

**POTENTIAL IMPACT OF
FOOT-AND-MOUTH DISEASE
IN CALIFORNIA**

THE ROLE AND CONTRIBUTION
OF ANIMAL HEALTH SURVEILLANCE
AND MONITORING SERVICES

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POTENTIAL IMPACT OF FOOT-AND-MOUTH DISEASE IN CALIFORNIA:
The Role and Contribution of Animal Health Surveillance and Monitoring Services

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Potential Impact of Foot-and-Mouth Disease in California
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ACRONYMS

AI	Artificial insemination
APHIS	Animal and Plant Health Inspection Service (USDA)
CASS	California Agricultural Statistical Service
CCA	California Cattlemen Association
C C C	Commodity Credit Corporation
CDFA	California Department of Food and Agriculture
C&D	Cleaning and disinfection
DHIA	Dairy Herd Improvement Association
EU	European Union
FAS	Foreign Agricultural Service (USDA)
FADDL	Foreign Animal Disease Diagnostic Laboratory
FEMA	Federal Emergency Management Agency
FMD	Foot and Mouth Disease
GATT	General Agreement on Trade and Tariffs
NASS	National Agricultural Statistics Service - (USDA)
OIE	International Office of Epizootics
UHT	Ultra high temperature
UR	Uruguay Round of GATT
USDA	United States Department of Agriculture
WRL	World Reference Laboratory
WTO	World Trade Organization

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The research reported here was conducted while I was a post-doctoral fellow at UC Davis in the Department of Agricultural and Resource Economics and the Department of Medicine and Epizootiology, School of Veterinary Medicine.

Javier M. Ekboir

CHAPTER 1

INTRODUCTION

Highly contagious exotic animal diseases can cause enormous economic losses to livestock producers, to related industries and to consumers. The U.S. government and the state of California enforce a number of measures to prevent the introduction of such diseases and to eradicate any outbreak at the lowest possible cost—for example, controls of incoming travelers, animals and animal products; monitoring and surveillance of animal health; information provided to livestock producers and others; and vaccination and/or eradication campaigns. In spite of these government efforts and industry collaboration, introduction of an exotic disease into California's livestock population is a real threat. Constant monitoring and surveillance, rapid diagnosis and preparedness for eradication are required to minimize the probability of occurrence and the costs of an outbreak.

Regulatory agencies with primary responsibility for protecting California's livestock and dairy industries against exotic diseases are the Division of Animal Health and Food Safety Services of the California Department of Food and Agriculture (CDFA) and the veterinary services of the federal Animal and Plant Health Inspection Service (APHIS). These two agencies and the Department of Medicine and Epidemiology, School of Veterinary Medicine, UC Davis, conducted a study to estimate the value of animal health monitoring and surveillance services in California. This report describes the results.

The study had as major objectives:

- To estimate the value of monitoring and surveillance services for animal health in California by analyzing the potential losses that those services are designed to minimize or prevent.
- To model the potential epidemiological and economic impacts of Foot and Mouth Disease (FMD) in California.
- To analyze current procedures for dealing with an outbreak of an exotic disease, identifying potential problems and solutions.
- To develop a methodology that can be used to evaluate alternative strategies to deal with an outbreak of an exotic disease.

To achieve these objectives an outbreak of FMD in California's South Valley was modeled. Two important conclusions of the study are:

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1. Provided that sufficient human, physical and financial resources are available in time to implement an effective first response to an outbreak of FMD, the value of public animal health services is very high. That value is growing because the probability of an outbreak is increasing due to changes in the travel and trade environment, and greater interaction among firms of the dairy and livestock industries, input suppliers and output buyers.

2. Under the present action plan to deal with a FMD outbreak, a stamping-out policy—the slaughter of all infected and all exposed animals, plus decontamination of infected and exposed premises—would be implemented. It is highly likely that, under current regulations and preparations, implementation of such policy would face enormous problems, seriously compromising its chances of success.

The value of animal health monitoring and surveillance services is equal to the expected losses they prevent. Even though these losses can be caused by a number of diseases, in this report it is assumed that they arise exclusively from a FMD outbreak. Hence, the reported estimates should be considered as a conservative estimate of the true value. FMD was chosen because, of all exotic diseases, it has the potential to cause the largest losses to California producers and consumers. FMD is probably the most contagious of all animal diseases known to man because of (1) its ability to gain entry to susceptible animals through virtually all portals of entry, (2) the small infective dose required for transmission, (3) the short incubation period, (4) the release of virus before the onset of clinical signs, (5) the massive quantities of virus excreted from infected animals, (6) ability of the disease to spread rapidly over large distances and (7) the survival of the virus in the environment (Donaldson and Doel, 1994; Forbes et al., 1994).

The expected losses are defined as the probability of an outbreak of an exotic disease multiplied by its estimated cost. Estimating the probability of occurrence of a FMD outbreak is a major task because the potential routes of entry have changed in recent years. While traditionally it has been assumed that the most likely sources of infection were imports of animals and animal products, import regulations and border controls have reduced this risk to negligible levels. On the other hand, an increasing number of international travelers, a larger volume of trade and faster transportation means have created new potential sources of infection, which have not been sufficiently studied yet. Due to the lack of information on these risks, estimation of the probability of an outbreak is beyond the scope of this project, and will not be dealt with in this report.

The cost of an outbreak is estimated here by simulating an outbreak of FMD that starts in Tulare County, California, and spreads to the entire South Valley (Fresno, Kern, Kings and Tulare counties). The outbreak is simulated for different intervention dates and different production conditions. If such an outbreak is not eradicated promptly, it would eventually spread to the entire San Joaquin and Chino Valleys. One estimate of the cost under this scenario is also included. Although limiting the outbreak to the South Valley is a very unlikely assumption, restrictions in the resources available for

this project prevented more detailed modeling of the spread to other regions in California, or consideration of the spread to other states.

Sources of cost

Although FMD is not considered a public health problem, it may cause huge economic losses. These potential losses have three components: eradication costs, production losses and trade restrictions.

- Eradication costs include cost of slaughter, compensation for destroyed animals and materials, cleaning and disinfection (C&D) of infected premises, and quarantine enforcement.

- Production losses arise from lost production in depopulated premises and industries linked to the livestock sector (e.g., input suppliers, slaughterhouses, or processors). Although FMD has a very high mortality rate among young animals, it usually only reduces milk and beef production in older animals. (See Chapter 2.) However, since stamping-out is the only strategy considered in this report, output losses arise exclusively from depopulation. Under the present guidelines for eradication (APHIS, 1991), infected premises cannot return to full production for at least 60 days after cleaning and disinfection.

- Until recently, FMD-affected countries could not export live animals or unprocessed animal products to countries free of the disease. Because of this restriction, the international beef market has been segmented into FMD-free and FMD-endemic markets. The price difference between the two segments for meat of similar quality can be as high as 50%. Recent changes in trade regulations (WTO sanitary and phytosanitary agreements) allow countries with FMD to export to FMD-free markets if the exports originate in FMD-free regions, and if the disease is contained within a quarantined area. However, the two largest markets for American fresh meats and other animal products, Japan and Korea, do not recognize the regionalization principle yet. (See Chapter 5.)

Increased threat of introduction

For more than half a century, enforcement of import restrictions on animals and animal products from countries known to have FMD has prevented introduction of the virus into the U.S. However, changes in travel and trade patterns and in trade regulations have increased the probability of an outbreak. The speed of international travel has increased substantially in recent years and the number of international travelers into the U.S. continues to grow. The FMD virus can survive for 24 hours in the human respiratory system and, given appropriate conditions, for several weeks in clothes. Thus, it is conceivably possible for a person to visit a FMD-endemic country and bring the virus inadvertently to the U.S. Other possible routes through which the virus could be introduced into the U.S. are smuggling of unprocessed meats and animal products, economic terrorism, and garbage transported in planes and ships (Donaldson and Doel, 1994). Since it is impossible to block all possible routes of introduction of FMD into the U.S., an outbreak must be considered possible.

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The U.S. operates a two-tier system of defense against FMD. The first involves border controls of travelers and imports. If an outbreak occurs, then a stamping-out campaign is activated as a second tier. Plans to deal with a FMD outbreak were last updated in 1991 (APHIS, 1991). These instructions contain only brief references to regional disparities, in particular to different animal densities. The magnitude of these differences, however, justifies a closer look at risks and regional strategies for dealing with an outbreak.

FMD in the United States

FMD has been introduced into the U.S. on eight occasions since the first reported occurrence in 1870 (McCauley et al., 1979). The most devastating epidemic occurred in 1914. Starting in Michigan, it spread to 22 states after contaminating the Chicago stockyards. During the eradication campaign, some 172,000 cattle, sheep, swine and goats were slaughtered.

In 1924, FMD was found in cattle in Alameda County, California, and the outbreak soon included 16 more counties. Quarantines were established to prevent movements from affected areas of animals, animal parts, manure, hay, fodder, grain and farm vehicles (unless cleaned and disinfected). Infected livestock were driven into trenches, shot and buried. A total of 109,855 cattle, goats, swine and sheep

Table 1: Foot and Mouth Disease California Outbreaks - 1924 vs. 1929

	1924	1929
Herds Affected	948	5
cattle	58,807	277
sheep	23,328	0
swine	21,194	3,271
goats	1,472	23
Total Animals	109,855	3,591
Appraised Value ^a	\$4,350,000	\$108,000
Wild deer	22,214	0
Days before Diagnosis	63	3
Days before Emergency Declaration	90	10

^a in nominal dollars.

Source: Personal communication from Animal Health Branch (CDFA) and Veterinary services (APHIS).

and 22,214 deer were killed. The eradication effort cost approximately \$7 million with \$4.4 million allocated for compensation for destroyed animals. In 1990 dollars, this equals approximately \$45 million in livestock losses and \$35 million in program costs (Dowell and Krass, 1992). These figures do not include production and trade losses. A second California outbreak occurred in 1929. The total eradication cost was substantially smaller than in 1924 because the disease was rapidly diagnosed and intervention was decisive. Table 1 compares these two FMD outbreaks in California.

FMD has not existed in the U.S. since 1929. The last appearances in neighboring countries were in Canada in 1952 and Mexico in 1954.

Should an outbreak occur today in California, the economic consequences would be significantly larger than in 1924 due to the intensification of production techniques, the integration of regional and state markets, and the larger volume of exports of animal products. As discussed in Chapter 8, if the outbreak were to occur in the southern San Joaquin Valley, containment to a small number of dairies would be extremely difficult. Depopulation of infected premises would create major logistic problems. Preventing the outbreak from spreading into the Chino Valley would also be extremely difficult.

For comparison, a study by New Zealand's Ministry of Agriculture and Fisheries estimates the cost of a hypothetical FMD outbreak involving 25 properties at \$1.2 billion over a one-year period and the loss of about 49,000 jobs (Forbes et al., 1994).

Contents of the Report

Chapter 2 discusses the epidemiology of FMD, with emphasis on the features that determine the characteristics of the model used in the study. Issues related to control and eradication of FMD outbreaks are reviewed in Chapter 3.

