total economic losses stayed the same proximity and on average decreased for the trace dc 10 outbreaks with the sensitivity/specificity changes. The losses were expected to be vastly different since the ability to find the subsequent infected herds was negatively affected. The hypothesis was that the losses would have at least doubled since the ability to accurately find the infected herds was reduced by about 50%. The reasons this did not occur might have been due to a lack of understanding of how the tracing sensitivity/specificity worked in the model. Instead of using a parallel shift, more useful results might have come from decreasing the sensitivity but increasing the specificity percentage. This would make sense because if accurately finding infected herds would go down, then finding false positives (potential infected areas but animals not infected) would increase. Another reason is that the probability changes were used in conjunction with the saleyard runs that did not work well across the trace periods in the first place. Lastly, the model may not be able to perform the tracing sensitivity/specificity levels when performed outside the original days_til_dc parameters, 1 to 3 days. One thing that is noteworthy from this modest analysis: the model is not as sensitive to animal traceability as expected, especially when changing the tracing sensitivity and specificity variables.

CHAPTER VI

CONCLUSIONS

VI.1 Summary and Discussion

Large impact changes from the earliest trace period (trace dc 1 day) to the latest trace period (trace dc 10 days) were not consistently seen in the different simulated FMD outbreaks as performed by the High Plains modified AUSSPREAD model. Although the economic losses increased for the outbreaks initiated at the large beef operation, the increased impact was modest and trace periods 4, 6, 8 and 10 days were not examined. As mentioned, decreased traceability did not show expected productive results, with losses fluctuating for many of the trace periods for both the feedlot and saleyard outbreaks. Clearly, there was some benefit from the animal trace-back as losses from the first three trace periods (trace dc 1, 2 ,and 3 days) were less than the last trace periods (trace dc 6, 8, and 10 days) for average total dead livestock, average economic costs, and the average of maximum economic costs. For the feedlots, the average and average maximum economic losses of the first three trace periods were $83,429,277 and $203, 551, 042 respectively. The average dead livestock totaled 102,260 animals and the average maximum dead were approximately 227,508 animals. The number of dead livestock for the last three trace periods only increased to 105,455 for the average infected, but jumped more than 70,000 to a total 300,348 animals dead for the average maximum infected. The average total costs also did not increase much over the last three trace periods ($84,952,263), but, again, the average maximum costs increased nearly 26% to $256,417,409.

The different lengths of the subsequent tracing periods gave very peculiar results in the saleyard outbreaks. For the first three trace periods, the total average and average maximum economic losses were $15,262,436 and $120,601,765, respectively. Although minimal, these average costs increased nearly 12% for the average and average maximum to $17,069,804 and $137,779,478, respectively. For the first three trace period outbreaks, the number of infected livestock that were culled due to the current U.S. policy was 20,163 and 154,246 animals for the average and average maximum infected. The average number of dead livestock increased 6% to 21,543 animals and the maximum culled increase nearly 11% to 170,895 animals. It is clear that the number of culled animals in an outbreak will directly impact the total effect of the outbreak. This study has shown that decreased animal traceability can impact the number of infected animals and well-illustrates how devastating an outbreak can become.

Regardless of how insensitive the AUSSPREAD model was for animal tracing, the simulated results clearly demonstrated how costly outbreaks of FMD can be, regardless of the location of the index case. There are many possible justifications for why the model was not as sensitive as expected. The outbreaks that began at the feedlot did not reach losses greater than the range of losses described in the original High Plains Report. Although this is due to the exclusion of vaccination practices, it does seem odd that the largest days_til_dc accommodated in the original model was three days. However in this study, the largest interval for subsequent tracing was 10 days, and the outbreak losses still did not exceed the original range of costs. The effect of vaccination could not be determined, and negatively affected the comparison of the two studies. The model also seemed insensitive for animal traceability in the Texas High Plains. Thus, we were unable to determine the ability of tracing sensitivity and tracing specificity to impact the effects of an outbreak in a substantial way.

