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THESIS

**THE VULNERABILITY OF U.S. AGRICULTURE TO
FOOT AND MOUTH DISEASE**

by

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June 2015

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**THE VULNERABILITY OF U.S. AGRICULTURE TO FOOT AND MOUTH
DISEASE**

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ABSTRACT

The U.S. livestock industry represents a critical economic infrastructure, due to its size and influence on national and international agricultural systems. The high-concentration farming practices that allow the United States to be a world leader in agriculture also present a vulnerability to biological pathogens, particularly foot and mouth disease (FMD). The purpose of this thesis is to stimulate and broaden the discussion of the U.S. livestock industry's susceptibility to an FMD outbreak, regardless of how it is introduced. It reviews case studies of prominent outbreaks in the United Kingdom (2001) and Taiwan (1997). The themes that emerged from these case studies—responsibility and response—informed a discussion of ways to increase U.S. efficiency when responding to an FMD outbreak. The case studies illustrate that FMD outbreaks in thriving livestock industries can have devastating economic, social, and political consequences. The United States should address these and other international FMD outbreaks to improve the preparedness and resilience of the U.S. livestock industry to an outbreak of FMD.

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LIST OF ACRONYMS AND ABBREVIATIONS

APHIS	Animal and Plant Health Information System
BZ	Buffer Zone
CA	Control Area
FAD PReP	Foreign Animal Disease Preparedness and Response Plan
FEMA	Federal Emergency Management Agency
FMD	Foot and Mouth Disease
GAO	Government Accounting Office
GDP	Gross Domestic Product
HSPD	Homeland Security Presidential Directive
IZ	Infected Zone
MAFF	Ministry of Agriculture Fisheries and Food
NAHEMS	National Animal Health Emergency Management System
NAHERC	National Animal Health Emergency Response Corps
NIMS	National Incident Management System
NRF	National Response Framework
NVSL FADDL	National Veterinarians Services Laboratories-Foreign Animal Disease Diagnostic Laboratory
OIE	World Organization for Animal Health
PPD	Presidential Policy Directive
SZ	Surveillance Zone
TCID ₅₀	Tissue Culture Infective Dose
U.K.	United Kingdom
U.S.	United States
USDA	United States Department of Agriculture
WTO	World Trade Organization

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I. INTRODUCTION

A. MAJOR RESEARCH QUESTION

The threat of the introduction of biological pathogens in United States agriculture is not only possible, but likely.¹ Relevant to this threat, experts have testified to Congress, political scientists have written about it, and farmers worry about the possibility. An aspect of this threat that deserves more attention is how this country is overwhelmingly dependent on large-scale agricultural production, which is increasingly vulnerable to foot and mouth disease (FMD). In particular, high-concentration areas where animals are kept before being sent to slaughter, feeder lots located “between the barn and butcher,” and large dairy farms present vulnerable centers of gravity. At these locations, the entry of FMD would cause heavy stress to the U.S. agricultural industry.

We should consider, in order to effectively and efficiently protect this vulnerable infrastructure, the potential large-scale effects of a biological pathogen introduced to United States. This thesis examines the potential effects of FMD on livestock agriculture in the United States. Specifically, this thesis asks: What are the consequences of introducing FMD into the high-concentration farming areas of the livestock industry, and what can be done to reduce the vulnerability of high-concentration livestock farming in the United States?

B. IMPORTANCE OF RESEARCH

The United States is currently responding to an outbreak of the avian flu. Thus far, nearly 37 million chickens have been killed and the cost to the

¹ *Agroterrorism's Perfect Storm: Where Human Animal Disease Collide: Hearing before the Subcommittee on Prevention of Nuclear and Biological Attack of the Committee on Homeland Security, U.S. House of Representatives, 109th Cong., 2 (2006).* There were many different oral testimonies given on this day, and all of the experts agreed that there is a threat and this issue needs more support at the national level.

economies of Minnesota and Iowa is almost \$1 billion and rising.² This thesis will show that experts believe that this cost could be relatively small compared to the effect an FMD outbreak could have on the nation's agricultural industry. According to the United States Department of Agriculture (USDA), a highly contagious biological agent—like foot and mouth disease—would effectively halt agricultural operations throughout the United States for an extended period of time.³ Exporting of all agricultural products would cease and those products would be subject to a long and tedious recertification process. It would not require a terrorist attack to cause such significant disruption; major FMD outbreaks in the United Kingdom and Taiwan were the result of the natural propagation of FMD and still registered significant economic and psychological damage to both countries. Still, the ill effects of an FMD outbreak could be much greater if it was purposefully introduced into animal populations with malice or technical sophistication.

FMD can affect all cloven-hooved animals. FMD is naturally a very destructive and contagious disease that spreads easily by air and other land based methods of transportation. Comprised of seven types and more than 80 subtypes, FMD is one of the agriculture industry's most dreaded viral diseases.⁴ The large amounts of variation in the virus make it difficult to produce an effective and universal vaccine.⁵ Another trait of the disease is its resilience; in optimal conditions, FMD can incubate as a viable virus for up to 200 days. This makes

² David Pitt, "Bird Flu Could Cost Nearly \$1 Billion in Minnesota and Iowa," *Washington Post*, May 18, 2015, http://www.washingtonpost.com/national/health-science/bird-flu-could-cost-nearly-1-billion-in-minnesota-and-iowa/2015/05/18/2ef0fe48-fda6-11e4-8c77-bf274685e1df_story.html.

³ U.S. Department of Agriculture (USDA), *Foot and Mouth Disease (FMD) Response Ready Reference Guide—Quarantine, Movement Control, and Continuity of Business* (Riverdale, MD: USDA Animal and Plant Health Inspection Service Veterinary Services, Preparedness and Incident Coordination, 2013), 1, http://www.aphis.usda.gov/animal_health/emergency_management/downloads/fmd_rrg_cob_qmc_plan.pdf.

⁴ U.S. Government Accountability Office (GAO), *Foot and Mouth Disease; To Protect U.S. Livestock, USDA Must Remain Vigilant and Resolve Outstanding Issues* (GAO-02-808) (Washington, DC: Author, 2002), 14.

⁵ Terrence K. Kelly et al., *The Office of Science and Technology Policy Blue Ribbon Panel on the Threat of Biological Terrorism Directed Against Livestock* (Santa Monica, CA: RAND Corporation, 2004), 62.

eradication of the disease very complex.⁶ These naturally occurring traits do not require weaponization or alteration. As is, FMD presents itself as a useful tool to devastate the livestock industry, a key aspect of the United States economy. As discussed throughout this thesis, an FMD outbreak has sobering implications.

C. IMPLICATIONS OF WORK

Political scientists, veterinarians, and farmers have argued, especially after September 11, 2001, that a terrorist attack on America's agricultural infrastructure—specifically against high-concentration farms—utilizing FMD should be a serious concern. The advancement of biotechnology has brought the level of knowledge required to make a serious pathogen to that of a high school graduate.⁷ Terrorists are not as familiar with bioweapons as they are with conventional weapons,⁸ but they recognize the value and vulnerability of the agricultural industry. Osama Bin Laden, in a 2003 sermon, said

America is a great power possessed of tremendous military might and a wide-ranging economy, but all this is built on an unstable foundation which can be targeted, with special attention to its obvious weak spots. If America is hit in one hundredth of these weak spots, God willing, it will stumble, wither away and relinquish world leadership.⁹

The Department of Homeland Security appropriates funding to address agriculture-related homeland security activities; this funding has tripled in the amount from \$225 million, before 9/11, to \$818 million in 2007.¹⁰ The increase in funding demonstrates recognition of an emerging threat. Still, of that allocated

⁶ Kelly et al., *Threat of Biological Terrorism*, 62.

⁷ Richard J. Danzig, *A Policymaker's Guide to Bioterrorism and What to Do About It* (Washington, DC: National Defense University, Center for Technology and National Security Policy, 2009), 9.

⁸ *Ibid.*, 12.

⁹ David Ignatius, "Winning a Battle of Wills," *Washington Post*, July 13, 2005, <http://www.washingtonpost.com/wp-dyn/content/article/2005/07/12/AR2005071201365.html>.

¹⁰ Jim Monke, *Agroterrorism: Threats and Preparedness* (CRS Report No. RL32521) (Washington, DC: Congressional Research Service, 2007), <https://www.fas.org/sgp/crs/terror/RL32521.pdf>.

amount, only 6 percent is used for emergency preparedness; of that 6 percent, 58 percent is used in border security.¹¹ Increased border security is vital and a useful way to prevent attacks, but more emphasis should be placed on how to respond once FMD is introduced into the United States. In 2002, hundreds of documents were recovered from a cave in Afghanistan that expressed al Qaeda's interest in attacking United States agricultural industry.¹² The documents discussed possible attacks that would exploit the size, scope, productivity, and lack of preparedness in the American agricultural infrastructure.¹³

The agriculture industry presents many vulnerabilities that groups looking to harm this critical infrastructure could target. In particular, high concentration areas of livestock are prime targets, because FMD is so contagious. For example, before cattle, pigs, and sheep are sent to slaughterhouses they are sent to feeder lots where they are fattened up to fetch a premium market price. At any given time, more than 70 percent of the nation's cattle may be located within a 500-mile radius of 2 percent of the nation's foodlots.¹⁴ Some of these "superlots" contain more than 250,000 animals; other studies suggest that 30 of America's feedlots prepare 50 percent of the cattle heading to the market.¹⁵ Billions of dollars are at risk if FMD is introduced to one or two of these critical nodes and is not met with a proper and planned response.

D. LITERATURE REVIEW

Inherent vulnerabilities in high-concentration farming are identified by many scholars and analysts, and authors like Richard Danzig, Jason Moats, and

¹¹ Monke, *Agroterrorism: Threats and Preparedness*, 37.

¹² *Agroterrorism: The Threat to America's Breadbasket: Hearing before the Committee on Governmental Affairs, Senate*, 108th Cong., 1 (2003) (statement of Susan M. Collins, Chairman of the Committee).

¹³ *Ibid.*, 1.

¹⁴ Aeneas R. Gooding, "Agricultural Terrorism (Agroterror) and Escalation Theory" (master's thesis, Naval Postgraduate School, 2007), 12, <http://hdl.handle.net/10945/3171>.

¹⁵ *Ibid.*, 12.

Jim Monke provide valuable insight to the threat and magnitude of damage FMD can inflict on the agricultural infrastructure. Many of these experts agree that the greatest deficiency, in high-concentration farming, of the United States is in its ability to respond to this threat and build a coordinated approach to contain and eradicate FMD from the United States.¹⁶

Merriam Webster defines agriculture as “the science or practice of farming, including cultivation of the soil for the growing of crops and rearing of animals to provide food, wool, and other products.”¹⁷ Historically, agriculture has fulfilled a vital niche in the United States economy. Native Americans grew corn and gathered naturally growing berries to supplement a diet of wild game. Today, the size and production of farms is much greater.

Since 1900, agriculture has experienced significant changes to become what it is today. In 1900, agriculture employed 41 percent of the work force.¹⁸ In 1920, farmers comprised 27 percent of the labor force, operated over six million farms with an average size of 148 acres, and produced up to five commodities on each farm.¹⁹ From 1920 to 1929 U.S. exports were \$1.94 billion per year.²⁰ In 2012, farmers operated just over two million farms in the United States, tilled acreage averaging over 430 acres per farm, and produced, on average, one

¹⁶ Danzig, *Policymaker's Guide to Bioterrorism*, 2; Monke, *Agroterrorism: Threats and Preparedness*, ii; Peter Chalk, *Hitting America's Soft Underbelly: The Potential Threat of Deliberate Biological Attacks against the U.S. Agricultural and Food Industry* (Santa Monica, CA: RAND Corporation, 2004), http://www.rand.org/content/dam/rand/pubs/monographs/2004/RAND_MG135.pdf.