The economic importance and characteristics of the livestock and dairy industries, particularly in relation to the threat of exotic diseases, are reviewed in Chapter 4. Most of the information used for this section was collected through personal interviews, surveys of producers, and visits to farms and processing plants. Issues involving FMD and international trade are discussed in Chapter 5, and the current federal action plan in case of an outbreak is described in Chapter 6.

Chapters 7 and 8 describe the simulations of a hypothetical outbreak of FMD in Tulare County, and cost projections. Chapter 9 contains conclusions and recommendations.

Appendices to this report include (1) additional detailed descriptions of California's livestock industries in Appendix A, (2) a technical description of key parameters of the epidemiological and economic models in Appendices B and C, (3) descriptions of recent outbreaks of FMD in Taiwan and Italy in Appendix E and (4) a review of the literature on modeling infectious diseases, with particular emphasis on FMD, in Appendix F.

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Many individuals in livestock production and transportation activities, and in academia and government, were involved as collaborators or provided consultation and background information for this study. Data were gathered from a wide variety of literature and personal interviews. A list of contacts is in Appendix D. Two previous research projects conducted by Animal Health Branch (CDFA) and Veterinary Services (APHIS) provided basic information. The first of these located most premises handling livestock in the San Joaquin Valley and stored that information in a geographical information system (GIS). The second project interviewed a number of livestock producers to identify patterns of movement into and from their premises.

CHAPTER 2

THE EPIDEMIOLOGY OF FMD

FMD virus is an aphthovirus within the *picornaviridae* family. The most important characteristics in the epidemiology of the disease include the rapid growth of the virus, its stability under a variety of conditions and the occurrence of serotypes (Donaldson, 1991). There are seven serotypes and several subtypes within each. The infections caused by different serotypes are clinically indistinguishable. The animals that survive a FMD infection become permanently infected to the particular strain that cause the infection; however, there is no cross-protection between serotypes.

FMD attacks all cloven-hoofed animals. In the U.S. this includes cattle, sheep, goats, pigs, camels, deer and bison. Cattle are the most susceptible animal species. Cattle, in particular, are important in the epidemiology of FMD because of their high susceptibility to airborne virus, because they may excrete the virus for at least four days before the first symptoms appear, and because of their economic importance. Even though sheep and goats can also be infected, their symptoms are often less severe or are subclinical. Pigs are the most important source of air dissemination of the virus; once infected, they excrete vast quantities of the virus. They also have a high susceptibility to infection by the oral route (Donaldson and Doel, 1994). Thus pigs can be described as amplifying hosts and cattle as indicators. Sheep can be described as maintenance hosts because they quite often have mild or even inapparent signs that can easily be missed (Donaldson, 1994a). In spite of its infectivity, FMD may infect some susceptible species and spare others in the same area (Dunn and Donaldson, 1997).

Several factors affect the spread of the disease. The most important are the species infected, the number of direct and indirect contacts among animals (mainly movements of animals and humans), animal density in the area, husbandry methods, environmental conditions, and delays in identifying the disease and applying control measures. Recent epidemics in Taiwan (1997) and Italy (1993), described in detail in Appendix E, illustrate the extreme contagiousness of the FMD virus.

The primary methods of FMD transmission are aerosol, direct contact and ingestion. It is generally accepted that the virus most commonly infects via the respiratory route, especially in ruminant species where very small doses can initiate infection (Donaldson, 1994a). Cattle, sheep and pigs can be infected by inhaling doses in the range of 10 to 25 infectious units. In contrast, the dose required to infect cattle by the oral route is almost 1 million infectious units. (Donaldson, 1991).

Of all mechanisms of transmission of FMD, movements of infected animals are by far the most important, followed by movement of contaminated animal products (Donaldson, 1994a). Once one or more animals in a herd have been infected, the quantity of virus in the environment will be greatly amplified, and transmission by different routes will be possible. The virus can be spread over long

distances by incubating or asymptomatic carrier animals; by vehicles such as feed trucks; by birds, coyotes, domestic animals such as dogs and cats, rodents and arthropods; by mechanical vectors; and by fomites.¹ Garbage containing uncooked meat scraps and bones from infected animals has been a source of infection in pigs. Humans may inhale and harbor the virus in the respiratory tract for as long as 24 hours, and may serve as a source of infection to animals (APHIS, 1991).

An important feature of FMD is that virus excretion occurs before infected animals manifest clinical signs. The length of the incubation period is variable and depends mainly on the virus strain, dose of exposure and the route of entry. With natural routes and high exposure doses the period can be as short as two to three days but could take up to 10 to 14 days with very low doses (Donaldson, 1994a). The airborne virus is emitted over a four to five day period by an animal infected with FMD and the excretion of the virus may start up to four days before the onset of the first clinical signs. The peak of excretion in a pig may reach 100 million infectious units per 24 hours, whereas the same peak is only 100 thousand in a cow, a sheep or a goat.

Even though there is large body of literature that has shown the possibility of airborne dissemination, this has not been proved.² Airborne spread over a distance of 60 km over land and 200 km over sea is believed to have occurred (Moutou and Durand, 1994; Donaldson, 1991). The factors which are believed to favor airborne spread of FMD virus are low to moderate wind spread; high humidity, since airborne virus survives optimally above 60% relative humidity; stable atmosphere, particularly a temperature inversion; absence of heavy precipitation which could cause a wash-out of virus; and high stocking density of cattle downwind (Donaldson, 1994a).

Apart from the respiratory route, less frequent routes of infection could be breaks in an animal's integument, i.e., the skin or mucous membrane. Thus the injection of faulty FMD vaccines, foot-rot in sheep, the feeding of rough fodder, harsh use of milking machines, surgical procedures and damage caused by fingernails during nose restraint of cattle can all provide entry points for the virus.

A high stocking density will facilitate spread as the crowding together of infected and susceptible animals will maintain a high level of challenge from both infected animals and the environment. On the other hand, under extensive beef rearing systems such as found in South America and Africa, the spread of the disease is generally more insidious (Donaldson, 1994a).

¹ Fomite: an inanimate object that can harbor pathogenic microorganisms and thus serve as an agent of transmission of an infection.

² Some veterinarians are skeptical about airborne transmission, believing that in most infections attributed to this vector, the virus was actually carried by unidentified mechanical means.

Period of infectiousness

The infectious period depends on the type and size of a herd, on husbandry practices, and on whether the disease is allowed to run its course, or controls are applied. In the 1951-1952 Canadian outbreak, the disease was allowed to pass through before slaughter of infected animals. Thus it was possible to determine the natural duration of the disease in the farms, based on the periods over which lesions developed. The mean period of infectivity was around 20 days for cattle herds (range nine to 66 days) and 13 days (range 10 to 17 days) for pigs, although herd sizes were relatively small (Sellers and Daggupaty, 1990).

During the acute phase of the disease, which generally lasts three to four days, all excretions, secretions and tissues contain virus. Such animals are very potent spreaders of virus. Their products will contain high quantities of virus, and must be decontaminated or destroyed. Matured and deboned meat has been shown to be free from the virus, which is inactivated by the drop in pH during rigor mortis. The virus, however, survives in the bone marrow and lymph nodes (Donaldson and Doel, 1994).

FMD in adult livestock does not usually result in a mortality rate above 5% except in rare circumstances. However, in young animals, especially under conditions of dense stocking, a rate of up to 90% may result (Donaldson, 1994a). After a relatively short period (between two to three weeks), most adult animals recover from the lesions and become productive again. In some cases, a permanent reduction in productivity has been observed. Healing of the erosions caused by the vesicles on the tongue and other parts of cattle takes place rapidly (within about 10 days) unless secondary bacterial infection occurs. Tongue lesions in pigs are much less dramatic and heal much more rapidly (Donaldson, 1991).

In certain cases, the virus has affected some susceptible species and spared others. During the epidemic in Morocco in 1989-91 there was a high morbidity rate in sheep and mortality in lambs, with only a few outbreaks in cattle (Donaldson, 1994a). Only pigs were infected in the 1997 epidemic in Taiwan. The preliminary results of transmission experiments done by the WRL revealed that the Taiwan outbreak strain failed to cause disease in cattle and goats mixed with diseased pigs which were artificially infected (Shieh, 1997; Dunn and Donaldson, 1997).

Sometimes more than one serotype can be found in a single infected animal. This phenomenon has been found only with samples submitted from countries where the disease is endemic (Donaldson, 1994a). This feature is important in relation to vaccine selection.

The stability of the FMD virus varies according to the medium in which it is present, particularly the pH and the temperature. The virus is inactivated by a low or high pH (pH below 6 or above 8), low relative humidity, sunlight and high temperatures. It may survive for extended periods outside the host in certain protected locations (APHIS, 1991). A comprehensive list of survival periods of the

FMD virus in different environments, animal parts and products is published in APHIS (1991).

The FMD virus can spread to the wildlife population. In the 1924 California infection the disease established itself in white-tailed deer. The initial investigation used poison to obtain a sample of deer; some 30% of the carcasses exhibited lesions of FMD. An intensive campaign followed in which 22,214 deer were killed and their carcasses examined by veterinarians. Of these, a little more than 10% exhibited lesions of FMD. It took until mid-1925 to eradicate the disease from the wild deer population (Sanson, 1994).

After recovery from FMD, up to 80% of ruminant species may become persistently infected. It is believed that these carriers can initiate fresh outbreaks when brought into contact with fully susceptible animals. Vaccinated or immune animals exposed to infection may also become carriers. The duration of the carrier state varies according to the species involved, the strain of the virus and probably other unidentified factors. The maximum recorded periods of carriage for different species are: over three years for cattle, nine months for sheep, four months for goats, five years for the African buffalo and two months for water buffalo (Donaldson, 1994a).

The carriers are particularly important in non-vaccinating countries that are normally free of the disease and fail to eliminate all carriers after suffering an outbreak. Even though the spread of FMD from carriers to susceptible animals has not been demonstrated (Donaldson, 1991; Callis, 1996), it is recommended that carriers not be mixed with susceptible animals.

Diagnosis of FMD

The symptoms of FMD are similar to those of other diseases occasionally occurring in the U.S. (e.g., vesicular stomatitis). Because of these similarities, the field diagnosis always has to be complemented by a laboratory test. Before a FMD outbreak, the only laboratory authorized to perform those tests is the FADDL at Plum Island.

In the presence of a vesicular disease, a producer has two alternatives. Either he/she assumes that it may be FMD, reports the disease (as current regulations require) and has the farm quarantined (with the consequent economic losses), or he/she assumes that it is a less severe disease, does not report it and waits until the symptoms disappear. The information collected during this research showed contradictory opinions among animal health officials and private practitioners on which of the two alternatives producers are more likely to choose. Due to the potential consequences of this behavior, prevention policies aimed at informing producers about the nature of FMD should be considered.