The small number of simulations used (50 and 100) may also have played a part in not achieving more practical results from AUSSPREAD. These simulation iterations were chosen because the average time taken to receive results from a one hundred iteration simulated outbreak ranged from 8 to 15 hours. The unexpected results could also been in connection with the herds chosen for the outbreaks. One of the other 11 herd types may have been impacted more by the animal tracing changes. The fluctuating results from the saleyard runs may have directly been affected by the parameters of buying and selling of the livestock. Traffic and the probability to buy and sell seemed pessimistic and may have influenced the outbreaks in a suppressive way. Many of the other scenarios could have made an impact on how well animal traceability worked. For example, late detection might have masked the initial disease spread, as well as the large percentage increases in costs and overall losses.

Other studies have suggested that the number of infected animals is one of the key factors to controlling an outbreak. It is difficult to compare the losses of this study to others since the applied costs/losses did not include trade losses, labor, or quarantine/welfare slaughter for all of the simulated outbreaks. The difference in losses and costs between the trace dc 2 days and trace 10 days outbreaks for the feedlot shows how effective traceability can be. The 8 days difference in subsequent animal tracing cost about $93 million dollars when comparing maximum possible costs between the two. The 8 days difference also resulted in an increase of more than 155,000 dead livestock when comparing the maximum culled livestock between the two outbreaks.

One of the key objectives of this study was to see if animal tracing could have an impact on the losses of a FMD outbreak. The goal was to present the changes in losses and to determine if the animal tracing could be economically effective. When comparing the benefits of animal tracing from our small subsequent tracing history (1 to 10 days) and the costs of the NAIS, animal tracing and identification can be supported and criticized under its current cost estimations. The USDA released a benefit cost analysis which estimated an effective NAIS would cost from 175.87 million (90% participation level) to 209.07 million annually (for 100% participation level) for the cattle sector, beef and dairy production (USDA, 2009a). Although these costs are significant, these implementation and maintenance "costs are less than one-half of a percent of the retail value of U.S. beef products" (USDA, 2009a). The USDA defines retrieval of traceback data within a 48 hour window as optimal for efficient, effective disease containment (USDA, 2008). As stated before, the difference in 2 days subsequent tracing and the largest tracing period examined in this study, 10 days, could amount to 93 million dollars lost in maximum potential costs. When considering welfare slaughter losses, the worst case scenarios show a total of 121,416,925 dollar difference. It is unlikely that if an outbreak occurs that these maximum costs would be realized, and although AUSSPREAD is intended to be a realistic model, "one is not dealing with reality; by definition, models just simplify the world" (Garner and Beckett, 2005). So even though some outbreak's (saleyard and large beef) average and maximum costs did not reach the levels of annual costs for the NAIS, the maximum losses from the feedlot show some benefits to implementing the system. The trace dc 10 day outbreak for the feedlot made some contributions and provided that an outbreak could cost near $585.98 million with the current study's costs ,and the 100% annual implementation costs for NAIS for all species would cost an estimated $228.27 million, a difference of approximately $357 million. Although this shows a significant benefit, it is unlikely that an outbreak would occur annually and the maximum losses would be attained, yet it does demonstrate a situation where it would be beneficial to have the NAIS. It is noteworthy to mention that this analysis includes direct costs of the outbreaks (euthanasia, slaughter, cleaning and disinfection, surveillance, disposal) and a few indirect costs (forgone income, indemnity payments and welfare slaughter losses), but does not include all possible indirect costs, induced costs (labor, loss of production, tourism, price changes, etc), and also losses from the restriction of export markets.