¹⁷ Webster's New World College Dictionary, 5th ed., s.v., “Agriculture” (Boston, MA: Houghton Mifflin Harcourt, 2014).

¹⁸ Carolyn Dimitri, Anne Effland, and Neilson Conklin, *The 20th Century Transformation of U.S. Agriculture and Farm Policy* (Economic Information Bulletin Number 3) (Washington, DC: Economic Research Service, USDA, 2005). http://www.ers.usda.gov/media/259572/eib3_1_.pdf.

¹⁹ “Growing a Nation: The Story of American Agriculture,” National Agriculture in the Classroom, last modified 2014, <http://www.agclassroom.org/gan/index.htm>.

²⁰ National Agriculture in the Classroom, “Growing a Nation.”

commodity.²¹ In 2012, agriculture and agriculture related industries contributed \$775.8 billion to the U.S. gross domestic product (GDP); of that figure American farmers contributed \$166.9 billion or 1 percent of GDP.²² In 2014, agricultural exports exceeded \$152 billion and imports totaled over \$109 billion.²³ The transformation that has taken place over the past century is a forced response to the increase in population, and specialization has allowed farmers to shift from small multiple commodity farms to large-scale single commodity operations.

Another point of interest is that a state, like Texas, can have as many animals as the country of South Korea.²⁴ Thirty-five of 50 states have susceptible livestock in excess of 1 million animals; 10 states have over 5 million; and 4 states have more than 10 million animals.²⁵ These high-concentration farms create a greater interconnectedness, because farmers now rely on others to supplement needed inputs such as feed, bedding, and waste processing.

1. Operation of American Agriculture

Agriculture in the United States is diverse and permeates many different industries and locations. Wisconsin is known as America's dairy land because of large dairy farms that produce milk for the production of cheese and other dairy products; Iowa is known for large pig farms; Texas has large ranches with many head of cattle to support a huge beef industry.²⁶

²¹ "Ag and Food Sectors and the Economy," USDA, Economic Research Service (ERS), last modified April 6, 2015, <http://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/ag-and-food-sectors-and-the-economy.aspx>.

²² USDA, ERS, "Ag and Food Sectors."

²³ "Foreign Agricultural Trade of the United States, FATUS," spreadsheet, United States Department of Agriculture, Economic Research Service, last modified April 6, 2015, http://www.ers.usda.gov/datafiles/Foreign_Agricultural_Trade_of_the_United_States_FATUS/Latest_U.S._Agricultural_Trade/monsumtable.xls.

²⁴ USDA, *Foot and Mouth Disease (FMD) Response Ready Reference Guide—Overview of FMD Vaccine Issues* (Riverdale, MD: USDA APHIS, Veterinary Services, PIC, 2013), 2, http://www.aphis.usda.gov/animal_health/emergency_management/downloads/fmd_plan_rrg_vaccine.pdf.

²⁵ USDA, *Overview of FMD Vaccine Issues*, 2.

²⁶ Jason B. Moats, *Agroterrorism: A Guide for First Responders* (College Station, TX: Texas A&M University Press, 2007), 6.

There are many layers to the agricultural system in the United States. Whether a farm is in Wisconsin or California, the foundation of each starts with the organism that is produced on each. The operation that grows or raises the organism is a farm. The farm can be a small family farm that keeps fewer than one hundred milking cows or a huge corporation that keeps over five thousand milking cows.²⁷ The USDA defines a farm as any place from which \$1,000 or more of agricultural products were produced and sold, or normally would have been sold, in a year.²⁸

A group of farms in a geographical area make up an agricultural community. The ability to specialize in one aspect of farming allows for higher levels of production, because farmers can put all their time and energy into a specific commodity. For example, a grain farmer will sell soybeans to the feed-mill which will subsequently sell feed to farmers that are raising livestock, alleviating the need for a livestock farmer to grow grains. This sharing provides a network between farms to support each other so they can specialize, but not have the burden of being self-sufficient.²⁹

The next layer of agriculture is the national agriculture system. This layer consists of agricultural communities and all of the supporting features that make farming possible. Some of the supporting industries are petrochemical manufacturing, which creates fertilizers and insecticides, and heavy machinery manufacturing, which builds implements for tilling and harvesting crops. This level also includes the interaction with wholesalers, retailers, and the federal government, which is a large buyer and seller of agricultural products.

The final layer of the U.S. agricultural industry is the international market. As discussed earlier, the United States exports billions of dollars in agricultural products, so the ability of the United States to continue meeting the needs of

²⁷ Moats, *Agroterrorism: A Guide for First Responders*, 6.

²⁸ "Glossary of Terms," USDA, ERS, last modified May 22, 2015, <http://www.ers.usda.gov/topics/farm-economy/farm-household-well-being/glossary.aspx#farm>.

²⁹ Moats, *Agroterrorism: A Guide for First Responders*, 6.

other countries is important to the overall health of U.S. agriculture. All of this interconnectedness provides the smooth sharing and growing of a vital industry, but interconnectedness also presents a vulnerable system that could be devastated by a disruption to operations.³⁰

2. Fragility of Livestock Industry

Jason Moats argues that the international agriculture industry will likely not fail if one farm stops producing milk or one farm stops growing corn; however, if a disease or natural disaster destroyed or debilitated a few farming communities, there is a very good chance that the interconnectedness of agriculture would result in massive losses across all levels.³¹ FMD exploits the mobility and closeness of the livestock industry. If a cow, pig, sheep, or goat is infected with FMD, and the disease has not been identified by the farmer or veterinarian, the potential for that animal to travel thousands of miles and infect other animals it comes in contact with is very great. The mobility and interconnectedness of concentration farming in the United States, and the world, only increases the chances of a biological agent to enter the United States and deliver a crippling blow to the agricultural industry as it is known today. An extremely contagious disease, like FMD, is just the type of biological agent that once introduced to the United States, whether accidentally or maliciously, would require a rehearsed, efficient, and robust response to minimize damages.³²

3. Why the American Livestock Industry Is at Risk

As previously discussed, the United States increasingly relies on agriculture to support the growing population and exportation of goods. Farms have also increased in size, resulting in higher vulnerability to biological agents from either natural causes or terrorist attacks. Farmers tend to specialize in one

³⁰ Moats, *Agroterrorism: A Guide for First Responders*, 7–8.

³¹ *Ibid.*, 8.

³² *Ibid.*, 8–9.

area of farming. According to experts, specialization creates huge monocultures of animals and creates greater vulnerabilities to pathogens.

Farmers are overconfident in this monoculture and rely on the stability and health of herds to not use vaccines against potential pathogens; moreover, statutes against vaccinating herds, due to the contagious nature of FMD, increase susceptibility to an outbreak.³³ According to a RAND study, if FMD was introduced to a cow at an auction, within 24–48 hours that animal could possibly travel up to 1000 miles and infect every cloven-hoofed animal with which it comes in contact—or even those animals it does not contact, because FMD can be transmitted through the air.³⁴

4. Entry into the United States

The Government Accountability Office (GAO) has identified many ways for FMD to enter in the United States. Every year approximately 470 million international passengers and pedestrians transit through U.S. ports of entry, and of those the USDA only has the capacity to inspect about 102 million.³⁵ Aside from terrorist plots and attempts to disperse pathogens, daily there are international flights that contain food waste, international mail that enters the U.S. every day and must be screened, and U.S. military personnel returning from tours overseas.³⁶

Every one of these situations presents a potential entrance for FMD to enter the United States, and the inability of the USDA to properly inspect every item is an understandable situation. However, the inability to inspect every person, bag, trash can, and boot that enters the United States poses a vulnerability for biological agents to enter the country.³⁷

³³ Henry S. Parker, *Agricultural Bioterrorism: A Federal Strategy to Meet the Threat* (Washington, DC: Institute for National Strategic Studies, National Defense University, 2002), 12.

³⁴ Chalk, *Hitting America's Soft Underbelly*, 8.

³⁵ GAO, *Foot and Mouth Disease*, 44.

³⁶ *Ibid.*, 44.

³⁷ *Ibid.*, 38.

5. Impact

An FMD outbreak in the United States would wreak devastating economic damage. The GAO recognizes the direct cost of hoof and mouth disease eradication to include the following measures: quarantines, intense inspections of meat products entering and exiting the United States, sanitation of facilities, disposal and burying of diseased and culled animals, vaccine creation and dissemination, and producer compensations.³⁸ In the United Kingdom's outbreak of 2001 direct costs of eradication cost over \$6 billion.³⁹ If there was an outbreak in the United States and the disease was identified early, confined, and efficiently eradicated, the cost could easily be that much.⁴⁰

The GAO and RAND researcher Henry Parker agree that the effects of FMD would decimate the job market. Agriculture may only directly employ 3 percent of the U.S. population, but 1 in 8 people are employed in the support of food production and dissemination.⁴¹ The cascading effect would go something like this: cattle producers detect the pathogen on their farm, that farm and every farm the animal was in contact with previously are immediately quarantined—not to mention every farmer in a 50-mile radius will be on high alert, all imports and exports of animal products are stopped, feed producers cannot sell their products, stores pull meat from shelves, consumers become afraid to eat meat, and the effects go on and on.⁴² The point of the illustration is to show the 2nd-, 3rd-, and 4th-order effects that are possible and often not factored into the calculus when determining a policy to prevent FMD from entering the United States.

A study published in the *Journal of Psychiatric Practice* identifies how traumatized farmers, workers, and a population can become when they witness

38 GAO, *Foot and Mouth Disease*, 19.

39 Ibid., 19.

40 Ibid., 19.

41 Parker, *Agricultural Bioterrorism*, 11.

42 GAO, *Foot and Mouth Disease*, 19.

the mass slaughtering and burning of hundreds of thousands of animals. Farmers are especially vulnerable to this from the human-animal relationship developed in rearing the livestock.⁴³ Farmers that witnessed the United Kingdom (U.K.) outbreak often described the traumatic experience as follows, “We could hear the lambs bleating even after leaving the yards, and we were no longer able to watch.”⁴⁴ The article also found that farmers were afflicted with feelings of guilt, shame, helplessness, anger, and grief over losing the farm.

6. Farmer Protections

The Farm Bill of 2014 signed by President Obama builds on the principles of investing, expanding, conserving, and increasing knowledge in agriculture from the 2008 version.⁴⁵ In 2011, disaster assistance programs expired leaving farmers impacted by disease or adverse weather situations without aid, but the Farm Bill of 2014 restored the livestock disaster assistance program and allows farmers to make claims from the expiration of assistance in 2011.⁴⁶ In addition to making retroactive payments, the 2014 bill established a permanent safety net for farmers affected by disease or adverse weather situations.⁴⁷ Establishing these protections is advantageous for farmers, but the bill does not place any focus on prevention. The bill is focused on programs to subsidize farmer’s losses by disease and weather.

In trade and foreign agriculture there is a continuing allotment of \$200 million annually for international market development and increased flexibility for assistance in emergency situations.⁴⁸ However, the bill vaguely addresses the

⁴³ Molly J. Hall et al., “Psychological Impact of the Animal-Human Bond in Disaster Preparedness and Response,” *Journal of Psychiatric Practice* 10, no. 6 (2004), 371.

⁴⁴ Hall et al., “Psychological Impact,” 371.

⁴⁵ Moats, *Argoterrorism: A Guide for First Responders*, 7. This paragraph and the previous are based on Moats; his description of the agricultural industry is the best I have seen.