COMMENT: OTHER FMD EPIDEMICS

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Information on other epidemics provides useful information to California. There are publications on the FMD epidemics in other industrialized countries such as Denmark (1982), Austria (1973) and England (1966-67). The Danish epidemic of March and April, 1982, has been well documented, and it is worthwhile to compare its data with the assumptions and simulations in the study reported here. There were 1,700 herds within a radius of 15 miles from the first affected (index) herd, which was initially misdiagnosed.

A “cordon sanitaire” of 750 feet radius was established around each clinically affected herd, with controlled movements of people and no movement of animals. A control area of 6.25 miles radius was also established around clinically affected herds, with no movement of animals among farms and controlled movement to slaughter. Only clinically affected herds, not “latent” herds, were quarantined and eventually slaughtered. Public media such as TV and radio were used extensively to keep the farmers appraised of the FMD situation, and the eradication efforts were kept highly “transparent.” In four weeks the dissemination rate dropped from an initial level of about eight to less than one. The epidemic was “stamped out” in less than two months with only 20 (i.e., 1.2%) of the herds in the area affected. The sharp decline in the dissemination rate (which was also observed in the English and Austrian epidemics) was mainly due to precautions taken by the farmers themselves. This illustrates that the success of an eradication program first and foremost depended on farmers’ actions; it did not succeed as a “command and control” activity.

The weather conditions in Denmark were favorable for windborne spread, but an attempt to simulate windborne spread failed. This type of spread was also contradicted by the sharp drop in dissemination rate. (Most virus is excreted early in the disease before there is any chance of depopulation; for this reason, prompt quarantine is more important than depopulation.)

Windborne spread of FMD has not been documented empirically and is supported only by theory and by some epidemiological studies of diseases other than FMD. Experience from previous cases suggests that long distance spread of FMD is mainly due to transport of animals or their products.

CHAPTER 3

CONTROL AND ERADICATION OF FMD

The major factors influencing eradication of a FMD outbreak are:

- Prompt identification and elimination of affected herds, which depend on the effectiveness of surveillance programs, and the timely availability of enough physical, human and financial resources to enforce quarantines and depopulation.
- The ability to identify and quantify the risks by using modern aids to decision-making such as computer models.
- Close cooperation between local/national/international teams and the livestock industry, particularly producers.

Evaluation of the risk period and the area at risk are important because they determine the manpower and other resources needed for surveillance and eradication. For eradication campaigns in areas containing large numbers of large livestock units, the ultimate constraint is manpower. Efficient use of manpower is gained by more precisely defining the area at risk, thus targeting the surveillance activity. For example, in the 1993 Italian epidemic, there were 132 livestock units within the protection zone and 897 units within the surveillance zone surrounding the outbreaks.³ Computer models showed that airborne diffusion was not likely; consequently, surveillance efforts were concentrated near the affected premises. Without the computer results, the resources would have been scattered over an area too large to control effectively.

Cost benefit analysis of different FMD control strategies suggest that the slaughter of infected animals and dangerous contacts can be more efficient than a strategy based solely on the slaughter of the clinically affected herds (Berentsen et al., 1992b). For instance, in the Italian epidemic, contact herds were destroyed because they presented an unacceptable risk, particularly in the case of the pig units. Because pigs can excrete between 1,000 and 3,000 times more virus than a cow or a sheep, infection of the pig units would have resulted in a massive extension of the area at risk. Given the resources available to the authorities, this area would have been too large to control effectively.

The design of animal health policies aimed at exotic diseases

The most important factors affecting the magnitude of a FMD outbreak are: 1) the time elapsed from the beginning of the outbreak until the disease is diagnosed, 2) the time elapsed until the start of the

³ The protection zone extended for 3 km around all infected premises; the surveillance zone was defined by a 25 km radius around infected premises.

eradication campaign, and 3) the quantity of human, financial and physical resources available when the disease is diagnosed. These factors depend crucially on the preparedness of all actors involved with the livestock industry (e.g., producers, animal health officials, private practitioners and processors), which in turn, depends on the resources invested in previous years.

A number of characteristics of exotic disease outbreaks make the determination of the optimal investment level in preparedness extremely difficult (Ekboir, 1997):

- Exotic diseases have a very low probability of occurrence, but can cause catastrophic losses.
- Because exotic diseases have been absent for a long period of time, the true probability of an outbreak is not known either to the livestock industry, animal health officials, or other government agencies. Consequently, policy makers and producers have to make decisions based on subjective probabilities. However, it is well known that in this type of situation the subjective probabilities will be below the true probabilities if a country and its neighbors have been free of the disease for a long period of time. Conversely, the subjective probabilities will be above the true probabilities in the period following eradication of an outbreak in the country or in neighboring countries (Viscusi et al., 1995).
- Each producer decides his/her sanitary practices independently of what his/her neighbors do. Also, effectiveness of the prevention measures taken by a single producer depends crucially on the measures taken by his/her neighbors.⁴ However, he/she has no recourse against neighbors who do not take adequate measures. The optimal investment in prevention by an individual producer equates marginal expected loss due to an outbreak with marginal expected cost in prevention. If the producer's subjective expectation of an outbreak is lower than the true probability, then his/her investment will be lower than the objective (social) optimum. In the presence of externalities, the optimal individual investment is lower than the social optimum unless a government takes appropriate measures to induce producers to invest an amount equal to the social optimum.

Usually a large number of producers are affected by an outbreak. Because of the magnitude of the losses in the case of an outbreak and lack of knowledge about the true probability of an outbreak, private insurance companies cannot provide insurance against an exotic disease (Ekboir, 1997).

Due to these market failures (i.e., externalities, magnitude of the potential losses and ignorance of the true probability of an outbreak), governments have a crucial role to play in the implementation of surveillance policies, and—in the case of an outbreak—in control and eradication, and in compensation of industries affected by the outbreak.

⁴ In economic theory this is known as an externality.

Because of these difficulties and their interaction, no methodologies have yet been created to estimate either the private or social optimal investment levels.

The producer's crucial role

Modern dairy and pork technologies involve high animal densities. Under these conditions, strict sanitary practices and preventive measures are necessary. Economic considerations, however, dictate that veterinary services are used mainly for reproductive checks and design of preventive plans. Only in extreme cases are veterinarians called to treat clinical symptoms, and it is common to cull animals at the early signs of disease. This practice could favor spread of an exotic disease.

This bias against the use of veterinary services creates problems for the design of animal health policies. The actions taken by producers depend on their judgement about the seriousness of the symptoms. Only if they are aware of the possibility of an exotic disease will they report the symptoms. In fact, prompt reporting depends crucially on the farmers' observations and actions. This allows early diagnosis and intervention. Early detection was the main factor that determined the difference in magnitude of the 1924 and the 1929 California outbreaks (Table 1).

It must be stressed that from the individual farmer's point of view, infected animals need not be eliminated from the herd, because they usually become productive again after the acute period. If other producers do not take measures to control the disease, it makes no sense to the farmer to depopulate a farm and repopulate it with non-exposed animals. Thus, it is only the societal decision to eradicate (stamp-out) the disease that justifies depopulation. This point is of crucial importance in considering the government's role in controlling an outbreak, particularly the need for prompt compensation for depopulation.

The solution to this problem is to establish a system that involves all producers in a particular area. The appropriate mechanism varies with local conditions, existing political and legal institutions, capability of government (in particular animal health services), strength of farmers' organizations, and past experiences with animal health programs. In almost all cases, the coordinating mechanism should be set up by the government with significant participation by the livestock industry. Without strong support of producers and producers' organizations, it is impossible to maintain proper surveillance and to conduct a successful eradication campaign.

Alternative control and eradication policies

Alternative control strategies are possible. Each is optimal for particular production and environmental conditions. In some cases, these alternative policies could be a more economical way of dealing with an epidemic (Garner and Lack, 1995):

- Partial stamping-out (slaughter of only clinically infected animals). This requires elimination of a smaller number of animals; however, the risk that carriers will remain increases.

- Total stamping-out with vaccination. In areas with high animal densities, vaccination can be used to limit the spread of the outbreak, followed by depopulation of all vaccinated animals.
- Partial stamping-out with early or late ring vaccination.
- Eradication through vaccination only.

The latest version of the federal action plan to deal with a FMD outbreak (APHIS, 1991) considers the possibility of using vaccination when the outbreak reaches epidemic dimensions. The essential goal of ring vaccination is to reduce the volume of virus circulating in the affected region by lowering the number of receptive animals and, consequently, the quantity of excreted virus. If this policy is successful, the logistics of the eradication campaign are greatly simplified by slowing the speed of depopulation. Additionally, the environmental impact in the infected area could be significantly reduced because the number of carcasses to be burned or buried is reduced and more animals can be used for protein utilization.

Major drawbacks of the use of vaccination are (1) the persistence of quarantines and trade restrictions for a longer period, (2) the need to ensure that vaccinated animals do not leave the quarantine area, (3) the increased risk of extending the outbreak due to the increased contacts between animals and humans conducting the vaccination, (4) animal welfare complications resulting from the continued production while movements are restricted, (5) longer disruption of processing industries inside and outside the quarantine areas, and (6) a possible meat surplus in the quarantine area (Donaldson and Doel, 1994).

There have been a few examples of successful control and eradication through vaccination. Zimbabwe suffered an epidemic in its non-vaccinated area in 1991.⁵ By a policy of mainly movement control and ring vaccination, supplemented in some cases by stamping-out, zonal freedom from FMD has been re-established and the export trade resumed. Argentina and Uruguay succeeded in eradicating the disease through high vaccination coverage of the cattle population and restrictions on movement. Although sheep outnumbered cattle by 2.6 to 1 it was not necessary to continue vaccinating the sheep, and vaccination was abandoned several years before complete eradication was achieved (Donaldson, 1994a). Three southern Brazilian states have eradicated FMD through sustained vaccination campaigns.

The question of incentives

The proven method of eliminating an outbreak of a highly contagious exotic disease such as FMD is total stamping-out, i.e., the slaughter and disposal of all susceptible animals that could have been

⁵ FMD is endemic in Zimbabwe's wild animal population in national parks. Authorities vaccinate all susceptible animals in a buffer zone around the park. Animals in the rest of the country are not vaccinated.

exposed to the virus, whether they are clinically affected or not—followed by decontamination of the infected and exposed premises.

Stamping-out requires total cooperation by farmers, and a basic condition to secure their cooperation is that they receive prompt and adequate compensation. Determination of adequate compensation is crucial. If compensation is set too low, producers have no incentive to report sick animals and may sell them at the first sign of sickness, thus favoring the spread of an outbreak; and if compensation is set too high, producers conceivably could have an incentive to introduce healthy animals into infected premises to claim compensation for their destruction.

In any case, since the cost of stamping-out depends on the number of affected animals, it can only be implemented when the expected number of outbreaks and/or animals infected is relatively small (Donaldson, 1994a). For the production conditions prevailing in California and the U.S., however, the threshold above which stamping out is no longer the best policy is not known. Cost benefit analyses could identify the optimal policies for outbreaks of different magnitudes.

