MOVEMENT RESTRICTION IMPLICATIONS ON POTENTIAL WELFARE SLAUGHTER FOR TEXAS HIGH PLAINS FEEDLOTS

A Thesis

by

MONICA ESTER GALLI

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 2011

Major Subject: Agricultural Economics

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Approved by:

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ABSTRACT

Movement Restriction Implications on Potential Welfare Slaughter

For Texas High Plains Feedlots. (December 2011)

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Co-Chairs of Advisory Committee: Dr. Bruce A. McCarl
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Foot and mouth disease (FMD) is regarded as one of the greatest biological threats to the U.S. livestock industry because of its potential to cause catastrophic economic damages and massive livestock depopulation. Current U.S. contingency plans call for "stamping out" of FMD. An integral component of a "stamping out" policy is movement restrictions. The main purpose for movement restrictions is to stop the spread of disease, but they also disrupt the agribusiness sector. Welfare slaughter, the depopulation of healthy quarantined animals, is a possibility if movement restrictions are kept in place for prolonged periods of time. Many studies have analyzed the economic consequences of alternative mitigation strategies, but generally these studies have ignored the costs that might arise because of movement restrictions affecting uninfected premises located within the quarantine zone. Ultimately this study seeks to improve preparedness in the event of a FMD outbreak. It does this by developing information for those formulating plans on the costs associated with movement restrictions regarding quarantined, uninfected large feedlots located in the Texas High Plains Region.

To accomplish this objective two strategies were compared: an unrestricted feed strategy, where feed is allowed to be brought onto uninfected premises and finished cattle are sold; and a welfare slaughter strategy, where feed isn't allowed to be brought onto the uninfected premises so animals are depopulated. In addition, seasonal differences in total costs were examined. This study expanded on the High Plains Study conducted by M. Ward, L. Highfield, P. Vongseng, and M. Garner by using their epidemiological data combined with a cost accounting framework to estimate the total cost of each strategy. This study examined direct disease management costs (indemnity payments, feed costs, marketing costs, surveillance costs, cleaning and disinfecting costs, appraisal cost, euthanasia costs, and disposal costs). Overall, the unrestricted feed strategy was less expensive than the welfare slaughter strategy, costing on average $22.6 million compared to $48.5 million, respectively. Disease outbreak timing did impact the overall cost of both strategies. The results suggest the policy makers should strongly consider creating movement policies that address feed supply and finished cattle movement for uninfected large feedlots in prolonged quarantine zones; as such policies appear to reduce outbreak related costs for stakeholder and the U.S. government.

ACKNOWLEDGEMENTS

First, I would like to thank Dr. Amy Hagerman, without her guidance, support, and direction I would have never finished my research. Her encouragement and kind words helped me push myself to complete this thesis and I am very grateful to have had the chance to work with her.

I would also like to thank to my advisory committee chair, Dr. Bruce McCarl, for the opportunity to research under the USDA National Needs Fellowship. I feel very privileged to have worked under him. I chose the topic of my thesis under his direction and I now have expanded opportunities in my current career at USDA Animal and Plant Health Inspection Service because of my research topic.

In addition, I would like to thank my remaining committee members, Dr. David Bessler, Dr. David Anderson, and Dr. Bo Norby for their help and guidance with my research. Dr. David Anderson deserves a special thank you for helping me realize the practical relevance of my research and for his words encouragement.

Finally, I would like thank all the staff and faculty in the Agricultural Economics Departments for helping make my time there wonderful and memorable. They exemplify what it means to be part of the Aggie family.

NOMENCLATURE

APHIS	Animal and Plant Health Inspection Service
FMD	Foot and Mouth Disease
FAD	Foreign Animal Disease
FADD	Foreign Animal Disease Diagnostician
HSPD	Homeland Security Presidential Directive
ICS	Incident Command System
LLS	Light Lamb Scheme
LWDS	Livestock Welfare Disposal Scheme
NAADSM	North American Animal Disease Spread Model
NAIS	National Animal Identification System
NIMS	National Incident Management System
NRMT	National Response Management Team
NVS	National Veterinary Stockpile
OIE	World Organization for Animal Health
RRAP	Regional Resiliency Assessment Program
TAHC	Texas Animal Health Commission
THPR	Texas High Plains Region
USDA	United States Department of Agriculture
USNAHERC	United States National Animal Health Emergency Response Corps

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1. INTRODUCTION

A foot and mouth disease (FMD) outbreak can be economically devastating to a nation, having large impacts on trade, tourism, food security and safety, and the livestock industry (Gilpen et al. 2009; Hennessy 2008). In addition, terrorism may increase the likelihood of possible events (Elbakidze 2003; Pendell et al. 2007). Research has shown that intentional outbreaks could be more expensive and larger than unintentional outbreaks (Pendell et al. 2007). Whether a FMD outbreak is unintentional or the result of a deliberate introduction, it is important to develop control strategies that are scalable and economically practical regardless of the size or nature of the outbreak.

In the event of a FMD outbreak local, state, and federal officials will work in conjunction to eradicate FMD. Currently, the U.S. has a national "stamping out" or eradication policy for exotic, highly contagious, viral diseases (Whiting 2008). An integral part of a "stamping out" policy is movement restrictions combined with quarantine zones. The main purpose for movement restrictions and quarantine zones is to stop the spread of disease, but these actions also disrupt livestock production and other sectors in the region, including tourism, transportation, and agribusiness. Theoretically, no potentially contaminated vector material, object, or living being can enter or exit the quarantine zone without being decontaminated.

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

In past FMD outbreaks movement restrictions led to overcrowding, lack of feed, and lack of bedding for quarantined premises (Crispin et al. 2002; Laurence 2002; Dijkhuizen 1999). These conditions were not only inhumane for the affected livestock, but they also caused public outcry of concern for animal welfare. Producers also experienced negative psychological effects, such as stress and depression (Scott, Christie, and Midmore 2004). In order to prevent the furtherance of such adverse consequences of movement restrictions, welfare slaughter, the depopulation of animals not infected with a foreign animal disease (FAD), to prevent suffering, became the solution to the animal welfare issues.

During the 1997 outbreak of classical swine fever (CSF) in the Netherlands, 9.2 million hogs were slaughtered for welfare reasons (Burrell 2002). During the 2001 FMD outbreak in the U.K., which lasted from February to November, movement restriction and quarantine zones caused welfare slaughter, with approximately 2.05 million animals slaughtered for welfare slaughter reasons, plus an additional 525,000 lambs slaughtered because of loss of market access; a total of 2.58 million animals were depopulated by means of welfare slaughter in the 2001 U.K. FMD outbreak which accounted for approximately 38 percent of all depopulated animals (NAO 2002).

The United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) has developed contingency plans for certain FADs and premises types which outline the procedures that will be taken in the event of a disease outbreak. Welfare slaughter concerns is an area that could merit attention as movement restrictions and quarantine zones pose a threat to the health of the livestock industry, and development of contingency plans might facilitate continuity of business if a FMD outbreak occurs.

1.1 **Thesis Objectives**

The ultimate objective of this thesis is to improve preparedness in the event of a FAD outbreak, particularly a FMD virus outbreak. More specifically this project aims to add to the existing literature by analyzing the economic costs associated with animal welfare and movement restriction policies for uninfected quarantined large feedlots. To accomplish the objective, this study utilizes simulated data from a previous Texas High Plains study (Ward et al. 2009) and focuses on movement restrictions regarding uninfected large feedlots located within a quarantine zone in a case study outbreak. A FMD outbreak originating in that region could be particularly disastrous because of the size and scope of the cattle industry. In particular the region is dominated by cattle production and characterized by a large number of varying sized confined livestock feeding operations, otherwise known as feedlots.

The study will analyze the cost differences between two scenarios for uninfected, quarantined large feedlots in the Texas High Plains Region (THPR):

- an unrestricted feed situation and
- a welfare slaughter situation.

The unrestricted feed situation allows unrestricted feed delivery and marketing of finished cattle from uninfected premises, while the welfare slaughter situation minimizes movement and reduces risk by feeding cattle a subsistence ration, presumably using on-site feed ingredients, and euthanizing uninfected herds as on-site feed no longer is available.

1.2 **Motivation**

The terrorist attacks of September 11th, 2001 highlighted the need for multiagency response plans that deal with terrorism and emergency situations. Homeland Security Presidential Directive 7 (HSPD-7) (2003) and HSPD-9 (2004) both highlighted that the infrastructure supporting the U.S. agriculture industry is vulnerable to terrorist attacks. In the event of a terrorist attack or other disaster, the continued operation of the agriculture industry is vital to the country's survival.

HSPD-9 (2004) recognized that the pre-harvest livestock industry is vulnerable to FAD because of the scale of livestock production, international trade and travel, and bioterrorism (Western Institute for Food Safety and Security 2009). FMD is considered to be the most contagious disease in cloven-hoofed livestock and, as such, it is the greatest FAD threat faced by U.S. livestock producers (USDA, APHIS 2007a). The fact that FMD is highly contagious and its introduction could cripple many U.S. high value and high output livestock operations also makes it an appealing bioterrorism agent.

The U.S. livestock industry is highly specialized. Livestock rarely live out their entire lives on one premises. For example, it is standard practice in the cattle industry to send feeder cattle from cow-calf operations to stocker operations then on to feedlots (USDA, ERS 2009). Cattle may be moved three or even four times in their life from birth to slaughter. A study of two concentrated feeding areas in Texas and Kansas found that 80 percent of all feeder cattle are shipped into the area from more than 200 miles away (Shields and Mathews 2003; Bailey, Brorsen, and Thomsen 1995). In addition, the trend in some aspects of livestock production is toward larger, more concentrated facilities; 80-90 percent of all marketed beef cattle are finished in feedlots with at least 1,000 head of cattle (USDA, ERS 2009). Although it is important to note that many cow calf herds remain small with the average herd having 40 head, hence movement is an integral part of the system (USDA, ERS 2009). Calves from smaller cow calf herds are routinely sold to increasingly larger operations throughout the finishing stages, so movement is an integral part of the beef cattle industry. One study showed that on average meat travels 994 miles from farm to fork (Cupp, Walker, and Hillison 2004).

2. OVERVIEW OF TEXAS HIGH PLAINS REGION, FMD, PAST OUTBREAKS, AND CURRENT USDA POLICIES

2.1 **Cattle Industry**

The cattle industry is a highly segmented industry, with producers usually specializing in a single stage of production. The four main segments of the cattle industry are cow-calf, stocker, feedlots, and packers. Typically, each segment sells to the next in line. Cow-calf producers raise calves to weaning, typically until calves are six or seven months old and around 600 pounds. Stocker operations purchase weaned calves and feed them, usually on pasture, for further weight gain. Feedlots purchase calves or stocker calves and finish them for harvest. Packers purchase the finished cattle from feedlots and process the cattle into wholesale cuts of beef, which then continue down the marketing stream. The cattle industry is similar to a funnel, a lot of producers are involved in raising cow calf herds and their calves supply a smaller number of stocker operations or an even more concentrated number of feedlots and packers.

This study specifically examines the quarantine costs for large uninfected feedlots. In this study large feedlots are considered to be feedlots with more than 5,000 head. Feedlots are confined livestock feeding operations, where cattle are fed a corn based diet before reaching their desired harvest weight. Movement of inputs and outputs plays an integral role for feedlots. The day to day operations of feedlots require the large scale movement of feed, veterinary care, calves, stocker cattle, finished cattle, and human workers among other items. Feedlots are able to produce a large volume of high value cattle because as soon as finished cattle are marketed new stocker cattle and calves take their place.

Seasonality, regular patterns and variations occurring within a year, strongly affect the cattle industry. Seasonality is often driven by biological factors and climate, which result in supply fluctuations throughout the year. For example, seasonality in cattle sales and movements are created mainly because the climatic seasons greatly influence the timing of calf weaning and stocker cattle production (Peel and Meyer 2002). Seasonal prices greatly impact how feedlot producers run their feedlot and maximize profit. Feedlot populations have a seasonal pattern. This study accounts for the affects of seasonal feedlot populations and feed costs and market value of cattle when examining the overall costs for quarantined large uninfected feedlots.

2.2 **Texas High Plains Region**

This study is specific to the THPR. The THPR refers to an eight county area (20,570 sq. km) located in the Texas Panhandle. The eight counties encompassed by the THPR are Bailey, Castro, Deaf Smith, Hale, Lamb, Parmer, Randall, and Swisher counties. The region is dominated by cattle production and characterized by a large number of varying sized feedlots. High-density livestock production is especially common in the region, with an estimated 1.8 million cattle on feed (Ward et al. 2009). Other FMD susceptible livestock species raised in the region include dairy cattle, sheep, swine, and goats.

2.3 FMD Virus Background

FMD is considered to be the most contagious disease in livestock and, as such, it is the greatest FAD threat U.S. livestock producers face (USDA, APHIS 2007a). FMD is an economically significant disease which carries major international trade limitations (Kitching, et al. 2007). The most recent FMD outbreak in the United States occurred in 1929, although FMD outbreaks occur regularly around the world. According to the World Organization for Animal Health (OIE) (2011a), the intergovernmental organization responsible for improving animal health globally, 10 countries were experiencing disease events as of August 2011(Figure 1). The majority of the countries experiencing disease events were located in Southern Africa, where FMD is considered endemic within the water buffalo population. In fact, FMD is considered to be endemic in most of Asia and Africa (Kitching et al. 2007).

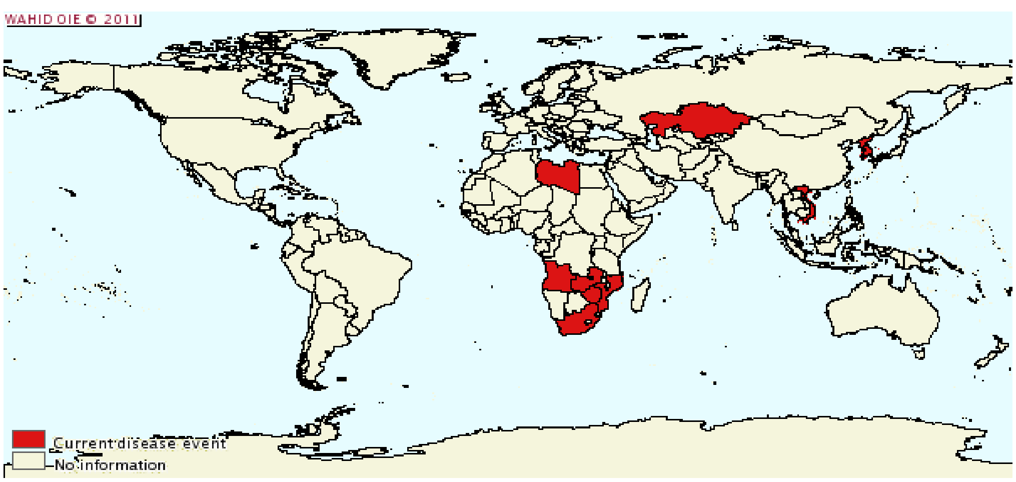

Figure 1. Current FMD Events as of August 2011
(OIE WAHID Interface Disease Distribution Maps 2009)

The OIE classifies countries based on their FMD status. There are two ways a country or region without FMD can be classified; “FMD free where vaccination is not practiced” and “FMD free where vaccination is practiced” (OIE 2011b). In countries classified as “FMD free where vaccination is practiced”, FMD is endemic in populations of cloven-hoofed animals and has the potential to spread; these countries vaccinate against FMD to prevent the spread of the disease and minimize production losses. Countries can also be regionalized into FMD free zones without or with vaccination practiced. Countries and zones with the designation “FMD free where vaccination is not practiced” have the most lenient requirements for international trade of animals and animal products imposed by the OIE (USDA, APHIS 2008). Countries or zones with the status “FMD free where vaccination is practiced” often face trade bans and restrictions that cripple their international market for live animals and meat exports (Junker, Komorowska, and Tongeren 2009). As of May 2011, the U.S. and 64 other countries were officially classified as free from FMD without vaccination (OIE 2011a). When outbreaks occur, nations usually try and regain the status “FMD free where vaccination is not practiced” as quickly as possible; this will be discussed in more detail later on in section 2.11.1 Stamping Out and Trade Implications.

The FMD virus is a highly contagious, vesicular disease affecting all cloven-hoofed animals, including bovine, bison, swine, sheep, goats, and deer. As reported by USDA APHIS, the threat posed by a FMD outbreak is not due to the mortality rate the disease poses; most adult animals survive infection and the young animal death rate is approximately 50% (USDA, APHIS 2007b). Rather, it is the almost 100% morbidity rate, reduced meat and milk productivity, and trade implications that make the disease so dangerous to U.S. livestock producers (Hagerman 2009).

There are seven serotypes of FMD: O, A, C, SAT 1, SAT 2, SAT 3 and Asia 1; plus more than 60 sub-serotypes (USDA, APHIS 2007b). Serotype O is the most common and was responsible for the pan-Asia epidemic, which began in 1990 (Center for Food Security and Public Health 2007). In general, only one serotype is present during a specific FMD outbreak, but in cases where more than serotype is infecting animals eradication becomes more difficult because immunity against one serotype does not provide cross-protection against the others, so if vaccination is used to slow the spread of disease then doses of each serotype vaccination would be needed (Center for Food Security and Public Health 2007). For example, in 2005 serotype A outbreaks appeared and escalated in Iran and locally produced vaccines provided no protection against that serotype; as a result, serotype A outbreaks spread to Turkey and 2.5 million doses of emergency vaccine were provided by the European Union vaccine bank (FAO 2007). Once an animal is infected, the FMD virus can be spread through any secretion, excretion, or tissue, including the animal's breath, milk, semen, saliva, urine, feces or blood. Infected animals shed the disease for days or weeks and even after recovery can become carriers of the virus (USDA, APHIS 2007b). Cattle can typically shed the disease for 8 to 11 days (Center for Food Security and Public Health 2007). Hogs shed the greatest amount of virus, but cattle appear to have the greatest morbidity (Ekboir 1999).

Direct contact is not the only way the disease can spread. Anything that comes in contact with the infected animal can become a carrier, including trucks, feed, clothes, non-susceptible species, and other fomites[1]. The FMD virus is not considered zoonotic because of the mildness and rarity of human infection. The disease rarely infects humans, and even then it causes only mild symptoms (Bickett-Weddle et al. 2004). A person can carry the disease in their nose and lungs for up to 48 hours (Musser 2004) and could potentially spread the disease to any susceptible animal they come in contact with during that time period. Under the right conditions, the disease can also become windborne. Cattle are more susceptible to the airborne virus compared to other livestock (Ekboir 1999).

Cattle that are infected with FMD undergo at least three distinct disease transition phases: latent, sub-clinically infectious, and a clinically infectious stage. The latent stage is estimated to last an average of 3.7 days; during this stage the virus is not detectable and the animal is not shedding the virus (Thurmond and Perez 2006). During the sub-clinically infectious stage, the animal begins to shed the virus, but does not yet exhibit clinical signs of the disease. During the clinically infectious stage, the animal continues to shed the disease and starts to exhibit clinical signs of the disease, which

[1] Fomites are inanimate objects capable of carrying and spreading infectious disease.

include blisters in and around the mouth and feet, lameness, and excess salivation (USDA, APHIS 2007a). It is important to note that the signs of FMD can vary in severity across animal species and FMD serotypes; in addition, symptoms of certain benign health problems mimic those of FMD. For example, during the 2001 U.K. FMD outbreak, sheep were misdiagnosed because they were foraging on brambles and gorse (Crisipin et al. 2002). While visual symptoms of FMD are a good indication of infection, the only way to definitively diagnose FMD is through laboratory testing.

2.4 **Welfare Slaughter Issues**

In past FMD outbreaks in the United Kingdom (U.K.) and classical swine fever (CSF) outbreaks the Netherlands, movement restrictions led to overcrowding, lack of feed, and lack of bedding for quarantined premises (Crispin et al. 2002; Laurence 2002; Dijkhuizen 1999). These conditions were not only inhumane for the affected livestock, but they also caused public outcry of concern for animal welfare. Producers also experienced negative psychological effects, such as stress and depression (Scott, Christie, and Midmore 2004). Because quarantine zones and movement restrictions were kept in place to minimize the risk of disease spread, welfare slaughter became the solution to the animal welfare issues. Welfare slaughter is the depopulation of healthy animals due to inhumane conditions or the potential for inhumane conditions caused by the disease eradication efforts, such as, quarantine zones and movement restrictions. In past outbreaks, animals killed under welfare slaughter were treated the same as diseased and disease exposed animals as far as depopulation, carcass disposal, and indemnity payments. Welfare slaughter programs have been expensive and competed for the resources needed for disease eradication efforts (Whiting 2008; Mangen, Nielen, and Burrell 2002).

2.4.1 2001 United Kingdom FMD Outbreak

During the 2001 FMD outbreak in the U.K., which lasted from February to November, movement restriction and quarantine zones caused hardship for producers. After the initial detection of the disease and halt of all movement, a permit system was set up to allow restricted movement for uninfected animals. The government did not provide sufficient resources and, as a result, the permitting system was slow, bureaucratic, and inflexible (Crispin et al. 2002; Laurence 2002). For example, producers were sometimes denied the opportunity to move livestock from an overgrazed pasture to a neighboring field with more available feed resources (FAWC 2002).