⁴⁶ USDA, “2014 Farm Bill Highlights,” last modified March 2014, <http://www.usda.gov/documents/usda-2014-farm-bill-highlights.pdf>.

⁴⁷ Ibid.

⁴⁸ Ibid.

need to develop programs that prevent the entrance of disease into the United States or the identification and response to a biological outbreak in U.S. territory. These continuations and increases still fail to place a precedence on the importance of prevention, response, and level of complexity a biological outbreak would place on the United States and International agricultural industry. The Farm Bill of 2014 may not focus on prevention, but there are organizations that are working to prevent the entrance of FMD into the United States and minimize the impact of FMD if it does reach the United States.

Organizations like the World Organization for Animal Health (OIE), the World Trade Organization (WTO), and the USDA continually strive to develop tracking mechanisms, early detection technology, standardized responses, and effective vaccines for contagious biological pathogens.⁴⁹ The World Trade Organization uses the OIE, and its 180 member countries, as reference organizations to monitor animal health worldwide in order to preserve international trade volume through intergovernmental relationships.⁵⁰ In order to minimize the chances of FMD spreading to countries that are designated as “FMD free,” the World Animal Health Organization has statutory reporting requirements by its member countries.⁵¹ Since the United States is a member of the World Animal Health Organization it is subject to guidelines delineated by the OIE.⁵²

In recent years, USDA scientists have continually developed more sophisticated vaccines that significantly reduce the time to develop antigens preventing the contraction of FMD. In 2014, the agricultural research service, a part of the USDA that studies FMD, developed a new vaccine that can make pigs

⁴⁹ “About Us,” World Organization for Animal Health, last modified 2015, <http://www.oie.int/about-us/>.

⁵⁰ Susan M. Dixon, “Collaborative Response and Recovery from a Foot-and-Mouth Disease Animal Health Emergency: Supporting Decision Making in a Complex Environment with Multiple Stakeholders” (master’s thesis, Naval Postgraduate School, 2013), 2.

⁵¹ Ibid.

⁵² Ibid.

resistant to FMD within 24 hours. Prior to this breakthrough there was a 4–7 day wait before swine were protected.⁵³ These continued advances in vaccinations are the key to minimizing the effects of an FMD outbreak in the United States.

This literature review presents the transformation and current situation of U.S. agriculture by scientists and academics. They reinforce that the livestock industry is vitally important to the United States and increases in size and production have created vulnerabilities that could devastate this infrastructure if exploited accidentally or maliciously. However, there is solace in the advances organizations like the USDA's Agricultural Research Center and World Animal Health Organization are making to better understand and control this contagious biological pathogen. The results of underestimating the probability and scope of a biological outbreak in the United States could lead to the culling of millions of animals and billions of dollars in response-related expenses.

E. METHODOLOGY

This thesis compares two case studies where FMD devastated thriving agricultural industries in the U.K. (2001) and Taiwan (1997). Each case study's analysis focuses on four categories: origin and propagation, response, implications of disposal and clean-up, and economic impact.

Standardizing these case studies allowed the author to note the similarities and shortcomings in each case. The lessons learned from the case studies provide the United States with valuable tools to decrease the vulnerability of U.S. agriculture to FMD. Ideally, this thesis will continue the discussion and make suggestions to increase the resilience of the livestock industry through training and policy recommendations.

⁵³ USDA, Agriculture Research Service, "ARS Project: Intervention Strategies to Support the Global Control and Eradication of Foot-and-Mouth Disease Virus (Fmdv) (422203) Annual Report," last modified April 22, 2015, http://www.ars.usda.gov/research/projects/projects.htm?ACCN_NO=422203&fy=2014.

F. THESIS OVERVIEW

This thesis is organized into four chapters. Chapter I offers the reader an overview of agriculture in the United States and the vulnerabilities that exist in this large interconnected infrastructure. Chapter II examines two recent instances of FMD: the United Kingdom (2001) and Taiwan (1997). Each case will begin by examining the origin and propagation of the outbreak, followed by an analysis of the government's response, the disposal and clean-up operation, and the overall economic impact of the outbreak. The chapter concludes with a review of the lessons learned from these two outbreaks. Chapter III applies what was learned from the U.K. and Taiwan to navigate U.S. risk in an FMD outbreak, and determine the factors that can minimize the effects of FMD. The fourth and final chapter explores a terrorism-motivated exposure of FMD and an analysis of the current readiness level of the United States.

II. CASE STUDIES OF FMD IN THE U.K. AND TAIWAN

While there are many dangerous diseases that could be introduced into the United States, the World Organization for Animal Health established foot and mouth disease as a first priority on its official list of free countries and zones.⁵⁴ The United States has been foot and mouth disease free since 1929, but that does not mean the country's agriculture infrastructure is secure from the threat of this dangerous biological pathogen entering the U.S. again.⁵⁵ The introduction of a biological pathogen, like FMD, can truly decimate a thriving agricultural industry, especially when the interconnectedness and mobility of the infrastructure allow for thousands of animals to be moved thousands of miles in a couple of days. The experiences of the United Kingdom and Taiwan⁵⁶ in 2001 and 1997 paint a vivid picture of the dangerous characteristics of FMD. The consequences of poor preparation and execution are represented in the case studies that will be examined in this chapter. Specifically, this chapter asks if there are areas these two countries could have better prepared and responded to minimize the prodigious impact FMD had on their economies.

A. UNITED KINGDOM OUTBREAK

The first case study this chapter will examine is that of the United Kingdom, where more than 3 million sheep, 590,000 cattle, 140,000 pigs, 2,000 goats, and 1,000 deer were killed in 2001 to stop the proliferation of FMD.⁵⁷ Over 12,000 farmers and farm workers lost their jobs and the outbreak cost the

⁵⁴ "About FMD," World Organization for Animal Health, last modified 2015, <http://www.oie.int/en/animal-health-in-the-world/fmd-portal/about-fmd/>.

⁵⁵ USDA, *Foot and Mouth Disease (FMD) Response Ready Reference Guide*— (Riverdale, MD: USDA APHIS, Veterinary Services, PIC, 2015), http://www.aphis.usda.gov/animal_health/emergency_management/downloads/fmd_rrg_freedom_and_vaccination.pdf.

⁵⁶ Taiwan is also known as China (Taipei) depending on who you ask, but for the purposes of this thesis it will be referred to as Taiwan.

⁵⁷ Parker, *Agricultural Bioterrorism*, 14–15.

government approximately \$6 billion.⁵⁸ The contagious nature of FMD and a month of its undetected spread allowed FMD to permeate many layers of the agricultural industry in the U.K.

Just as in a car crash, getting professional medical attention to the injured is critical and often the biggest factor in minimizing the spread of damage; responding to FMD is the same—early detection and corrective measures are paramount in containing and eradicating the disease. Symptoms in animals, sufficient for an FMD diagnosis, could have been identified as early as January 20, 2001, but no phone call was made until February 19, when the resident vet at the abattoir called state veterinarians to confirm what he thought was either FMD or swine vesicular disease.⁵⁹

1. Origin and Propagation

On February 20, 2001, the U.K. reported its first case of FMD in Essex from an abattoir,⁶⁰ but the index case (the first case of the disease) is thought to have come from Burnside Farm, a pig finishing lot⁶¹ in Northumberland, which feeds pigs processed food waste, known as pigswill.⁶² Unfortunately, this pigswill was most likely contaminated with FMD from illegally imported meat. Moreover,

⁵⁸ Rosa Tennenbaum, "Britain and HMD One Year Later: Many Questions, No Answers," Schiller Institute, March 2002, http://www.schillerinstitute.org/food_for_peace/ffp_uk_0402_rtb.html.

⁵⁹ Iain Anderson, *Foot and Mouth Disease 2001: Lessons to be Learned Inquiry Report* (London: Stationary Office, 2002), 54.

⁶⁰ An abattoir is a slaughterhouse used to process cattle, sheep, pigs etc., for human consumption.

⁶¹ A pig finishing lot is the production phase between nursery and market designed to feed the pigs until an optimum weight is achieved to maximize profits in an open market. "Pork Glossary," U.S. Environmental Protection Agency, n.d., <http://www.epa.gov/agriculture/ag101/porkglossary.html>.

⁶² J. M. Scudamore, *Origin of the UK Foot and Mouth Disease Epidemic in 2001* (London: Department for Environment, Food and Rural Affairs, 2002), 3. Pigswill is human food waste that is often mixed with water and fed to pigs, by law it is supposed to be heat treated prior to use to kill disease—in this case it was not heated resulting in the start of the FMD epidemic in the U.K.

as the meat entered the country illegally there was no way to trace its origin, but the same strain of FMD is prominent in the Far East.⁶³

Although only 1.4 percent of the pig population was fed using swill, on May 24, 2001, the government implemented a ban on this feeding practice due to the high probability of illegally imported meat infected with FMD being used.⁶⁴ Some of the pigs at Burnside farm had lesions that were 12 days old, indicating the possibility of FMD being present as early as January of 2001, which allowed for almost a month of unhindered spread.⁶⁵ Since FMD was allowed to propagate undetected for over a month it allowed pigs to be transferred to farms over 300 miles away.

Pigs are large, and thus they produce large amounts of aerosolized FMD. Their movement throughout the country exposed very susceptible yet asymptomatic sheep⁶⁶ almost two miles away. As a result, sheep became infected by inhaling the pathogen as it traveled through the air.⁶⁷ Delays in reporting allowed Burnside Farm to move infected animals to other farms and abattoirs, increasing the range of the virus and delaying critical response times.

One can imagine that farmers heard about the looming ban on transporting animals and decided to move every animal they could (Figure 1). This last-minute movement of animals would ensure the farmers had the opportunity to collect profits before the transportation ban took place. It was estimated that 25,000 sheep, all exposed to FMD, were transported throughout the country from February 14 to February 23.⁶⁸

⁶³ Anderson, *Foot and Mouth Disease*, 48.

⁶⁴ Ibid., 51.

⁶⁵ Scudamore, *Origin, Foot and Mouth Disease*, 3.

⁶⁶ Sheep often do not display the typical symptoms and are much harder to diagnose, as a result, the sheep ended up spreading FMD; Anderson, *Foot and Mouth Disease*, 49.

⁶⁷ Anderson, *Foot and Mouth Disease*, 49.

⁶⁸ Ibid., 61.