Mobilizing resources for control and eradication

The U.S. Secretary of Agriculture has the authority to declare an emergency in case of a disease outbreak which constitutes a threat to the livestock or poultry industries of the United States. Some resources for control and eradication can be mobilized only after an emergency declaration. It is expected, though, that additional resources would be required to deal with a large scale event.

Delays in declaring the federal emergency have been commonly experienced. The delays were caused by disagreements on whether eradication was possible, the method to achieve it—use of vaccines was a major issue—and the high expected cost of the eradication campaign. Advanced evaluation of alternative eradication policies could help to accelerate the decision making process in the event of an outbreak.

Vaccination considerations

To be effective, a vaccine must be potent, safe, antigenically matched against the strains of virus likely to pose a threat, and properly administered. To be operative, a vaccine bank should keep a relatively large volume of different types of serotypes to produce the right vaccine on short notice. Additionally, it should invest consistently in the latest developments in vaccine technology. However, because an outbreak has a very low probability of occurrence in FMD-free countries, the resources invested in a vaccine bank are unlikely to be used. The cost of maintaining a vaccine bank can be reduced by sharing it with other countries. Presently the largest bank is located at Pirbright (the world reference laboratory) and is funded by a number of countries. The U.S., however, maintains a separate vaccine bank. The benefits of this should be compared with the cost reductions and potential efficiency gains obtained from joining the vaccine bank at Pirbright.

When vaccine is used in the face of disease as part of an emergency control policy, vaccinated animals are likely to be severely challenged. In this situation it is desirable to ensure that they are isolated before coming into contact with other animals. Therefore, vaccines employed for this purpose must be formulated to contain an especially high antigenic payload (Donaldson, 1994a). Donaldson and Kitching (1989) indicate that during emergency vaccination programs all FMD-susceptible animals within the vaccination zone should be vaccinated, and vaccinated animals should be kept separated from unvaccinated stock at the outer boundary of the zone for at least three weeks. Availability of trained personnel to administer the vaccines may be a constraint. Advance identification of the conditions under which it is convenient to vaccinate would provide important information to support the decision process in case of an epidemic.

Production losses in vaccinated animals are smaller than among fully susceptible animals. However, vaccination will not necessarily prevent immunized animals that are exposed to infection from replicating and excreting the virus (Donaldson, 1994a). Such silently infected animals can be an important and usually unrecognized disseminator of the virus.

Other considerations

Depopulation of areas with large number of animals creates major logistical and legal problems, as evidenced by previous experiences (Donaldson and Doel, 1994). The recent outbreak in Taiwan highlights the difficulties of eradicating an outbreak in a highly dense animal population: 1) a very large amount of human, physical and financial resources have to be mobilized on a very short notice, 2) a large proportion of the personnel in charge of depopulation, C&D and quarantine enforcement will likely require training (delaying the full implementation of the eradication campaign), 3) disposal of carcasses must comply with federal, state and local environmental regulations, and 4) public opinion may object to the massive killing and burial, in particular if it involves a large number of asymptomatic animals.

Eradication of FMD from wildlife populations is extremely difficult. There seem to be two approaches to deal with this problem. The first is to pursue eradication through poisoning and/or hunting of susceptible species to either eliminate the local population or reduce the number of individuals below the threshold density required to maintain the disease, meanwhile attempting to keep the infected group isolated from contiguous populations. This was the approach taken in the 1924 California outbreak. The second approach is to leave the feral animal population undisturbed in the hope that the disease will die out naturally through an eventual lack of susceptibles as happened in the 1985 Israeli outbreak where mountain gazelles were infected.

COMMENT: THE ROLE OF FARMERS

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The creation of huge data bases and large committees for early detection or tracing of FMD is only one approach, and not necessarily the most important. Farmers and their employees are the ones who must be relied upon for reporting of infected herds. Tracing exposed herds depends on local conditions and the detective acumen of the responsible veterinarian(s). Misdiagnosis is likely, and farmers should be encouraged to report not only suspect lesions. The first thing that happens when an animal gets FMD is that it stops eating and producing milk. This is something the dairy operator will invariably observe, and should be encouraged to report if two or more animals are affected.

During the Pennsylvania avian influenza epidemic in 1983, it was observed retrospectively that the affected flocks showed a significant drop in feed and water consumption two weeks before peak mortality. Early warning systems based on abnormal changes in consumption or production parameters may be applicable to other diseases such as Newcastle disease and FMD. There will be false alarms, but even these will provide opportunity to educate farmers and improve their operations.

CHAPTER 4

ROLE OF THE LIVESTOCK INDUSTRY

California's highest-value agricultural industry, livestock, has two major components, dairy and beef, as well as other smaller activities—hogs, sheep, goats, and exotic animals such as llamas. Compared to dairy and beef, the economic relevance of other species is small but they could play a role in the spread of a FMD outbreak.

In 1995, gross cash receipts from farm marketing of dairy products in California amounted to \$3.1 billion, and \$1.3 billion from cattle marketing (CASS). Recorded sales of hogs in the state that year were \$38 million, and sales of sheep, \$56 million. However, the actual value of hog and sheep sales was substantially larger because a large number of backyard operations do not enter formal commercial channels.

In addition to the direct effect on the state economy, the dairy and livestock industries have a large economic impact through backward linkages such as purchased inputs, supplies, and services used by farmers and forward linkages such as milk processing, meat preparation and processing. The dairy industry is a major supplier for the beef industry, selling live animals for fattening and slaughter as well as animal feed in the form of whole milk or by-products from milk processing. The pig and sheep industries involve a smaller number of linkages.

Although the total cattle inventory has remained almost constant in the last decade, its composition has changed. California's beef herd has been shrinking slowly, but this decline has been offset by expansion of the dairy industry. These trends have increased the risks associated with a FMD outbreak because dairy farms tend to form denser clusters than beef ranches, and dairy cows are confined in larger herds and smaller pens.

Various types of firms interact in the beef and dairy industrial chain—cow-calf operations, breeding stock ranches, stocker operations, feedlots, dairy farms, heifer ranches, milk processing plants, saleyards, slaughterhouses, custom-kills, beef packers, trucking companies, input suppliers and service providers such as veterinarians and AI technicians. All these are potentially important in case of a FMD outbreak.

The state dairy and livestock industries are undergoing substantial changes due to new technologies, demographic shifts and stricter environmental regulations. These changes affect the options in dealing with a FMD outbreak. Because the new technologies have important economies of scale, the average size of dairy herds has increased while the number of dairies has fallen. Similar trends occur in the cattle and hog industries (Perez, 1994). Decreasing transportation costs encouraged interstate

cattle movement to take advantage of seasonal pastures. A few examples are feeder cattle imported at the start of the winter to take advantage of California's mild climate and re-exported to other states in the spring; feeder pigs imported into the state for finishing and slaughter; and sows exported to other states for slaughter. Since the receiving states also have important livestock industries, it seems unlikely that a FMD outbreak would be restricted to California. Meanwhile, the growth of California's population has had two effects on the livestock industry: (1) interstate and international trade in livestock products has increased to satisfy a growing urban demand for meat and dairy products, and (2) as the price of land has been raised by the expansion of urban areas, farms have been forced to relocate. As a consequence of this relocation, animal densities in the destination areas are rising.

Detailed descriptions of California's beef, dairy, swine and sheep industries are in Appendix A.

Significant facilities

Saleyards. Even though saleyards generally handle all types of cattle, in any particular day they specialize in one type. Most of the cattle sold in the South Valley (Fresno, Kings, Tulare and Kern counties) come from local dairies and ranches, and are sold to local buyers. A small number of animals, however, originate in or are sold to farmers as far away as the East Coast. Some heifers are sold to dairymen from the Chino Valley. Usually the animals arrive to the saleyard on the same day of the sale; some stay overnight after the sale. Milking cows are milked in a milk barn adjacent to the main facilities and this milk is used to feed calves. Animals sold or bought locally are generally transported by the farmer, but in some cases a trucking company delivers animals to different local dairies in the same trip. Multiple deliveries occur when the dairies belong to the same owner, or the owners are linked by family ties. Specialized transportation companies may be used to move large lots of animals either locally or to distant locations. Animals raised in youth programs and not sold at fairs are usually sent to saleyards.

It is not economically feasible to have a veterinarian inspect all animals upon arrival to the saleyard. Some dairy heifers are checked for pregnancy by a veterinarian. In most cases, a state livestock inspector and a brand inspector check incoming animals, and determine whether they have to be checked more closely in the slaughterhouse. Saleyard employees help the inspectors identify sick animals. Saleyards generally impose voluntary quarantines on premises suspected of being infected because they cannot afford to be seen as careless about the health of the animals they sell. Many saleyard employees have other employment in close contact with susceptible animals.

Cull dairy cows are generally sold to slaughterhouses, but a few (less than 5%) are bought by other milk producers, some in the Chino Valley. Between 15% and 20% of cull cows are sold to slaughterhouses in the Los Angeles basin. About 90% of heifer buyers and 70% of sellers are located within 50 miles of Tulare. Most of the remaining customers are located within 100 miles. Less than 2% travel more than 100 miles.

Two saleyards in the South Valley specialize in smaller livestock, but on auction days some dairy cows are on the premises. Because these sales occur on Fridays, very sick cows are common; producers cull them rather than run the risk of the cow dying during the weekend. Small hog producers send their animals to the saleyard in Dinuba, from where they are shipped to the slaughterhouses. Traditional buyers of small animals (other than pigs) are custom-kill operators and backyard operations, including small commercial premises, youth program participants and families. Sanitary controls on these premises are practically nonexistent.

Saleyards would have no problems in returning to business after eradication of an outbreak of FMD.

Fairs and shows. During the spring and summer, a number of fairs and shows congregate breeding stock and animals of various species raised in youth programs. There is no sanitary control of participating animals. Small trucks offer their services to the fairs, and usually stop at several ranches. Many 4H members buy their animals directly from farms (sometimes out of state), raise them at home or in livestock facilities owned by family or friends, and sell them at fairs. Participants in youth programs generally do not use veterinary services.

The number of species involved and the lack of sanitary controls make the risk posed by fairs and shows relatively high. The risk is compounded by the fact that these events are the only place where animals raised in backyard operations come into contact with breeding stock that return to commercial operations. Measures to increase sanitary controls in fairs and shows should be evaluated. In particular, a requirement that all animals be checked by a veterinarian upon arrival should be considered. This would provide minimum health coverage to producers who generally have no bio-sanitary controls. A complementary program could target preventive information to participants in youth programs.

The fairs and shows would have no problem in returning to business after an outbreak of FMD because they serve primarily local producers.

Slaughterhouses. Because of strict quality specifications in beef markets, slaughterhouses tend to specialize in particular types of animals. Slaughterhouses are controlled by either federal or state inspectors to insure that they comply with technical and sanitary standards. In 1996, 26 federally-inspected plants in California killed 1.02 million head of cattle and 17 such plants killed 270,400 calves. The total number of state-inspected plants in that year was 45 (NASS).