Due to animal welfare issues, mainly lack of feed, government officials introduced the Livestock Welfare Disposal Scheme (LWDS) on March 22, 2001. Under the LWDS, the U.K. government culled uninfected livestock and indemnified livestock producers. Although the LWDS was a voluntary program, many livestock producers subscribed, as the program offered generous compensation for culled animals. In many instances, the indemnity payments offered by the program were higher than market values for livestock; thus, the LWDS was susceptible to fraud and misuse and became very expensive to maintain. Over time, the U.K. government reduced indemnity payments and began allowing additional movement within the control zone to reduce the costs of the program (FAWC 2002; NAO 2002).

In addition to the LWDS, the U.K. government introduced and funded the Light Lamb Scheme (LLS) from September 3, 2001 until late October 2001. The LLS was developed for producers who couldn't find a market for their lambs as a result of export bans or in-country movement restrictions. The scheme was designed to help producers recoup funds and alleviate animal welfare problems before they began.

The total FMD outbreak cost to the U.K. national treasury was £2.7 billion (approximately \$3.97 billion U.S. dollars), which included £471 million (approximately \$696 million U.S. dollars) paid to producers for the compensation of livestock destroyed due to animal welfare reasons, about 18 percent of the total cost (Davies 2002). Approximately 2.05 million animals were slaughtered under the LWDS, plus an additional 525,000 lambs were slaughtered under the LLS during the FMD epidemic (NAO 2002). Table 1 summarizes the reasons, numbers, and types of livestock slaughtered during the U.K. 2001 FMD epidemic.

Table 1. Livestock Slaughter Amounts for the 2001 U.K. FMD Outbreak

	Sheep		Cattle		Pig	
	Number of Head	Percentage of Total Sheep Slaughtered	Number of Head	Percentage of Total Cattle Slaughtered	Number of Head	Percentage of Total Pigs Slaughtered
Slaughtered For:						
Disease Purposes	3.4 million	61.5%	590,000	77.7%	145,000	33.6%
Livestock Welfare Disposal Scheme	1.6 million	29.0%	169,000	22.3%	287,000	66.4%
Light Lamb Scheme	525,000	9.5%				
Total Slaughtered	5.525 million		759,000		432,000	
(Crispin, Roger, O'Hare, and Binn 2002)						

The welfare slaughter schemes competed with the FMD eradication strategies for human resources, especially for slaughtering and disposal activities (Whiting 2008; Mangen, Nielen, and Burrell 2002). The Farm Animal Welfare Council (2002), an expert committee on animal welfare in the U.K., recommended that in the event of future outbreaks, more attention and funding should be given to "welfare vouchers", which could be used by producers to purchase the feed and other supplies necessary to finish uninfected animals, instead of focusing only on slaughter and disposal strategies.

2.4.2 1997 Netherlands Classical Swine Fever Outbreak

During the 1997 outbreak of classical swine fever (CSF) in the Netherlands, 9.2 million hogs were slaughtered for welfare reasons (Burrell 2002). The main reason for welfare slaughter in the Netherlands was overcrowding (Mangen, Nielen, and Burrell 2003; Burrell 2002). Hog farming is divided into three main stages in the Netherlands: breeding, multiplication, and fatting. Each stage is usually carried out on a different premises; consequently, live animal movement is vital to production. In addition, producers often do not have the facilities necessary to house animals past certain production stages. Within a few weeks of the movement restrictions being enforced, overcrowding occurred on most hog farms (Mangen, Nielen, and Burrell 2003). Overcrowding is problematic because it can cause stress, cannibalism, fighting, and even structural problems for pen floors because overweight animals can cause the floor to break (Mangen, Nielen, and Burrell 2003). In 1997, the government of the Netherlands developed and implemented a program where hogs from overcrowded farms where bought, slaughtered, and rendered. Saatkamp, Berentsen, and Horst (2000) found that approximately 45 percent of total eradication costs in past CSF outbreaks in the Netherlands and Belgium were associated with welfare slaughter. An insemination ban was also issued to prevent the spread of the disease. The European Union later stated that insemination bans should not be repeated because it disrupted the piglet market in 1998 when large-scale synchronized insemination of sows at the end of the ban flooded the market (Mangen, Nielen, and Burrell 2003).

2.4.3 Lesson from Past Outbreaks

Both FAD outbreaks illustrate the animal welfare problems that may arise on uninfected premises due to movement restrictions. In both cases, it became necessary for the government to establish programs to help producers deal with movement restrictions and quarantine zones. The expensive cost and large number of animals slaughtered under the welfare slaughter schemes also raised questions about the ethical nature of the programs. In the U.K. and the Netherlands, for example, welfare slaughter animals were not marketed for human consumption. Both FMD and CSF are considered non-zoonotic. Welfare slaughter animals are not infected or directly in contact with infected animals, meaning animals could have been harvested for consumption or other uses. The U.S. could face similar challenges concerning animal welfare during an outbreak. Past outbreaks illustrate why it is important to understand, plan and prepare for these potential challenges.

2.5 **The Threat of FMD**

According to Texas State Veterinarian Dr. Dee Ellis, "In today's world where people travel and trade so much internationally, we need to remember that the introduction of FMD to Texas livestock is an ongoing threat" (TAHC 2011). The intentional release on FMD is a real threat. For example, in February 2011, Brian Roach, a 64 year old South African man was arrested for threatening to release FMD virus in the U.S. and Britain (Guardian.co.uk 2011). Many experts argue that maintaining a "stamping out" policy increases the threat of an intentional FMD outbreak because with minimum effort terrorist could cause substantial economic and psychological havoc (DeOtte Jr. 2007; DeOtte and DeOtte 2010). Research has shown that intentional outbreaks could be more expensive and larger than unintentional outbreaks (Pendell et al. 2007). Political instability, public fear, and significant economic damages are three consequences that could result from an intentional animal disease outbreak (Jin, McCarl, Elbakidze 2009). Since the terrorist attacks of September 11, 2001 Texas has increased its a priori planning for intentional and unintentional outbreaks of FMD (DeOtte 2007). For example, Operation Palo Duro (Giovachino et al. 2007) was a multiagency table-top exercise that examined how an outbreak of FMD would be responded to in the Texas High Plains. In addition, the Department of Homeland Security also commissioned a Regional Resiliency Assessment Program (RRAP) Systems Recovery Analysis (Miller 2010) to identify gaps in existing emergency plans and to identify ideas that will strengthen the preparedness of the Texas cattle feeding industry in the event of a FMD outbreak.

The results from Operation Palo Duro (Giovachino et al. 2007) and the RRAP Systems Recovery Analysis (Miller, 2010) provide a justification for studying quarantine implications for uninfected premises, specifically the idea of marketing cattle from these premises. The “need to identify ways to minimize losses to producers and incentivize producers so they are willing to feed animals for slaughter in the affected zone” was an outcome idea identified during the RRAP Systems Recovery Analysis (Miller 2010) because of resource availability.

2.6 Potential Welfare Slaughter in the Event of an U.S. FMD Outbreak

Exploring the implications of harvesting and marketing potential welfare slaughter livestock is an area of interest for emergency planners. Having contingency plans that minimize animal welfare issues that arise under movement restitutions is critical for the U.S. because it could help lower the overall cost and minimize the number of animals slaughtered. The U.S. livestock industry is vulnerable to the same welfare problems that arose in the U.K. and the Netherlands. In fact, DeOtte and DeOtte (2010) highlighted the need to consider alternatives to mass depopulation and carcass disposal during an infectious disease outbreak because euthanizing and disposing of a large number of animals isn't feasible.

Livestock production in the THPR is susceptible to the same conditions that created animal welfare issues during the disease outbreaks in the U.K. and the Netherlands. Depending on the time of year and weather conditions, feed and water shortages for livestock in the THPR are a possibility. Movement restrictions would put many operations at risk for feed shortages, especially feedlots, and possibly necessitate welfare slaughter. Limited on-farm storage capacity and reliance on deliveries of inputs are two factors that will require planning to minimize negative animal welfare effects under movement restrictions.

The U.S. livestock industry, particularly production in the THPR, relies heavily on concentrated large-scale animal feeding operations, otherwise known as feedlots. This means that moving feed onto uninfected feedlots is very time sensitive. Large feedlots generally maintain approximately three to five days worth of feed on hand (Ward et al. 2009). Luckily, the existing structure of the U.S. livestock industry has developed an infrastructure with the capability to deliver feed anywhere in the country within a matter of days, meaning that welfare slaughter in affected areas could be avoided with proper planning and policies (Cleveland 2010).

In the event of an FMD outbreak, overcrowding isn't projected to be a major issue in the THPR because the majority of livestock are cattle housed on feedlots. The growth rate of cattle is slower than hogs and feedlot pens allow for more leeway in weight gain before overcrowding becomes an issue. Overcrowding could become an issue for swine operations located within the THPR, because all pork-processing facilities are located out-of-state. Also there may be issues with dairy calf raising operations, stocker operations and animals in transit at time of quarantine imposition. In order for THPR producers to process hogs, USDA would have to develop a permitting process for interstate movement of hogs to areas outside of the quarantine zone.

This research will assume that, based on previous litigation (Yancey v. United States), in the event of a FMD outbreak, the U.S. government would essentially "become the market" and an authorized "taking" of healthy, un-infected animals would proceed because movement restrictions would cause producers to lose access to markets. The ruling of this case is based on the Fifth Amendment, which states that individuals must be compensated when the government assumes ownership of property for the public good. The logic is that by performing “takings”, the government will be better able to ensure animal welfare standards and maintain movement restrictions, while still providing compensation to livestock producers for culled animals.

2.7 U.S. FMD Prevention Policies and Programs

Currently, resources are employed to prevent the introduction of FMD into the U.S. Strict trade policies ensure that possible contaminated materials aren’t imported from infected countries. For example, regions of Argentina, Brazil, and Columbia either are not permitted to export meat products or are only permitted to export canned beef products to the U.S. (USDA, Food Safety and Inspection Service 2011). The magnitude of international trade restrictions have been shown to have implications on the disease eradication method chosen (Paarlberg, Lee and Seitzinger 2002). Because of negative trade consequences, many countries will take a more aggressive approach to eradicate disease. In addition, people returning from visiting infected countries are questioned by customs agents and precautions like shoe baths are taken if they have visited a farm or have been in contact with livestock while abroad (USDA, APHIS 2003). USDA APHIS also works in conjunction with governmental agencies in countries experiencing FMD outbreaks. USDA APHIS provides monetary and resource support to help countries regain and maintain FMD-free status (USDA, APHIS 2003). During the 2001 U.K. FMD outbreak, American veterinarians assisted in the surveillance, diagnosing, testing, and euthanasia of livestock (Cleveland 2010).

2.8 Ex Ante Spending on Planning, Preparedness, and Response

Ex ante governmental spending on planning, preparedness, and response capabilities for emergencies increased after the terrorist attacks of September 11, 2001. The Bioterrorism Act of 2002, 2002 Farm Bill, HSPD-7, and HSPD-9 all provided funding and legislation which allowed for ex ante spending to protect U.S. agriculture (Gilpen et al. 2009). As a result, USDA APHIS has expanded over the past decade, adding new programs to address emergency management and FMD outbreaks.

USDA APHIS and many state agencies have contingency plans that outline certain procedures and chains of command during an FMD outbreak. Most of these plans are based on highly uncertain information, making constant revision and critiquing necessary to refine policies and programs. In addition, USDA APHIS is currently working on updating the Foreign Animal Disease Preparedness and Response Plan, the last version was released in 2003. Leaders in the THPR have recognized the need to modify and adapt the existing Texas State plan, *Foreign and Emerging Animal Disease Response Plan* (2004), to realistically deal with the needs of the THPR in a FMD outbreak (DeOtte 2007). In February 2007 the Texas Animal Health Commission (TAHC) and USDA APHIS jointly held a table-top exercise, known as Operation Palo Duro, to facilitate multiagency training in a hypothetical unintentional FMD outbreak exercise. Operation Palo Duro highlighted the fact that there are many logistical issues associated with a “stamping out” policy and specifics on how to deal with different possible scenarios are still unaddressed in this region.

To bolster national response capabilities the USDA APHIS developed the National Response Management Team (NRMT) which is a group of individuals who are considered specialists in incident management and have the ability to provided leadership in the event of an agricultural emergency. The NRMT also facilitated the USDA APHIS incorporation into the National Incident Management System (NIMS) and Incident Command System (ICS), which are multiagency systems that allow for the flexibility to contract and expand response actions depending on the emergency. The goal of ex ante spending directed towards FMD is to allow for quicker response which ideally will lead to decreased spread and quicker eradication. The NIMS and ICS may be beneficial for uninfected premises by expediting the permitting process for quarantine zones.

An assessment of U.S. agricultural vulnerabilities emphasizes the fact that, in the event of an FMD outbreak, agricultural veterinary personnel would be limited. The U.S. National Animal Health Emergency Response Corps (USNAHERC), was created in 2001, and is a roster of agricultural veterinary professional volunteers who can be mobilized quickly by USDA APHIS. Per Diem (food and lodging costs) and travel costs are paid for by USDA APHIS (Hennessy 2008). The USNAHERC will be available to help with surveillance, diagnosis, and testing on uninfected premises. Having the USNAHER established and funded is a good foundation in ensuring resources during times of emergency.

The National Veterinary Stockpile (NVS) was developed under the HSPD-9 to coordinate and provided veterinary resources (supplies, equipment, field tests, vaccines, and support staff) to states experiencing animal disease outbreaks which have exhausted the state's resources. The NVS became operational in 2006 and is designed to be able to deploy countermeasures to states within 24 hours. The NVS has resources strategically located and works in conjunction with states on designing the logistics of emergency response plans. For example, the NVS has personal protective equipment stocked and ready for deployment and contracts in place with suppliers.

Animal tracing capabilities are an important component in getting ahead of disease spread. USDA APHIS tried to launch the National Animal Identification System (NAIS) to address animal tracing capabilities in the event of a disease outbreak. NAIS was designed with the long term goal of identifying all direct contact herds and premises within 48 hours of disease diagnosis (USDA, APHIS 2010a). NAIS was very controversial and the majority of industry stakeholders were strongly opposed to NAIS, citing increased costs and too much government intervention. As a result of lobbying, NAIS went from being mandatory to voluntary. NAIS was largely seen as unsuccessful, with over $120 million invested and only 36 percent participation (USDA, APHIS 2010a). In February 2010 USDA APHIS closed the NAIS program and has begun the initial steps for implementing the new Animal Disease Traceability (ADT) program. ADT is designed to be state and tribal run mandatory programs and will only focus on premises that transport animals interstate (USDA, APHIS 2010a).

2.9 **Transport Plans for Uninfected Premises**

Continuity of business is important for business survival. Allowing safe movement of certain agricultural commodities, products, and services in and out of a control area is necessary for business survival and animal welfare. Many agricultural industries operate on a "just-in-time" basis. For example, dairies and commercial egg production relay on daily transport of inputs and outputs. Commonly, commercial egg production facilities have maximum storage capacity limited to the number of eggs that can be produced in a 48 hours time period (Trampel et al. 2009). To help facilitate movement during animal disease movement restrictions and quarantine zones USDA APHIS has begun to develop transport plans for movement of products from premises located within control areas. The goals of these plans are to ensure business continuity, protect export markets, and to minimize the chance of disease spread though movement. Similar plans need to be developed for livestock producers, especially in areas with highly concentrated animal production. This research aims to provide the economic justification for developing such plans.

2.9.1 FAST Egg Plan

The overall goal of the FAST Egg Plan is to facilitate business continuity and economic survival of participating uninfected premises, plus ensure the egg and egg product supply for consumers (Trampel et al. 2009). The FAST Eggs Plan is a voluntary plan developed for commercial table egg producers. It was created by USDA APHIS and Iowa State faculty and designed to allow for movement of eggs and egg products from uninfected premises within a high pathogen avian influenza control area. The FAST Egg Plan is based on five main components that incorporate biosecurity, testing requirements, and permits. Once a premises is registered, premises data will be stored in a state's databases and will be accessible to authorized individuals only. When an outbreak occurs quarantine boundaries and disease spread information is updated in real-time. It is the responsibility of the producer to release their premises-specific information within the system in order to request permits for movement. Ex Ante investment in plans and systems such as this will benefit both producers and consumers.

2.9.2 Secure Milk Supply

USDA APHIS has also begun work on creating a transportation plan for dairies called the Secure Milk Supply (SMS) Plan in the event of a FMD outbreak. USDA APHIS recognizes that "just-in-time" supply practices on dairies could result in significant milk disposal and animal welfare issues during times of movement restrictions. Dairies are dependent on milk tankers to haul their milk to processing plants and they have limited storage capacity. Most dairy operations have enough storage capacity for the amount of milk produced during a 48 hour time period; but some have a more limited storage capacity limited to the production from a 24 hour time period (USDA, APHIS 2010b). The overall goal of the SMS Plan is to develop accepted practices that can form a FAST plan for movement of milk and dairy products from dairies and milk processing facilities located within a FMD control area in order to ensure continuity of business and the availability of milk and dairy products for consumers. The SMS Plan is in its infancy, currently, working groups have formed to collect information and develop process and procedures that all stakeholders can agree are feasible and will facilitate safe movement of milk without increasing the risk of FMD spread or impairing the ability to export US agricultural products.

2.10 **Initial Response**

In the early stages of an outbreak, before laboratory test confirmation, the initial responding agency would be the state and local officials. In the case of an FMD outbreak in the THPR the TAHC would be first responder. A foreign animal disease diagnostician (FADD) will immediately be deployed to the suspected infected premises to collect epidemiological samples and review records. Based on expert opinion, clinical signs, and history the FADD will classify the likelihood of infection as "unlikely," "possible," or "highly likely" until lab test results are able to prove or disprove the presence of the FMD virus (USDA, APHIS 2008). When a suspect case of FMD occurs in the THPR epidemiological samples would be shipped to the USDA APHIS Plum Island Research Facility.

Before receiving the test results, which usually occurs within a 24 hour time period but could take as long as 48 hours, the FADD will use their best judgment to establish temporary quarantine zones. After receiving a confirmed positive test result, an initial minimum 48-hour ban on the movement of all susceptible livestock and related industries will be enforced, most likely on the entire Southwestern U.S. Region (Cleveland 2010).

The size of the movement ban will be established by USDA APHIS and can vary in size depending on a number of factors; such as number of infected animals detected, how long the animals have been located on the premises, the origins of infected animals, and even weather conditions. It is estimated that the initial stop movement ban will last 48 hours, but it may be enforced for a longer period of time. The initial strict movement ban has multiple purposes and will be enforced until those purposes are accomplished. The top priority is to research the infected premises and animals in order to estimate the amount of direct and indirect contact and the scope of the outbreak. The initial movement ban may also allow enough time for other infected animals to express clinical signs and be identified as well as time for the movement of resources into the infected region to execute the eradication plan. Finally, the initial complete movement ban allows officials and scientists to set what they deem appropriate quarantine zones and movement restrictions. Overall, the initial movement ban allows for multiagency response coordination and planning that is based on scientific studies, expert opinion, local geographical knowledge, and ex ante preparation. APHIS would join the TAHC in setting up a unified command post, where people representing all jurisdiction would collectively work together to stop the spread of FMD. As stated earlier, USDA APHIS FMD guidelines call for a “stamping out” policy and a series of response zones and movement restrictions in order to eradicate and contain an FMD outbreak once a positive test result is received.

During the Operation Palo Duro Exercise (2007) stakeholders brought up the concern of livestock in transit during the announcement of the initial movement ban. In that exercise it was assumed that animals in transit to slaughter facilities would be allowed to be delivered and slaughtered pending veterinary examination at a processing facility. Livestock not in transit to slaughter but to another stage of production would either be euthanized and rendered or returned to where transit originated from. Livestock in transit during the initial movement ban is unaddressed in the current USDA APHIS FMD guidelines.

2.11 **Stamping Out**

Eradicating FMD would be the overall goal of any initial FMD control program. The aggressive eradication policy of a "stamping out" policy is preferred because FMD is highly contagious and "stamping out" has proven to be the most timely and epidemiologically effective way for eradicating FMD (Hagerman 2009). According to the OIE, the globally recognized animal health organization, stamping-out means:

> carrying out under the authority of the Veterinary Administration, on confirmation of a disease, the killing of the animals which are affected and those suspected of being affected in the herd and, where appropriate, those in other herds which have been exposed to infection by direct animal to animal contact,

> or by indirect contact of a kind likely to cause the transmission of the causal pathogen. All susceptible animals, vaccinated or unvaccinated, on an infected premises should be killed and their carcasses destroyed by burning or burial, or by any other method which will eliminate the spread of infection through the carcasses or products of the animals killed (USDA 2005, page 6).

Diagnosing, zoning, movement restrictions, euthanasia, disposal, and cleaning and disinfection are essential parts of a successful "stamping out" program. Dangerous indirect contact is contact of an animal with a person, feedstuff, vehicle, or other fomite that has been on an infected premises shortly before the outbreak was discovered or after the discovery. A downfall of a "stamping out" policy is the scope of welfare slaughter; in past outbreaks, welfare slaughter compared to the cost of controlling the disease on infected premises has been one half to ten times the cost (Whiting 2008; Bourn 2002; Dijkhuizen 1999; Saatkamp, Berentsen, and Horst 2000). This is mainly because movement restrictions along with limited resources on hand have caused feed shortages on uninfected premises in the past.