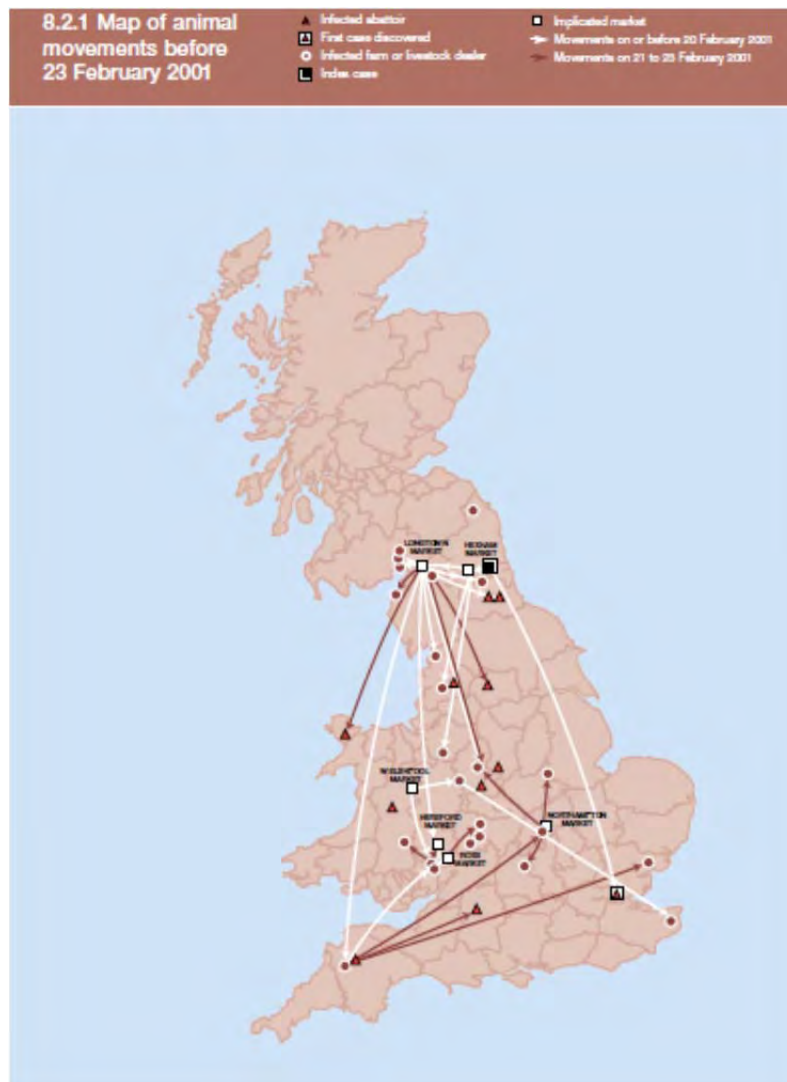


Figure 1. Map of Animal Movements before February 23, 2001⁶⁹

2. Response

There was an immediate quarantine placed on the abattoir to properly assess the animals on site, to determine the origin of the infected pigs, and blood samples were sent to the state laboratory to be tested.⁷⁰ However, poor communication resulted in the samples sitting until the following day. Only then

⁶⁹ Anderson, *Foot and Mouth Disease*, 59.

⁷⁰ Ibid., 54.

was the identification of FMD confirmed and relayed to the Ministry of Agriculture Fisheries and Food (MAFF).⁷¹

Even with a positive FMD sample, the MAFF not only required a second sample, it required that Dr. Alex Donaldson, Head of Pirbright Laboratory, observe first-hand the symptoms displayed by the pigs at the abattoir.⁷² One can appreciate the credence placed on a positive diagnosis due to the economic ramifications of FMD, but these actions eliminated precious response time. His identification of FMD was needed to allow the culling of infected animals to begin. Now, not many people, especially farmers, want to cull animals that are perceived to be healthy and saleable, but a situation involving extremely contagious pathogens has much greater costs to the farmer and industry when animals are allowed to remain a viable medium capable of spreading the virus further. Exports were promptly stopped on the February 20, 2001, but animal movements inside the country were authorized until February 23. The decision to allow animal transports, already in progress, to be completed resulted in a record number of animals being moved around the country, greatly increasing the potential spread of FMD.⁷³

a. Personnel

The personnel issues are manning and training. Each farm potentially exposed to FMD needed a team consisting of one veterinarian and at least two helpers, and once the team finished on one farm it was considered dirty and unable to move to the next area until a certain period of time had passed.⁷⁴ The personnel resources and tasking, especially in veterinarians, was often concentrated on non-vet tasks because people were not properly trained, resulting in wasted time and resources. The number of veterinarians who

⁷¹ Anderson, *Foot and Mouth Disease*, 54.

⁷² Ibid., 57.

⁷³ Ibid., 59.

⁷⁴ Ibid., 69.

responded was insufficient to bring about the eradication of the disease; on April 1, 2001, more than 600,000 animals awaited slaughter and approximately 1,200 veterinarians oversaw these operations.⁷⁵

Adequate levels of veterinarian support were not attained until the government called all veterinarians, military and civilian, to assist in the efforts.⁷⁶ The critics of waiting to involve the military in support of the response think the delay was to avoid promulgating a negative political message during an election year.⁷⁷

b. Vaccinations

In an outbreak of FMD, vaccinations can be the most hotly debated topic because of policy and scientific issues.⁷⁸ There are three methods of vaccinating animals:

1. Routine, mass vaccination for long-term prevention when FMD is endemic or recurrent-outlawed in the EU because vaccine is a live virus;
2. Protective vaccine, emergency vaccination of a limited number of animals in a restricted area—vaccinate-to-live;
3. Suppressive vaccination, emergency vaccination and subsequent slaughter of a limited number of animals in a restricted area—vaccinate-to-die.⁷⁹

Each of the three methods has implications for the international trading market. International trade restrictions are enforced to isolate the outbreak country and prevent more infected animals from entering or exiting the country. For example, an animal vaccinated to live will finish out its economic life, but will prevent the clearing of trade restrictions. This method raises pressure to eliminate those animals so international trade will resume earlier, instead of

⁷⁵ Anderson, *Foot and Mouth Disease*, 79.

⁷⁶ *Ibid.*, 81.

⁷⁷ *Ibid.*

⁷⁸ *Ibid.*, 120.

⁷⁹ *Ibid.*

waiting up to 12 months to gain a cleared status.⁸⁰ There are many moral discussions with respect to slaughtering millions of healthy, vaccinated animals—particularly if the mass killing serves only to reduce the time a country is restricted from international trade.⁸¹ The requirements to be designated an FMD-free country and to resume international trade are provided in Figure 2.

13.2.1 International Animal Health Code in 2001	
FMD-free country without vaccination	• No outbreak for the past 12 months • No vaccination for at least 12 months • No importation of vaccinated animals since the cessation of vaccination
FMD-free country with vaccination	• No outbreak for the past 2 years • Routine vaccination with a vaccine complying with the OIE standards • System of intensive surveillance for detection of any viral activity
FMD-free zones require surveillance or buffer zones, or physical or geographical barriers that separate the free zone from the infected territories.	
The Code stated: When FMD occurs in an FMD-free country or zone where vaccination is not practised, the following waiting periods are required to regain the disease-free status: a) 3 months after the last case where a stamping-out policy and serological surveillance are applied, or b) 3 months after the slaughter of the last vaccinated animal where stamping-out, serological surveillance and emergency vaccination are applied. When FMD occurs in an FMD-free country or zone where vaccination is practised, the following waiting periods are required to regain the disease free status: a) 12 months after the last case where stamping-out is applied, or b) 2 years after the last case without stamping-out, provided that an effective surveillance has been carried out.	

Figure 2. International Animal Health Code in 2001⁸²

⁸⁰ Ibid.

⁸¹ Andy Coghlan, "Vaccine Promises to Cull Foot and Mouth Slaughter," *New Scientist*, March 28, 2013, <http://www.newscientist.com/article/dn23327-vaccine-promises-to-cull-foot-and-mouth-slaughter.html#.VUrOpN2yug>. This argument is outside the scope of this thesis, but presents valid points on the moral, economic, and psychological aspect of FMD responses. Many articles are available on a quick Google search.

⁸² Anderson, *Foot and Mouth Disease*, 122.

Vaccination in the U.K. was not seen as a viable option because the virus had already spread throughout the country, and restrictions on exports were already implemented.⁸³ The looming economic losses dictated a plan that expedited the reinstatement of international trade. The effectiveness of vaccinations is dependent on the timely discovery and implementation of responses—which, as seen above, was not the case.

3. Implications of Disposal and Clean-up

In order to fully eradicate FMD from 8,450 farms, over 3 million animals were culled, often requiring the slaying of 80,000 animals per day.⁸⁴ The U.K. fielded many issues in response to the mass eradication of animals, including opposition from farmers, the public, and law-makers. The government was accused of preemptively killing animals on farms that may not have become infected, a practice called “contiguous killing.” One of the biggest lessons learned from an outbreak of classical swine fever in the Netherlands in 1997,⁸⁵ however, was that the suspension of contiguous culling at all possible establishments was the reason for the massive spread of infection.⁸⁶ A problem with contiguous killing was the large area it covered; disposing of large numbers of seemingly healthy animals; and the serious personnel, environmental, and psychological problems that accompany this type of tactic.⁸⁷

British authorities could have drawn important lessons regarding the disposal of animal carcasses from the disposal of pigs in the Netherlands during the 1997 classical swine fever outbreak.⁸⁸ The U.K. disposal tactics experienced the same logistical hurdles; even though mass burial sites are the easiest and

⁸³ Ibid., 125.

⁸⁴ Chalk, *Hitting America's Soft Underbelly*, 23.

⁸⁵ The classical swine fever outbreak in the Netherlands resulted in the culling of over 11 million pigs.

⁸⁶ Anderson, *Foot and Mouth Disease*, 96.

⁸⁷ Ibid., 97.

⁸⁸ Mary-Louise Penrith, “Classic Swine Fever (CSF),” African Veterinary Information Portal, n.d., http://www.afrivip.org/sites/default/files/classic_swine_fever_5_control_1.pdf.

quickest method of disposing carcasses, there are possibilities of negative environmental consequences. The effects include large burial sites leaving large areas of land unusable for many years, and the possibility of contaminating local drinking water if toxins leach through the ground.⁸⁹ The landfill owners were reluctant to accept the carcasses because of community implications, which resulted in the digging of mass disposal sites elsewhere.

The use of incineration is also quick and easy, but the large number of carcasses, in this case, could result in large plumes of smoke polluting the air and the negative psychological effects of seeing thousands of burning carcasses weighs heavily on some.⁹⁰ Moreover, the media took many photos when large piles of pig carcasses were burned in 1997 and the effect on the tourism industry lingered for many years.⁹¹ However, the longer the infected carcasses remain above ground or intact, the higher the probability of spreading FMD.⁹² This was particularly apparent in Cumbria, as 40,000 carcasses lay rotting for weeks prior to disposal.⁹³ Killing and disposing of affected animals was not possible until the military was called upon to bring large machinery and manpower to assist in controlling measures.⁹⁴ The military was able to use its specialty in logistics and management to effectively and efficiently dispatch resources to bring the outbreak under control.⁹⁵

4. Economic Impact

The economic impact of the FMD outbreak in the U.K. was equivalent to over \$6 billion and affected not only the agricultural industry but the tourism

⁸⁹ Chalk, *Hitting America's Soft Underbelly*, 24.

⁹⁰ Chalk, *Hitting America's Soft Underbelly*, 24.

⁹¹ Anderson, *Foot and Mouth Disease*, 114.

⁹² Chalk, *Hitting America's Soft Underbelly*, 24, 25.

⁹³ Anderson, *Foot and Mouth Disease*, 79.

⁹⁴ *Ibid.*, 82.

⁹⁵ *Ibid.*

industry as well.⁹⁶ The financial cost of FMD was not taken on by farmers, many of whom received welfare payments from the government and other private business, but there were others employed in agriculture and in the tourism industry who were not subsidized, forcing them to close businesses and seek other employment.⁹⁷ After a 1967 FMD outbreak, a comprehensive cost-benefit analysis was conducted and found that the economic benefits of implementing control measures exceeded the cost of controls and eradication of FMD.⁹⁸

B. TAIWAN OUTBREAK

Taiwan enjoyed more than 68 years without an FMD outbreak, but on March 14, 1997, a pig farm called in a suspected case of FMD. Upon confirmation of FMD, Taiwan closed its export market, suffering large economic losses. In addition to losses in exports, over 65,000 jobs in feed mills, pharmaceuticals, meat packing, machinery manufacturing, and transportation were lost. These huge losses can be reduced through mitigating and controlling measures taken in pre- and post-pandemic situations. The factors that hindered the response in the U.K. were also found in Taiwan's response, and reinforce the requirement to be ready and capable of an effective reaction when faced with this type of situation. The size and speed of the 1997 Taiwan FMD outbreak is attributed to the following factors: inability to shutdown livestock auction markets, delays in depopulation methods, pig density was very high (1922 pigs/km²), and a shortage of vaccines.⁹⁹

1. Origin and Propagation

The case of FMD in the U.K. took just over 24 hours to confirm with deficiencies that could have provided an earlier diagnosis and response.