If all possible losses were realized and estimated, it is most likely that there would be a net benefit to have a NAIS. The trade losses from the value of beef exports (US $2.2 billion) alone may validate the NAIS for the beef and dairy industry. Yet, the possibility of an animal disease outbreak such as FMD annually in the U.S. is doubtful, so it will be unrealistic to see the benefits of NAIS with the USDA's current cost estimations to the average producer. This study presents how costly the direct costs and indirect costs of an FMD outbreak can be within the United States and how traceability can aid in minimizing those associated costs. The USDA's NAIS system will be costly to the average cattle producer ($5.97/per head), but can help producers in protecting their cattle from destruction in the event of an any animal disease outbreak, can aid in global competitiveness of their products, and reduce producer's from previous disease testing costs. One of the most significant aspects of NAIS is its ability to not only help respond to FMD outbreaks, but can help in all other animal diseases that could surface whether it be in cattle, swine, poultry, or etc. The costs of NAIS are high, but with more government aid, private industry involvement, and participation from U.S. producers, real costs when the NAIS is fully functional ought to be less than the cost analysis given by the USDA (USDA, 2009a).

VI.2 Conclusion

There are some drawbacks to using the High Plains /AUSSPREAD model as configured by Ward and Norby. The results showed that the variables, days till dangerous contacts are found (days_til_dc), and tracing sensitivity/specificity, may not be sensitive enough to show consistent and practical results when considering the relationship between outbreak length and total costs of an outbreak. However, AUSSPREAD's variables and abilities should not be invalidated; rather the assumptions may have to be re-thought. Another factor that could have influenced the current study's results was the AUSSPREAD variable, effectiveness of trace-back. The probability variable was set to 90%, which enabled the model to find all the trace-back animals at a 90% success rate regardless of how many days taken to find the subsequent infected animals. As shown in previous research by Pendell et al. (2006-2008), the success rate of finding subsequent infected animals directly affected the total costs of a FMD outbreak. If future traceability studies were examined with AUSSPREAD, the trace-back effectiveness rate should be considered when altering the parameters.

The feedlot traceability study did show that added traceability could account for near a hundred million dollars in direct costs from an outbreak and prevention of eradication for over a hundred and fifty-five thousand animals. The results did prove that decreasing animal tracing levels can negatively impact the costs of a FMD outbreak. Throughout this study, maximum costs and losses increased with the increase of subsequent tracing periods, yet the average costs either stayed in a similar range or increased marginally. This study presents the possibility of animal traceability reducing the risk of extreme disease outcomes. This risk reduction can be beneficial in the support of animal tracing and identification. If the worst case scenarios can be minimized, it will be more likely for the industry to rapidly recover from an animal disease outbreak.

It is important to realize that animal tracing can help in the process of responding and controlling an animal disease outbreak, and that such a system should be implemented. It is also imperative to realize that such a system is necessary to keep up with the global industry and to help in preserving animal disease security. Although rational, a tracing system capable of producing results shown in this study would be expensive. If and when the NAIS is fully implemented, the annual costs need to be as inexpensive to the producers as possible with added incentives, and also have the government consider it a public benefit and undertake a significant portion of the implementation and annual maintenance costs. In conclusion, longer tracing periods, larger simulations (by iteration), and further study of the model is necessary in order to more accurately imitate FMD outbreaks within the Texas High Plains and its detrimental effects.

REFERENCES

Bailey, D. 2004. “Benefits and Costs Associated with an Animal Identification System for Cattle in the United States.” Pub. No. WEMC FS#2, Western Extension Marketing Committee, Dept. of Econ., Coop. Ext. Ser., Utah State University, Logan, Utah.

Bailey, D., and J. Slade. 2004. “Factors Influencing Support for a National Animal Identification System for Cattle in the United States.” Selected paper presented at the American Agricultural Economics Association Annual Meetings. Denver, CO. August 1-4.

Bates, T.W., M.C. Thurmond, S.K. Hietala, K.S. Venkatesvaran, T.M. Wilson, B.W. Colston, Jr., J.E. Trebes, and F.P. Lianovich. 2003a. “Surveillance for Detection of Foot-and-Mouth Disease” [commentary]. *Journal of American Veterinary Medical Asso*ciation 223(9):609-614.