2.11.1 Stamping Out Policy and Trade Implications

One important attribute of implementing a "stamping out" control program is that the OIE recognizes it as the response policy that allows for the fastest return to the disease classification of "FMD-free where vaccination is not practiced." There are negative trade implications that would impact the agribusiness industry if the OIE disease classification were changed. Countries with the designation "FMD-free where vaccination is not practiced" have the most lenient requirements for international trade of animals and animal products imposed by the OIE (USDA, APHIS 2008). The earliest a country can return to the classification of "FMD-free where vaccination is not practiced" under the OIE standards is three months after the last occurrence of the virus; by establishing early zoning, using a stamping out policy, and enforcing movement restrictions and quarantine zones (USDA, APHIS 2008). Countries where the disease is not considered endemic usually turn to "stamping out" as the primary method of eradication to protect international trade markets (Rich, Miller, and Winter-Nelson 2005). In countries like Uruguay, where the disease is considered endemic, vaccination is the primary control strategy practiced in the affected areas (OIE 2009).

Establishing early zoning and enforcing movement restrictions is important because it can minimize the severity of international trade restrictions by allowing for compartmentalization and zoning of a country (OIE 2009). OIE committees can approve the status of FMD free zones and compartments within a FMD infected country; thereby regionalizing the global trade implications to the infected areas (Garner, Fisher, and Murray 2002). Paarlberg, Lee, and Seitzinger (2002) concluded that regionalizing an outbreak and maintaining FMD-free export markets would be critical to minimizing the adverse economic effects of a FMD out-break in the U.S. If an outbreak occurred in the THPR, regionalization of the outbreak may be able to protect export markets for livestock producers located in other regions of the U.S. Although, it is hard to predict how other countries would react to a FMD outbreak since reactions are often politically driven.

2.12 **Zoning, Movement Restrictions, and Premises Designation**

Premises designation, proximity to the infected herd, and contact rates of the infected herds are some of the factors that dictate the size of response zones and movement restrictions put in place. Response zones combined with movement restrictions and premises designation work to eradicate and stop the spread of FMD (Hagerman and McCarl 2009). Federal response zones will ultimately be established by APHIS, but collaboration is needed with state and local officials to set understandable and enforceable quarantines (Giovachino et al. 2007). Quarantine zones are theoretically designed as circular zones from the point of infection, but in reality they should be established using geographical markers which are easily identifiable and understood. Therefore, local knowledge is critical when deciding quarantine zone barriers (Giovachino et al. 2007).

The three types of response zones USDA APHIS uses are: the control area, the surveillance zone, and the free zone. The control area consists of the infected zone, which has a minimum designated size of 6.2 miles around each infected premises, and the buffer-surveillance zone, which has no minimum size. In this study the infected zone is considered the quarantine zone. Depending of the scope and duration of a FMD outbreak, the USDA may try and regionalize the free zone and submit it to be recognized by the OIE as “FMD free zone without vaccination in a FMD infected country”. Table 2 summarizes the response zones and purpose of each zone.

Table 2. Response Zones Defined by the USDA APHIS

Zone	Size	Purpose
Control Area	Entire state, tribal nation, or territory at minimum	All animal movement will be stopped until the scope of the outbreak can be determined.
Infected Zone	6.2 miles around each infected premises	This will be the area of concentrated stamping out of the disease. Within this area all movement of animals and carries will be completely halted except by special permit.
Buffer-Surveillance Zone	No minimum size	Surveillance of all susceptible animals with a minimum of 2 inspections every 14 days until the disease is eradicated. Movement is allowable using permits.
Surveillance Zone	Minimum size is 6.2 miles beyond the perimeter of the control area	Surveillance of high risk herds with movement allowable using permits
Free Zone	Surrounds the surveillance zone and extends to the boundaries of the U.S.	Surveillance continues according to standard animal health code practices.
(USDA, APHIS 2007b)		

Premises designations are used to describe premises located within the control area. During a FMD outbreak APHIS uses four main premises designations: infected, contact, suspect, and at risk. Table 3 describes the premises designations as defined by USDA APHIS. This study only examines movement restriction and animal welfare issues for suspect premises located within the infected zone.

Table 3. Premises Designations Defined by the USDA APHIS

Premises Type	Status	Action
Infected	The FMD virus has been identified or is presumed to exist.	All infected premises are located within the infected zone. An individual level quarantine is imposed on each infected premises and all susceptible animals are euthanized and disposed of.
Contact	Premises has been exposed either directly or indirectly to FMD carriers.	All contact premises must be inside the control area. All susceptible animals are euthanized and disposed of except in special exceptions. Animals exempted from slaughter are placed under intensive surveillance for not less than 28 days.
Suspect	Premises with susceptible animals located in any response zone, but not classified as infected or contact.	Premises are placed under quarantine and intensive surveillance for not less than 28 days, past three inspections every 14 days, and possibly additional surveillance after removal from the surveillance zone to the free zone.
At Risk	Premises in the buffer surveillance zone with susceptible animals, but no clinical sign are present.	Movement is allowed within the buffer zone, but not into the free zone. Non-susceptible animals may move in and out of the free zone with a permit.
(USDA, APHIS 2007b)		

2.13 **FMD Response Policy Considerations**

Quarantine zones and movement restrictions have the potential to cause welfare slaughter. Over the past decade, FMD outbreak policies concerning movement restrictions have led to the necessity of welfare slaughter (Garner, Fisher, and Murray 2007). Animals that have to be euthanized and disposed of for welfare slaughter reasons require the same resources needed to execute the disease eradication goals. DeOtte Jr. and DeOtte III (2010) call for reexamining and finding alternatives to massive depopulation and carcass disposal because of resource availability. Minimizing depopulation and carcass disposal in areas where livestock production is highly concentrated is an important issue because as the number of livestock that needs to be euthanized and disposed of increases, the feasibility of completing those tasks according to the time specified in emergency plans decreases and the overall cost of the outbreak increases. DeOtte Jr. and DeOtte III (2010) propose that limited depopulation be explored as an alternative mitigation strategy to “stamping out”. Limited depopulation allows large numbers of exposed animals that are not exhibiting clinical signs of disease to continue towards harvest. The authors acknowledge the there would be a loss in economic value for the harvested cattle and an increased cost for additional surveillance requirements, but that the protein value remains unchanged and the animals would be going to their “highest and best available good” (DeOtte and DeOtte 2010). Garner, Fisher, and Murray (2002) also suggest that research be conducted in the area of modified movement restrictions, such as, movement being allowed directly to abattoirs in order to minimize conditions that warrant welfare slaughter.

3. LITERATURE REVIEW

Of the World Animal Health Organizations' Listed Diseases, the most extensively researched disease is FMD. The disease can spread quickly and become endemic if aggressive measures aren't taken. Much of the research has used Monte Carlo simulation methods to model FMD spread and analyze alternative mitigation tactics to identify the most effective and economical control tactics. Previous studies have paid little attention to the effects on uninfected premises located within the quarantine zone of an outbreak, even though previous outbreaks have illustrated that uninfected quarantined premises face many challenges. The possibility of an FMD outbreak is real, especially with the threat of bioterrorism.

3.1 **Prior Studies of FMD**

There have been many studies that focus on foot-and-mouth disease implications. Most studies and publications use epidemiological models linked with economic framework to explore the affects of simulated FMD outbreaks. Trade impacts, sector impacts, producer and consumer welfare, and mitigation strategies are commonly investigated using the linked framework. While most studies incorporate quarantine zones, the direct linkage between the economic framework and quarantine implications for uninfected premises is lacking.

Conrad (2004) used a commodity production cycle model to analyze the impacts of a widespread, large-scale FMD outbreak in both the beef and dairy industries in the US.

The model allowed for positive and negative feedback between the corn, beef, and dairy sectors. Those three sectors account for approximately 40 percent of cash receipts for U.S. agricultural products. The scenario examined a stamping out policy combined with export market losses of one or two years. The cattle population was decreased by 10 percent to illustrate the potential impact of the existing stamping out policy. To model the loss of export markets, demand was decreased by 10 percent since exports account for approximately 10 percent of beef sales; it was assumed that domestic demand is only affected by changes in price. Beef and dairy populations, prices, and sales were simulated over a 30 year horizon. The results were unexpected and showed that the two year export ban provided the beef sector more stability in price and population compared to the one year export ban. This suggests the aggressive actions to restore the export markets after a FMD outbreak may be counterproductive for the beef sector. The author suggested that low cost preventative measures to protect cow and calf operations should be implemented along with quarantines and destruction of herds because protecting cow and calf operations helped stabilize beef prices, sales, and populations, as well as, corn prices and sales to feedlots.

Hagerman and McCarl (2009) used the Davis Animal Disease Simulation (DADS) model combined with cost calculations to analyze the costs associated with varying control strategies and movement restriction for a simulated FMD outbreak in California. The study focused on the direct costs of disease mitigation based on varying movement restriction policies. The control strategies considered varied detections times combined with a no vaccination and vaccinations strategies. A total of 16 control strategy scenarios combined 7, 10, 14, 21, or 22 day detection times from initial infection with vaccination policies of no vaccination, 10 km ring vaccination, and 20 km ring vaccination. To obtain a distribution of the potential outcomes for the control strategies the DADS model was simulated 100 times for each control strategy using a random large dairy (more than 2,000 head) as the index herd. Each epidemic trial was considered statistically independent in the economic model. Three distinct movement policies that specifically applied to dairy operations were considered in the economic framework. The first policy, "lockdown," represented a complete movement ban on feed trucks and milk tankers. The second movement policy, "dumping only," represented a situation where feed trucks were allowed movement into and out of the response zone at an increased cost; although, movement of milk tankers wasn't allow, therefore milk had to be dumped and indemnified. The third policy, "business as usual," represents a situation where normal business was allowed to continue, but at an increased cost of cleaning and disinfecting. The cost categories accounted for were indemnity payments for animals and milk, forgone income, slaughter, cleaning and disinfecting, surveillance, vaccination, and additional feed costs.

The "dumping only" and "business as usual" policies, which allowed feed to be trucked into a response zone, were preferred to the "lockdown" policy, which did not allow for feed to be brought in. In addition, generalized stochastic dominance showed that risk neutral and risk adverse decision makers slightly preferred the "dumping only" policy to the “business as usual” movement policy. The study concluded that movement restriction policies that allow feed to be brought onto a premises in the control area is less expensive than movement restriction policies that don’t allow for feed to be brought in (Hagerman and McCarl 2009). Across all three movement restriction policies early detection (7 days) combined with no vaccination produced the lowest median control cost per head. The additional cost of feed plus cleaning and disinfecting feed trucks is far less than the cost of additional indemnity payments and forgone income. This research will use similar cost calculation framework to analyze movement restrictions in the THPR for large feedlots.

Pendell, Leatherman, Schroeder, and Alward (2007) examined the economic impacts associated with a simulated FMD outbreak in Southwest Kansas using the North American Animal Disease Spread Model (NAADSM) combined with economic models. The research focused on the regional economic implications under varying introduction scenarios. NAADSM is a spatial state-transition simulation model developed by USDA APHIS. Partial equilibrium analysis and input-output approaches were used to build the economic framework that evaluated welfare changes and regional impacts. The region of study was chosen because, similar to the THPR, Southwest Kansas is characterized by a high concentration of large confined cattle feeding operations. A stamping out control method was simulated 1,000 times for each scenario in the epidemiological NAADSM. The expected values obtained from the NAADSM were then entered into the economic framework. The introduction scenarios considered were introduction on a single cow-calf herd, introduction on a single medium sized feedlot (10,000-30,000 head capacity), and introduction simultaneously on five large feedlots (more than 40,000 head capacity). The last scenario, where FMD was introduced simultaneously on five large feedlots, was used to illustrate the impacts of what an intentional introduction could cause. The probability of the outbreak being large is much greater in the simultaneous introduction scenario compared to the single introduction scenarios.

In the scenario where FMD was introduced in a single cow-calf herd the average number of destroyed livestock was approximately 126,000 head and the disease outbreak lasted 29 days. Total producer surplus for the beef industry decreased by $43.2 million. In addition, the total economic impact for the region was approximately $32.1 million. In the scenario where FMD was introduced in a single medium feedlot the average number of destroyed livestock was approximately 407,000 head and the disease outbreak lasted 39 days. Total producer surplus for the beef industry decreased by $166.5 million. The total economic impact for the region was approximately $193 million for introduction in a single medium feedlot. In the scenario where FMD was introduced simultaneously into five large feedlots the average number of destroyed livestock was approximately 1.68 million head and the disease outbreak lasted 89 days. Total producer surplus for the beef industry decreased by $728.5 million. In addition, the total economic impact for the region was approximately $940 million. The average economic damage for the simultaneous introduction scenarios is exponentially greater than the other two introduction scenarios on smaller singular premises. The authors concluded that disease surveillance, management investment, and management strategies need to be a main focus in regions with large concentrated cattle feeding operations. The results of Pendell, Leatherman, Schroeder, and Alward (2007) provide justification for looking at management strategies for uninfected premises in the THPR, because as modeled movement restrictions may be enforced for long periods of time.

Another study estimated the producer costs associated with a quarantine affecting a commercial feedlot located in Southwest Kansas (Stroade and Schroder 2007). The main cost categories computed were additional feed cost, opportunity cost, and forgone future profit. The main problem associated with quarantines investigated by this study was the inability to market the fed cattle at the desired time because of movement restrictions, which prohibited the movement of cattle off the premises. A discount rate of eight percent was assumed for the opportunity cost and forgone profit calculations. The main focus was on producer costs. This study ignored reduced yield-grade and heavy-weight discounts. It also ignored the potential for loss of customers and other added costs associated with movement restriction that could arise. Therefore, the results were considered to be a conservative estimate of the cost associated with movement restrictions. Additional feed cost was the largest cost category each week of quarantine. The total quarantine cost was approximately $10,275 for the first week of quarantine for a 40,000 head feedlot that marketed 1,900 head per week. The cost increased exponentially as the quarantine continued because new cattle reached optimum marketing each week. The total quarantine cost grows to $197,853 for a quarantine lasting five weeks and to $921,562 for a quarantine lasting ten weeks (Stroade and Schroder 2007). This study illustrated the potential financial risk commercial feedlots face because of quarantines and movement restrictions.

Ward, Highfield, Vongseng, and Garner (2009) adapted the AUSSPREAD model (Garner and Beckett 2005; Beckett and Garner 2007) to fit the THPR specifications. The considered infection pathways parameters were direct contact, indirect contact, spread through sale barns, and windborne spread. Contact and spread probabilities were estimated from survey data and local industry opinion. In total thirteen herd types were identified as susceptible to an FMD outbreak, five of those herd types were feedlots. The five types of feedlots identified were i) company feedlot- herd of ≥50,000 head, ii) stockholder feedlot- herd of ≥20,000 to <50,000 head, iii) custom feedlot- herd of ≥5,000 to <20,000 head, iv) backgrounder feedlot, and v) yearling-pasture feedlot; the last two types of feedlots were not classified based on capacity information but their mean herd sizes were 6,171 and 2,453 head, respectively. Four different types of single-site introduction index herds were studied in the epidemiological model: company feedlot backgrounder feedlot, large grazing herd (more than 100 head), and a backyard herd (less than 10 head). AUSSPREAD was used to simulate the spread of the disease under the four index herd types combined with 16 various control strategy combinations. The control strategies varied detection time, vaccination strategy, vaccination availability, and surveillance levels. The index herd type and mitigation strategy employed were the two main factors associated with the predicted outbreak length and the number of herds depopulated. Epidemics initiated in company feedlots had median lengths of 25-52 days, but had a range up to 188 days. The average number of herds that had to be depopulated ranged from 4-101 for epidemics initiated in company feedlots (Ward et al. 2009). This research will utilize the epidemiological data from four specific scenarios to quantify the number and size of uninfected feedlots located within the quarantine zone.

Elbakidze et al. (2009) linked the AUSSPREAD model (as described in Ward, Highfield, Vongseng, and Garner (2009)) with an economic costing module to evaluate mitigation strategies of FMD in the THPR under various introduction scenarios. In order to evaluate strategy desirability based on risk preferences, stochastic dominance-based breakeven risk aversion coefficient analysis was used. The two reported outbreak costs calculated by the economic costing module were losses incurred within the cattle industry and the cost of the disease eradication strategy. Losses incurred by the cattle industry were calculated by summing the gross lost value of animals plus forgone income due to temporary business inactivity caused by not being allowed to restock, which was assumed to be at least 60 days after cleaning and disinfection took place. Disease eradication strategies were based on the costs associated with vaccination, surveillance, slaughter, appraisal, euthanasia, carcass disposal, cleaning and disinfection, and quarantine implementation. It was assumed that vaccinated livestock lost 50 percent of their value. Quarantine costs were only accounted for in herds with more than 50 head. The economic model assumed quarantine of all herds in the “neighborhood” of infected premises plus all direct and indirect contact premises. Quarantine costs were dependent on number of herds under quarantine, daily disinfection cost per head, loss per day per animal type, and number of days that the herd was under movement restrictions. Quarantines costs were not directly discussed in the results or conclusion of the study, but were calculated under the assumed cost of $50, $75, and $100 per head per day and were based on small (less than 100 head), medium (100 to 500 head), and large (more than 500 head) herd sizes, respectively.

The results showed that total costs potential of FMD originating in a large feedlot was approximately $1 billion. Introduction under the three alternative index herd types yielded smaller total costs potentials that ranged from $600 to $800 million. Early detection generally provided the greatest cost saving of any eradication strategy considered in the study. In addition the economic cost differences between early and late detection were significantly different at the 99 percent level of confidence for all introduction scenarios, with early detection resulting in significantly lower costs. Early vaccination vs. delayed vaccination was also significantly different across all introduction scenarios at the 99 percent level of confidence, resulting in significantly higher total economic costs for all premises types. All dominate strategies incorporated slaughter of infected herds, slaughter of dangerous contact herds, and early detection. Eradication strategies that combined enhanced surveillance with slaughter of infected herds, slaughter of dangerous contact herds, and early detection were dominate across all values of RAC for backyard introduction scenarios. The above strategy also dominated large feedlot introduction when the RAC is between 0.01-0.099, introduction into backgrounder feedlots when the RAC is less than -0.099, and introduction into large grazing operations when the RAC is more than 0.13. The eradication strategy of regular surveillance combined with slaughter of infected herds, slaughter of dangerous contact herds, and early detection was dominate in large feedlot introductions when the RAC is less than 0.01 or greater then 0.099, backgrounder feedlot introductions when the RAC is greater than -0.099, and in large grazing operation inductions when the RAC is less than 0.13. My research will use a similar costing framework to explore movement policies that incorporate continuity of business practices during an outbreak, such as, allowing the movement of livestock to slaughter from uninfected premises.

3.2 **Summary**

The previous literature concerning FMD has mainly focused on control and mitigation strategies for infected premises; little attention has been paid to the affect on uninfected premises. With the exception of the quarantine assumptions in the High Plains Project (Elbakidze et al. 2009), all previous studies focusing on the implications of FMD outbreaks in the THPR have ignored welfare slaughter and how movement restrictions will affect quarantined uninfected premises. In addition, none of the previous literature on FMD has addressed how the timing of an outbreak will affect the costs associated with movement restrictions.

4. METHODOLOGY

This project will focus on and study how welfare strategies for uninfected large feedlots affect FMD outbreak costs for a case study in the Texas High Plains. It expands previous work completed in the High Plains Project (Elbakidze et al. 2009; Ward et al. 2009) by applying the quarantine and herd results for quarantined uninfected large feedlots coupled with a costing framework that compares a feed provision strategy to a welfare slaughter strategy. Linked epidemic-economic models, such as the models used in this study, are commonly used to examine FMD impacts and mitigation strategies (Elbakidze et al. 2009; Hagerman 2009). The stochastic epidemic results are often used as statistically independent trials in the economic model; this gives the economic results a range and distribution. This research is unique in that it adds a seasonal component to the costing framework in order to highlight the differences in cost between outbreak initiation months.

4.1 **Epidemiological Model**

The High Plains Project (Elbakidze et al. 2009; Ward et al. 2009) used the simulated epidemic model AUSSPREAD to estimate the spread of a FMD outbreak in the THPR. Through extensive data collection concerning contact rates and premises spatial distribution, the AUSSPREAD model was calibrated to estimated disease spread and status for susceptible premises types in the THPR. Thirteen susceptible herd types were identified in the THPR (Table 4). This study only focuses on feedlots; the types of feedlots considered are company feedlots, stockholder feedlots, and custom feedlots.

Since these feedlots are the larger of the operation types shown in Table 4, I will refer to these three types of feedlots collectively as "large feedlots" throughout the paper. These feedlots are assumed to have similar production practices, cost structures, and movement requirements. AUSSPREAD is a stochastic state transition model where herds are classified as susceptible, latent, infected, or recovered. The High Plains Project (Ward et al. 2009) examined 64 scenarios (Table 5) that varied index herd type, disease detection time, disease control methods, and surveillance levels. This project used the results from four of the 64 scenarios as input variables in the costing framework.