The largest slaughterhouse in the South Valley is now expanding its processing capacity to 1,500 head per day. There are two other relatively large facilities in the area, each with a capacity of about 800 head per day. The slaughter capacity of all slaughterhouses and custom-kills in the South Valley is about 4,800 animals per day. In the course of this study a number of livestock concentration points and plants processing livestock products were visited. None had a contingency plan to deal with an outbreak of a foreign disease. In a few cases, particularly in those sectors of the industry closer to the

consumers, some measures were taken to deal with perceived threats such as bovine spongiform encephalopathy (BSE).

Large lots of cattle (38 to 40 head) are hauled for slaughter in trucks owned by the slaughterhouses. Smaller lots (10 to 20 head) are hauled by private trucking companies. These trucks generally stop in more than one premise but do not enter the pens. Trucks generally make three to four trips a day and are washed every night. Slaughterhouses are also cleaned every night.

In one large slaughterhouse, about 5% of the animals slaughtered traveled less than 10 miles, 25% less than 50 miles, 75% less than 100 miles, and 25% came from out of state.

Slaughterhouses could have severe problems in regaining lost markets after eradication of a FMD outbreak. Most difficult would be regaining access to foreign markets, because of the increased competition from other suppliers and the reluctance of importers to buy from a recently infected country.⁶ Difficulties in the domestic market would depend on the extent of the outbreak. If other states are also affected, it should be easier for California slaughterhouses to sell out of the state than if the outbreak is contained in the state. Even in the latter case, it should be possible to sell the meat in-state, given that California has a large beef deficit.

Milk processing plants. Milk processing plants generally specialize in broad groups of dairy products (fluid milk, dry milk, cheeses of a certain type, etc.). In 1997, 20 plants were registered to process milk in the South Valley. Their combined capacity is not sufficient to process all the milk produced in the region; a substantial volume of milk is shipped to facilities in the Chino Valley (Butler, 1992).

Milk processing plants in the South Valley cooperate to process additional milk when one plant cannot operate normally; these milk transfers, however, are expected to last one or two days at most. It is expected that in the case of a FMD outbreak these arrangements would not allow processing of all milk produced in the area in the first days of the quarantine. The reason is that production of certain products (e.g., dry milk) would have to cease completely. The remaining plants would have to absorb an increased volume until the disease or depopulation reduces milk production to manageable levels. The problem would be compounded because shipments into the Chino valley would be halted unless that region is also quarantined.

Custom-kills and backyard operations. A small number of animals are slaughtered in custom-kills inspected by state inspectors. In some cases the inspector owns the premises and rents them to the animal owner who does the killing. The inspector insures that the animals are healthy and that the premises are clean. A smaller but unknown number of animals—small ruminants and hogs in particular—is slaughtered without inspection in backyard operations. These are not subject to sanitary

⁶ For instance, Fuller, Fabiosa and Premakumar (1997) estimated that it could take Taiwan 10 years to become a major pork exporter again.

controls nor are the remains disposed of with appropriate procedures. These animals, however, pose relatively low risk to the rest of the livestock industry because they have very little contact with commercial premises—except when they are owned by an employee of a commercial livestock operation. Still, the role that backyard operations could play in a FMD outbreak should be further investigated.

Some small custom-kills have cattle, pigs, sheep and goats on the premises. Even though these do not use veterinary services, they are forced by their customers to maintain high quality standards. In a few cases, the animals are brought directly by the customer. These are inspected at the entrance and allowed in only if they are healthy. Rejected animals are taken back by their owners and disposed of without any sanitary controls. Occasionally, healthy pigs are lent by the operator of the custom-kill to persons in Asian communities who use the animals for religious ceremonies. After the ritual, the animals are returned to the custom-kill.

Custom-kills operate for a very small and selective clientele. If the disease outbreak is widespread, affecting a large number of establishments, it should be easy for these small operations to return to business. However, it might be difficult to regain customers who have experienced the convenience of prepackaged meats for several months.

Rendering services. Dead livestock in the South Valley generally are collected by rendering trucks, which make an average of 30 stops in each trip and pick up all species except sheep. On average, the trucks operate within 100 miles of the rendering plant. Carcasses are picked up wherever producers leave them—the trucks may go into the pens or remain at the entrance. In a few cases, producers take the carcasses to the rendering plants; when the plants are closed, carcasses may be dumped at the gate. Truck drivers refuse to collect from premises with an abnormally large number of carcasses unless the cause of death has been determined by a veterinarian. Even though the carcasses may not be picked up for several hours, or a couple of days during weekends, very few are eaten by wild animals.

Veterinary services. As the size of dairy and beef herds has increased, the nature of veterinary services demanded has shifted from emergency attention to preventive plans and reproductive checks—a trend that has also been observed in Europe (Dijkhuizen, Renkema, and Stelwagen, 1991). The animals are routinely vaccinated, and antibiotics are given as a preventive measure. To avoid medicine and veterinary costs, and the risk of having a milk load rejected because of antibiotic residues, producers tend to cull animals at the early signs of sickness. Generally the dairies receive two veterinary visits per week for pregnancy checks and health management.

Veterinarians usually visit more than one premise per day except when working on large herds where they stay the entire day. It is not customary for these professionals to thoroughly clean and disinfect equipment and clothes between visits on the same day.

Presently there is little formal interaction between veterinarians in private practice and Animal Health Branch (CDFA) or APHIS. Private practitioners may not be aware of official contingency plans to deal with an outbreak of a foreign disease.

The dairy industry: Risk factors

The dairy industry in the South Valley is very vulnerable to FMD because it is geographically concentrated in extremely dense clusters of premises and animals. Dairies in this area are larger than the state average; the typical large dairy has about 1,500 lactating cows and the largest one has 8,000 cows. Because premises of this size are extremely specialized in milk production, they buy large quantities of inputs and services. A large number of movements in and out of a dairy are necessary to deliver them.

A second risk factor is that, in these conditions, an infection will spread very fast. The large number of infected animals will shed massive amounts of virus, which can be carried by wind, feral and domestic animals to neighboring herds. Finally, depopulation of herds this large pose major logistical problems which have not yet been studied (see Chapter 6, The Action Plan and Related Issues).

Depending on the dairy size and production practices, milk is collected up to three times a day. Trucks visit as many dairies as necessary to fill the tank. Approximately half of all collection trips stop at more than one dairy, most commonly at three. The trucks are washed daily or when a load is rejected. Non-commercial milk is picked up daily; these trucks visit about 10 dairies per day.

The truckers conduct an antibiotic residue test before unloading the milk at the milk processing plant. If the residues are above the acceptable level, the load is rejected and the producer of the rejected milk is financially responsible for the entire load. The number of rejections generally increases during the winter due to climatic conditions favoring development of mastitis and use of antibiotics. Approximately 300 trucks, with an approximate volume of 1.8 million gallons of milk, are rejected each year in the entire state. The number of rejected loads has been falling in recent years.

The trucking company or the producer may try to sell the rejected milk to livestock operators; only if a buyer cannot be found is the milk dumped. A market for rejected milk has developed; for example, the value of rejected milk in April, 1997, varied between \$0.25 and \$0.50 per gallon. Only relatively large livestock operations have the equipment to store a truckload of rejected milk. None of these are hog operations.

Rejected milk fed to animals could be a major source of diffusion of a FMD outbreak because large quantities of the virus are present in the milk up to four days before clinical signs appear. Considering the small volume of milk involved and the risk it creates, a ban on feeding rejected milk should be studied.

It is usual for dairies in the region to sell their bull calves to calf buyers, who visit the premises every day. On any day these buyers visit about 25 dairies. Heifer cows are sold to heifer buyers who also visit the dairies daily; each visits about 15 dairies per day. Hoof trimmers visit smaller dairies about twice a year, large dairies more often. They visit about two dairies per day. About 25% of the dairies use AI services. On average, AI technicians visit about three dairies every day; fewer in the case of larger herds.

All commercial dairies buy commercial feed, and the daily number of arriving feed trucks depends on the size of the dairy. Larger dairies receive about two visits per day. In some cases these trucks drive through the alleys, close to the pens. The trucks are not washed between visits. Inspectors also visit the dairies and get close to the cows or milking equipment. On average, dairies receive one inspector per week and each inspector visits five dairies per day. Once or twice a year manure is removed from the corrals. The usual manure removal team consists of a loader and three or four trucks; larger dairies have more than one team working simultaneously.

The number of movements in and out of a typical dairy in the South Valley during a two week period is close to 100. For dairies close to the milk plant they ship to, most of these movements are within 10 miles. Very few movements exceed a 100 mile radius. Sometimes a single owner owns more than one dairy, or several owners are linked by family ties. It is common for these operations to share equipment and facilities such as cattle trailers, calf ranches or hospital pens. About 15% of the dairies move cattle between their premises in this way. Cattle movements between non-linked dairies are very unusual.

The identified high risk movements are:

- Cattle movements between dairies.
- Neighbor dairymen visiting the pens.
- Movements of dairy employees in close contact with the animals, particularly when they live with employees from other dairies.
- Movements of AI technicians (daily), veterinarians (approximately once a week), manure removal (once or twice a year), hoof trimmers (twice a year).
- Visits of milk trucks (once or twice a day), and feed trucks if they drive close to cows to reach the commodity barn (daily).
- Deliveries of supplies and repairs that get close to the cows (twice a week).
- Visits of calf buyers (daily), dairy inspectors and utilities personnel who work close to the cows.
- Cull cows sent to saleyards (weekly), and heifers sent to heifer ranches (weekly).

Low risk movements are:

- Visits of feed trucks if they do not drive close to cows (daily).
- Deliveries of supplies and repairs that do not get close to the cows (twice a week).
- Visit by milk tester (once a month).
- Cull cows sent directly to slaughterhouses (weekly).

The risk posed by rendering trucks (daily or every three days according to the season) depends on where the carcasses are picked up. If it is outside the dairy, the risk is low. However, in the few cases when the trucks drive into the premises to load dead animals, these movements pose a high risk.

A small percentage of dairies in the South Valley, in particular those of smaller size, have pigs in the premises. Most dairies have dogs and cats. Birds, rodents, stray dogs and a few coyotes visit the facilities. All of these could spread FMD. In the South Valley no other wild animals come in contact with dairy cattle.

Dairy market impacts

It is difficult to anticipate the behavior of milk prices in the case of an outbreak of FMD. At the national level, reactions would be determined by the geographic extent of the outbreak. The U.S. supply of fluid milk would be severely disrupted and milk would have to be imported from outside the quarantine area, probably from other states and Canada. Due to location advantages, the industry in California should have no problem in eventually reentering the fluid milk market. The national supply of milk for processing would also be interrupted. The feasibility of returning to this market, however, would depend on the magnitude of the outbreak, the eradication policies implemented and the performance of the industry outside the quarantine area. The larger the area infected, the larger the impact on national dairy markets, but California's dairy processing industry would have less problems in retaining its market share.