Bates, T.W., T.E. Carpenter., and M.C. Thurmond. 2003b. “Benefit-Cost Analysis of Vaccination and Preemptive Slaughter as a Means of Eradicating Foot-and-Mouth Disease.” *American Journal of Veterinary Research* 64(5):805-12.

Blasi, D.A., K.C. Dhuyvetter, M.F. Spire, M.P. Epp, and B.B. Barnhardt. 2003. “A Guide for Electronic Identification of Cattle.” Agriculture Experiment Station and Cooperative Extension Service. Kansas State University, Manhattan, Kansas.

Buhr, B. 2002. “Electronic Traceability in European and U.S. Meat Supply Chains.” Presentation at the National Pork Industry Forum, Denver, Colorado, February 28.

Disney, W.T., J.W. Green, K.W. Forsythe, J.F. Wiemers., and S. Weber. 2001. “Benefit-Cost Analysis of Animal Identification for Disease Prevention and Control.” *Scientific and Technical Review of the International Office of Epizootics* 20(2):385-405.

Ekboir, J.M. 1999. “Potential Impact of Foot and Mouth Disease in California.” Agricultural Issues Center, Division of Agricultural and Natural Resources, University of California Davis, Davis, California.

Ekboir, J.M., J.E. Berveijillo, and L.S. Jarvis. 2003. “Evaluating the Potential Impact of a Foot-and-Mouth Disease Outbreak.” In Frank H. Buck and Daniel A. Sumner, ed. *Exotic Pests and Diseases: Biology and Economics for Biosecurity*. Iowa: Wiley-Blackwell, pp.85-120.

Elbakidze, L. 2007. “Economic Benefits of Animal Tracing in the Cattle Production Sector.” *Journal of Agricultural and Resource Economics* 32(1):169-180.

Elbakidze, L., L. Highfield, B.A. McCarl, B. Norby, and M. Ward. 2008. “Economic Analysis of Mitigation Strategies for FMD Introduction in Highly Concentrated Animal Feeding Regions”. Selected paper at the Agricultural and Applied Economics Association Annual Meeting, Orlando, Florida, July 27-29.

Farm Foundation. 2004. “Food Traceability and Assurance: An Emerging Frontier Driving Developments in the Global Food System.” Farm Foundation’s Traceability and Assurance Panel Report, July.

Foster, H. 2008. “Cattle Identification: Status Report-NAIS.” Article from cattlenetwork.com. Available at http://www.cattlenetwork.com/Content.asp?ContentID=245465 (accessed September 2008)

Garner, M.G., and M.B. Lack. 1995. “An Evaluation of Alternative Control Strategies for Foot-and-Mouth Disease in Australia: A Regional Approach.” *Preventative Veterinary Medicine* 23(1):9-32.

Garner, M.G., and S.D. Beckett. 2005. “Modeling the Spread of Foot-and-Mouth Disease in Australia.” *Australian Veterinary Journal* 83(12):758-766.

Jensen, K., B.C. English, and J. Menard. 2003. “Projected Economic Impacts of a Foot and Mouth Disease (FMD) Outbreak in Tennessee”. AIM-AG Industry Brief, Available at http://aimag.ag.utk.edu/pubs/FMD.pdf (accessed December 2008)

Meuwissen, M.P.M., S.H. Horst, R.B.M. Huirne., and A.A. Dijkhuizen. 1999. “A Model to Estimate the Financial Consequences of Classical Swine Fever Outbreaks: Principles and Outcomes.” *Preventive Veterinary Medicine* 42(3):249-270.

National Cattlemen’s Beef Association (NCBA). *Foot and Mouth Disease: Information, News and Resources-Cattle Producer Information*. Available at http://www.fmdinfo.org/resources.aspx (accessed August 2008)

Pendell, D.L. 2006. “Value of Animal Traceability Systems in Managing a Foot-and-Mouth Disease Outbreak in Southwest Kansas.” Thesis Dissertation. Department of Agricultural Economics, Kansas State University.