Table 4. Susceptible Herd Types by Number of Herds and Mean Herd Size

Herd Type	Number of Herds	Mean Herd Size	Herd Size Parameters
Company Feedlot	5	69,600	≥ 50,000 Head
Stockholder Feedlot	32	33,159	≥ 20,000 and < 50,000 Head
Custom Feedlot	25	11,360	≥5,000 and <20,000 Head
Backgrounder Feedlot	7	6,171	Not Specified
Yearling-pasture Feedlot	22	2,453	<5,000 Head
Dairy-calf Raiser	1	8,000	8,000 Head
Small Beef	6,403	30	≥1,000 Head
Large Beef	754	260	<1,000 Head
Small Dairy	14	636	<1,000 Head
Large Dairy	62	5,578	≥1,000 Head
Backyard	2,435	4	≤10 Head
Small Ruminant	913	14	N/A
Swine	2	2,915	N/A

(Ward et al. 2009)

Table 5. Scenarios from the Texas High Plains Project

Strategy	Index Herd			
	Company Owned Feedlot	Backgrounder	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

* Direct contact herds
(Ward et al. 2009)

4.1.1 Scenarios

The four scenarios examined in this project were scenario 17, scenario 21, scenario 37, and scenario 53 (Table 5). Additional scenarios were not included in order to reduce the number of confounding factors in the analysis. In all four scenarios the index herd, the herd in which FMD was initially confirmed, was a company owned feedlot. Early detection, late detection, regular surveillance, and enhanced surveillance were mitigation tactics that varied across the four scenarios examined.

In the AUSSPREAD model early detection was defined as the discovery of FMD seven days post-infection in the index herd, whereas, late detection was defined as, discovering FMD 14 days post-infection in the index herd. Surveillance visits were prioritized by user-defined categorization; for regular surveillance scenarios, suspect premises were visited twice per week during a 30 day period, with visits discontinuing if the premises hadn't been visited within 10 days. Enhanced surveillance assumed that suspect premises were visited four times per week during a 30-day period, with visits ceasing if the premises hadn't been visited in the previous 20 days. In each case, if the premises had five consecutive surveillance visits in which no disease is detected, surveillance is discontinued. In addition, if a herd is found to be infected at any surveillance visit, the surveillance is discontinued and depopulation, disinfection and disposal procedures are initiated.

Scenario 17 combined early detection with enhanced surveillance, while scenario 21 combined late detection with enhanced surveillance. Scenario 37 combined early detection with regular surveillance, and scenario 53, combined late detection with regular surveillance. The four scenarios were simulated 100 times by the AUSSPREAD model and the stochastic epidemiological outputs for the number of head, days under quarantine, and number of surveillance visits at the end of the outbreak were used as input variables in the costing framework.

4.2 **Economic Model**

Seasonality, the regular patterns and variations occurring within a year, is common throughout most sectors of the agriculture industry. Seasonality is often driven by biological factors and climate, which result in systematic supply fluctuations throughout the year. For example, seasonality in cattle sales and movements are created mainly because the climatic seasons greatly influence the timing of calf weaning and stocker cattle production (Peel and Meyer 2002). Consumer demand for beef also has a seasonal component; demand increases during the spring and summer months when consumers tend to barbeque (Hirsch and Person 2010).

Seasonality and price are two main factors that affect feedlot managers' decisions regarding cattle placement levels. Throughout the year the number of head and the mixture of heavy and lightweight cattle in the herd[2] fluctuate on feedlots to meet supply and demand factors. In order to capture the seasonal effects a monthly feedlot cattle weight mixture was created.

4.2.1 Monthly Feedlot Cattle Weight Mixture

The monthly feedlot cattle weight mixture shows the percentage of steers and heifers by weight category for any given month for large feedlots in the THPR. It was developed based on marketing data collected by Gerry Kuhl from Kansas State University. The marketing data provided monthly averages for marketed steers and heifers from 22 Kansas feedlots. Monthly averages for the number of marketings, final weight, days on feed, average daily gain, and the feed to grain ration on a dry basis from January 1997-October 2010 were used to build the monthly feedlot cattle weight mixture (Table 6).

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[2] For simplification, I will use the term "herd" to refer to the collective cattle on the feedlot at any given time, including placements, cattle on feed but not yet ready for market, and marketed cattle.

Table 6. Monthly Kansas Feedlot Data Used to Create the Monthly Texas Feedlot Cattle Weight Mixture

Marketing Month	Calculated Incoming Weight (Pounds)	DOF (Days)	ADG (Pounds)	Final Weight (Pounds)	Feed/Gain (Dry Basis) (Pounds)
Steer					
January	789	145	3.411	1285	6.24
February	777	149	3.278	1266	6.34
March	758	156	3.161	1251	6.34
April	726	163	3.048	1222	6.25
May	726	163	3.144	1239	6.04
June	740	156	3.369	1266	5.84
July	765	151	3.479	1289	5.87
August	784	149	3.511	1306	5.93
September	813	140	3.566	1312	5.92
October	800	142	3.575	1309	5.94
November	807	138	3.580	1301	6.05
December	802	141	3.569	1305	6.09
Heifer					
Marketing Month	**Calculated Incoming Weight (Pounds)**	**DOF (Days)**	**ADG (Pounds)**	**Final Weight (Pounds)**	**Feed/Gain (Dry Basis) (Pounds)**
January	722	146	3.136	1178	6.41
February	716	148	3.040	1164	6.45
March	699	155	2.908	1149	6.53
April	669	162	2.783	1120	6.47
May	670	162	2.823	1126	6.34
June	677	158	2.967	1144	6.14
July	690	155	3.030	1160	6.20
August	710	150	3.061	1170	6.23
September	728	144	3.124	1178	6.21
October	724	145	3.146	1180	6.23
November	724	141	3.212	1177	6.21
December	720	142	3.208	1176	6.25

DOF: Days on Feed
ADG: Average Daily Gain

When developing the monthly feedlot cattle weight mixture it was assumed that feedlots operated at full capacity throughout the year. Thus, a 5,000 head capacity feedlot will always have 5,000 head on site; what varies throughout the year is the cattle weight mixture across the herd. In addition, it was assumed that Kansas feedlots' monthly feedlot cattle weight mixture was similar to Texas High Plains feedlots' monthly feedlot cattle weight mixture because the two locations have similar climates and production practices. However the regions are not identical, and based upon expert advice, adjustments were made in the steer to heifer ratio in order to fit Texas production more closely. This adjustment was made using the average Texas quarterly cattle on feed percentages (1997 to 2010) for steers and heifers.

One item needed herein is a livestock age distribution by month. The Kansas feedlot data was manipulated to obtain average placement date for steers and heifers by subtracting the average days on feed from the marketing date, which was assumed to be the first of each month. Incoming weights were obtained by subtracting the weight gained from the final live weight. Using the placement date, incoming weight, and average daily gain information, the lifespan of steers and heifers were tracked by weight class across months. The number of head in each weight class per month was summed and divided by the total number of same-sex head; for example the number of heifers in the weight category 700-749 pounds in June was divided by the total number of heifers in June. Tables 7-8 show the proportion of steers and heifers by weight category for each month for Kansas feedlots.

Table 7. Kansas Steer Mixture by Month and Weight Class

Feeding Month	650-699 Pounds	700-749 Pounds	750-799 Pounds	800-849 Pounds	850-899 Pounds	900-949 Pounds	950-999 Pounds
January	0%	0%	20%	0%	20%	0%	17%
February	0%	0%	0%	0%	24%	0%	23%
March	0%	0%	0%	0%	20%	0%	22%
April	0%	0%	0%	0%	16%	0%	20%
May	0%	0%	0%	0%	15%	0%	17%
June	0%	0%	0%	0%	13%	0%	17%
July	0%	0%	0%	0%	19%	0%	15%
August	0%	0%	0%	0%	20%	0%	20%
September	0%	0%	18%	0%	17%	0%	17%
October	0%	0%	19%	0%	18%	0%	17%
November	0%	0%	20%	0%	18%	0%	17%
December	0%	0%	22%	0%	18%	16%	0%
Feeding Month	**1000-1049 Pounds**	**1050-1099 Pounds**	**1100-1149 Pounds**	**1150-1199 Pounds**	**1200-1249 Pounds**	**1250-1299 Pounds**	**1300-1349 Pounds**
January	15%	0%	0%	14%	0%	14%	0%
February	19%	0%	17%	0%	16%	1%	0%
March	0%	22%	18%	0%	16%	1%	0%
April	0%	23%	0%	22%	19%	0%	0%
May	0%	21%	0%	23%	1%	23%	0%
June	0%	19%	0%	24%	0%	27%	0%
July	0%	18%	0%	22%	0%	0%	26%
August	0%	16%	0%	20%	0%	0%	24%
September	0%	17%	0%	13%	0%	0%	17%
October	0%	16%	0%	17%	0%	13%	1%
November	0%	16%	0%	15%	0%	0%	16%
December	0%	15%	0%	14%	0%	14%	0%

Table 8. Kansas Heifer Mixture by Month and Weight Class

Feeding Month	650-699 Pounds	700-749 Pounds	750-799 Pounds	800-849 Pounds	850-899 Pounds	900-949 Pounds	950-999 Pounds
January	0%	17%	18%	0%	15%	0%	16%
February	0%	0%	21%	0%	22%	0%	18%
March	0%	0%	22%	0%	20%	0%	21%
April	0%	0%	18%	0%	22%	0%	20%
May	0%	0%	18%	0%	18%	0%	22%
June	0%	0%	16%	0%	19%	0%	19%
July	0%	0%	21%	0%	16%	0%	19%
August	0%	0%	22%	0%	21%	0%	16%
September	0%	17%	17%	0%	18%	0%	18%
October	16%	0%	17%	0%	17%	0%	18%
November	15%	0%	16%	0%	17%	0%	16%
December	18%	0%	15%	0%	16%	0%	16%
Feeding Month	**1000-1049 Pounds**	**1050-1099 Pounds**	**1100-1149 Pounds**	**1150-1199 Pounds**	**1200-1249 Pounds**	**1250-1299 Pounds**	**1300-1349 Pounds**
January	0%	17%	0%	17%	0%	0%	0%
February	19%	0%	20%	1%	0%	0%	0%
March	18%	0%	18%	0%	0%	0%	0%
April	0%	21%	18%	0%	0%	0%	0%
May	0%	20%	22%	0%	0%	0%	0%
June	0%	24%	0%	21%	0%	0%	0%
July	0%	19%	0%	25%	0%	0%	0%
August	0%	20%	0%	20%	0%	0%	0%
September	0%	13%	0%	17%	0%	0%	0%
October	0%	18%	0%	14%	0%	0%	0%
November	0%	18%	0%	18%	0%	0%	0%
December	0%	16%	0%	18%	0%	0%	0%

Table 9. Average Quarterly Texas Cattle on Feed Percentages by Sex (2007-2010)

	Heifer	Steer
January 1 -March 31	39%	61%
April 1- June 30	39%	61%
July 1- September 30	41%	59%
October 1- December 31	40%	60%

Average quarterly Texas steer and heifer cattle on feed percentages (Table 9) from 1997 to 2010 were multiplied with the proportion of steers and heifers by weight class and month for Kansas feedlots in order to match the steer to heifer ratio of Texas feedlots.

Tables 10-11 present the monthly herd mixture percentages by weight category and outbreak month for large Texas feedlots. The herd was divided into weight categories by 50 pound weight classes so that at the start of any new feeding month cattle would move into a new weight class, separate from any of the other lots of cattle based on their average daily gain in the previous feeding month. Weight categories with 0% show that no cattle began the month in that weight category. The monthly feedlot cattle weight mixture percentages were used to classify cattle in three broad groups: placements (Table 12), cattle on feed (Table 13), and marketings (Table 14). Placements are cattle that entered the feedlot during the previous month before the outbreak, steer placements weighed between 750 pounds and 799 pounds, while, heifer placements weighed between 650 pounds and 799 pounds depending on the placement month. Cattle on feed are all cattle that entered the feedlot earlier than the previous month before the outbreak began and won't reach market weights within the next month, steer cattle on feed weighed between 850 pounds and 1,249 pounds, while, heifer cattle on feed weighed between 750 pounds and 1099 pounds. Marketings are cattle that will reach market weight and be harvested within the next month, steer marketings weighed between 1200 pounds and 1349 pounds, while, heifer marketings weighed between 1100 pounds and 1199 pounds depanding on the marketed month. There is overlap between the placement weight categories and cattle on feed weight categories for heifers because light weight heifers were placed in October, November, and December and based on their average daily gain after a month of feeding they were in similar weight categories as heavier heifers placed in March through August. The sum of total placements, cattle on feed, and marketings for each month equals 100 percent. Each monthly lot of steer and heifer placements had unique average incoming weights, days on feed, average daily gains, feed to gain ratios, and final weights. It is important to note that no placement lots were placed in February and two placement lots were placed September; this was a consequence of how the data was manipulated to fit the study. It occurred because of the assumption that finished cattle were marketed on the first day of the month, subtracting the average days on feed from the first day of each month arranged placement lots so that February placements didn’t exist and September had two placement lots, one in the beginning of the month and one towards the end of the month. The January herd mixture is composed of placement lots from August, September, October, November, and December. Whereas, the July herd mixture is composed of placement lots from March, April, May, and June.

Table 10. Texas Steer Mixture by Weight Category and Month

Feeding Month	650-699 Pounds	700-749 Pounds	750-799 Pounds	800-849 Pounds	850-899 Pounds	900-949 Pounds	950-999 Pounds
January	0%	0%	12%	0%	12%	0%	10%
February	0%	0%	0%	0%	14%	0%	14%
March	0%	0%	0%	0%	12%	0%	14%
April	0%	0%	0%	0%	10%	0%	12%
May	0%	0%	0%	0%	9%	0%	10%
June	0%	0%	0%	0%	8%	0%	10%
July	0%	0%	0%	0%	11%	0%	9%
August	0%	0%	0%	0%	12%	0%	12%
September	0%	0%	11%	0%	10%	0%	10%
October	0%	0%	11%	0%	11%	0%	10%
November	0%	0%	12%	0%	10%	0%	10%
December	0%	0%	13%	0%	11%	10%	0%
Feeding Month	**1000-1049 Pounds**	**1050-1099 Pounds**	**1100-1149 Pounds**	**1150-1199 Pounds**	**1200-1249 Pounds**	**1250-1299 Pounds**	**1300-1349 Pounds**
January	9%	0%	0%	9%	0%	8%	0%
February	12%	0%	10%	0%	10%	0%	0%
March	0%	13%	11%	0%	10%	0%	0%
April	0%	14%	0%	13%	11%	0%	0%
May	0%	13%	0%	14%	1%	14%	0%
June	0%	12%	0%	14%	0%	17%	0%
July	0%	11%	0%	13%	0%	0%	16%
August	0%	9%	0%	12%	0%	0%	14%
September	0%	10%	0%	8%	0%	0%	10%
October	0%	10%	0%	10%	0%	8%	0%
November	0%	9%	0%	9%	0%	0%	9%
December	0%	9%	0%	9%	0%	8%	0%

Table 11. Texas Heifer Mixture by Weight Category and Month

Feeding Month	650-699 Pounds	700-749 Pounds	750-799 Pounds	800-849 Pounds	850-899 Pounds	900-949 Pounds	950-999 Pounds
January	0%	7%	7%	0%	6%	0%	6%
February	0%	0%	8%	0%	9%	0%	7%
March	0%	0%	9%	0%	8%	0%	8%
April	0%	0%	7%	0%	9%	0%	8%
May	0%	0%	7%	0%	7%	0%	9%
June	0%	0%	6%	0%	8%	0%	7%
July	0%	0%	9%	0%	6%	0%	8%
August	0%	0%	9%	0%	9%	0%	7%
September	0%	7%	7%	0%	7%	0%	7%
October	6%	0%	7%	0%	7%	0%	7%
November	6%	0%	6%	0%	7%	0%	7%
December	7%	0%	6%	0%	6%	0%	7%
Feeding Month	**1000-1049 Pounds**	**1050-1099 Pounds**	**1100-1149 Pounds**	**1150-1199 Pounds**	**1200-1249 Pounds**	**1250-1299 Pounds**	**1300-1349 Pounds**
January	0%	7%	0%	7%	0%	0%	0%
February	7%	0%	8%	0%	0%	0%	0%
March	7%	0%	7%	0%	0%	0%	0%
April	0%	8%	7%	0%	0%	0%	0%
May	0%	8%	9%	0%	0%	0%	0%
June	0%	9%	0%	8%	0%	0%	0%
July	0%	8%	0%	10%	0%	0%	0%
August	0%	8%	0%	8%	0%	0%	0%
September	0%	5%	0%	7%	0%	0%	0%
October	0%	7%	0%	6%	0%	0%	0%
November	0%	7%	0%	7%	0%	0%	0%
December	0%	7%	0%	7%	0%	0%	0%

Table 12. Herd Mixture Placement Percentages by Calendar Month

	Steer	Heifer	Total
January	12%	7%	19%
February	0%	0%	0%
March	12%	9%	21%
April	10%	7%	17%
May	9%	7%	16%
June	8%	6%	14%
July	11%	9%	20%
August	12%	9%	21%
September	21%	14%	35%
October	11%	6%	17%
November	12%	6%	18%
December	13%	7%	20%

Table 13. Herd Mixture Cattle on Feed Percentages by Calendar Month

	Steer	Heifer	Total
January	41%	26%	67%
February	51%	31%	82%
March	39%	23%	62%
April	40%	25%	65%
May	38%	24%	62%
June	36%	25%	61%
July	33%	22%	55%
August	33%	24%	57%
September	28%	20%	48%
October	41%	29%	70%
November	39%	27%	66%
December	39%	26%	65%

Table 14. Herd Mixture Marketing Percentages by Calendar Month

	Steer	Heifer	Total
January	8%	6%	14%
February	10%	8%	18%
March	10%	7%	17%
April	11%	7%	18%
May	14%	8%	22%
June	17%	8%	25%
July	15%	10%	25%
August	14%	8%	22%
September	10%	7%	17%
October	8%	5%	13%
November	9%	7%	16%
December	8%	7%	15%

4.3 Unrestricted Feed Strategy

The unrestricted feed strategy assumes that feed is allowed to be brought onto the uninfected, quarantined large feedlots and that finished cattle are allowed to be transported for harvest to nearby packing plants. However this occurs at an increased cost reflecting cleaning and disinfection of trucks as they enter and exit the premises. This strategy was designed to allow business to continue for the feed elevators, feedlots, and packing plants in the region and reduce overall economic stress. It is important to note that as more movement was allowed onto and off of quarantined feedlots the risk of spreading the disease increased. The AUSSPREAD model did not account for the increased probability of spread due to movements associated with the unrestricted feed strategy; therefore this study will ignore the increased risk of disease spread caused by the unrestricted feed strategy movement requirements. This is equivalent to assuming that the disinfection of trucks is 100% effective.

The unrestricted feed strategy costing framework involved three main cost components; feeding costs, finished cattle marketing costs, and surveillance costs. Each was implemented in a costing module. The feeding costs module calculated the cost and tons of feed stuffs needed throughout the quarantine for each possible outbreak month. It also calculated the number of feed trucks required to deliver feed throughout the quarantine and the hauling and decontamination costs associated with the feed deliveries. The finished cattle marketing costs module calculated the total number of cattle marketed during the quarantine period and the number of cattle trucks needed to haul the finished cattle to the packing plant. The indemnity payment amounts, cattle truck hauling costs, and cattle truck decontamination costs were also calculated within the marketing costs module. In the unrestricted feed strategy, indemnity payments were assumed to be the difference between the regular average monthly market value and reduced market value received. Indemnity payment calculations are discusses in more detail in the marketing costs section. The surveillance costs calculated the total cost of surveillance team visits and tests for the uninfected quarantined large feedlots. The sum of the feeding costs, marketing costs, and surveillance costs makeup the total unrestricted feed strategy cost.

4.3.1 Feeding Costs

During the time the feedlot is placed under quarantine it was assumed that feeding continued at the pre-outbreak level so that cattle continued gaining weight at the normal rate and finished at the expected time. It was assumed that large feedlots had enough feed on hand to feed cattle for five days, therefore the number of days that require feed to be brought onto the feedlot was the total quarantine period length minus five days. The assumed feed ration for the feedlots was a mixture of steamed flake corn, soybean meal, and hay. It was assumed that corn was processed and mixed with the other feed ingredients on the feedlot meaning that corn was delivered by the ton. The ration was composed of 87.1 percent dry matter; Table 15 shows the feed stuff ingredient percentages used in the ration and their percent dry matter. The ratio was designed based on the expert opinion of Dr. David Anderson and the National Research Council (1996).

Table 15. Large Feedlots Feed Ration Ingredient Percentages and Percent Dry Matter

Feed Ration Ingredients	Percent of Ration	Percent Dry
Steam Flaked Corn	70%	86%
Soybean Meal	10%	89%
Hay	20%	90%

(Anderson 2010; National Research Council 1996)

Table 16. Quarterly Feed Ingredient Prices (U.S. Dollars per Ton)

($ /Ton)	Quarter 1[a]	Quarter 2[b]	Quarter 3[c]	Quarter 4[d]
Corn	$133.22	$136.27	$131.60	$139.42
Soybean Meal	$302.74	$308.92	$360.00	$314.32
Hay	$127.70	$127.70	$127.70	$127.70

[a] December 1-Feburary 28
[b] March 1-May 31
[c] June 1-August 31
[d] August 31- November 30
(USDA, AMS 2010a)

The cost of the ration ingredients were based on quarterly average prices for the U.S. and the Texas Triangle Region[3]. The quarterly corn price was obtained from the 2008-2010 monthly average corn prices for the Texas Triangle Region. The quarterly soybean meal price was obtained from the Economic Research Service Oil Seed Outlook Report and is the quarterly average price for 2008-2010 US soybean meal. Hay prices were obtained from Drovers CattleNetwork and were an average price of various hay types including alfalfa. The average monthly Texas hay price over 27 months (September 2008 to December 2010) was used as the average price for hay for each quarter. Table 16 shows the average quarterly feed prices used in calculating the feed costs.