⁹⁶ Ibid., 134.

⁹⁷ Ibid., 137.

⁹⁸ Anderson, *Foot and Mouth Disease*, 139.

⁹⁹ P. C. Yang et al., "Epidemiological Characteristics and Financial Costs of the 1997 Foot-and-Mouth Disease Epidemic in Taiwan," *Veterinary Record: Journal of the British Veterinary Association* 145, no. 25 (1999), 733.

Taiwan's FMD outbreak took five days to confirm, and in that time, FMD spread to 28 pig farms. On March 19, 1997, after FMD was confirmed in Taiwan, the policy to cull all pigs on infected farms and vaccinate all farms in the surveillance zone (SZ) was enacted immediately.¹⁰⁰ In Taiwan's FMD outbreak, the infected and surrounding areas were classified in two zones. Taiwan designated the area where FMD was first discovered as the protection zone, and it extended three kilometers in all directions from infected farms.

The surveillance zone extends another three kilometers and ideally provides enough of a buffer to stop the spread of FMD by airborne methods. However, this tactic did not curb the spread of FMD,¹⁰¹ because pigs infected with FMD can produce up to 10^8 Tissue Culture Infective Doses (TCID₅₀) when only 10 TCID₅₀ is needed to infect other animals with the virus.¹⁰² These large amounts of airborne FMD allowed easy transmission between the densely populated farming communities of Taiwan.¹⁰³ As of April 15, 1997, there were over 3,700 farms infected with FMD and there was no sign of decelerating the pandemic. The failure to stop transportation of pigs was a major contributor to the spread of FMD, because the livestock market was a nexus of the pandemic.¹⁰⁴

The strain of FMD introduced to Taiwan did not affect ruminant animals even when they came in direct contact with pigs infected by FMD. This may have reduced the number of animals to cull, but the high density of pig farms in Taiwan resulted in the exposure of 78.1 percent of the entire pig population to FMD.¹⁰⁵

¹⁰⁰ Yang et al., "Epidemiological Characteristics," 731.

¹⁰¹ Yang et al., "Epidemiological Characteristics," 731.

¹⁰² Dolores Gavier-Widén, J. Paul Duff, and Anna Meredith, *Infectious Diseases of Wild Mammals and Birds in Europe* (Oxford, UK: Wiley-Blackwell, 2012).

¹⁰³ Yang et al., "Epidemiological Characteristics," 734.

¹⁰⁴ Ibid., 731.

¹⁰⁵ Ibid., 733.

2. Response

During the outbreak in Taiwan there were over 4 million pigs killed to stop the spread of FMD, and an important problem of FMD response is finding a way to dispose of this many carcasses. The military brought heavy machinery, personnel, and experience in logistics and management that aided the responders and was able to clear the backlog of animals needing to be culled or disposed.¹⁰⁶

The benefits of the military responding included large machinery that was used to help dig large holes to bury carcasses. They also supplemented non-skilled positions that allowed veterinarians to concentrate on treating sick animals. Lastly, the military was able to use its experience in moving large amounts of supplies and managing large operations in restricted environments.

a. Personnel

Like the U.K. outbreak, response personnel were unable to contain and keep up with the rapid spread of FMD. The number of farms and animals infected with FMD significantly increased the need for skilled and unskilled manpower and was supplemented by military personnel. Taiwan, like the U.K., was very short on personnel and responders, which led to infected farms being placed on a waiting list of one to four weeks before eradication was able to be carried out.¹⁰⁷ It was not until the military intervened that the backlog of actions was cleared and some level of control was attained.

b. Vaccines

Vaccinations are a key element of eradicating FMD from a country. However, the shortages in vaccinations left partially vaccinated farms vulnerable to FMD infection and merely served as a node to advance the spread of FMD. In late April, attempting to control the outbreak, Taiwan decided to vaccinate all

¹⁰⁶ Ibid.

¹⁰⁷ Yang et al., "Epidemiological Characteristics," 733.

animals. The blanket vaccination led to vaccine shortages, so triage dictated that farms in the surveillance zone received vaccines first. The inability to vaccinate was reversed when a shipments of vaccines started to arrive in late April and early May.¹⁰⁸ As the supply replenished, priority would go to animals in the protection zone.¹⁰⁹

When Taiwan was able to enforce transportation restrictions, in conjunction with newly adopted vaccination practices, the disease started to show a decrease in new cases and relieved the requirement to kill all animals on infected premises to only eradicating clinically ill animals. The successful vaccination of all animals significantly slowed the spread of FMD, and on July 15, 1997, the last new case of FMD was reported in Taichung County.¹¹⁰ In total there were 6,147 farms infected with FMD and over 4 million pigs were destroyed.¹¹¹

The vaccines did allow for country-wide vaccinations, but a perpetual reliance on them prevents an OIE classification of FMD free without vaccination. An OIE classification of FMD-free with vaccination significantly reduces the number of countries one can trade with. Taiwan is still battling FMD outbreaks and suffers great economic losses from what was once a primary exporter of pork in the region. The waiting periods for vaccinate-to-live practices require twice the wait time to regain export privileges and can incur huge monetary costs.¹¹² Unfortunately, sporadic outbreaks of FMD have prevented Taiwan from achieving a FMD-free status without vaccination.

¹⁰⁸ Ibid., 734.

¹⁰⁹ Ibid., 731–32.

¹¹⁰ Yang et al., “Epidemiological Characteristics,” 732.

¹¹¹ Ibid., 733.

¹¹² D. W. Geale et al., *A Review of OIE Country Status Recovery Using Vaccinate-to-Live Versus Vaccinate-to-Die Foot-and-Mouth Disease Response Policies II: Waiting Periods After Emergency Vaccination in FMD Free Countries* (Canada: Wiley, 2013), doi: 10.1111/tbed.12165.

3. Implication of Disposal and Clean-up

There were over 4 million pigs culled to stop the spread of FMD in Taiwan, and there was a backlog, ranging from one to four weeks, of farms that needed help slaughtering and disposing of dead animals. Animals with acute symptoms of FMD made up 4.5 percent of animals killed. The remaining 95.5 percent—or 3.85 million healthy pigs—were casualties of eradication strategies. There are controversial discussions in regard to killing millions of healthy animals to gain an FMD free without vaccination status using a stamping out method. A stamping out method merely uses vaccines to stop the spread of FMD and once the spread is stopped every healthy animals that received a vaccination is killed.¹¹³ This argument is outside the scope of this thesis, but it will be recommended in the future work section to, ideally, create more discussion on a controversial topic.

4. Economic Impact

The 1997 outbreak of FMD in Taiwan resulted in a price tag of over \$6 billion dollars.¹¹⁴ Most of the losses stem from the restrictions on international trade, because Taiwan, once a net exporter of pork and pork products, now relies on imports.¹¹⁵ The outbreak lowered the price of pork across the board, so even farms that were not exposed to FMD suffered a 70-percent decrease in market prices.¹¹⁶ In order to offset the price drop in pork, the government agreed on indemnity payments to farmers affected by FMD. However, since the indemnity payments were higher than market value, some farmer purposefully infected their otherwise clean farms.

¹¹³ Geale et al., *Review of OIE Country*.

¹¹⁴ “Economic Impact of FMD Outbreaks,” Federation of American Scientists (FAS), last modified 2011, <http://fas.org/biosecurity/education/dualuse-agriculture/1.-agrorterrorism-and-foodsafety/economic-impact-of-fmd-outbreaks.html>.

¹¹⁵ FAS, “Economic Impact of FMD Outbreaks.”

¹¹⁶ Yang et al., “Epidemiological Characteristics,” 733.

Taiwan's government bore the majority of indemnity payments, but many businesses and industries were unable to continue operating. The total number of jobs lost from the Taiwan outbreak is estimated to be over 65,000.¹¹⁷ Additionally, some estimates value the total economic impact at \$19 billion in lost revenue.¹¹⁸

C. LESSONS LEARNED

In both of the case studies presented, experts were able to determine the origin of animal-zero (the index case). Interestingly, according to some reports, the 1997 Taiwan case may have originated with a pig placed deliberately by China; although this claim is unproven, it represents the difficulty in preventing and laying blame on a possible attack aimed at disrupting a country's critical agricultural infrastructure.¹¹⁹ In both cases, the terrible destruction and financial burden placed on the country involved highlight the importance of developing a response, mitigating risk, and maintaining communication between players involved and the public. Regardless of how FMD enters the United States, one can appreciate the destructive power of this disease, and place credence on learning from other countries affected by this devastating disease. If this is the case, the United States would be remiss not to learn from the mistakes of other countries and take appropriate measures to ensure the chances of an FMD happening are at or approaching zero.

1. United Kingdom

J. M. Scudamore, the Chief Veterinary Officer in the U.K., attributed the size and extent of the outbreak to seven key factors:

¹¹⁷ Ibid.

¹¹⁸ *Agroterrorism: The Threat to America's Breadbasket: Hearing before the Committee on Governmental Affairs, Senate, 108th Cong., 1* (2003) (statement of Susan M. Collins, Chairman of the Committee), 1.

¹¹⁹ Parker, *Agricultural Bioterrorism*, 14, 15.

1. Delay in reporting the index case¹²⁰
2. Airborne infection of nearby sheep farm
3. Movement of infected sheep before index case was reported
4. Optimal climate increased virus survival during a time when large numbers of sheep were being transported about the country
5. FMD in sheep rarely includes lesions, making diagnosis harder
6. Large herd size and reductions in labor fostered shared and contracted labor
7. Sheep herding practices bring sheep together often allowing for easier spread of the disease through prolonged contact and shared labor¹²¹

The United Kingdom had plans drawn up to respond to a biological disaster, but they never practiced or disseminated emergency actions to farmers and local law enforcement. Another problem was that the threat of an outbreak was never seen as a serious danger. Low-level farmers and state workers felt the state was not adequately prepared to respond to a disease outbreak; however, these concerns were never discussed at a decision-makers' level.¹²² The inability to relay concerns to leaders, the under-practiced emergency actions, and the passive approach of the government to a viable threat resulted in the late detection, underestimation, and ultimate devastation to a portion of the U.K.'s agricultural system.¹²³

¹²⁰ An index case as defined by the Center for Disease Control (CDC) is the first case or instance of a patient coming to the attention of health authorities. "Principles of Epidemiology: Glossary|Self-Study Course SS1978|CDC," Centers for Disease Control and Prevention, last modified July 2, 2014, <http://www.cdc.gov/OPHSS/CSELS/DSEPD/SS1978/Glossary.html#caseIndex>. This diagnosis is important because it can give insight to the cause, weaknesses, and propagation of a disease.

¹²¹ Scudamore, *Origin, Foot and Mouth Disease*, 2.

¹²² The National Archives, United Kingdom, accessed June 4, 2014, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69456/fmd-control-strategy111128.pdf

¹²³ The National Archives, United Kingdom, accessed June 4, 2014, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69456/fmd-control-strategy111128.pdf

The U.K. case points up many recommendations to reduce or prevent a recurrence of this magnitude. The recommendations start by increasing pressure on the root cause of the outbreak—illegally imported meat. In order to accomplish this, there was increased power given to enforcement officers when searching baggage and governmental powers implemented strict rules on imports from third-world countries while reforming personal import regulations.¹²⁴ The poor levels of communication during the outbreak served as an exacerbating factor and were not only present between farmers and response authorities but between the population and government as well.