Pendell, D.L. 2008. “Animal Diseases and Traceability”. Working Paper. Department of Agricultural and Resource Economics, Colorado State University. Available at http://www.cattlenetwork.com/Content.asp?ContentID=246957 (accessed November 2008)

Pendell, D.L., and T.C. Schroeder. 2007. “Value of Animal Traceability Systems in Managing a FMD Outbreak.” Final Report submitted to USDA-Economic Research Service. October. Available at http://www.naiber.com/Publications/NAIBER/Value.of.Animal.Traceability.Systems.pdf (accessed May 2009).

Pendell, D.L., J. Leatherman, T.C. Schroeder, and G.S. Alward. 2007. “The Economic Impacts of a Foot-and-Mouth Disease Outbreak: A Regional Analysis”, *Journal of Agricultural and Applied Economics*, 39(Special Issue October):19-33.

Pritchett, J., D. Thilmany, and K. Johnson. 2005. “Animal Disease Economic Impacts: A Survey of Literature and Typology of Research Approaches.” *International Food and Agribusiness Management Review* 8(1): 23-39.

Schoenbaum, M.A., and W.T. Disney. 2003. “Modeling Alternative Mitigation Strategies for a Hypothetical Outbreak of Foot-and-Mouth Disease in the United States.” *Preventative Veterinary Medicine* 58(1):25-52.

Sparks Companies, Inc. 2002. “Linking the Food Chain: Sharing Information and Verifying Sources, Materials and Processes across Traditional Boundaries.” Multi-client study. Memphis, TN, November.

United States Department of Agriculture, National Agricultural Statistics Service. 2003. *NASS 2002 Census of Agriculture.* Available at http://www.agcensus.usda.gov/Publications/2002/index.asp (accessed June 2009)

USDA, Animal and Plant Health Inspection Service. 2007. *National Animal Identification System (NAIS) – A User Guide and Additional Information Resources*. Version 2.0. December. Available at http://animalid.aphis.usda.gov/nais/naislibrary/documents/guidelines/NAIS-UserGuide.pdf (accessed December 2008)

USDA, Animal and Plant Health Inspection. 2008. *National Animal Identification System (NAIS). Animal Tracing: Take the First Step*. Available at http://www.aphis.usda.gov/publications/animal_health/content/printable_version/FAQ-AnimalID_Tracing_bw_rev08.indd.pdf (accessed October 2008)

USDA, Animal and Plant Health Inspection Service. 2009a. "Overview Report of the Benefit-Cost Analysis of the National Animal Identification System." Available at http://animalid.aphis.usda.gov/nais/naislibrary/documents/plans_reports/NAIS_overview_report.pdf (accessed May 2009)

USDA, Economic Research Service. 2009b. *U.S. Beef and Cattle Industry: Background Statistics and Information.* Available at http://www.ers.usda.gov/news/BSECoverage.htm (accessed June 2009).

Ward, M.P., L. Elbakidze, L.D. Highfield, S. Loneragan, B.A. McCarl, and B. Norby. 2007. "The High Plains Project". DRAFT. Texas A&M University, and Foreign Animal and Zoonotic Disease (FAZD) Center. September 30.

Ward, M.P., L.D. Highfield, P. Vongseng, M.G. Garner. 2009. Simulation of Foot-and-Mouth Disease Spread within an Integrated Livestock System in Texas, USA. *Preventive Veterinary Medicine* 88(4) 286−297.

Whiting, T.L. 2003. "Foreign Animal Disease Outbreaks, The Animal Welfare Implications for Canada: Risks Apparent from International Experience." *Canadian Veterinary Journal* 44(10): 805–815.

VITA

Name: John Christopher Looney

Address: Department of Agricultural Economics
Texas A&M University
2124 TAMU
College Station, TX 77843-2124

Email Address: looneyjc@gmail.com

Education: B.S. Agricultural Business and Animal Science, The University of Arkansas at Fayetteville, 2007

M.S. Agricultural Economics, Texas A&M University at College Station, 2009