In order to calculate the amount of feed required throughout the quarantine length, the sum of pounds gained each month per animal for all age groups present during each month was calculated and divided by the age group rate of gain per unit feed; this calculated the tons of feed needed per month animal and this was multiplied by the animal population assuming the feedlot is at full capacity. To obtain the amount of feed needed during the quarantine, the tons of feed needed per month were then multiplied by the monthly proportion of feedlot capacity utilization with marketings allowed for each initial outbreak month (Table 17). The total tons of feed needed per month with marketings was then multiplied by the proportion of time the feedlot spent under quarantine during each month in order to obtain the average tons of feed needed during

[3] The Texas Triangle Region is a statistical reporting region of the USDA National Agricultural Statistics Service and is located in the Texas High Plains. It includes elevators in an area from Plainview to Canyon to Farwell and is comprised of Castro, Deaf Smith, Parmer, Randall, and Swisher counties in the Texas panhandle.

the quarantine. The average tons of feed needed throughout the quarantine was then converted to a daily total. The average tons of feed needed per day was multiplied by the feed parts ration in order to obtain the tons of corn, soybean, and hay needed daily. Feed costs for corn were calculated by multiplying the tons of corn required throughout the quarantine by the average quarterly price of corn per ton. Soybean meal and hay costs were calculated the same way as corn costs. An implication of these assumptions is that feed needs decline as the quarantine goes on because the total number of cattle in the feedlot herd reduces by marketings that are not replaced by new placements.

The number of feed deliveries and feed truck hauling costs were based on the assumption that an eight bin feed truck was used which has a hauling capacity of 23 tons. To calculate the number of feed deliveries the average tons of feed needed per day during the quarantine months were divided by the feed truck hauling capacity. It was assumed that feed transportation costs were $110.75 per delivery; this was based on the Agricultural Marketing Services' Grain Transportation 2010 Second Quarterly Update prices for the South Central US of $4.43 per mile for short distances of 25 miles or less. The feed transportation cost was calculated by multiplying the number of daily feed deliveries during each month by the cost per delivery. Cleaning and disinfecting costs were adopted from Hagerman (2009) and were assumed to be $130 per feed truck delivery. To calculate the feed truck cleaning and disinfecting cost the number of feed deliveries was multiplied by the cleaning and disinfecting cost per delivery.

Table 17. Proportion of Large Texas Feedlot Capacity in any Given Month during Quarantine with Marketings Allowed

Initial Outbreak Month	Outbreak Month											
	January	February	March	April	May	June	July	August	September	October	November	December
January	100%	82%	64%	46%	23%	0%	0%	0%	0%	0%	0%	0%
February	0%	100%	79%	56%	28%	0%	0%	0%	0%	0%	0%	0%
March	0%	0%	100%	78%	52%	26%	1%	0%	0%	0%	0%	0%
April	0%	0%	0%	100%	73%	47%	22%	1%	0%	0%	0%	0%
May	0%	0%	0%	0%	100%	71%	44%	21%	1%	0%	0%	0%
June	0%	0%	0%	0%	0%	100%	69%	43%	20%	1%	0%	0%
July	0%	0%	0%	0%	0%	0%	100%	72%	48%	27%	1%	0%
August	0%	0%	0%	0%	0%	0%	0%	100%	75%	54%	28%	1%
September	22%	1%	0%	0%	0%	0%	0%	0%	100%	84%	63%	43%
October	42%	21%	1%	0%	0%	0%	0%	0%	0%	100%	80%	61%
November	62%	42%	22%	1%	0%	0%	0%	0%	0%	0%	100%	81%
December	82%	63%	45%	25%	1%	0%	0%	0%	0%	0%	0%	100%

This table illustrates how the percentage of feedlot capacity would change during the duration of the quarantine given that marketings are allowed.

4.3.2 Marketing Costs

Marketings of finished cattle were assumed to continue as normally scheduled two days after the initial quarantine was put into place. The first two days that marketings were stopped were assumed to be caused by the initial stop movement ban. The total number of head marketed was calculated by summing the number of average daily marketings over the quarantine length. The number of average daily marketings over the quarantine was calculated by dividing the number of regular marketings per month by the days in each month the feedlot was quarantined; in the initial quarantine month two days were subtracted from number of days in that month to represent the initial halt movement order. The number of cattle hauling trucks needed was estimated from the total number of cattle marketings during the quarantine. According to the Master Cattle Transporter Guide (2008) a 48 foot cattle hauling trailer has a payload of 50,000 pounds. The cattle loading density per load was calculated for each month and was based on the average weighted final weights of the finished steers and heifers. The number of cattle hauling trucks needed per day was calculated by taking the average number of cattle marketed each day for a particular month and dividing it by the cattle loading density for the particular month. The cost of cattle hauling was assumed to be $100 per load, which was the mode price in Texas for custom cattle hauling per load in 2008 (USDA, NASS 2009). Cleaning and disinfecting costs for cattle hauling trailers and trucks were assumed to be $170 per load, this cost was derived by increasing the $130 cleaning and disinfecting cost for feed trucks from Hagerman (2009) by 30 percent in order to account for the need of more extensive cleaning of cattle hauling trailers. It is more expensive to clean and disinfect cattle hauling trailers and trucks than feed trucks because more labor and supplies are required since the trailers have to be disinfected inside and out.

Marketed cattle from quarantined feedlots were assumed to lose 50 percent of their market value to reflect the fact that quarantined animals would most likely not be eligible for higher value fresh and frozen beef products in the domestic market. This is due to efforts that will likely be undertaken to source fresh meat product from areas outside of the infected region and employ regionalization to speed trade recovery. However, marketings from uninfected, quarantined feedlots would likely be eligible for lower value cooked and canned meat products as well as non-human consumption products such as dog food. It was assumed the 50 percent market value loss would be recouped by feedlots in the form of an indemnity payment from the government. Indemnity payments were calculated for each animal by multiplying the average final weight of marketed steers or heifers by 50 percent of the corresponding average monthly live weight price (Table 18). The average monthly live weight price was calculated using the mandatory price reporting data for Texas and Oklahoma fed cattle; average 2010 steer and heifer prices were used as the base along with a 3-year (2008-2010) monthly price index to incorporate seasonal variation in price.

Table 18. Monthly Average 2010 Texas and Oklahoma Steer and Heifer Live Weight Price (U.S. Dollars per Pound)

	Steer	Heifers
January	0.916	0.917
February	0.928	0.929
March	0.938	0.938
April	0.965	0.965
May	0.972	0.973
June	0.947	0.948
July	0.965	0.964
August	0.979	0.979
September	0.985	0.985
October	0.967	0.968
November	0.967	0.968
December	0.954	0.954

(USDA, AMS 2010b)

4.3.2 Surveillance Costs

The number of surveillance visits for each uninfected large feedlot was simulated by the AUSSPREAD model. Surveillance costs were composed of labor, testing supplies, and equipment. Surveillance cost assumptions were adopted from previous FMD costing work done by USDA APHIS for the North American Animal Disease Spread Model (NAADSM) (2009). It was assumed that nine man hours were required per 1,000 head and that 17 percent of the herd was tested for FMD with polymerase chain reaction (PCR) assay tests during each surveillance visit. The labor cost used was $34.87 per hour, which was the 2010 national average hourly base and overtime pay rates for government workers at pay grades five through 15 across steps one through 10. PCR assay tests were assumed to cost $40 per test, testing costs include lab fees and were based on estimates provided by the USDA National Animal Health Laboratory Network.

It was assumed that each animal tested was tagged with a tamper evident radio frequency identification (RFID) tag for the ease of future identification and monitoring. The cost per RFID tag was assumed to be $2.93. An additional $500 was added to each surveillance visit to account for miscellaneous costs such as personal protective equipment and cleaning and disinfecting of vehicles.

4.4 **Welfare Slaughter Strategy**

The welfare slaughter strategy assumed that strict movement restriction policies were imposed. Under this case, no feed was allowed to be transported onto the quarantined, uninfected large feedlots and no cattle were allowed to be transported off. Instead, the cattle were assumed to be placed on subsistence rations until euthanasia crews were able to euthanize and dispose of the cattle through on-site burial. It was assumed that officials decided to depopulate large feedlots as soon as resources were available because of the potential animal welfare conditions caused by the movement restrictions and quarantine zone. It was assumed that cattle would be disposed of through onsite burial; land deprecation and burial site upkeep costs were not factored into the costs. This strategy does not promote continuity of business, but it does minimize movement of disease vectors thereby minimizing the risk of spread. The minimized disease spread is not captured within this study, but is an important difference between the welfare slaughter strategy and unrestricted feed strategy.

Appraisal, euthanasia, disposal, cleaning and disinfecting costs were all adopted from previous USDA APHIS estimates developed for the NAADSM model (Table 19). The cost estimates adopted from the NAADSM model (USDA, APHIS 2009) were based on total costs for the average feedlot herd size according to the 2007 Agricultural Census (322 head). The total costs were converted to a per head cost and applied to the large feedlots. The appraisal cost accounts for the labor required to count and appraise the cattle located on the feedlot. The euthanasia cost is an estimate of the costs associated with euthanizing all the cattle on uninfected, quarantined large feedlots using a captive bolt method. Specialized labor and equipment, like captive bolt operators and guns, are needed for the euthanasia portion of the welfare slaughter strategy. Disposal cost is an estimated cost of burying cattle on the feedlot grounds, it is mainly composed of estimated cost for heavy equipment rentals and labor. The cleaning and disinfecting cost include costs associated with cleaning and disinfecting vehicles and equipments used to euthanize and dispose of the cattle.

Table 19. Welfare Slaughter Costs Adopted from NAADSM Assumptions

Welfare Slaughter Costs	$/Head
Appraisal	0.58
Euthanasia	50.00
Disposal	31.00
Cleaning and Disinfection	21.00

(USDA, APHIS 2009)

Indemnity costs were calculated using an adjusted 2010 average monthly live weight price, which was calculated from mandatory price reporting data for Texas and Oklahoma fed cattle; average 2010 prices were used as the base along with a 3-year (2008-2010) monthly price index (USDA, AMS 2010b). The purpose of indemnity payments is to provide an incentive for producers to comply with disease eradication efforts and movement restrictions orders. Indemnity payments are not meant to cover all the costs incurred by producers, instead, they are meant to cover the lost market value of the depopulated herd.

At the moment, indemnity payment policy does not currently have direct provisions for welfare slaughter; however, the Secretary of Agriculture has the power to grant indemnity payments for welfare slaughter in the state of emergency. It was assumed that appraisals for indemnity payment amounts were performed by specialists visually inspecting and counting the head and analyzing feedlot records. To obtain the placement indemnity and marketings indemnity costs, the incoming weights and final weights for steer and heifers was averaged and multiplied by the number of placements and marketings, respectively, and the corresponding monthly average 2010 adjusted live weight price.

In order to calculate the indemnity cost for cattle on feed the average weight of cattle on feed was estimated by taking the monthly difference between the weighted steer and heifer incoming weights and final weights and dividing by two, and then adding the weighted incoming weight. The average weight of cattle on feed by month was then multiplied by the corresponding monthly average 2010 adjusted live weight price and the number of cattle on feed.

4.5 **Summary**

By combining the epidemiological data with the cost accounting models, differences in costs depending on the movement strategy and when an outbreak occurs for quarantined, uninfected large feedlots were highlighted. The research was done in this way to inform policy makers of the implications of quarantine and movement restrictions for uninfected large feedlots in the THPR.

5. RESULTS

Now I compare the total costs of the two policies: welfare slaughter and feed provision. In turn, the average total cost associated with an FMD outbreak motivated quarantine as it affected uninfected THPR large feedlots ranged between $16.2 million and $57.2 million, depending on the movement policy, mitigation tactics used, and initial outbreak month.

Average total cost for the unrestricted feed strategy ranged from $16.2 million to $30.9 million depending on the detection delay and initial outbreak month. For the welfare slaughter strategy, average total cost ranged from $39.8 million to $57.2 million depending on the mitigation tactic and initial outbreak month. The unrestricted feed strategy was less costly than the welfare slaughter strategy for every initial outbreak month.

Early detection, late detection, enhanced surveillance, and regular surveillance were mitigation tactics used to compare and contrast the two movement strategies (Figure 2). The mitigation tactic costs are the average cost results from scenarios used in the AUSSPREAD model and in the previous Texas High Plains Study (Ward et al. 2009). Early detection (average of scenarios 17 and 37), assumed that FMD was discovered seven days after the initial infection and late detection mitigation tactic (average of scenarios 21 and 53), assumed that FMD was discovered 14 days after the initial infection in the epidemiological model. Enhanced surveillance (average of scenarios 17 and 21) assumed that suspect premises were visited four times per week, while regular surveillance (average of scenarios 37 and 53) assumed that suspect premises were visited two times per week. Minimum, maximum, and average costs were compared for unrestricted feed and welfare slaughter strategies by the initial outbreak month.

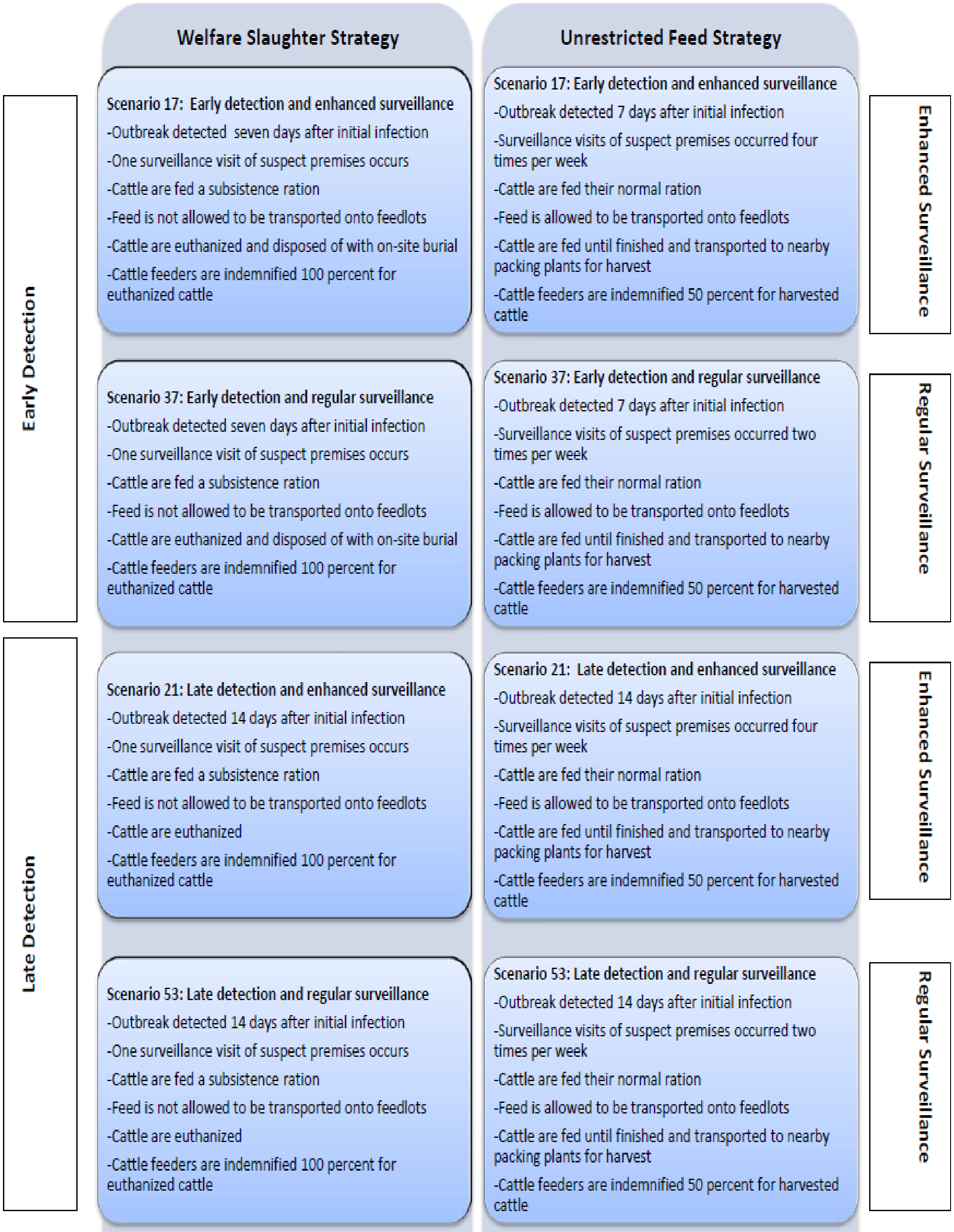

Figure 2. Description of Scenarios and Mitigations Tactics Used to Analyze Welfare Slaughter and Unrestricted Feeds Strategies

5.1 AUSSPREAD Results

The AUSSPREAD model simulated the status of herd types at the end of the quarantine, number of head in each herd, number of surveillance visits, and days under quarantine for each scenario 100 times. The minimum, maximum, and average results from the 100 simulated iterations for quarantined, uninfected large feedlots are presented in Table 20. On average, early detection quarantine length lasted six days longer than late detection. This result was surprising because the Texas High Plains Study (Ward et al. 2009) found that early detection significantly reduced the length of the quarantine when all herd types were examined, so this result may be the result of only examining a company feedlot initiation or may be the result of using a subset of the total scenarios. Early detection reduced the number of uninfected quarantined head compared to late detection. On average, late detection quarantined an additional 13,478 head compared to early detection. The difference in the average number of head quarantined suggests that mitigation tactics that incorporate early detection result in smaller quarantine zones compared to mitigation tactics that incorporate late detection. These results were consistent with what was expected, since Ward et al. (2009) found that early detection significantly reduced that number of infected and exposed head depopulated. Enhanced surveillance reduced the average quarantine length on uninfected large feedlots by two days compared to regular surveillance.

Regular surveillance simulations had a larger range between the minimum and maximum number of uninfected quarantined head, but overall the average number of quarantined uninfected head was less than enhanced surveillance. On average, enhanced surveillance quarantined an additional 2,934 head on uninfected large feedlots compared to regular surveillance. These results suggest that in general, quarantine zones are larger when mitigation strategies incorporate enhanced surveillance instead of regular surveillance. The Texas High Plains Study (Ward et al. 2009) found that enhanced surveillance did not significantly reduce the length of quarantine or the number of head depopulated. The number of simulated surveillance visits for uninfected large feedlots were constant throughout the scenarios; this resulted because of underlying assumptions within the AUSSPREAD model. In reality, one would expect there to be differences in the number of times each feedlot was visited between the enhanced and regular surveillance scenarios. Consequently, in the cost accounting model surveillance costs differences are only realized through the differences in the number of head quarantined.

Table 20. Comparison of Quarantined Uninfected Large Feedlot AUSSPREAD Data Used in Costing Model

	Early Detection	Late Detection	Enhanced Surveillance	Regular Surveillance
Herds Quarantined				
Minimum	1	1	1	1
Maximum	6	8	7	7
Mean	1.7	2.1	2.0	1.9
Head Quarantined				
Minimum	7,600	6,400	7,200	6,800
Maximum	165,840	263,600	211,600	217,840
Mean	39,261	52,739	47,467	44,533
Quarantine Length (Days)				
Minimum	90	68	77	80
Maximum	109	109	109	109
Mean	103	97	99	101
Surveillance Visits				
Minimum	5	5	5	5
Maximum	5	5	5	5
Mean	5	5	5	5

(Ward et al. 2009)

5.2 Unrestricted Feed Strategy Compared to Welfare Slaughter Strategy

Overall, the unrestricted feed strategy was less costly than the welfare slaughter strategy. The average cost difference between the two strategies ranged from $20.6 million, for outbreaks initiated in May, to $31.2 million for outbreaks initiated in November (Figure 3). For all mitigation tactics, outbreaks that began in May had the smallest average cost difference between unrestricted feed and welfare slaughter strategies, and outbreaks that began in November had the largest average cost difference. On average there was a 71 percent difference between the early detection unrestricted feed strategy total cost and the early detection welfare slaughter strategy total cost, with an average cost difference totaling $21.5 million (Table 21). The percent difference for total cost between the late detection unrestricted feed strategy and the late detection welfare slaughter strategy averaged 76 percent, with an average cost difference totaling $30.4 million (Table 22). The percent difference for total cost between the regular surveillance unrestricted feed strategy and the regular surveillance welfare slaughter strategy averaged 73 percent for all outbreak months, with an average cost difference equaling $25 million (Table 23). On average the percent difference for total cost for the enhanced surveillance unrestricted feed strategy and the enhanced surveillance welfare slaughter strategy was 74 percent, with an average cost difference totaling $26.9 million (Table 24). Feeding quarantined uninfected cattle on large feedlots and indemnifying producers for 50 percent of their value is less expensive compared to euthanizing the cattle and indemnifying producers for 100 percent of their value.