The government is increasing its support to advance the education and training of vets, farmers, and civilians alike with the goal of increasing the importance of effectively communicating during an emergency—where timely diagnostics are imperative on setting response measures in action.¹²⁵ There are still problematic issues with vaccinations and culling tactics, and they need to be addressed at the highest levels of government.¹²⁶ However, the U.K. provides great insight to the potential problems the United States would face in the event of an FMD outbreak.

2. Taiwan

Taiwan was lulled into a false sense of security after being FMD-free for 68 years. The levels of preparedness in Taiwan probably would have easily contained an outbreak of FMD, but increases in farm and animal density and reliance on pork products superseded the preplanned responses implemented by Taiwan.¹²⁷ Taiwan attributes four factors to the extent of their outbreak:¹²⁸

¹²⁴ Anderson, *Foot and Mouth Disease*, 158.

¹²⁵ Anderson, *Foot and Mouth Disease*, 161–62.

¹²⁶ Ibid., 163–65.

¹²⁷ Yang et al., “Epidemiological Characteristics,” 733.

¹²⁸ Ibid.

1. Delays in shutting down livestock markets
2. Backlog of farms waiting for animals to be culled
3. Shortage of vaccines during the emergency
4. High density of pig farms

Taiwan's enormous reliance on pork prompted farmers to resist shutting down markets that acted as a cesspool of FMD and spread the virus throughout the country. A total shutdown of the market took five days to enforce, and by that time the damage was irreversible.¹²⁹ The ability to enact immediate restrictions that stop all animal movements is a key in minimizing the spread of FMD. The backlog of farms with animals waiting to be culled served as a source of transmission to other farms.

It was not until the military was involved that the backlog was eliminated. The importance of seeking outside help early to prevent backlogs will decrease the vulnerability of other farms to FMD. As a result, planning for military involvement in responses to outbreaks is another key take-away in the event of a biological outbreak.

A shortage in vaccines is, in many regards, the same as being unable to cull livestock on a farm. Only vaccinating part of a herd leaves the other animals susceptible to contracting and subsequently spreading the disease. There needs to be enough vaccines to provide a vaccination blanket early in the outbreak.¹³⁰ An increase in the number of initial vaccines would also alleviate some of the personnel costs, because the need to quickly kill livestock would be reduced.

The geographical constraints on the island of Taiwan concentrate 83 percent the pig population to the southwest. Having almost 2000 pigs per km² in conjunction with the high concentration of aerosolized FMD made containing the spread of FMD virtually impossible. This factor is the hardest to mitigate, because of geographical limits. However, it places more importance on

¹²⁹ Ibid., 734.

¹³⁰ Yang et al., "Epidemiological Characteristics," 734.

perfecting the response in more controllable methods, because many farming communities around the world are in close proximity and rely on one another for support.

The United States has much to learn from these case studies and applying them synchronously with feedback from exercises that take place every year will help build a response capable of minimizing losses in an FMD outbreak. In addition the United States can apply them to its *Foot-and-Mouth-Disease Response Plan: The Red Book 2014* put together by the USDA, APHIS, National Center for Animal Health Emergency Management, and Foreign Animal Disease Preparedness & Response Plan (FAD PReP). The following chapter will explore the weaknesses of an outbreak of FMD in the United States and attempt to identify problems in the response plan in order to give policy recommendations that may save precious time and resources.

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III. MEASURES THE UNITED STATES SHOULD TAKE TO MINIMIZE THE EFFECTS OF AN FMD OUTBREAK

The United States has been FMD-free since 1929, and a report from 1930 shows that the importance of an early response is still important today when it said:

So highly infectious is this foreign malady that prompt and drastic eradication measures are necessary to prevent its rapid spread, with resulting heavy losses to agriculture and industry.¹³¹

Many issues plagued the U.K. and Taiwan responses to their FMD outbreaks. The lessons learned from these two case studies can guide the United States as it develops policies that government and private organizations can follow to minimize a potential FMD outbreak. However, the lessons learned must take into account the differences in agriculture, between the U.K., Taiwan, and the United States. For example, the United States is much larger than both of these countries and would require many more resources to respond to an outbreak.

The U.S. Department of Agriculture is responsible for developing a response plan that accounts for lessons learned and meets the goals of the organization in an outbreak. The USDA has three goals when responding to a foot and mouth disease outbreak in the United States:

1. Detect, control, and contain FMD in animals as quickly as possible
2. Eradicate FMD using strategies that seek to stabilize animal agriculture, the food supply, and the economy, and protect public health and the environment.

¹³¹ John R. Mohler and Rudolph Snyder, *The 1929 Outbreak of Foot-And-Mouth Disease in Southern California* (Washington, DC: USDA, 1930), 1.

3. Provide science-and risk based approaches and systems to facilitate continuity of business for non-infected animals and non-contaminated animal products.¹³²

If federal, state, and local responders accomplish these goals, the time to return to previous operations in the United States could be significantly reduced.¹³³ This chapter will explore the ways the United States can accomplish these stated goals while taking into account lessons learned from the U.K. and Taiwan.

A. RESPONSIBILITY

The case studies show that, in order to properly develop a response to FMD, everyone potentially involved must know in which role and capacity they can serve. In the United States, this starts at the federal level and permeates to state, local, and tribal responders.

1. Federal Responsibilities

The federal government is responsible for developing laws and policies to guide a national-level crisis response. In order to accomplish the aforementioned goals, the United States has developed policies that dictate the strategies each agency must follow in the event of an FMD outbreak. Responding to a multistate pandemic with travel restrictions is complicated and must include all participating agencies. The involvement of all agencies can increase coordination during a multiagency response. The National Response Framework (NRF), National Incident Management System (NIMS), and the National Animal Health Emergency Management System must collectively agree on the preparedness

¹³² USDA, *Foot-and-Mouth Disease (FMD) Response Ready Reference Guide—Overview of the FMD Response Plan: The Red Book* (MD: USDA APHIS, Veterinary Services, PIC, 2013), 1, http://www.aphis.usda.gov/animal_health/emergency_management/downloads/fmd_rrg_overview.pdf.

¹³³ USDA, *Foot-and-Mouth Disease (FMD) Response Ready Reference Guide—Comparing U.S. and U.K. FMD Response Planning* (MD: USDA APHIS, Veterinary Services, PIC, 2013), http://www.aphis.usda.gov/animal_health/emergency_management/downloads/fmd_rrg_usuk_plan.pdf.

and response in order to develop a successful strategy.¹³⁴ The United States Department of Agriculture uses policy guidance to plan state and federal responses to agricultural disasters. The statutes developed to guide the USDA are: the Animal Health Protection Act, Animal Welfare Act, Homeland Security Presidential Directive (HSPD)-5, Presidential Policy Directive (PPD)-8, HSPD-9, HSPD-12, PPD-21, Homeland Security Act of 2002, and the Stafford Act.¹³⁵ The Federal Emergency Management Agency (FEMA) is in charge of implementing this plan, and it would designate the USDA as the lead agency in an FMD outbreak.¹³⁶ The USDA Animal and Plant Health Inspection Service (APHIS) is the authority on animal disease control and would liaise with state, tribal, and local authorities on everything related to an FMD outbreak.¹³⁷ These regulations guided the USDA as they developed the *FMD Response Plan: The Red Book*.

The federal government also has access to supplemental resources in the National Animal Health Emergency Response Corps (NAHERC) and the National Guard. In both the U.K. and Taiwan cases, the military proved invaluable in supplementing manpower to clear backlogs and allowing veterinarians to develop treatment plans for infected farms. The development of NAHERC provides an avenue for veterinarians to gain knowledge of foreign animal diseases and become familiar with the symptoms and treatment method during immersion tours in countries where these diseases are prevalent.¹³⁸ In the event of an outbreak, the federal government must utilize these assets before responders are overwhelmed and fall behind in treating animals and farms.

¹³⁴ USDA, *Overview of the FMD Response Plan: The Red Book*, 27.

¹³⁵ “Animal Health Emergency Management,” USDA, APHIS, last modified February 25, 2015, http://www.aphis.usda.gov/wps/portal/aphis/ourfocus/animalhealth?urile=wcm%3Apath%3A%2FAPHIS_Content_Library%2FSA_Our_Focus%2FSA_Animal_Health%2FSA_Emergency_Management.

¹³⁶ GAO, *Foot and Mouth Disease*, 54.

¹³⁷ USDA, *Overview of the FMD Response Plan: The Red Book*, 32.

¹³⁸ USDA, APHIS, “Animal Health Emergency Management.”

2. State and Local Responsibilities

The National Animal Health Emergency Management System (NAHEMS) recommends that states develop plans to respond to animal health emergencies.¹³⁹ The plans should include the following:

1. Animal health surveillance and detection systems
2. Control and eradication procedures
3. Communication between key partners
4. Involvement of emergency management officials
5. Collaboration between state and federal emergency responders
6. Involvement of state and federal animal health officials in responding to natural disasters¹⁴⁰

States should also participate in periodic tabletop exercises to develop and practice communication routines and simulate resource allocation. Ideally, they would disseminate the results of these exercises to stakeholders for evaluation and ways to improvement.

One of the most important roles held by local farmers and veterinarians is their ability to identify the symptoms of FMD. These skills are critical to implementing a response in a timely manner. Specifically, it is the veterinarian's responsibility to distinguish between FMD and other diseases that present the same symptoms, but are not nearly as devastating. The importance of farmers and veterinarians cannot be overstated, because their actions play a large part in determining the extent of an outbreak.

B. RESPONSE

Before any level of response can be initiated, there must first be a suspicion of FMD in livestock. Early and accurate detection is required in order to implement the FMD response plan. Unfortunately, on site testing for FMD has not

¹³⁹ GAO, *Foot and Mouth Disease*, 54.

¹⁴⁰ GAO, *Foot and Mouth Disease*, 54.

been developed. The ability to diagnose FMD at the local level would increase a community's resilience to an FMD outbreak. While advances are being made in determining the presence of FMD in laboratories, the development of technology that can diagnose FMD immediately would improve response time and possibly minimize the extent of an outbreak. In the U.K., a positive diagnosis was not determined until the head of veterinary medicine personally visited the infected farm. This precedent is a waste of resources and displays a lack of trust in individuals trained to fight this type of outbreak. A flow chart that is followed to determine whether or not there is a presence of FMD is shown in Figure 3.

Currently, all testing for FMD in the United States is done at National Veterinary Services Laboratories—Foreign Animal Disease Diagnostic Laboratory (NVSL FADDL) at Plum Island, New York. The laboratory can usually deliver a positive or negative determination in less than 24 hours, but isolating the serotype to determine the vaccine specific to an FMD strain can take approximately one week.¹⁴¹ Identification of serotypes is used to determine the type of vaccination that treats the type of FMD identified. This is a step that, if reduced, could potentially reduce the reach of FMD.

The United States realizes this ageing facility is approaching the end of its service life and has already identified a replacement site in Manhattan, Kansas. The new laboratory site in Kansas will be a state of the art facility that will lead the way in research of foreign animal diseases. This facility will allow the United States to research highly contagious diseases and not only develop but produce its own vaccines when responding to outbreaks of FMD and other harmful pathogens. When the United States produces vaccinations, their reliance on other countries drops significantly. This critical capability can reduce response

¹⁴¹ USDA, *Foot and Mouth Disease (FMD) Response Ready Reference Guide—Overview of FMD Diagnostics* (Riverdale, MD: USDA APHIS, Veterinary Services, PIC, 2013), 1, http://www.aphis.usda.gov/animal_health/emergency_management/downloads/fmd_rrg_diagnostics.pdf.

times and ensure the quality of the vaccines being sent to U.S. farmers.¹⁴² Another key aspect of this facility will be its ability to train veterinarians and other responders in proper responses against threats like FMD.¹⁴³ Federal officials broke ground in Manhattan, Kansas on May 27, 2015, and the \$1.25 billion facility is expected to take over the mission Plum Island currently fills in 2023.¹⁴⁴

¹⁴² “National Bio and Agro-Defense Facility,” U.S. Department of Homeland Security (DHS), n.d., <http://www.dhs.gov/science-and-technology/national-bio-and-agro-defense-facility>.