Past federal support policies have induced dairy processors to produce mostly products purchased by the CCC. For California, this has meant butter, nonfat dry milk, and cheddar and mozzarella cheese. More recent changes in federal dairy support policies will likely induce some processors to shift to the production of other cheese varieties or other dairy products. This change in the state's output mix could have an impact in dealing with a FMD outbreak because the virus does not survive in cheddar and mozzarella cheeses but does in many other dairy products.

The beef industry: Risk factors

There are four types of beef cattle operations in California: cow-calf, breeding stock, stocker and feedlot (Jensen and Oltjen).

Cow-calf operations maintain a breeding herd of cows, replacement heifers and bulls. The cow herds

tend to be located near low-cost forages. These ranches have little interaction with other premises in the South Valley. Most of their animal movements range between 30 and 50 miles and involve purchases and sales of animals. However, an increasing number of cow-calf operations are raising calves for dairy farms in the Valley. The herd is rotated on average twice a year. Visits by veterinarians and input suppliers are rare. Rendering trucks seldom visit the premises; sick animals are generally sold before they become too sick to travel.

Breeding stock (seedstock) production is a specialized cow-calf operation producing purebred or registered cattle. Seedstock are marketed as herd sires and replacement females to other seedstock producers or to cow-calf operators. Many of these ranches participate in fairs and shows, where they come into contact with backyard animals.

Stocker operations raise steers and/or heifer calves or yearlings on rangeland or other roughages. Generally, the cattle are purchased following weaning in the fall and are wintered on low quality feed until new grass can support them. An important, although undetermined, portion of these animals is imported from other states. Stocker operations also may buy young animals from dairy farms. Heavy stocker cattle are normally marketed or transported to feedlots at 650 lb.; light cattle may stay for one more feeding season or be moved to farms out of the state. Most of the sales occur at the end of the grazing season when the nutritional quality of the forage starts to decline. Some stockers also grow dairy heifers which are sold to dairies when they reach the appropriate weight. Cattle movements occur generally twice a year, most beyond 10 miles.

The number of feedlots in California has fallen over the years; their average size, however, has increased (in certain areas, air and water regulations limit potential growth of the industry). CCA listed 31 associated feedlots in 1996, with an average capacity of 23,300 head. They were concentrated in two areas—the Imperial Valley, ranging in size between 30,000 and 50,000 head, and the San Joaquin Valley, generally between 15,000 and 20,000 head. However, the largest single feedlot in the CCA list (80,000 head) as well as the smallest (210) both were located in the San Joaquin Valley. Animal Health branch (CDFA) has identified 15 feedlots in the South Valley. There is also a relatively large, but unknown, number of backyard operations with small herds of less than 20 head.

Larger heifer ranches have about 8,000 head, the smaller, 1,000. Many of these feedlots share personnel with dairies. Calves are brought in almost every day, while out-movements occur about twice a month. Many of these feedlots use colostrum from dairies to feed the calves. The premises are visited daily by several calf buyers.

From the disease standpoint, feedlots are the riskier beef cattle operations in the South Valley, due to the aerosols and contaminated waste water generated by the large number of animals on the premises. A feedlot receives about two feed trucks per day. Particularly high risk is posed by pen riders who work in more than one feedlot. About one inspector per week visits a premise; buyers, supply dealers, cattle trucks and veterinarians visit almost every day.

Beef market impacts

Should a FMD outbreak occur, domestic and foreign trade would be disrupted. The exposed animals that show no signs of infection can be consumed within the quarantine area but infected animals must be destroyed. As depopulation advances, there would be need to import more beef into California. After eradication, beef producers should be able to return to business in the state because of favorable growing conditions and large in-state demand. Reopening markets in other states would depend on whether FMD occurred in other states and the market gains made by non-infected states during the outbreak. Markets in FMD-free countries would be closed for at least two years after eradication of the last outbreak or cessation of vaccination, and it would be very difficult to return to them—at least in the medium term of about 10 years after elimination of the outbreak.

The swine industry: risk factors

Most hogs and pigs sold in the state are born in California. Inshipments, mostly feeder pigs and market pigs for slaughter, are less than 10% of the animals marketed. When culled, many sows are shipped to the Midwest for slaughter. In-state, culled sows are killed only in custom kills. In 1996 there were 16 federally inspected plants in California that killed almost 2 million hogs (NASS). The number of animals slaughtered without sanitary control has risen in recent years due to the increased demand from ethnic minorities. It is estimated that about 5% of the annual slaughter is carried out in backyard operations. The statewide swine industry is described in Appendix A.

A survey of facilities with pigs in the South Valley showed that 23 operations have more than 200 pigs each and several large operations have more than 2,000. A large number of small operations have less than 200. Many of these smaller premises specialize in raising animals for ethnic markets that demand special types of carcasses. There is also an unknown number of backyard operations with a few animals for self consumption or direct sale. In a recent survey, Animal Health Branch of CDFA identified 181 operations ranging from one to 200 pigs (it is believed, however, that the real number of backyard operations is much larger).

Some dairy employees raise a few pigs on the premises. Also, pigs are the most common project chosen in youth programs such as 4H; it is estimated that several thousand hogs are raised in these programs. A large number of children visit pig operations in a clear seasonal pattern coinciding with the start of youth projects. In buying a pig, 4H members usually visit more than one premise in a day.

In general, bio-security measures are tightly observed only in the larger operations. The medium sized operations have minimal observance and smaller operations take no precautions at all. The latter usually do not use veterinary services. Sick animals are sold in saleyards. In most cases dead animals are picked up within the premise by renderers.

Commercial operations usually feed their pigs with commercial rations. Smaller operations use

commercial feed and also garbage from supermarkets and restaurants. Feed trucks usually visit the premises twice a month, dropping their load anywhere in the premises. Farms with more than a 100 sows usually sell pigs every week.

Garbage feeding is allowed in California only in licensed operations, which have an obligation to cook the garbage. These operations are monitored at least twice a month by state inspectors. However, these operations reportedly feed uncooked garbage when inspectors are not present. Presently there are 20 licensed operations. It is known also that unlicensed garbage feeders operate in the state. Considering the low efficiency of the licensing system and its high cost, termination of the program should be considered, freeing resources for more useful programs.

Occasionally a few hogs sent to slaughter have been diverted at the slaughterhouse to feeder operations. Even though only a small number of animals is involved, this practice could become a source of diffusion of FMD since the animals are not checked by a veterinarian before moving to the new premises.

Large hog producers ship directly to the slaughterhouses. The small producers sell in local saleyards, or directly on the premises to custom-kill operators and individuals.

The largest custom kills haul animals in their own trucks, which usually stop in several farms until the load is completed. In many cases, hogs imported from other states are gathered at collection points and sent directly to slaughterhouses in California. Some owners of smaller custom-kills buy pigs in the saleyards, haul them in small trucks—usually with other animal species—and keep them on the premises with cattle, sheep and goats. In a few cases, the animals are brought directly by the customer, inspected at the entrance and allowed in only if they are healthy.

The larger hog operations that sell to commercial slaughterhouses should not have problems in returning to the market after eradication of an outbreak of FMD. The smaller operations catering for ethnic minorities could permanently lose their customers if these become used to the convenience of prepackaged meats.

The sheep industry: risk factors

Sheep in the South Valley can get very close to dairy herds when grazing in adjacent pastures. It is highly unusual, however, to find sheep actually on dairy farms. Thus, the number of direct contacts between dairy cows and sheep is small. Usually, sheep ranchers do not use veterinary services or commercial feed in a quantity that justifies the use of a truck. Very few rendering plants in the state collect sheep. Dead sheep are either taken to landfills, left in the fields or, in a few cases, taken to a diagnostic laboratory.

Slaughter of adult sheep ended in California in 1990; currently all adult sheep are exported for slaughter to Colorado, Texas or Mexico. A slaughterhouse in Dixon specializes in lambs. Even

though the registered slaughter of sheep and lambs in California in 1996 was just 600 head (NASS), it is estimated that the actual number is substantially higher. Very few sheep are slaughtered in custom-kills or illegally. The state's sheep industry is described in Appendix A.

The role of wildlife

Wildlife poses two problems for the eradication of a FMD outbreak: (1) control of the disease in susceptible wild populations and (2) spread of the disease by non-susceptible wild animals that come into contact with livestock.

There are no susceptible wild species in the South Valley itself. In the foothills the main susceptible species are deer and wild pigs. Eradication of an outbreak is more complex when wild animals are involved because they must be tracked and killed. Although susceptible wild animals in the foothills should not play an important role in the diffusion of an outbreak, they could be a major problem in the eradication process. If a substantial number of wild animals is involved, eradication could require a large number of hunters, and pressure by animal rights and environmentalists might cause delays in the eradication.

Non-susceptible wild animals can spread the disease when they come in contact with susceptible animals. Thus, a number of wild animals in the South Valley could play a role in the spread of FMD — stray dogs, coyotes, rodents and birds. Domestic pets could also be vectors. In general these species are highly territorial and are not very abundant. It is expected that they would not play an important role in the spread of an outbreak.

The State Department of Fish and Game is in charge of control and monitoring of wildlife populations. The Department operates a comprehensive information management system that identifies clusters of wild animals and tracks their movements.

CHAPTER 5

TRADE ISSUES

Two major trends have changed the trade environment in recent years:

- New rules governing trade were introduced in the WTO agreement — in particular, the regionalization principle, sanitary and phytosanitary barriers based on scientific considerations, and minimum market access.

- Improvements in transportation technology have reduced travel time for both commodities and passengers, while the volume of trade and number of international travelers have increased.

Meanwhile, the population of California has become more diverse with several ethnic communities originating in FMD-endemic countries, mainly in Asia and Eastern Europe.

This chapter reviews recent changes in regulations governing trade, with particular emphasis in the role of sanitary and phytosanitary barriers, and analyzes the composition and destination of California's livestock exports. In 1995, California exported \$11.7 billion in agricultural products; of this amount, \$1.23 billion was beef and dairy products (CDFA, 1997).

Regulatory changes

The new regulatory framework was introduced in 1995 at the conclusion of the Uruguay Round (UR) of the GATT. The main changes are (1) creation of the WTO; (2) the principle of regionalization, (3) risk assessment and assessment of the scientific grounds for the imposition of non-tariff barriers, (4) prohibition of the use of sanitary and phytosanitary barriers as barriers to trade, (5) the creation of expert panels to resolve trade disputes, (6) minimum access to domestic markets, and (7) introduction of tariff quotas in the U.S. and Canada, reduction in import tariffs in Japan, increase in minimum access commitments in Korea, and limits to subsidized exports by the EU process (O'Riordan and Jordan, 1995). These changes have increased the importance of the International Office of Epizootics (OIE) in the definition of the scientific standards that can be used to impose sanitary barriers to trade.

A country that has been affected by an outbreak of FMD, or where FMD is in the process of being eliminated, must take certain steps to be certified as FMD-free. According to the International Animal Health Code (Part 2, Sec. 2.1, Article 2.1.1.2), such a country, in order to be listed as FMD-free with vaccination, must send a declaration to the OIE stating that there has been no outbreak of FMD within the previous two years, and must demonstrate the absence of any viral activity. After an

additional 12 months without vaccination, a country may ask to be recognized as FMD-free without vaccination.