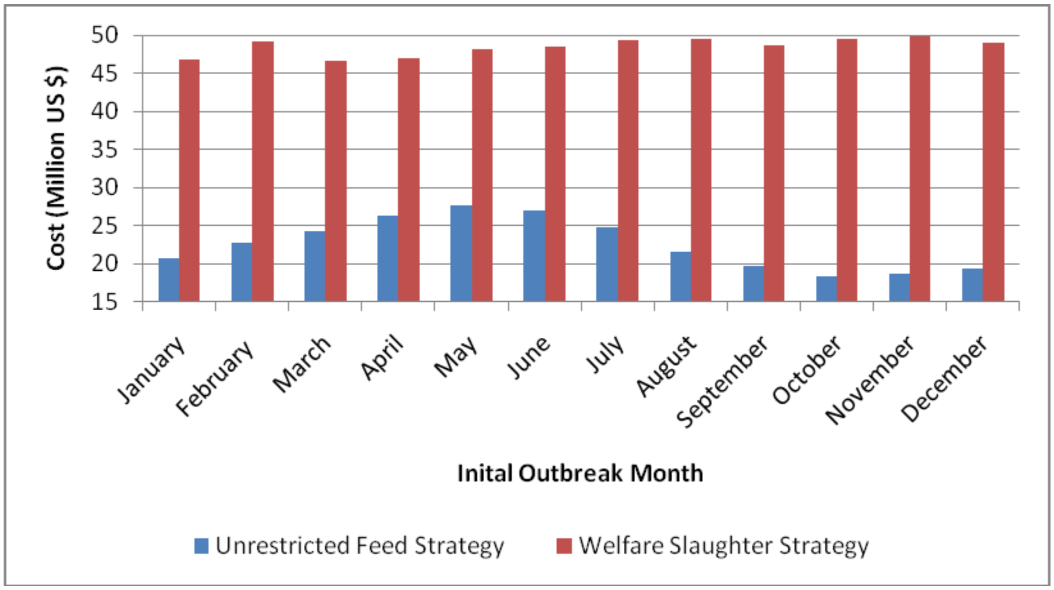

Figure 3. Average Total Cost for Unrestricted Feed Strategies and Welfare Slaughter Strategies

Table 21. Early Detection Average Total Cost Comparison (Million U.S. Dollars)

Outbreak Month	Welfare Slaughter	Unrestricted Feed	Difference	Percent Difference
January	40.01	18.39	21.62	74%
February	41.97	20.19	21.77	70%
March	39.82	21.51	18.32	60%
April	40.16	23.27	16.89	53%
May	41.14	24.31	16.82	51%
June	41.32	23.68	17.64	54%
July	42.13	21.61	20.52	64%
August	42.28	18.94	23.34	76%
September	41.58	17.33	24.25	82%
October	42.24	16.16	26.07	89%
November	42.57	16.57	26.00	88%
December	41.85	17.16	24.69	84%
Average All Months	41.42	19.93	21.49	71%

Table 22. Late Detection Average Total Cost Comparison (Million U.S. Dollars)

Outbreak Month	Welfare Slaughter	Unrestricted Feed	Difference	Percent Difference
January	53.74	23.14	30.60	80%
February	56.37	25.43	30.94	76%
March	53.50	26.99	26.50	66%
April	53.94	29.34	24.60	59%
May	55.26	30.88	24.38	57%
June	55.50	30.30	25.20	59%
July	56.60	27.83	28.76	68%
August	56.80	24.24	32.55	80%
September	55.85	22.03	33.82	87%
October	56.74	20.58	36.16	94%
November	57.18	20.88	36.30	93%
December	56.21	21.58	34.63	89%
Average All Months	55.64	25.27	30.37	76%

Table 23. Regular Surveillance Average Total Cost Comparison (Million U.S. Dollars)

Outbreak Month	Welfare Slaughter	Unrestricted Feed	Difference	Percent Difference
January	45.38	20.25	25.13	77%
February	47.60	22.24	25.36	73%
March	45.17	23.65	21.52	63%
April	45.55	25.63	19.92	56%
May	46.66	26.86	19.80	54%
June	46.87	26.24	20.63	56%
July	47.79	24.02	23.77	66%
August	47.96	21.02	26.94	78%
September	47.16	19.16	28.01	84%
October	47.91	17.88	30.03	91%
November	48.28	18.27	30.01	90%
December	47.47	18.88	28.59	86%
Average All Months	46.98	22.01	24.98	73%

Table 24. Enhanced Surveillance Cost Comparison (Million U.S. Dollars)

Outbreak Month	Welfare Slaughter	Unrestricted Feed	Difference	Percent Difference
January	48.37	21.28	27.09	78%
February	50.74	23.38	27.36	74%
March	48.15	24.85	23.30	64%
April	48.55	26.98	21.57	57%
May	49.73	28.33	21.41	55%
June	49.96	27.74	22.22	57%
July	50.94	25.42	25.51	67%
August	51.12	22.17	28.95	79%
September	50.27	20.21	30.06	85%
October	51.07	18.86	32.20	92%
November	51.46	19.17	32.29	91%
December	50.59	19.86	30.73	87%
Average All Months	50.08	23.19	26.89	74%

5.3 Unrestricted Feed Strategy

The overall average total cost for the unrestricted feed strategy was $22.6 million. Total cost included indemnity payments, hauling costs for marketed cattle, cleaning and disinfection of cattle hauling trucks, feed costs, hauling costs for feed, cleaning and disinfecting of feed trucks, and surveillance visits costs. Early detection was the most economical mitigation tactic, with an average total cost of $19.9 million. Late detection was most expensive mitigation tactic, with an average total cost of $25.3 million. Regular surveillance was slightly less costly than enhanced surveillance, with average total costs of $22 million and $23.2 million, respectively.

The cost differences between the mitigation tactics were mainly driven by the number of uninfected cattle quarantined on the feedlots; early detection had the smallest number of head quarantined and was the most economically desirable outcome, while late detection had the largest number of head quarantined and was the most expensive. The two main input drivers of the unrestricted feed costing model were the number of head quarantined and the quarantine length. The three most expensive components of average total cost were indemnity payments, feed cost, and surveillance visits. The largest cost component, regardless of when the outbreak initiated, was the indemnity payment amount. It was assumed that indemnity payments were equal to 50 percent of market value before the outbreak began.

5.3.1 Unrestricted Feed Strategy Seasonal Results

The results illustrated that costs for uninfected feedlots quarantined during an FMD outbreak will vary depending on the time of year the outbreak occurs. Based on mean average total cost, the month of May was the most expensive month for an outbreak to begin and October was the least expensive month for an outbreak to begin. Figure 4 presents the average total cost by initial outbreak month for all unrestricted feed strategy mitigation tactics.

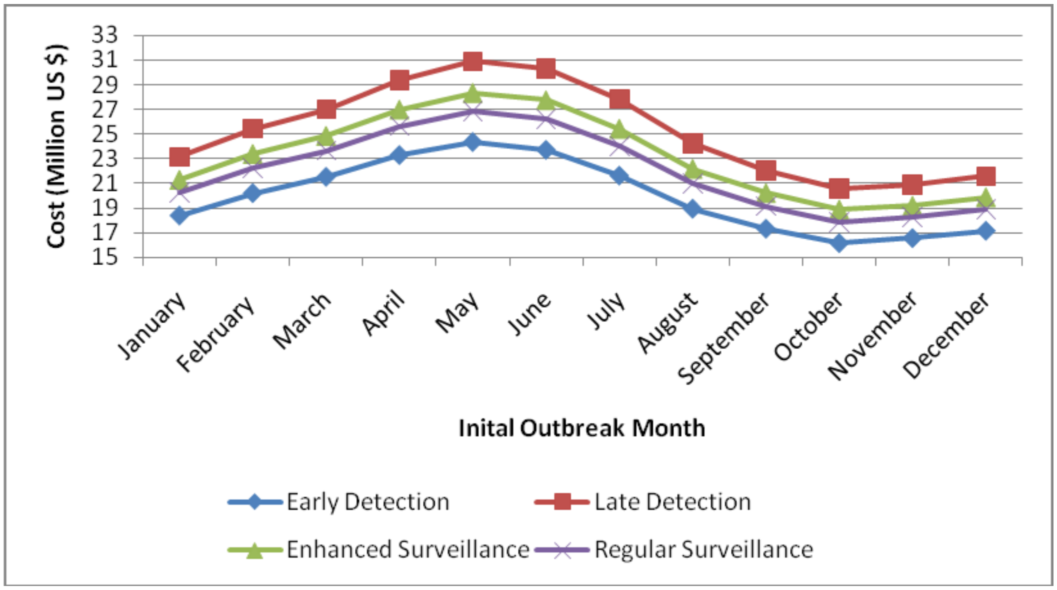

Figure 4. Average Total Cost for Unrestricted Feed Strategy Mitigation Tactics by Outbreak Month

Depending on the initial outbreak month, indemnity payment costs ranged from approximately 66 percent to 76 percent of average total cost, feed costs ranged from 15 percent to 22 percent of average total cost, surveillance visit costs ranged from 6 percent to 10 percent of average total cost, and hauling costs and cleaning and disinfecting costs for cattle hauling and feed trucks were consistently less than or close to one percent of the average total costs depending on the initial outbreak month (Table 25 and Figure 5). The cost component percentages of total cost differed less than one percent between all mitigation tactics for each initial outbreak months. Tables 26-29 show the minimum, maximum, and average costs for all mitigation tactic.

Table 25. Average Percentage of Average Total Cost for Cost Components by Initial Outbreak Month for all Unrestricted Feed Mitigation Tactics

Initial Outbreak Month	Indemnity Payments	Cattle Truck Disinfecting	Cattle Truck Hauling	Feed Cost	Feed Truck Disinfecting	Feed Truck Hauling	Surveillance Visits
January	68.7%	0.6%	0.4%	20.5%	0.8%	0.7%	8.4%
February	70.7%	0.6%	0.4%	19.4%	0.8%	0.6%	7.7%
March	71.1%	0.6%	0.4%	19.3%	0.8%	0.7%	7.2%
April	74.7%	0.6%	0.4%	16.6%	0.7%	0.6%	6.6%
May	76.3%	0.6%	0.4%	15.3%	0.6%	0.5%	6.3%
June	76.4%	0.6%	0.4%	15.1%	0.6%	0.5%	6.5%
July	73.4%	0.6%	0.4%	17.4%	0.7%	0.6%	7.1%
August	69.7%	0.5%	0.4%	19.9%	0.8%	0.7%	8.1%
September	66.7%	0.5%	0.4%	22.0%	0.9%	0.7%	8.9%
October	66.4%	0.5%	0.4%	21.6%	0.9%	0.7%	9.5%
November	67.9%	0.5%	0.4%	20.4%	0.8%	0.7%	9.3%
December	68.8%	0.6%	0.4%	19.8%	0.8%	0.7%	9.0%
Average	70.90%	0.57%	0.40%	18.94%	0.77%	0.64%	7.88%

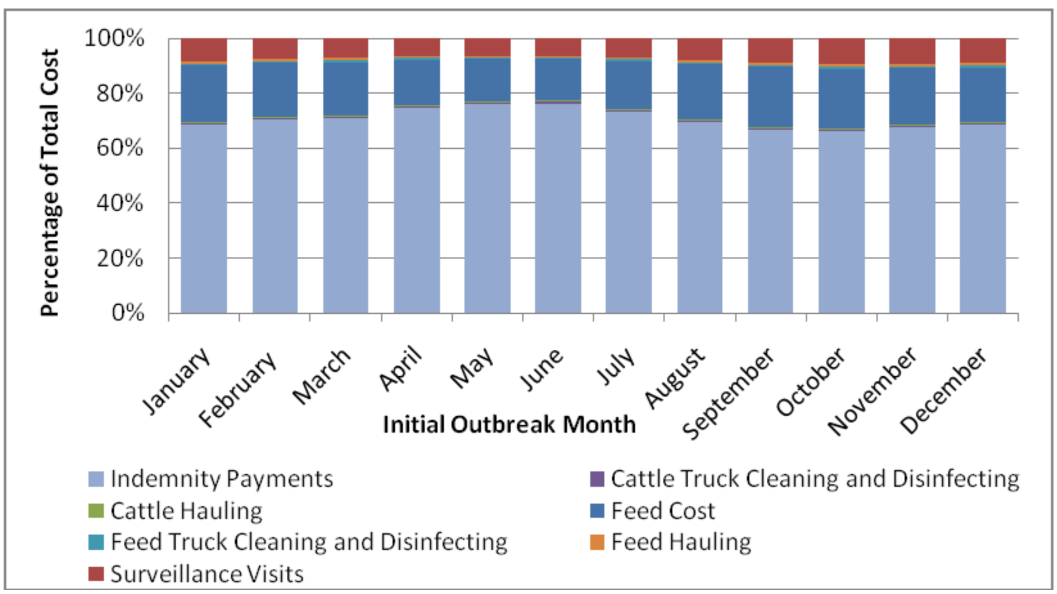

Figure 5. Average Cost Components Percentage of Average Total Cost by Initial Outbreak Month for all Unrestricted Feed Mitigation Tactics

Table 26. Unrestricted Feed Early Detection FMD Outbreak Costs for Quarantined Uninfected Large Feedlots

Costs (Thousand US $)	January	February	March	April	May	June	July	August	September	October	November	December
Indemnity Payment												
Minimum	2,250	2,526	2,681	3,083	3,367	3,342	2,965	2,446	2,122	1,971	1,991	2,112
Maximum	55,165	62,677	67,514	75,865	80,087	77,579	67,846	57,013	50,040	46,448	49,629	51,422
Average	12,694	14,379	15,430	17,491	18,638	18,157	15,913	13,270	11,629	10,803	11,334	11,870
Feed												
Minimum	688	721	763	711	690	664	699	698	704	646	619	621
Maximum	16,011	16,390	17,362	16,085	15,636	15,048	15,855	15,861	16,106	14,774	14,256	14,487
Average	3,748	3,854	4,087	3,788	3,682	3,545	3,733	3,733	3,784	3,471	3,342	3,387
Feed Truck Hauling												
Minimum	28	25	28	28	28	27	27	28	27	25	25	22
Maximum	547	545	582	545	529	505	524	530	538	504	488	494
Average	130	129	138	129	126	121	126	127	127	119	116	116
Feed Truck Cleaning/Disinfecting												
Minimum	33	29	33	33	33	32	32	33	32	30	29	26
Maximum	642	640	684	639	622	593	615	623	631	592	573	579
Average	153	152	162	152	148	142	147	149	150	140	136	137
Cattle Hauling												
Minimum	15	18	18	18	18	18	17	14	11	9	9	12
Maximum	258	285	300	333	352	344	304	256	228	214	228	241
Average	62	69	72	79	83	81	72	61	54	50	54	58
Cattle Truck Cleaning/Disinfecting												
Minimum	25	30	30	30	30	30	28	24	19	15	15	20
Maximum	439	484	510	565	598	585	516	435	387	363	387	410
Average	105	117	122	135	142	139	123	104	92	86	91	98
Surveillance												
Minimum	290	290	290	290	290	290	290	290	290	290	290	290
Maximum	6,315	6,315	6,315	6,315	6,315	6,315	6,315	6,315	6,315	6,315	6,315	6,315
Average	1,495	1,495	1,495	1,495	1,495	1,495	1,495	1,495	1,495	1,495	1,495	1,495
Total												
Minimum	3,329	3,638	3,843	4,193	4,455	4,403	4,059	3,532	3,204	2,985	2,979	3,103
Maximum	79,378	87,337	93,266	100,346	104,139	100,970	91,975	81,033	74,244	69,209	71,875	73,948
Average	18,387	20,194	21,506	23,269	24,315	23,680	21,609	18,938	17,330	16,164	16,569	17,161

Table 27. Unrestricted Feed Late Detection FMD Outbreak Costs for Quarantined Uninfected Large Feedlots

Costs (Thousand US $)	January	February	March	April	May	June	July	August	September	October	November	December
Indemnity Payment												
Minimum	1,616	1,793	1,877	2,193	2,448	2,482	2,259	1,850	1,529	1,433	1,664	1,478
Maximum	79,384	89,643	95,727	109,092	117,305	115,293	101,809	84,480	73,219	68,087	70,933	73,929
Average	15,810	17,845	19,057	21,770	23,441	23,063	20,371	16,827	14,613	13,591	14,082	14,762
Feed												
Minimum	507	563	604	570	553	531	558	556	545	504	519	460
Maximum	23,779	24,876	26,430	24,602	23,895	23,001	24,206	24,180	24,337	22,358	21,448	21,497
Average	4,760	4,986	5,301	4,933	4,790	4,614	4,852	4,846	4,876	4,477	4,288	4,295
Feed Truck Hauling												
Minimum	20	22	24	24	22	21	21	22	21	21	22	19
Maximum	804	823	878	816	799	758	786	800	801	743	719	720
Average	164	167	179	168	163	155	161	163	163	152	147	148
Feed Truck Cleaning/Disinfecting												
Minimum	23	26	28	28	25	24	24	25	24	24	25	22
Maximum	944	966	1,031	958	938	889	923	939	940	872	844	845
Average	192	196	211	197	191	182	189	191	192	179	173	173
Cattle Hauling												
Minimum	9	10	11	14	15	15	14	11	8	8	9	8
Maximum	366	401	423	474	507	501	445	374	325	304	321	341
Average	76	84	88	99	105	104	92	77	67	63	66	71
Cattle Truck Cleaning/Disinfecting												
Minimum	15	17	18	23	26	26	23	18	13	13	15	14
Maximum	622	682	719	806	861	851	757	635	553	517	546	580
Average	129	143	150	168	179	176	157	131	114	107	112	121
Surveillance												
Minimum	244	244	244	244	244	244	244	244	244	244	244	244
Maximum	10,036	10,036	10,036	10,036	10,036	10,036	10,036	10,036	10,036	10,036	10,036	10,036
Average	2,008	2,008	2,008	2,008	2,008	2,008	2,008	2,008	2,008	2,008	2,008	2,008
Total												
Minimum	2,434	2,675	2,805	3,096	3,333	3,343	3,144	2,725	2,383	2,247	2,498	2,246
Maximum	115,935	127,429	135,244	146,785	154,341	151,329	138,962	121,443	110,211	102,918	104,848	107,947
Average	23,139	25,430	26,994	29,342	30,877	30,303	27,831	24,244	22,034	20,578	20,877	21,578

Table 28. Unrestricted Feed Regular Surveillance FMD Outbreak Costs for Quarantined Uninfected Large Feedlots

Costs (Thousand US $)	January	February	March	April	May	June	July	August	September	October	November	December
Indemnity Payment												
Minimum	1,962	2,200	2,331	2,686	2,944	2,929	2,599	2,152	1,843	1,717	1,744	1,829
Maximum	72,008	81,750	87,983	99,061	104,801	101,654	88,936	74,597	65,452	60,765	64,665	67,171
Average	13,918	15,743	16,857	19,160	20,504	20,056	17,637	14,670	12,789	11,888	12,430	12,994
Feed												
Minimum	600	630	669	625	607	583	614	614	616	567	545	544
Maximum	20,980	21,498	22,778	21,105	20,515	19,746	20,802	20,807	21,120	19,374	18,686	18,978
Average	4,139	4,290	4,553	4,229	4,109	3,956	4,164	4,162	4,205	3,859	3,710	3,740
Feed Truck Hauling												
Minimum	23	24	26	26	24	23	23	24	23	23	22	21
Maximum	711	714	760	709	691	658	682	692	696	655	633	641
Average	143	144	154	144	141	134	139	141	141	132	128	129
Feed Truck Cleaning/Disinfecting												
Minimum	27	28	30	30	28	27	27	28	27	27	26	25
Maximum	835	838	892	832	811	773	801	813	817	769	743	753
Average	168	169	181	169	165	158	163	165	166	155	150	151
Cattle Hauling												
Minimum	12	13	14	16	17	17	15	12	9	9	9	10
Maximum	332	365	386	432	458	449	393	331	294	277	295	312
Average	67	75	78	87	92	90	80	67	59	55	59	63
Cattle Truck Cleaning/Disinfecting												
Minimum	20	22	24	27	29	29	26	21	16	15	15	17
Maximum	564	621	657	734	779	762	668	562	500	471	502	530
Average	114	127	133	148	156	154	136	114	100	94	100	107
Surveillance												
Minimum	259	259	259	259	259	259	259	259	259	259	259	259
Maximum	8,294	8,294	8,294	8,294	8,294	8,294	8,294	8,294	8,294	8,294	8,294	8,294
Average	1,696	1,696	1,696	1,696	1,696	1,696	1,696	1,696	1,696	1,696	1,696	1,696
Total												
Minimum	2,903	3,177	3,353	3,668	3,908	3,868	3,565	3,109	2,794	2,616	2,620	2,706
Maximum	103,724	114,080	121,751	131,166	136,349	132,336	120,577	106,097	97,174	90,606	93,819	96,679
Average	20,246	22,244	23,653	25,634	26,862	26,244	24,016	21,016	19,157	17,880	18,273	18,879

Table 29. Unrestricted Feed Enhanced Surveillance FMD Outbreak Costs for Quarantined Uninfected Large Feedlots