¹⁴³ DHS, “National Bio and Agro-Defense Facility.”

¹⁴⁴ Tom Brune, “Plum Island Laboratory’s Replacement in Kansas Breaks Ground,” *Newsday*, May 27, 2015, <http://www.newsday.com/news/nation/groundbreaking-held-for-plum-island-lab-s-replacement-in-kansas-1.10480519>.

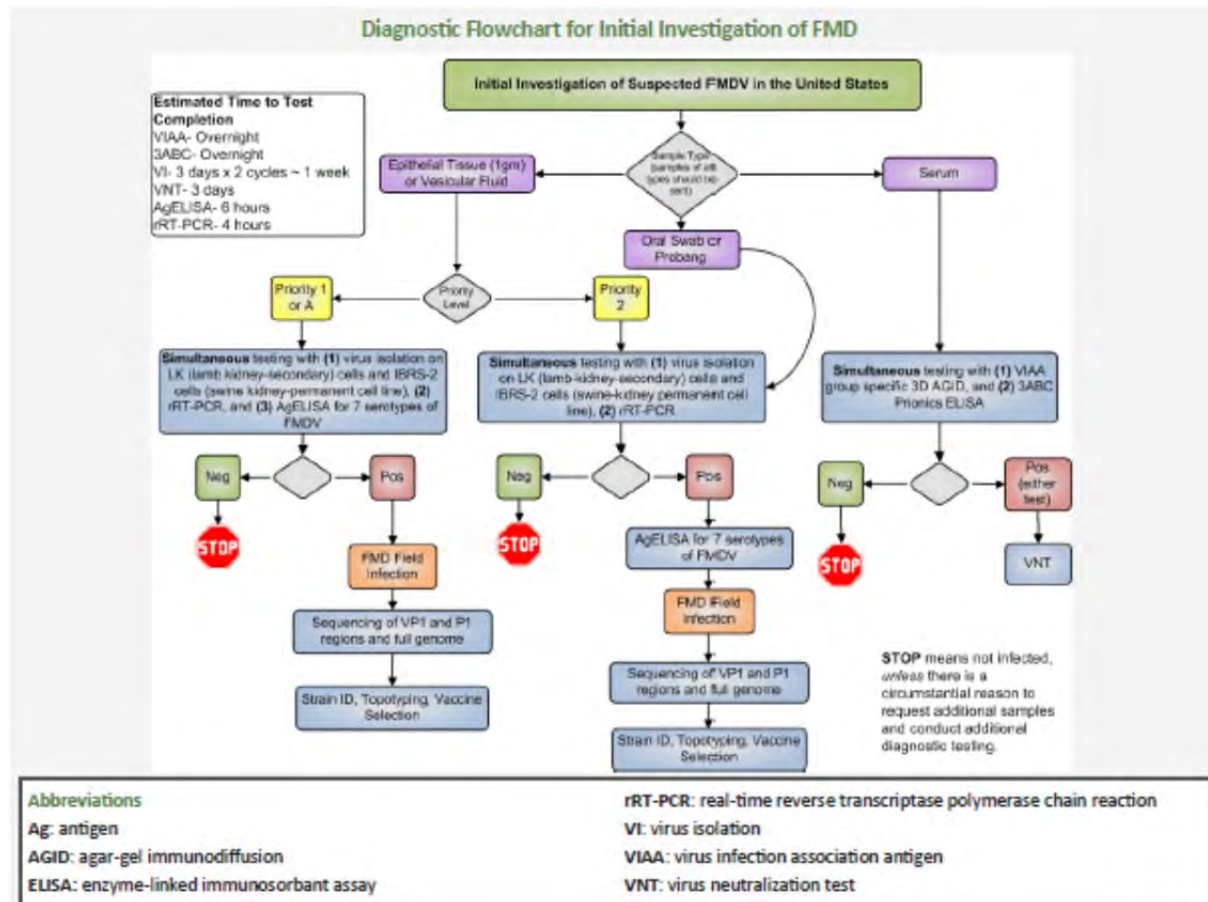


Figure 3. Diagnostic Flowchart for Initial Investigation of FMD¹⁴⁵

¹⁴⁵ USDA, Overview of FMD Diagnostics, 1.

1. Communications

The U.K. and Taiwan case studies highlight the importance of communication in an FMD response plan. In the U.K. a sample, which eventually tested positive for FMD, from the first suspicious animal was not tested for twelve hours, because an email was never sent alerting the technicians of its arrival. This lack of communication resulted in valuable time lost that could have been used to initiate controlling measures. The presence of flowcharts and timelines are great, but only when properly utilized by responders. It is essential that responders of all types communicate efficiently and effectively to each other and that consumers are provided with quality, up-to-date information.¹⁴⁶

FMD response teams conduct periodic table top exercises that create or reinforce lines of communication. These exercises update responders as new people enter positions, or as agencies change tactics to conform to new guidelines. The responders, through exercises, ensure everyone is taking actions based on the same material. The potential to advance the spread of FMD is increased if some responders are referencing information from an outdated source. Responders should have regular discussions with industry leaders like the USDA and local veterinarians to convey the restrictions on travel and scope of the problem.¹⁴⁷

Another important aspect of communication is delivering information to consumers. Public awareness can be delivered through the evening news, newspapers, and technology-based avenues. A study from the FMD Cross-Species communications team determined that people think they have heard of

¹⁴⁶ FMD Cross-Species Communication Team, "2012 Research Overview: Effective FMD Outbreak Communication," presentation, October 29, 2013, <http://www.usaha.org/Portals/6/Committees/animalemergency/presentations2013/Cunningham-FMDVaccination-CAEM2013.pdf>.

¹⁴⁷ FMD Cross-Species Communication Team, "Effective FMD Outbreak Communication".

FMD, people want more details, and people want reassurance during an outbreak.¹⁴⁸

The necessity to inform consumers about FMD during an outbreak is important because most people confuse FMD with Hand, Foot and Mouth disease (a disease that affects humans) when FMD does not affect the human body. The study also found that consumers want to be made aware of the relevant FMD response events. Consumers are impacted from movement restrictions to carcass disposal, not to mention, whether or not they will still have their job in the agriculture industry. Effective and honest communication to consumers can alleviate the sense of public insecurity that often accompanies major disaster.¹⁴⁹

The study also found that there are methods of communication that work and methods that do not. It determined that consumers were receptive to messages that stated the relevance of the FMD outbreak, were safety conscious, presented information at a consumer's level of understanding, were credible, provided more resources, and explained the impact.¹⁵⁰ The types of messages that failed to inspire confidence were messages with outdated resources, messages with no research to support claims, messages that raised more questions than answers, and messages with ambiguous ways to get more information.¹⁵¹

2. Early Assistance

In both the U.K. and Taiwan case studies, the response teams quickly developed backlogs of farms and animals to be tested and destroyed. It was not until supplemental personnel, in the form of military and conscripted veterinarians, were called to help an undermanned response team that the

¹⁴⁸ FMD Cross-Species Communication Team, "Effective FMD Outbreak Communication".

¹⁴⁹ Ibid.

¹⁵⁰ Ibid.

¹⁵¹ Ibid.

backlogs developed were reduced or removed. The U.S. livestock industry is expansive, and responders can quickly become exhausted, if an outbreak spreads too far. The USDA, in the event of an outbreak, has the ability to ask the federal government to supplement response efforts with the National Guard. This is particularly convenient because each state has its own component. In addition to the National Guard, NAHERC can activate and provide trained veterinarians to assist in the diagnosis and treatment of animal herds.¹⁵² Ideally, the veterinarians of NAHERC will have experience in FMD from their time serving in countries where the disease is prevalent.

3. Adopting a Response Strategy

There are seven traditional response strategies to FMD, and Figure 4 explains a strategy, how likely it is to be used, and an example of application for each response strategy. The United States identifies five of those seven as possible methods for eradicating FMD. Those methods are: stamping-out (no emergency vaccine), stamping-out modified with emergency vaccinate-to-kill, stamping-out modified with emergency vaccinate-to-slaughter, stamping-out modified with emergency vaccinate-to-live, and vaccinate-to-live (without stamping-out).¹⁵³ Each of these strategies depends on a number of different criteria and some are more socially, politically, and medically accepted than others. For example, a stamping-out method will require the killing of all animals even if the animals appear healthy and may not contract the disease. This would more than likely spark protest and discontent in some subcultures throughout the United States.¹⁵⁴ The factors that determine the decision-making process are presented in Figure 5.

¹⁵² GAO, *Foot and Mouth Disease*, 61.

¹⁵³ USDA, *Foot and Mouth Disease (FMD) Response Ready Reference Guide—Overview of Emergency Vaccination* (Riverdale, MD: USDA APHIS, Veterinary Services, PIC, 2013), 1, http://www.aphis.usda.gov/animal_health/emergency_management/downloads/fmd_rrg_freedom_and_vaccination.pdf.

¹⁵⁴ USDA, *Overview of Emergency Vaccination*, 2.

Strategy or Strategies	Definition of Strategy	Likelihood of Use	Example of Application
Stamping-Out (No Emergency Vaccination)	Depopulation of clinically affected and in-contact susceptible animals.	Possible (if outbreak is contained in jurisdictional areas in which FMD can be readily contained and further dissemination of the virus is unlikely).	Stamping-out Infected Premises.
Stamping-Out Modified with Emergency Vaccination to Kill	Depopulation of clinically affected and in-contact susceptible animals and vaccination of at-risk animals, with subsequent depopulation and disposal of vaccinated animals. Depopulation and disposal of vaccinated animals may be delayed until logistically feasible, as determined by Incident Command and the VS Deputy Administrator (U.S. CVO).	Possible (if outbreak is contained in jurisdictional areas in which FMD can be readily contained and further dissemination of the virus is unlikely).	Stamping-out Infected Premises, emergency vaccination to kill within the selected areas of the Buffer Zone in Containment Vaccination Zones.
Stamping-Out Modified with Emergency Vaccination to Slaughter	Depopulation of clinically affected and in-contact susceptible animals and vaccination of at-risk animals, with subsequent slaughter of vaccinated animals if animals are eligible for slaughter under USDA Food Safety and Inspection Service authority and rules and/or State and Tribal authority and rules.	Highly likely (depending on the type of the FMD outbreak).	Stamping-out Infected Premises; emergency vaccination to slaughter within the Control Area in Containment Vaccination Zones.
Stamping-Out Modified with Emergency Vaccination to Live	Depopulation of clinically affected and in-contact susceptible animals and vaccination of at-risk animals, without subsequent depopulation of vaccinated animals. Vaccinated animals intended for breeding, slaughter, or other purposes live out their useful lives.	Highly likely (depending on the type of the FMD outbreak).	Stamping-out Infected Premises; emergency vaccination to live outside of the Control Area in Protection Vaccination Zones.
Combination of Stamping-Out Modified with Emergency Vaccination to Kill, Slaughter, and Live	Combination of emergency vaccination to kill, slaughter, and live.	Highly likely (depending on the type of the FMD outbreak).	Stamping-out Infected Premises; emergency vaccination to slaughter within the Control Area in Containment Vaccination Zones and emergency vaccination to live outside of the Control Area in Protection Vaccination Zones.
Vaccination to Live (without Stamping-Out)	Vaccination used without depopulation of infected animals or subsequent depopulation or slaughter of vaccinated animals.	Less likely (unlikely to be implemented at start of outbreak).	No stamping-out Infected Premises; Vaccination to live outside of the Control Area in Protection Vaccination Zones.
No Action	FMD would take its course in the affected population; measures may be implemented to stop spread.	Highly unlikely.	Quarantine and movement control measures; biosecurity measures; cleaning and disinfection measures implemented. No stamping-out and no vaccination.