Before the UR, any country signatory to the GATT could ask for the formation of a panel to review a trade complaint against other members; however, both the formation of the panel and its conclusions had to be accepted by consensus. As a result, a single party could block or delay a report's adoption. Currently, under the WTO, the power of any one country to prevent the formation of a panel is greatly reduced. Additionally, the adoption of a panel's report is presumed, unless the Dispute Settlement Body decides by consensus not to adopt it or unless it is appealed by one of the parties to the dispute. The new rules also set stricter time limits to the complaint process (O'Riordan and Jordan, 1995).

Another major change to the rules of trade introduced by the WTO is the requirement that non-tariff barriers must be backed by scientific evidence. In the case of FMD, this will mean that countries that do not accept the zoning principle could be subject to a dispute within the framework of the WTO.

The principle of regionalization has been accepted by European and North American authorities since the Italian outbreak in 1993. It allows beef originating in FMD-free zones within FMD-endemic countries into a FMD-free country if the disease is contained within quarantine areas. Conversely, if a FMD-free country suffers an outbreak, it may continue to export to FMD-free countries provided that the outbreak is successfully contained within a quarantined area. This is a substantial change from the previous rule that only recognized FMD-free countries.

These changes will foster a more formal, rule-oriented approach to dispute resolution. As the procedures reflect a more legalistic approach, the entire process becomes more adjudicatory and less diplomatic. However, since the international bodies have no legal or administrative capacity to implement their rulings, the final decisions on sanitary controls still lie with national authorities in importing countries. Even though the new dispute settlement mechanism introduced by the WTO reduces the power of individual states to impose barriers to trade, it is still not known how much control individual states will actually lose in the process (O'Riordan and Jordan, 1995).

This point is reinforced by the fact that, in the case of an outbreak, acceptance by importing countries of the efficiency of the quarantines is not automatic, and must be demonstrated by the infected country to the satisfaction of foreign animal health inspectors. Until now, the attitude towards the regionalization principle of major importing countries (in particular, how demanding they will be on the evidence of quarantine success) has not been tested. Italy exports only within the European Community and Taiwan could not contain the outbreak before the whole country was affected. Until better information is available, the best assumption on the behavior of the major US beef foreign markets is that they would be closed for a substantial length of time. In the simulations, it was assumed that Japan and Korea would respond to a FMD outbreak by banning all imports of American beef for two years after eradication of the last reported case (or cessation of vaccination), regard-

less of whether the beef originated in an affected or clean region.

The most probable scenario in Japan and Korea following a FMD outbreak in the United States is that domestic meat prices would rise as supply would be seriously disrupted. Given the large share of U.S. exports in these markets, the price increase is likely to be substantial. Domestic producers of meat, poultry and fish, and exporters in other countries (i.e., Australia, New Zealand and Canada) would try to capture the share of the meat market abandoned by the U.S. Due to the characteristics of the Japanese and Korean beef markets, it is unlikely that other countries will be able to become exporters on short notice (Ekboir et al., 1996a). The long term impact of the outbreak would be determined by the capability of U.S. beef to regain its lost market share.

U.S. meat trade

Beef is an important export commodity, amounting to about \$2.6 billion in 1995. It is known that California has a large beef deficit, but also that the major slaughterhouses export substantial volumes of beef, mainly to Canada and Asia. Additionally, a large volume of beef originating in other states is exported through California ports. Because there are no reliable figures on the origin of these exports, it is impossible to know how many originated in California. Consequently, we will make no effort to estimate the losses to California derived from disruptions to beef exports; only the losses for the whole U.S. are estimated.

The international market for meats is divided into several segments according to differing qualities. The broadest division is between countries that are free of FMD and countries where the disease is endemic. FMD-free countries allow only imports originating in regions (or countries, according to their import policies) that are FMD-free. For beef of similar quality, prices in the FMD-free market are about twice as high as in the FMD-endemic market (Ekboir et al., 1996a).

U.S. beef exports are heavily concentrated in a few countries (Table 2). Japan is the primary destination with 64% of U.S. exports. Following are Canada with 14%, Korea with 12% , Mexico with 3.2% , and Taiwan with 1.7% (CDEFA, 1997 and F.A.S.,b). The four most important markets are free from FMD.

The imported portion of U.S. beef supply varies from 11% to 18% of the total. Most imports are of manufacture quality (Cothorn, 1991). It is likely that a FMD outbreak would shock the domestic beef market both in the short and medium term, seriously disrupting imports. The most likely scenario is that imports would fall initially as the domestic supply rises due to the depopulation of exposed but non-infected premises. After this initial surge, the domestic supply should fall abruptly until depopulated areas can return to production and herds are rebuilt—a process that could take between six months to five years, depending on the magnitude of the outbreak. During this period, imports should increase. If domestic policies do not change with the emergency, it is likely that imports would fall in the long run, but not to the levels prior to the outbreak. The long disruption of domestic

Table 2: Beef and Dairy Exports - Calendar Year 1995

Rank	Beef U.S.		Dairy Products California		US ¹		Pork U.S.	
	Country	Value (\$1,000)	Country	Value (\$1,000)	Country	Value (\$1,000)	Country	Value (\$1,000)
1	Japan	1,699,111	Algeria	71,039	Mexico	123,926	Japan	594,378
2	Canada	363,466	Japan	48,869	Algeria	97,758	Russia	71,631
3	Korea	320,753	Mexico	32,503	Japan	77,364	Canada	45,604
4	Mexico	85,778	Hong Kong	16,265	Canada	53,994	Mexico	37,840
5	Taiwan	43,487	Korea	12,331	Taiwan	51,476	Korea	27,436
6	Hong Kong	23,296	Taiwan	10,026	Russia	35,873	Hong Kong	23,474
7	Switzerland	13,547	Canada	9,183	Korea	23,310	Taiwan	7,728
8	Netherlands	12,223	Philippines	4,546	Egypt	16,160	Others	72,292
9	Russia	10,088	China	3,966	Hong Kong	13,664	Caribbean	9,369
10	Singapore	9,508	Indonesia	3,219	Georgia Rep.	8,951	S.E. Asia	5,064
	Total	2,647,209	Total	235,661	Total	778,080	Total	846,865

¹ Only includes those products in which the country is a major exporter.

Source: CDFA (1997), F.A.S. (b) and ERS (1997).

production would give foreign exporters a chance to develop market channels that would be difficult to close.

Dairy and other exports

California dairy exports, ranking 12th among the state's agricultural exports, totalled \$128 million in 1995 (CDFA, 1997). In general, importing countries specialize in a few items. For example, 87% of Algeria's imports are dry milk products (whole and non-fat) and 45% of Japanese dairy imports are ice cream. Mexico is the only major importer that has a diversified demand for U.S. dairy products. Fluid and dried milk accounted for 33.4% of U.S. dairy exports in 1995 while 20.6% of the total was composed of cheese, ice cream and yogurt (F.A.S.,b).

Survival of the FMD virus in dairy products depends on several factors, including the type of product, processing method, and storage length and temperature. The virus survives for up to two years in dry milk and more than a month in pasteurized milk. It can also survive in certain types of cheeses but is generally destroyed during the ripening process (APHIS,1991). Since most high value products such as cheese and ice cream are exported to FMD-free countries, it is almost certain that this trade would be disrupted. However, dry milk is exported to both FMD-endemic and FMD-free countries, e.g., Algeria and Mexico. Presently both groups of countries have similar sanitary requirements for dairy imports. It should be expected that all countries would restrict imports of dry milk, at least initially, after an outbreak. If prices fall enough or if the U.S. government presses enough, some markets would open slowly. In any case there would be major losses until at least two years after eradication.

In 1995 the U.S. exported \$1.4 billion worth of cattle hides and calf skins, mainly to Korea (\$615 million), Japan (\$257 million) and Taiwan (\$204 million). Pig and sheepskin exports amounted to \$36 million and \$30 million respectively. In case of an outbreak, these exports would also be subject to a trade ban. Livestock hides are salted in California and exported to tanneries in Japan and Korea. A few tanneries in the east coast could treat raw hides, but it is not known how many additional hides from California they could handle in the case of an emergency, or if it would be worth the additional handling and transportation costs. New export markets would have to be found to treat American hides, almost surely entailing a price reduction.

CHAPTER 6

THE ACTION PLAN AND RELATED ISSUES

The U.S. strategy dealing with a FMD outbreak is described in the “Foot-and-Mouth Disease Emergency Disease Guidelines,” published by APHIS in October 1991. These guidelines are the basis for the actions to be taken by the Animal Health Branch of CDFA, and APHIS offices at the national, regional and state levels.

The U.S. operates a two-tier system of defense against FMD. The first tier involves border controls of travelers and imports. The USDA defines protocols covering the importation of live animals and animal products into the U.S., and inspects imports both in the country of origin and the U.S. In recent years import policies have moved away from the concept of “zero risk” to one of risk assessment. Controls of animals and animal products are very strict, particularly in the country of origin, and it is unlikely that the FMD virus could be introduced through this route. Alternative paths through which FMD could be introduced are travelers who visited farms in infected countries; smuggling of infected animal products, particularly meat products; garbage transported in planes and ships; and economic terrorism (Heron and Suther, 1983; Forbes et al, 1994). All travelers who visited premises with susceptible animals in FMD-infected countries are supposed to go through an inspection and disinfection upon entering the U.S. There is anecdotal evidence, though, that the efficiency of these controls could be improved.

The second tier of defense is based on the surveillance and monitoring of existing herds, and rapid intervention in case of an outbreak. In such an event, the U.S. would follow a “stamping-out” policy. The major components of this policy involve slaughter and burning or burial of all infected and exposed (even though asymptomatic) susceptible animals in the quarantine area, followed by cleaning and disinfection (C&D) of all exposed premises. The action plan includes vaccination as an option when:

- The disease has not been contained within six months of the outbreak, or other appropriate time based on the situation.
- The outbreak reaches epidemic proportions—25% of the susceptible population in areas of high density livestock.
- The cost/benefit ratio of the slaughter program approaches a 1 to 2 ratio.
- FMD becomes endemic in wildlife in three or more states.
- Legal restrictions by U.S. courts prevent carrying out the slaughter program.

The most important factor in containing the spread of a FMD outbreak is rapid and efficient intervention by state and federal animal health services. The efficiency of their actions depends on four factors: (1) preparedness for dealing with an emergency, (2) early diagnosis, (3) timely and adequate access to financial as well as human and physical resources, and (4) support from other civil and military authorities, private veterinarians, processing industries—and, in particular, dairy and livestock producers.

The clinical signs of FMD are easily confused with other diseases such as vesicular stomatitis, vesicular exanthema and swine vesicular disease. Since these diseases are present in the U.S., although with low prevalence, it is likely that FMD would not be properly identified at the start of the outbreak. One of the major problems in identifying a FMD outbreak is that any farm in the nation with animals showing vesicular lesions is strictly quarantined until the field diagnosis can be verified by the Foreign Animal Disease Diagnostic Laboratory (FADDL) at Plum Island. Because of the economic losses caused by such a quarantine, it is believed that some producers do not report vesicular diseases—assuming that it is vesicular stomatitis, and that the infected animals will heal in two weeks.