Costs (Thousand US $)	January	February	March	April	May	June	July	August	September	October	November	December
Indemnity Payment												
Minimum	1,903	2,119	2,227	2,591	2,871	2,894	2,626	2,144	1,808	1,687	1,911	1,761
Maximum	62,541	70,571	75,257	85,895	92,590	91,219	80,718	66,895	57,807	53,770	55,898	58,180
Average	14,586	16,481	17,629	20,100	21,576	21,164	18,647	15,427	13,453	12,507	12,986	13,639
Feed												
Minimum	595	654	698	656	636	612	643	640	633	583	593	537
Maximum	18,809	19,768	21,014	19,582	19,016	18,303	19,259	19,233	19,322	17,758	17,017	17,006
Average	4,369	4,550	4,834	4,492	4,363	4,204	4,421	4,417	4,455	4,089	3,921	3,942
Feed Truck Hauling												
Minimum	25	23	26	26	26	25	25	26	25	23	24	20
Maximum	640	655	701	653	638	605	628	638	642	592	573	572
Average	150	153	164	153	149	142	147	149	149	139	135	135
Feed Truck Cleaning/Disinfecting												
Minimum	29	27	31	30	30	29	29	30	29	27	28	23
Maximum	751	769	822	766	749	710	738	749	754	695	673	671
Average	177	179	192	179	174	167	173	175	175	163	159	159
Cattle Hauling												
Minimum	12	14	14	16	16	16	15	12	9	8	9	10
Maximum	293	321	336	375	400	397	356	299	259	241	254	271
Average	70	78	82	91	96	95	85	71	62	58	61	66
Cattle Truck Cleaning/Disinfecting												
Minimum	18	20	21	26	26	26	23	18	13	13	18	15
Maximum	498	545	572	637	681	674	604	508	440	409	431	460
Average	120	133	139	155	164	161	144	120	105	98	104	112
Surveillance												
Minimum	275	275	275	275	275	275	275	275	275	275	275	275
Maximum	8,057	8,057	8,057	8,057	8,057	8,057	8,057	8,057	8,057	8,057	8,057	8,057
Average	1,808	1,808	1,808	1,808	1,808	1,808	1,808	1,808	1,808	1,808	1,808	1,808
Total												
Minimum	2,860	3,135	3,295	3,621	3,880	3,877	3,638	3,148	2,794	2,617	2,857	2,642
Maximum	91,589	100,686	106,759	115,965	122,131	119,964	110,360	96,379	87,280	81,521	82,903	85,216
Average	21,280	23,381	24,847	26,978	28,329	27,740	25,425	22,166	20,207	18,861	19,173	19,860

5.3.1.1 Marketing Costs

Indemnity payments, cattle hauling, and cattle truck cleaning and disinfecting costs were most expensive for May initiated outbreaks because May initiated outbreaks marketed a greater number of finish cattle throughout the quarantine length than outbreaks initiated in other months. It was assumed that two days after the quarantine was established finished cattle were allowed to be marketed. Indemnity payment amounts for May initiated outbreaks averaged $18.6 million, $23.4 million, $20.5 million, and $21.6 million for early detection, late detection, regular surveillance, and enhanced surveillance, respectively. The transportation and cleaning and disinfecting costs associated with marketing cattle were relatively small when compared to the other cost components. The combined average cost of hauling cattle and cleaning and disinfecting cattle trucks for May initiated outbreaks was less than $300,000 for all mitigation tactics. Early detection marketed an average of 30,798 head throughout May initiated outbreaks, while late detection marketed 38,744 head. Regular surveillance and enhanced surveillance marketed 33,883 head and 35,659 head on average for May initiated outbreaks, respectively. For outbreaks that began in May, early detection required 833 cattle truckloads to haul the finished cattle to the packing plant for harvest over the quarantine length, while late detection required 1,051 cattle truckloads. Regular surveillance required 919 cattle truckloads and enhanced surveillance required 964 cattle truckloads for May initiated outbreaks. June and April initiated outbreaks marketed slightly smaller numbers of head than May initiated outbreaks and were the second and third most expensive months to have an outbreak begin.

October initiated outbreaks marketed the smallest number of cattle throughout the quarantine length; therefore, indemnity payments, cattle hauling, and cattle truck cleaning and disinfecting costs were the lowest for October initiated outbreaks. Early detection, late detection, regular surveillance, and enhanced surveillance each marketed an average of 18,914 head, 23,763 head, 20,802 head, and 21,876 head, respectively, for October initiated outbreaks. Early detection and late detection indemnity payments for October initiated outbreaks had a $2.8 million difference, with indemnity payment amounts averaging $10.8 million and $13.6 million, respectively. Regular surveillance and enhanced surveillance indemnity payments had a $600,000 difference, with indemnity payments averaging $11.9 million and $12.5 million, respectively. For October initiated outbreaks early detection required 503 cattle truckloads, late detection required 629 cattle truckloads, regular surveillance required 555 cattle truckloads, and enhanced surveillance required 919 cattle truckloads in order to haul the finished cattle to nearby packing plants for harvest. For all mitigation tactics, November and December initiated outbreaks marketed fewer than three thousand additional head than October initiated outbreaks are were the second and third least expensive months to have outbreaks begin.

5.3.1.2 Feeding Costs

Outbreaks that began in March required the most feed and had the largest feed costs of all monthly outbreaks. It was assumed that feed deliveries for quarantined large uninfected feedlots started five days after the quarantine was established. For March initiated outbreaks, early detection required approximately 26,905 tons of feedstuff throughout the quarantine, with an average total feed cost of $4.1 million. Late detection required approximately 34,904 tons of feedstuff for March initiated outbreaks, and total feed cost averaged $5.3 million. Regular surveillance required 29,978 tons of feedstuff, while; enhanced surveillance required 34,904 tons of feedstuff for March initiated outbreaks. Average total feed cost for regular surveillance and enhanced surveillance was $4.6 million and $4.8 million for outbreaks that began in March, respectively. The number of total feed deliveries required throughout March initiated outbreaks ranged from 1,249 feed truck deliveries, for early detection, to 1,620 feed truck deliveries, for late detection. Early detection and late detection mitigation tactics required an average of 13 and 18 feed truck deliveries per day, respectively, for March initiated outbreaks. Regular surveillance required 1,392 feed truck deliveries total or 15 feed truck deliveries per day throughout March initiated outbreaks. Enhanced surveillance required 1,477 feed truck deliveries total or 16 feed delivers per day for outbreaks that began in March. For March initiated outbreaks, the average cleaning and disinfecting cost for feed trucks totaled $162,000 for early detection, $211,000 for late detection, $181,000 for regular surveillance, and $192,000 for enhanced surveillance. Feed truck-hauling costs ranged from $138,000 to $179,000 for early detection and late detection, respectively, for March initiated outbreaks. Regular surveillance and enhanced surveillance feed truck-hauling costs averaged $154,000 and $164,000, respectively. April and February initiated outbreaks were slightly less costly than March initiated outbreaks and on average were second and third most expensive months for outbreaks to take place, respectively.

Feed and feed delivery associated costs were the least expensive for November initiated outbreaks and most expensive for March initiated outbreaks. For November initiated outbreaks the cost of feed averaged \$3.3 million, \$4.3 million, \$3.7 million, and \$3.9 million for early detection, late detection, regular surveillance, and enhanced surveillance mitigation tactics, respectively. Corn was the most expensive feedstuff ingredient, followed by soybean meal and then hay. For November initiated outbreaks, 63 percent of the total feed cost was the cost of corn; soybean meal and hay accounted for 20 percent and 17 percent of average total feed cost, respectively. The number of feed truck deliveries required for November initiated outbreaks ranged between 1,049 deliveries for early detection, and 1,329 deliveries for late detection. Regular surveillance required 1,157 feed truck deliveries and enhanced surveillance required 1,220 deliveries for outbreaks that began in November. The average number of feed deliveries needed per day for November initiated outbreaks ranged from 11 deliveries to 15 deliveries, for early and late detection, respectively. Regular surveillance and enhanced surveillance both required an average of 13 feed deliveries per day over the duration of the quarantine for November initiated outbreaks. Early detection required 22,125 tons of feedstuff throughout the quarantine length, while late detection required 28,366 tons of feedstuff. Regular surveillance required 24,549 tons of feedstuff throughout the quarantine length, while enhanced surveillance required 25,941 tons of feedstuff. The cleaning and disinfecting cost for feed trucks and feed transportation cost for early detection averaged $136,000 and $116,000 respectively. Late detection cleaning and disinfecting cost for feed trucks averaged $173,000, and feed transportation cost averaged $147,000 for November initiated outbreaks. Regular surveillance and enhanced surveillance cleaning and disinfecting cost for feed truck averaged $150,000 and $159,000, while transportation costs averaged $128,000 and $135,000 respectively. Feeding costs for December and October initiated outbreaks were slightly more expensive than November initiated outbreaks but were the second and third least expensive months, respectively, for an outbreak to begin in terms of feeding costs.

5.3.1.3 Surveillance Cost

In the AUSSPREAD model every quarantined large uninfected feedlot was visited five times regardless of the mitigation tactic and initial outbreak month. Therefore, the surveillance costs for each mitigation tactic were constant for each initial outbreak month. Surveillance cost was dependent on the number of head quarantined. Labor, supplies, and equipment costs for FMD surveillance were calculated within the surveillance cost. Early detection had the lowest average surveillance cost of $1.5 million, since it quarantined the lowest number of head on average. Late detection had the highest average surveillance cost of $2 million, followed by enhanced surveillance with an average surveillance cost of $1.8 million, and regular surveillance with an average surveillance cost of $1.7 million. The average cost of one surveillance visit ranged between $300,000 and $403,000. Surveillance cost were bases entirely on the number of head present when the quarantine was established.

5.4 **Welfare Slaughter Strategy**

The overall average total cost for the welfare slaughter strategy was $48.5 million; this can be considered the amount of losses expected if no quarantine policies are established. Total cost included surveillance, appraisal, euthanasia, disposal, cleaning and disinfecting, and indemnity payments for placements, cattle on feed, and marketings. Similar to the unrestricted feed strategy, early detection was the most economical mitigation tactic for the welfare slaughter strategy, with an average total cost of $41.4 million. Late detection was most expensive mitigation tactic, with an average total cost of $55.6 million. Regular surveillance was approximately $3.1 million less costly than enhanced surveillance, with average total costs of $47 million and $50.1 million, respectively.

The cost differences between the mitigation tactics were driven by the number of uninfected cattle quarantined on the feedlots; early detection had the smallest number of head quarantined and was the most economically desirable outcome, while late detection had the largest number of head quarantine and was the most expensive. Quarantine length did not influence costs in the welfare slaughter model because it was assumed that quarantined uninfected cattle would be euthanized as quickly as possible, before feed supplies ran out. The three most expensive components of average total cost were indemnity payments, euthanasia, and disposal. The largest cost component was the indemnity payment amount, which on average accounted for approximately 90 percent of total cost. Euthanasia accounted for approximately 5 percent of total cost and disposal accounted for 3 percent of total cost; while, cleaning and disinfecting, appraisal, and surveillance combined accounted for approximately 3 percent of total cost on average (Table 30). Indemnity payments for cattle on feed account for 57 percent of total cost and 63 percent of total indemnity payments on average, while indemnity payments for marketings and placements accounted for 20 percent and 12 percent of total cost on average and 23 percent and 14 percent of total indemnity payments, respectively (Table 31). It was assumed that indemnity payments were equal to 100 percent of market value before the outbreak began and were calculated based on the monthly herd mixture and average cattle weight.

Table 30. Average Percentage of Average Total Cost for Cost Components by Initial Outbreak Month for all Welfare Slaughter Mitigation Tactics

Initial Outbreak Month	Surveillance Visit	Appraisal	Euthanasia	Disposal	Cleaning and Disinfecting	Total Indemnity Payments
January	0.7%	0.1%	4.9%	3.0%	2.1%	89.2%
February	0.7%	0.1%	4.7%	2.9%	2.0%	89.7%
March	0.8%	0.1%	4.9%	3.1%	2.1%	89.1%
April	0.7%	0.1%	4.9%	3.0%	2.1%	89.2%
May	0.7%	0.1%	4.8%	3.0%	2.0%	89.5%
June	0.7%	0.1%	4.8%	2.9%	2.0%	89.5%
July	0.7%	0.1%	4.7%	2.9%	2.0%	89.7%
August	0.7%	0.1%	4.6%	2.9%	1.9%	89.8%
September	0.7%	0.1%	4.7%	2.9%	2.0%	89.6%
October	0.7%	0.1%	4.6%	2.9%	2.0%	89.8%
November	0.7%	0.1%	4.6%	2.9%	1.9%	89.8%
December	0.7%	0.1%	4.7%	2.9%	2.0%	89.7%
Average	0.7%	0.1%	4.7%	2.9%	2.0%	89.5%

Table 31. Percent of Average Total Cost and Total Indemnity Payments for Placements, Cattle on Feed, and Marketings by Initial Outbreak Month for all Welfare Slaughter Mitigation Tactics

	Placement Indemnity Payments		Cattle on Feed Indemnity Payments		Marketings Indemnity Payments	
Initial Outbreak Month	% Total Cost	% Indemnity Total	% Total Cost	% Indemnity Total	% Total Cost	% Indemnity Total
January	13.0%	14.6%	60.5%	67.8%	15.7%	17.6%
February	0.0%	0.0%	70.5%	78.6%	19.2%	21.4%
March	14.3%	16.0%	55.8%	62.6%	19.0%	21.4%
April	11.3%	12.7%	57.8%	64.8%	20.1%	22.5%
May	10.5%	11.7%	54.6%	61.1%	24.4%	27.3%
June	9.0%	10.1%	53.1%	59.3%	27.4%	30.6%
July	13.2%	14.7%	48.7%	54.3%	27.8%	31.0%
August	14.4%	16.0%	51.9%	57.7%	23.4%	26.1%
September	25.4%	28.3%	45.5%	50.7%	18.8%	20.9%
October	11.8%	13.1%	63.8%	71.1%	14.2%	15.9%
November	12.4%	13.8%	59.6%	66.4%	17.8%	19.8%
December	13.8%	15.3%	58.8%	65.6%	17.1%	19.1%
Average	12.4%	13.9%	56.7%	63.3%	20.4%	22.8%

5.4.1 Welfare Slaughter Strategy Seasonal Results

Based on average total cost, the month of November was the most expensive month for an outbreak to begin and March was the least expensive month for an outbreak to begin. Depending on the initial outbreak month, average total cost for early detection ranged from $39.8 million, for March initiated outbreaks, to $42.6 million, for October initiated outbreaks. Average total cost for regular surveillance ranged from $45.17 million to $48.3 million, while, enhanced surveillance average total cost ranged from $48.2 million to $51.5 million and average total cost for late detection ranged from $53.5 million to $57.2 million. Figure 6 compares the average total cost of mitigation tactics for each initial outbreak month.

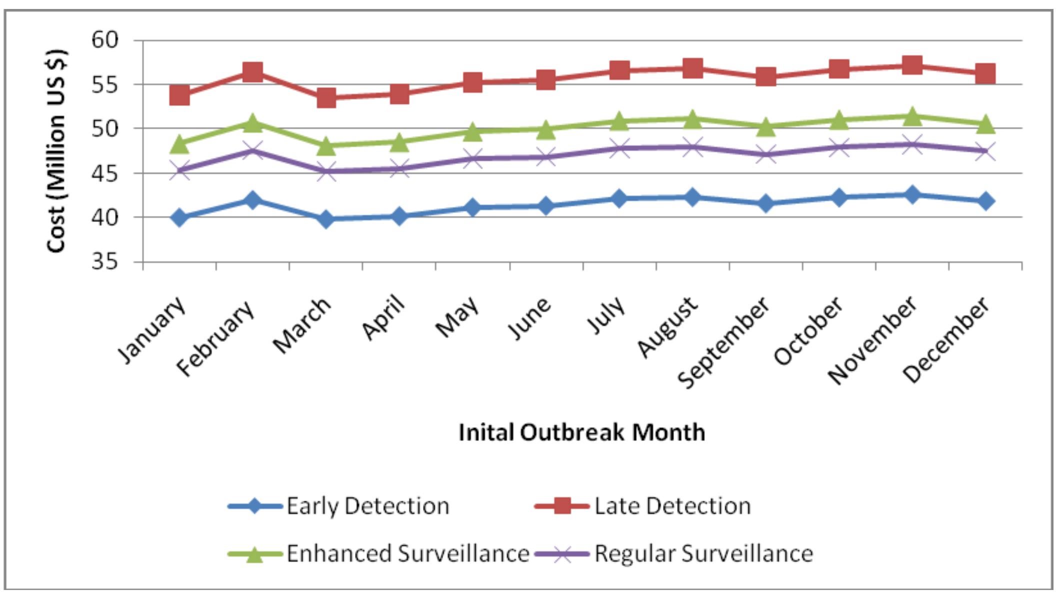

Figure 6. Average Total Cost for Welfare Slaughter Strategy Mitigation Tactics by Initial Outbreak Month

Outbreaks that begun in November were the most expensive followed by October and February initiated outbreaks. The percent difference between average total cost for November and October initiated outbreaks was less than one percent. In addition, the percent difference between November and February initiated outbreaks was only slightly more than one percent. March initiated outbreaks were the least expensive followed by January and April initiated outbreaks. The percent difference between average total cost for March and January initiated outbreaks and March and April initiated outbreaks were both less than one percent. The percent difference for average total cost between November and March initiated outbreaks was approximately 7 percent for all mitigation tactics. Tables 32-35 present the minimum, maximum, and average total costs for all cost components by initial outbreak month for all welfare slaughter strategy mitigation tactics.

Table 32. Welfare Slaughter Early Detection FMD Outbreak Costs for Quarantined Uninfected Large Feedlots

Costs (Thousand US $)	January	February	March	April	May	June	July	August	September	October	November	December
Surveillance												
Minimum	58	58	58	58	58	58	58	58	58	58	58	58
Maximum	1,265	1,265	1,265	1,265	1,265	1,265	1,265	1,265	1,265	1,265	1,265	1,265
Average	300	300	300	300	300	300	300	300	300	300	300	300
Appraisal												
Minimum	4	4	4	4	4	4	4	4	4	4	4	4
Maximum	96	96	96	96	96	96	96	96	96	96	96	96
Average	23	23	23	23	23	23	23	23	23	23	23	23
Euthanasia												
Minimum	380	380	380	380	380	380	380	380	380	380	380	380
Maximum	8,292	8,292	8,292	8,292	8,292	8,292	8,292	8,292	8,292	8,292	8,292	8,292
Average	1,963	1,963	1,963	1,963	1,963	1,963	1,963	1,963	1,963	1,963	1,963	1,963
Disposal												
Minimum	236	236	236	236	236	236	236	236	236	236	236	236
Maximum	5,141	5,141	5,141	5,141	5,141	5,141	5,141	5,141	5,141	5,141	5,141	5,141
Average	1,217	1,217	1,217	1,217	1,217	1,217	1,217	1,217	1,217	1,217	1,217	1,217
C&D												
Minimum	160	160	160	160	160	160	160	160	160	160	160	160
Maximum	3,483	3,483	3,483	3,483	3,483	3,483	3,483	3,483	3,483	3,483	3,483	3,483
Average	824	824	824	824	824	824	824	824	824	824	824	824
Indemnity Payments												
Minimum	6,907	7,286	6,871	6,936	7,126	7,161	7,318	7,347	7,211	7,339	7,402	7,263
Maximum	150,714	158,992	149,941	151,347	155,486	156,260	159,690	160,325	157,360	160,139	161,527	158,487
Average	35,680	37,640	35,497	35,830	36,810	36,993	37,805	37,956	37,254	37,911	38,240	37,520
Total												
Minimum	7,745	8,124	7,709	7,774	7,963	7,999	8,156	8,185	8,049	8,177	8,240	8,101
Maximum	168,992	177,269	168,218	169,624	173,763	174,538	177,967	178,602	175,638	178,416	179,804	176,764
Average	40,007	41,967	39,824	40,157	41,137	41,320	42,132	42,283	41,581	42,239	42,567	41,847

Table 33. Welfare Slaughter Late Detection FMD Outbreak Costs for Quarantined Uninfected Large Feedlots

Costs (Thousand US $)	January	February	March	April	May	June	July	August	September	October	November	December
Surveillance												
Minimum	49	49	49	49	49	49	49	49	49	49	49	49
Maximum	2,010	2,010	2,010	2,010	2,010	2,010	2,010	2,010	2,010	2,010	2,010	2,010
Average	403	403	403	403	403	403	403	403	403	403	403	403
Appraisal												
Minimum	4	4	4	4	4	4	4	4	4	4	4	4
Maximum	153	153	153	153	153	153	153	153	153	153	153	153
Average	31	31	31	31	31	31	31	31	31	31	31	31
Euthanasia												
Minimum	320	320	320	320	320	320	320	320	320	320	320	320
Maximum	13,180	13,180	13,180	13,180	13,180	13,180	13,180	13,180	13,180	13,180	13,180	13,180
Average	2,637	2,637	2,637	2,637	2,637	2,637	2,637	2,637	2,637	2,637	2,637	2,637
Disposal												
Minimum	198	198	198	198	198	198	198	198	198	198	198	198
Maximum	8,172	8,172	8,172	8,172	8,172	8,172	8,172	8,172	8,172	8,172	8,172	8,172
Average	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635	1,635
C&D												
Minimum	134	134	134	134	134	134	134	134	134	134	134	134
Maximum	5,536	5,536	5,536	5,536	5,536	5,536	5,536	5,536	5,536	5,536	5,536	5,536
Average	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108	1,108
Indemnity Payments												
Minimum	5,816	6,136	5,786	5,841	6,000	6,030	6,163	6,187	6,073	6,180	6,234	6,116
Maximum	239,558	252,715	238,328	240,563	247,143	248,373	253,824	254,834	250,122	254,538	256,744	251,912
Average	47,929	50,561	47,683	48,130	49,446	49,692	50,783	50,985	50,042	50,926	51,367	50,400
Total												
Minimum	6,522	6,841	6,492	6,546	6,706	6,736	6,868	6,893	6,778	6,886	6,939	6,822
Maximum	268,608	281,766	267,379	269,613	276,193	277,424	282,874	283,884	279,172	283,588	285,795	280,963
Average	53,741	56,373	53,495	53,942	55,259	55,505	56,595	56,797	55,855	56,738	57,180	56,213