Figure 4. Overview of Traditional FMD Response Strategies¹⁵⁵

¹⁵⁵ USDA, *Overview of Emergency Vaccination*, 1.

Factor or Criterion Supporting the Response Strategy	Strategy				
	<i>Stamping-Out</i>	<i>Stamping-Out Modified with Emergency Vaccination to Kill</i>	<i>Stamping-Out Modified with Emergency Vaccination to Slaughter</i>	<i>Stamping-Out Modified with Emergency Vaccination to Live</i>	<i>Emergency Vaccination to Live Without Stamping-Out</i>
Suitable vaccine for FMD outbreak strain	Not available/feasible	Available	Available	Available	Available
Resources for stamping-out (such as disposal)	Adequate	Adequate	Moderately limited	Limited	Limited
Resources for vaccination (such as diagnostic testing, tracing efforts, and permitting activities)	Limited	Moderately Limited	Adequate	Adequate	Adequate
Population density of susceptible animals at high risk of becoming infected	Low	Moderate	High	High	High
Population density of virus amplifying animals	Low	Moderate	Moderate	High	High
Movement of infected animals, products, or fomites out of Control Area	No evidence of extensive movement	Evidence of movement	Evidence of extensive movement	Evidence of extensive movement	Evidence of extensive movement
Origin of outbreak	Known	Known	Unknown	Unknown	Unknown
Location of initial outbreak	Isolated premises	Livestock producing area	Livestock producing area	Livestock producing area	Livestock producing area
Spread of outbreak	Slow	Rapid	Rapid	Rapid	Rapid
Distribution of outbreak	Limited or restricted	Regional	Widespread	Widespread	Widespread
Risk of infection in valuable, rare, endangered, or high-value genetic livestock	High	High	High	Moderate	Low
Likelihood that FMD could become prevalent in feral swine, deer, or other wildlife	High	High	High	Moderate	Low
Public acceptance of stamping-out strategy	Neutral reaction or weak opposition	Neutral reaction or weak opposition	Weak opposition	Strong opposition	Strong opposition
Surveillance, diagnostic, and laboratory resources for serosurveillance after vaccination	Limited	Limited	Limited	Available	Available
Domestic stakeholders' acceptance of regionalization with stamping-out or vaccination to kill	Yes	Yes	No	No	No
Domestic stakeholders' acceptance of regionalization with vaccination to live or vaccination to slaughter	No	No	Yes	Yes	Yes

Figure 5. Factors Influencing the Decision to Use Emergency Vaccination Strategies¹⁵⁶

¹⁵⁶ USDA, *Overview of Emergency Vaccination*, 2.

There are many important considerations to be made when determining a response strategy and no individual factor will determine the strategy chosen.¹⁵⁷ The decision will be based on all known information, because region, serotype, species affected, and size of outbreak all have roles in a strategic decision—with the final decision resting on the USDA. In order for the United States to minimize the effects of FMD, the chosen strategy must be decided on early.

After observing Figures 4 and 5, one can appreciate the complexity of developing a response strategy for an outbreak, but one can also see the potential for confusion as the outbreak becomes more widespread. The framework of these strategies provides a fluid response mechanism that can adapt to the changing environment of an FMD outbreak. However, having so many different courses of action can convolute the communication spectrum and lead to different regions applying different strategies. This potential problem emphasizes the requirement of clear and concise communication practices.

Vaccines play a key role in determining a response plan, and there are a couple key factors to consider when adopting a response plan, where vaccines play a critical role. Because the United States has been FMD since 1929, the contagious disease is restricted from laboratories on the United States mainland.¹⁵⁸ The only laboratory that allows scientists to study FMD is located on Plum Island, NY. The decision to use this island was to provide a buffer zone, in hopes of preventing the spread of dangerous pathogens stored there, if there was ever an emergency at the facility. Ideally, this facility would provide all vaccinations for the United States in the event of an outbreak, but Plum Island does not have the capacity to manufacture the amount of vaccine needed to respond to an FMD outbreak in the United States.

¹⁵⁷ USDA, *Overview of Emergency Vaccination*, 2.

¹⁵⁸ USDA, *Overview of FMD Vaccine Issues*, 1.

Because of this, if the FMD serotype is identified by Plum Island, the United States would need to have the vaccine produced overseas.¹⁵⁹ In a crisis, the United States should not rely on other countries to develop FMD vaccines. The United States is developing the capability to manufacture the amount and type of vaccines needed in an outbreak, but the facility will not be operational until 2023.¹⁶⁰

4. Zoning of FMD

In order to minimize the spread of FMD, zones are placed around the origin of the disease outbreak; they increase in size as the disease spreads. The outbreak areas are broken in two or three zones, as dictated by the USDA, and determine the actions responders take in each. The area immediately surrounding the infected premises is labeled the infected zone (IZ) and it extends at least three kilometers (km) beyond the perimeters of the infected premises. The area surrounding the IZ is called the buffer zone (BZ). This zone extends 7 km beyond the perimeter of the IZ, and it is intended to provide an area large enough to allow responders to vaccinate animals and prevent the spread of FMD outside the control area (CA).¹⁶¹ The U.K. and Taiwan failed to implement movement restrictions in and out of these areas, allowing animal transport that undermined the purpose of these zones. State and local officials will be key in preventing a breach in the integrity of zone enforcement.

5. Economic Impact

The economic effects of FMD are determined by the size of the outbreak. Once an outbreak of FMD is detected, the number of animals that will be infected

¹⁵⁹ USDA, *Overview of FMD Vaccine Issues*, 1.

¹⁶⁰ Ibid.

¹⁶¹ IZ+BZ=CA, The control area extends at least 10 km beyond the perimeter of the closest infected premises. USDA, *Foot and Mouth Disease (FMD) Response Ready Reference Guide—Understanding Response Strategies* (Riverdale, MD: USDA APHIS, Veterinary Services, PIC, 2013), 5, http://www.aphis.usda.gov/animal_health/emergency_management/downloads/fmd_rrg_understanding_strategies.pdf.

depends on the effectiveness of the controls implemented.¹⁶² In a regional analysis scenario, centered in Kansas, where five large farms were infected with FMD there would be over 1.68 million head of cattle culled over a duration of 89 days.¹⁶³ The massive loss of animals would have a huge impact on the livestock industry and create a loss in consumer confidence. The impact of FMD on five large farms in Kansas would have an impact of approximately \$12.7 billion of total losses.¹⁶⁴ The GAO reports that an outbreak in the United States, comparable to Taiwan's 1997 outbreak, could total \$24 billion in just controlling and eradication costs—not including the losses in trade and decreased domestic consumer confidence.¹⁶⁵

¹⁶² Dustin L. Pendell et al., “The Economic Impacts of a Foot-And-Mouth Disease Outbreak: A Regional Analysis,” paper presented at the Annual Meeting of the Western Agricultural Economics Association, Portland, OR, July 29–August 1, 2007, 14.

¹⁶³ Pendell et al., “Economic Impacts of a Foot-And-Mouth Disease Outbreak,” 14.

¹⁶⁴ Pendell et al., “Economic Impacts of a Foot-And-Mouth Disease Outbreak,” 25.

¹⁶⁵ GAO, *Foot and Mouth Disease*, 19.

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IV. CONCLUSION

A. LIVESTOCK AND FOOT AND MOUTH DISEASE

This thesis has shown that introducing FMD into the United States could have a devastating effect on the agriculture industry, specifically, the high concentration areas of the livestock industry. The United States has established and reinforced governing policies, a lead organization, a response plan, and training opportunities for veterinarians and responding agencies to follow during an FMD outbreak. All of these measures are significant steps toward increasing resilience and sustainability of the U.S. livestock industry.

Chapter I described the critical infrastructure of agriculture in the United States. It systematically explained the different levels of agriculture while developing a basal knowledge of livestock farming practices. In addition, it described the interconnectedness of the livestock industry and the inherent vulnerabilities high concentration farming practices have to dangerous biological pathogens, like FMD. Chapter one also described the economic value of the livestock industry and its significant contribution to U.S. GDP.

Chapter II dissected two case studies, U.K. 2001 and Taiwan 1997, wherein FMD was introduced and devastated livestock industries that had been FMD-free for decades. These case studies provided lessons learned that allowed the author to compare, in Chapter III, the United States implementation of lessons learned in its response plan. Chapter III provided a look at the United States approach in responding to an FMD outbreak and the measures that can still be implemented to minimize the effects of FMD. The chapter started by describing the responsibilities of the federal government, state government, and responders to an outbreak. It also walked through different decisions that must be made during an outbreak, demonstrating the need for clear communication.

This thesis confirmed that there are significant economic, social, and psychological consequences to an FMD outbreak, as seen in the case studies

from the U.K. and Taiwan. There are measures the United States can take to reduce its vulnerability to this type of outbreak. The United State has addressed many of the issues that overwhelmed responders in the U.K. and Taiwan. However, there are ways that the U.S. response can be optimized.

1. Ensure the FMD response plan is disseminated to all veterinary offices and understood by key players: veterinarians and first responders.
2. Reduce the amount of time between farmer suspicion of FMD and diagnosis of FMD by developing testing methods at state veterinary labs to allow for immediate control measure to be taken.
3. Develop a laboratory capable of testing and manufacturing vaccinations on the U.S. mainland to eliminate the requirement to involve other countries in our response efforts.
4. Ask for help before responders are overwhelmed this will reduce the number of vulnerable node that can spread FMD.
5. Have a clear picture of the operating environment when determining a response strategy to reduce the chance of a change in strategy. Get it right the first time.

The United States is continuing to improve prevention and response measures every year, but the interconnectedness of U.S. agriculture to the rest of the world and high-concentration farming practices could allow a biological pathogen to be introduced. The cost of a negligent approach to this threat is too high, because it is just a matter time before the United States is faced with this type of outbreak.

B. FUTURE WORK: IMPLICATIONS OF TERROR THREAT

Farmers in the United States take great pride in running humane, clean, and profitable organizations. The threat of FMD being introduced in one of these herds is significantly reduced through these practices, by alleviating the need for vaccines. However, according to experts such as Jim Monke, Peter Chalk, and Richard Danzig, it is only a matter of time before a terrorist organization, foreign or domestic, exploits the lack of vaccines and uses the absence of vaccines

against farmers.¹⁶⁶ Terrorist attacks are nothing new, and the terrorist attacks of September 11 showed that seemingly far-fetched schemes are plausible and things once thought to be safe are potentially at risk.

This thesis has demonstrated that an outbreak of FMD is devastating even without an element of terrorist intent, and even though there has not been a successful large-scale terrorist attack on the agriculture industry, the danger is still there from natural causes. But the ability to eliminate all vulnerabilities in the livestock industry is very low, and a terrorist attack on the agricultural infrastructure of the United States could have lasting detrimental effects on the world economy. This strongly suggests more work should be done to assess the viability of terrorists targeting the livestock industry.

¹⁶⁶ Danzig, *Policymaker's Guide to Bioterrorism*, 2; Monke, *Agroterrorism: Threats and Preparedness*, ii; Chalk, *Hitting America's Soft Underbelly*.

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