Table 34. Welfare Slaughter Regular Surveillance FMD Outbreak Costs for Quarantined Uninfected Large Feedlots

Costs (Thousand US $)	January	February	March	April	May	June	July	August	September	October	November	December
Surveillance												
Minimum	52	52	52	52	52	52	52	52	52	52	52	52
Maximum	1,662	1,662	1,662	1,662	1,662	1,662	1,662	1,662	1,662	1,662	1,662	1,662
Average	340	340	340	340	340	340	340	340	340	340	340	340
Appraisal												
Minimum	4	4	4	4	4	4	4	4	4	4	4	4
Maximum	126	126	126	126	126	126	126	126	126	126	126	126
Average	26	26	26	26	26	26	26	26	26	26	26	26
Euthanasia												
Minimum	340	340	340	340	340	340	340	340	340	340	340	340
Maximum	10,892	10,892	10,892	10,892	10,892	10,892	10,892	10,892	10,892	10,892	10,892	10,892
Average	2,227	2,227	2,227	2,227	2,227	2,227	2,227	2,227	2,227	2,227	2,227	2,227
Disposal												
Minimum	211	211	211	211	211	211	211	211	211	211	211	211
Maximum	6,753	6,753	6,753	6,753	6,753	6,753	6,753	6,753	6,753	6,753	6,753	6,753
Average	1,381	1,381	1,381	1,381	1,381	1,381	1,381	1,381	1,381	1,381	1,381	1,381
C&D												
Minimum	143	143	143	143	143	143	143	143	143	143	143	143
Maximum	4,575	4,575	4,575	4,575	4,575	4,575	4,575	4,575	4,575	4,575	4,575	4,575
Average	935	935	935	935	935	935	935	935	935	935	935	935
Indemnity Payments												
Minimum	6,180	6,519	6,148	6,206	6,375	6,407	6,548	6,574	6,452	6,566	6,623	6,498
Maximum	197,972	208,845	196,955	198,802	204,240	205,257	209,761	210,596	206,702	210,351	212,175	208,181
Average	40,471	42,694	40,264	40,641	41,753	41,961	42,882	43,052	42,256	43,002	43,375	42,559
Total												
Minimum	6,930	7,269	6,898	6,956	7,125	7,157	7,298	7,324	7,202	7,316	7,373	7,248
Maximum	221,979	232,853	220,963	222,810	228,247	229,264	233,769	234,604	230,709	234,359	236,182	232,189
Average	45,380	47,602	45,172	45,549	46,661	46,869	47,790	47,960	47,164	47,910	48,283	47,467

Table 35. Welfare Slaughter Enhanced Surveillance FMD Outbreak Costs for Quarantined Uninfected Large Feedlots

Costs (Thousand US $)	January	February	March	April	May	June	July	August	September	October	November	December
Surveillance												
Minimum	55	55	55	55	55	55	55	55	55	55	55	55
Maximum	1,614	1,614	1,614	1,614	1,614	1,614	1,614	1,614	1,614	1,614	1,614	1,614
Average	362	362	362	362	362	362	362	362	362	362	362	362
Appraisal												
Minimum	4	4	4	4	4	4	4	4	4	4	4	4
Maximum	123	123	123	123	123	123	123	123	123	123	123	123
Average	28	28	28	28	28	28	28	28	28	28	28	28
Euthanasia												
Minimum	360	360	360	360	360	360	360	360	360	360	360	360
Maximum	10,580	10,580	10,580	10,580	10,580	10,580	10,580	10,580	10,580	10,580	10,580	10,580
Average	2,373	2,373	2,373	2,373	2,373	2,373	2,373	2,373	2,373	2,373	2,373	2,373
Disposal												
Minimum	223	223	223	223	223	223	223	223	223	223	223	223
Maximum	6,560	6,560	6,560	6,560	6,560	6,560	6,560	6,560	6,560	6,560	6,560	6,560
Average	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471
C&D												
Minimum	151	151	151	151	151	151	151	151	151	151	151	151
Maximum	4,444	4,444	4,444	4,444	4,444	4,444	4,444	4,444	4,444	4,444	4,444	4,444
Average	997	997	997	997	997	997	997	997	997	997	997	997
Indemnity Payments												
Minimum	6,543	6,903	6,510	6,571	6,750	6,784	6,933	6,961	6,832	6,952	7,013	6,881
Maximum	192,301	202,862	191,314	193,107	198,389	199,377	203,752	204,563	200,781	204,326	206,097	202,218
Average	43,137	45,507	42,916	43,318	44,503	44,725	45,706	45,888	45,040	45,835	46,232	45,362
Total												
Minimum	7,337	7,697	7,304	7,365	7,544	7,578	7,727	7,754	7,626	7,746	7,807	7,675
Maximum	215,621	226,182	214,634	216,427	221,709	222,697	227,072	227,883	224,101	227,645	229,417	225,538
Average	48,369	50,738	48,147	48,550	49,735	49,956	50,938	51,120	50,271	51,066	51,464	50,594

5.4.2 Seasonal Indemnity Payments

For the welfare slaughter strategy, cost differences between initial outbreak months were solely driven on varying indemnity payment amounts for placements, cattle on feed, and marketings. Placements were categorized as cattle that entered the feedlot right before the FMD outbreak occurred. Cattle on feed were categorized as cattle that entered the feedlot previous to the new placements and won't reach market weights within the next month, while marketings were cattle that would reach market weight and be harvested within the next month. Placements were indemnified based on the full value before the outbreak occurred for the weighted steer and heifer incoming weight. Marketings were indemnified based on the full value before the outbreak occurred for the weighted steer and heifer final weight and cattle on feed were assumed to be indemnified based on the average between the weighted incoming weights and final weights for steer and heifer. If this was not the case this would be reflective of the producer loss due to the movement restriction.

During each month the majority of the herd was classified as cattle on feed, so it's not surprising that indemnity payments for cattle on feed were the most expensive cost component. Depending on the mitigation tactic, indemnity payments for cattle on feed ranged from \$18.9 million, for outbreaks initiated in September, to \$39.8 million, for outbreaks initiated in February. Indemnity payments for marketing were the second most expensive cost component overall for each initial outbreak month, expect for September initiated outbreaks. Average cost of indemnity payments for marketings ranged from $6 million, for October initiated outbreaks, to $15.73 million, for outbreaks that began in July. Indemnity payments for placements were the third largest cost component of the welfare slaughter strategy for all initial outbreak months, except for February and September initiated outbreaks. There were no placements in the Texas feedlot herd makeup for the month of February because of the nature of original data used to build the Texas feedlot herd makeup, therefore, indemnity payments for placements for February initiated outbreaks were nonexistence. For September initiated outbreaks indemnity payments for placements were the second most expensive cost component; this happened because the original data used to build the Texas feedlot herd makeup had two placement lots arriving in September so the percentage of placements in September was unusually high. Average cost of indemnity payments for placements ranged from $0, for February initiated outbreaks, to $10.6 million, for September initiated outbreaks. Tables 36-39 summarize the minimum, maximum, and average indemnity payments amounts for each mitigation tactic and initial outbreak month.

Table 36. Welfare Slaughter Early Detection Indemnity Payment Costs for Quarantined Uninfected Large Feedlots

Cost (Thousand US $)	January	February	March	April	May	June	July	August	September	October	November	December
Placement Indemnity												
Minimum	1,010	0	1,101	878	833	721	1,077	1,179	2,042	961	1,024	1,114
Maximum	22,046	0	24,016	19,157	18,166	15,735	23,504	25,719	44,549	20,971	22,337	24,306
Average	5,219	0	5,686	4,535	4,301	3,725	5,564	6,089	10,546	4,965	5,288	5,754
Cattle on Feed Indemnity												
Minimum	4,684	5,729	4,302	4,497	4,350	4,247	3,974	4,251	3,661	5,213	4,911	4,761
Maximum	102,202	125,003	93,882	98,127	94,929	92,667	86,725	92,766	79,878	113,751	107,164	103,885
Average	24,195	29,593	22,226	23,231	22,474	21,938	20,531	21,961	18,910	26,930	25,370	24,594
Marketings Indemnity												
Minimum	1,213	1,558	1,468	1,561	1,943	2,193	2,267	1,917	1,509	1,165	1,468	1,388
Maximum	26,467	33,989	32,042	34,063	42,390	47,858	49,460	41,841	32,934	25,416	32,027	30,296
Average	6,266	8,047	7,586	8,064	10,036	11,330	11,709	9,905	7,797	6,017	7,582	7,172
Indemnity Total												
Minimum	6,907	7,286	6,871	6,936	7,126	7,161	7,318	7,347	7,211	7,339	7,402	7,263
Maximum	150,714	158,992	149,941	151,347	155,486	156,260	159,690	160,325	157,360	160,139	161,527	158,487
Average	35,680	37,640	35,497	35,830	36,810	36,993	37,805	37,956	37,254	37,911	38,240	37,520

Table 37. Welfare Slaughter Late Detection Indemnity Payment Costs for Quarantined Uninfected Large Feedlots

Cost (Thousand US $)	January	February	March	April	May	June	July	August	September	October	November	December
Placement Indemnity												
Minimum	851	0	927	739	701	607	907	993	1,719	809	862	938
Maximum	35,041	0	38,173	30,450	28,875	25,010	37,360	40,880	70,809	33,334	35,504	38,634
Average	7,011	0	7,637	6,092	5,777	5,004	7,475	8,179	14,167	6,669	7,103	7,730
Cattle on Feed Indemnity												
Minimum	3,944	4,824	3,623	3,787	3,663	3,576	3,347	3,580	3,083	4,390	4,136	4,009
Maximum	162,448	198,690	149,224	155,971	150,889	147,293	137,848	147,449	126,965	180,805	170,335	165,123
Average	32,501	39,752	29,855	31,205	30,188	29,469	27,579	29,500	25,402	36,174	34,079	33,036
Marketings Indemnity												
Minimum	1,021	1,312	1,237	1,315	1,636	1,847	1,909	1,615	1,271	981	1,236	1,169
Maximum	42,069	54,026	50,931	54,142	67,379	76,070	78,616	66,505	52,348	40,399	50,906	48,155
Average	8,417	10,809	10,190	10,832	13,481	15,219	15,729	13,306	10,473	8,083	10,185	9,634
Indemnity Total												
Minimum	5,816	6,136	5,786	5,841	6,000	6,030	6,163	6,187	6,073	6,180	6,234	6,116
Maximum	239,558	252,715	238,328	240,563	247,143	248,373	253,824	254,834	250,122	254,538	256,744	251,912
Average	47,929	50,561	47,683	48,130	49,446	49,692	50,783	50,985	50,042	50,926	51,367	50,400

Table 38. Welfare Slaughter Regular Surveillance Indemnity Payment Costs for Quarantined Uninfected Large Feedlots

Cost (Thousand US $)	January	February	March	April	May	June	July	August	September	October	November	December
Placement Indemnity												
Minimum	904	0	985	786	745	645	964	1,055	1,827	860	916	997
Maximum	28,958	0	31,546	25,164	23,863	20,669	30,874	33,783	58,517	27,547	29,341	31,928
Average	5,920	0	6,449	5,144	4,878	4,225	6,312	6,906	11,963	5,631	5,998	6,527
Cattle on Feed Indemnity												
Minimum	4,191	5,126	3,849	4,024	3,892	3,800	3,556	3,804	3,275	4,664	4,394	4,260
Maximum	134,248	164,198	123,320	128,895	124,695	121,723	113,918	121,853	104,924	149,418	140,765	136,458
Average	27,444	33,567	25,210	26,350	25,491	24,884	23,288	24,910	21,450	30,546	28,777	27,896
Marketings Indemnity												
Minimum	1,085	1,394	1,314	1,397	1,738	1,962	2,028	1,716	1,350	1,042	1,313	1,242
Maximum	34,766	44,647	42,089	44,743	55,682	62,865	64,969	54,960	43,260	33,386	42,069	39,796
Average	7,107	9,127	8,604	9,147	11,383	12,851	13,282	11,236	8,844	6,825	8,600	8,135
Indemnity Total												
Minimum	6,180	6,519	6,148	6,206	6,375	6,407	6,548	6,574	6,452	6,566	6,623	6,498
Maximum	197,972	208,845	196,955	198,802	204,240	205,257	209,761	210,596	206,702	210,351	212,175	208,181
Average	40,471	42,694	40,264	40,641	41,753	41,961	42,882	43,052	42,256	43,002	43,375	42,559

Table 39. Welfare Slaughter Enhanced Surveillance Indemnity Payment Costs for Quarantined Uninfected Large Feedlots

Cost (Thousand US $)	January	February	March	April	May	June	July	August	September	October	November	December
Placement Indemnity												
Minimum	957	0	1,043	832	789	683	1,020	1,117	1,934	910	970	1,055
Maximum	28,129	0	30,643	24,443	23,179	20,077	29,990	32,815	56,841	26,758	28,500	31,013
Average	6,310	0	6,874	5,483	5,200	4,504	6,727	7,361	12,751	6,002	6,393	6,957
Cattle on Feed Indemnity												
Minimum	4,437	5,427	4,076	4,260	4,121	4,023	3,765	4,027	3,468	4,939	4,653	4,510
Maximum	130,402	159,495	119,787	125,202	121,123	118,236	110,655	118,362	101,919	145,138	136,733	132,549
Average	29,252	35,778	26,871	28,086	27,171	26,523	24,822	26,551	22,863	32,558	30,672	29,734
Marketings Indemnity												
Minimum	1,149	1,476	1,391	1,479	1,840	2,078	2,147	1,817	1,430	1,103	1,390	1,315
Maximum	33,770	43,368	40,884	43,462	54,087	61,064	63,108	53,386	42,021	32,429	40,864	38,656
Average	7,575	9,728	9,171	9,749	12,133	13,698	14,157	11,976	9,426	7,275	9,167	8,671
Indemnity Total												
Minimum	6,543	6,903	6,510	6,571	6,750	6,784	6,933	6,961	6,832	6,952	7,013	6,881
Maximum	192,301	202,862	191,314	193,107	198,389	199,377	203,752	204,563	200,781	204,326	206,097	202,218
Average	43,137	45,507	42,916	43,318	44,503	44,725	45,706	45,888	45,040	45,835	46,232	45,362

6. SUMMARY AND DISCUSSION

6.1 Summary

This study investigated the costs and benefits of movement policies associated with large feedlots that fall within quarantine zones during a FMD outbreak. Specifically it examined welfare slaughter issues that could arise due to movement restrictions. Two alternatives were investigated: one where the movement restrictions held and animals were slaughtered because of feed insufficiencies or space constraints and the other where feed was able to move in and finished animals out but at higher costs, plus the finished animals were assumed to go into cooked or canned meat uses at a 50% price discount. The results show that regardless of when a FMD outbreak occurred, using an unrestricted feed strategy was more cost effective than using a welfare slaughter strategy. Intuitively, this implies that, if an effective truck disinfection regime can be put in place, it is more worthwhile to feed animals out and use the meat. Meaning, policies to provide feed to confined feeding operations and planning for moving meat to cooked and canned meat markets may be warranted as a part of preparedness planning.

These results were consistent with the results found in Hagerman and McCarl (2009), where movement restriction policies that allowed feed to be brought onto California dairy premises located within the quarantine zone were less expensive than movement restriction policies that didn't allow feed to be brought in.

For the unrestricted feed strategy the overall average total cost for all initial outbreaks months and mitigation tactics averaged $22.6 million, while, the overall total cost for the welfare slaughter strategy averaged $48.5 million The average total cost difference between the unrestricted feed strategy and the welfare slaughter strategy ranged from $16.8 million to $36.3 million, a percent difference ranging from 60 percent to 94 percent, depending on the mitigation tactic and initial outbreak month.

The timing of when an outbreak occurred had an impact on the overall cost because of the monthly feedlot cattle weight mixture and seasonal cost components, such as the market value of cattle and feed costs. For the unrestricted feed strategy, outbreaks that began in October were the least expensive on average. This was mainly due to the fact the October initiated outbreaks affected the marketing of the least number of cattle over the duration of the quarantine yielding the lowest indemnity payment amounts and associated marketing costs across all monthly outbreaks. Outbreaks that began in May were the most expensive because of the highest annual amount of marketings and in turn the highest indemnity payments and marketing costs. For the welfare slaughter strategy, March initiated outbreaks were the least costly on average, while outbreaks that began in November were the most expensive. In the welfare slaughter strategy indemnity payments weren't dominated by anyone herd segment type. Neither March nor November were initial outbreak months with minimum or maximum indemnity payments for placements, cattle on feed, or marketings. This suggests that the entire herd makeup must be examined to estimate indemnity payments for welfare slaughter strategies.

Finally it is worthwhile mentioning that under both scenarios there were substantial losses arising to the uninfected premises within the quarantine zone. But current US policy does not indicate that there would be indemnity payments for such parties. Consequently one other policy recommendation is that planners consider adding such payments to the suggested disease response policy.

6.2 **Limitations**

There are several limitations to this research that merit discussion. First, the AUSSPREAD model results used did not reflect the risk of greater disease spread probabilities associated with the feed in and animals out strategy and adding this might be in order plus the increased or decreased risk of disease spread was not considered or captured in the cost. Second the feedlot cattle weight mixture wasn't built using Texas feedlot data; the only data available was from Kansas feedlots, so the data was adjusted using the average quarterly Texas steer to heifer ratio for cattle on feed. Third, the total cost estimates should be considered conservative because no resource constraints were considered. The movement strategies, especially the welfare slaughter strategy, may require some of the same resources required by the disease eradication efforts; competing for resources needed for the eradication effort could add time to the overall quarantine length or additional costs. Fourth, portions of the epidemiological results from the AUSSPREAD model didn't match the findings of the High Plains Study (Ward et al. 2009). For example, the previous study found that early detection significantly reduced the quarantine length, which was not the case in this study; early detection quarantines had the longest minimum and average quarantine length of the mitigation tactics examined. This could have possibly happened because this study focused on a narrow portion of the epidemiological results, four scenarios and only quarantined, uninfected large feedlots; whereas, the High Plains Study included all epidemiological results for the thirteen premises types and 64 scenarios. However, early detection did reduce the average and maximum number of head quarantined compared to the other mitigation tactics, which matched the results of the High Plains Study (Ward et al. 2009). Fifth, the AUSSPREAD results did not show variation in the number of surveillance visits between mitigations tactics; especially regular surveillance tactics verses enhanced surveillance tactics. In future FMD cost research conducted using the AUSSPREAD model the underlying assumption that control surveillance visits should be adjusted so that the number of visits each uninfected premises receives varies.

6.3 **Application and Extension of Research**

Although the application of this research pertained to preventing animal welfare issues on uninfected, quarantined large feedlots in the THPR, the methodology developed and the results of this study potentially has other uses and broader implications for animal disease outbreak emergency and contingency planning. The timing of when an outbreak occurs affects the costs associated with mitigating the disease because herd mixtures, input prices, and output prices vary depending on the time of year. Previous animal disease outbreak studies have failed to take into account the seasonal affects of costs and herd mixture. Herd mixtures fluctuate throughout the year based on producers' expectations and biological factors. Understanding the seasonal fluctuations of herd mixtures is a step that can be taken to better inform policy makers of disease implications for multiple disease threats, not just FMD. The timing of an outbreak could impact the way policy makers choose to mitigate a disease outbreak.

In addition, animal welfare issues such as feed shortages could arise because of movement restrictions, especially in areas of concentrated livestock production. This work could be extended to examine other possible movement strategies or combinations of strategies that could minimize costs associated with movement restrictions. In addition, developing seasonal herd mixtures for the other THPR herd types would allow for a more thorough cost accounting of animal welfare strategies in the region. This study assumed that feedlots operate at full capacity throughout the year, but varying feedlot populations throughout the year would be another logical extension. Also, resource constraints could be modeled and integrated into the movement strategies to see how they would affect cost. Finally, the framework developed in this study could be applied to other livestock production areas outside of the THPR. Overall, this research serves as a foundation for future studies that examine costs of disease outbreaks based on when they occur.

6.4 **Conclusion**

During an FMD outbreak mitigating animal welfare issues on uninfected, quarantined large feedlots will be costly, just how costly will partially be dependent on when the outbreak occurs. The results show that regardless of when a FMD outbreak occurred, using an unrestricted feed strategy was more cost effective than using a welfare slaughter strategy in preventing animal welfare issues on uninfected quarantined large feedlots. Despite its shortcomings, the information generated by this study is of potential value to policy makers showing them the costs associated with mitigating animal welfare issues on quarantined, uninfected feedlots. The results suggest that policy makers should strongly consider creating movement policies that address feed supply and finished animal movement for facilities in long standing quarantine zones; as such policies appear to reduce outbreak related costs for stakeholders and the U.S. government. Indemnity policies for uninfected herds in the quarantine zone also merit consideration.

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