The diagnosis of FMD always requires laboratory tests to differentiate it from other vesicular conditions. These tests are carried out exclusively in the Plum Island laboratory. Since all samples have to be transported to the east coast, transportation arrangements are crucial in the early confirmation of the disease. If a plane is chartered to take the samples, confirmation could be obtained in less than 24 hours but if the samples are transported in commercial carriers, confirmation could take two or three days, depending on the time of day samples are collected, flight connections and weather.

The Chief of FADDL immediately informs the emergency program staff and APHIS Veterinary Services of diagnostic results. The information is usually passed on by phone to USDA personnel in the state who, in turn, inform state officials. There is consensus among authorities of Animal Health Branch (CDFA) that this process works reasonably well, and that confirmation of a suspected case would not be delayed by breaks in the information channels.

As soon as FMD is suspected in a farm, the farmer is asked to list all movements in and out of the premises during the previous 21 days (APHIS, 1991). Studies conducted in New Zealand and The Netherlands suggest that completion of such a list is very difficult under normal circumstances and almost impossible during an emergency (Sanson et al., 1993; Nielen et al., 1996).

In Ontario, Canada, a comprehensive database containing information related to the livestock industry is being set up to reduce this deficiency (Kelton and Lissenmore, 1997; Goodall et al., 1997). This information combined with farm registration of pigs and identification of main routes of regular contacts (veterinarians, AI technicians, etc.) would be used in defining the initial quarantine area. The Netherlands has a central registration system for cattle. California should discuss with producers and the industry the means for gathering information about animal movements and routes. The

database also should contain information on routes of regular contacts such as veterinarians, milk trucks or AI technicians. The arrangements could involve a public organization, a private organization such as DHIA (dairy herd improvement association), or individual producers.

Depopulation of infected and exposed premises

Under the stamping-out policy all infected and exposed animals should be killed as soon as possible and their carcasses disposed of in a secure manner. Implementation of this policy in the high density animal conditions of the South Valley could present several problems:

- The best methods for depopulation of infected and exposed premises and of carcass disposal are uncertain.
- Timely depopulation and C&D of premises in the quarantine area may require a volume of supplies too large to be obtained on short notice.
- Resources to compensate producers for the destroyed animals may not be available in a timely manner.
- Quarantines may be difficult to enforce.

The action plan states that in disposing of infected and diagnostic animals, all precautions should be observed both to prevent disease spread and to comply with environmental restrictions. Even though Special Order 9 authorizes the governor to overrule environmental regulations following an emergency declaration, public opinion and lack of knowledge of the long term environmental impacts of alternative disposal methods could delay depopulation. It is expected that, following an emergency declaration, EPA would not challenge the state's authority. In the past, EPA has granted temporary exceptions to environmental regulations in order to deal with outbreaks of exotic animal diseases.

There has been no evaluation of the efficiency of alternative procedures of killing a large number of animals in a very short period of time and disposing of the carcasses. It is likely that several procedures would have to be used depending on the particular circumstances of each premise.

Advanced evaluation of depopulation procedures could determine the feasibility of the stamping-out policy, and reduce the depopulation time.

The greatest logistical problem of a stamping-out policy is disposing of the carcasses. According to the APHIS guidelines, burial is the preferred method and should be used whenever practical. The alternative method is burning. Burial of a large number of animals will come under the jurisdiction of state and federal environmental laws and regulations (APHIS, 1991). Burying the carcasses in the South Valley would require excavation of miles of trenches, which could not be disturbed for several years. This would impose a major cost on producers as the land would be lost for most productive uses. It is unclear at this time whether the dairies could still comply with local environmental regulations on manure disposal in the area not used in the trenches.

Burning the carcasses would require massive amounts of wood or other fuel, which would probably be difficult to acquire in a short time. Use of an air curtain, assuming that enough equipment is available, would reduce the quantity of fuel needed and the environmental impact of massive burnings but would increase the burning time. Disposal in landfills would be limited because the carcasses have to be mixed with waste in a fixed proportion, and there is also the issue of the cost imposed on local communities by faster filling of the landfill.

Since carcasses cannot be left to rot in the open, the speed of depopulation is constrained by disposal capacity—and the longer depopulation is delayed, the greater the probability of continued spread of disease. A cost-benefit analysis of alternative methods for disposal in California should be conducted to determine the optimal investment in disposal capacity.

Exposed animals showing no signs of infection should also be slaughtered, but under the USDA plan they can be diverted to human consumption or protein utilization. However, the slaughter capacity in the South Valley probably would not be enough to process the required number of animals in a timely manner. Also, a major obstacle to depopulation of exposed herds could be lack of political or financial support for killing a large number of apparently healthy animals.

Preventing indirect spread of virus

The objective of cleaning and disinfection (C&D) is to eliminate the virus from contaminated premises to prevent virus spread by indirect contacts. Two major types of C&D would have to be performed during an outbreak: (1) infected and exposed premises (farms, processing plants, slaughterhouses, etc.), and (2) vehicles and travelers.

If burning is the carcass disposal method, C&D of premises would require two sets of crews, one for operation of heavy machinery to handle burning materials and carcass disposal, and one for disinfection by hand. If burial is the disposal method, an additional set would be required because the animals have to be herded into the trenches, and each carcass has to be opened in the belly. In the event that burning with air curtain is the disposal method, the composition of the crews would be: two site coordinators, three payloaders, five truck drivers, two air curtain operators (or fire operators) and eight ground cleaners. Working 12 hours a day, such crew would need four days for C&D of a small dairy (500 cows) and 10 days for a large dairy (2,000 cows).⁷ Since most premises handling livestock and livestock products would close or reduce the scale of operation during the quarantine, labor availability is not expected to be a problem.

Cleaning and disinfection of dairy plants and slaughterhouses in the quarantine area is a very complex process. These facilities usually have several interconnected and/or sequential processes, in-

⁷ For a description of the manpower required with other disposal methods, see Appendix C.

volving various buildings. Cleaning these plants would probably involve both fumigation and disinfection. A large crew, probably a few hundred workers, would be required to complete the work in about a week. Due to the complexities of the plant design and operation, even planning the C&D process could take a few days.

While being disinfected, milk plants would receive either smaller volumes than normal or no milk at all. Milk plants in the South Valley work together to cover temporary reductions in the operation of individual plants; however, this can be maintained only for about one day of operation. Meanwhile, the supply of milk to processing plants would fall as depopulation reduces the number of milking cows in the quarantine area. The likely scenario would be an excess supply of milk in the early days of the outbreak because milk originating in the South Valley could only be consumed in the quarantine area. Then, as depopulation advances, there would likely be a deficit of fluid milk because dairies cannot be repopulated until the quarantine is lifted. In order to minimize the lost revenue and to maintain their market share, processing plants might be forced to import milk from outside the quarantine area. Advanced planning for C&D of milk plants in the area would reduce disruption to the dairy industry.

A major issue to be dealt with will be contamination of urban areas within the quarantine zone. The massive movement of virus in the air may contaminate urban areas in the South Valley. Even though FMD does not affect humans, people and vehicles moving out of the quarantine area conceivably could carry the virus and spread the outbreak. Vehicles should be cleaned and disinfected when they exit infected premises and after unloading infected animals or animal products, as well as when they leave the quarantine area. Enforcing these procedures would require the establishment of a considerable number of disinfection points in the South Valley and could become extremely expensive.

Financial resources

Availability of financial resources depends on the amounts required and the urgency of the situation. Relatively small amounts, up to \$1 million, can be accessed immediately by both CDFA and APHIS. Access to larger amounts of financial and human resources to deal with an outbreak requires state and/or federal emergency declarations. Under normal conditions, these could be issued within hours of confirmation of the outbreak. Even if problems arise, such as lack of consensus on the proposed action, it is not expected that this delay would be substantial. However, in some cases, a federal declaration has been delayed for a relatively long period of time. For example, in the 1971-1974 epidemic of Newcastle disease the emergency was declared in approximately 100 days, and in the 1983-1984 epidemic of avian influenza it took approximately 180 days.⁸

⁸ Personal communication from CDFA and Veterinary Services, APHIS.

The U.S. Secretary of Agriculture has authority to declare an emergency when a disease exists that threatens the nation's livestock or poultry industries. When the deputy administrator of Veterinary Services and the administrator of APHIS concur with the diagnosis and the proposed course of action, the assistant secretary for Marketing and Inspection Services should be notified and a Secretarial declaration of a National Emergency requested. Before the formal declaration of an emergency, federal officials cooperate where possible, but will not obligate federal funds for disease control and eradication activities (APHIS, 1991). The emergency declaration does not oblige FEMA to participate or contribute funds.

After the declaration of an extraordinary national emergency, APHIS can use up to \$10 million from the CCC. However, due to the size of dairy farms in the South Valley, this would not be enough to contain an outbreak (See Chapter 8, Estimation of the Outbreak Cost). Thus, larger amounts must be authorized either by the state legislature or Congress. The time required to obtain this authorization will depend on the capability of CDFA and/or APHIS to inform political decision makers—but, considering the speed with which FMD spreads, it is likely to be too long. As the simulations show, delay of three days in starting the eradication would have substantial negative consequences.

Factors that could delay the allocation of funds are lack of consensus on the feasibility of eradicating the disease at a reasonable cost, and lack of understanding by lawmakers and executive officers of the veterinary and economic issues involved.

Issues of payment

Under provisions of Title 9 (CFR), Part 53, the U.S. Department of Agriculture has the authority to pay up to 100% of the expenses of the purchase, destruction and disposition of animals and materials required to be destroyed because they were contaminated by or exposed to FMD. The USDA also pays for cleaning and disinfection of infected premises. Compensation payments depend on the availability of funds. (APHIS, 1991).

Indemnification payments are a necessary component of any effective control program to eradicate FMD. Three reasons are cited to justify a program of indemnification:

1. During an outbreak, slaughter is equivalent to expropriation of the animals. From the perspective of an individual livestock producer there is no veterinary or economic need to slaughter infected animals since after a short period—between two to three weeks—most would become productive again, even though some may suffer a permanent loss of productivity. Stamping-out is required to eradicate the outbreak so that both consumers and producers can share the benefits of a FMD-free country. Thus, in economic terms, depopulation is a measure taken to eliminate the externality caused by the high infectiveness of FMD.
2. The effectiveness of the eradication campaign depends on strong and active support of the entire livestock industry. Without indemnification, the industry would not collaborate in the eradication

effort, reducing the probability of success.

3. Political pressure would force the government to make indemnity payments in any case.

Even though it is agreed that the destroyed animals and materials must be paid for, it may not be clear to whom indemnity payments should be made, or what appraisal method should be used. Aulaqui and Sundquist (1979) identified six criteria to be met by an indemnification program. It should:

- Obtain full cooperation of the livestock industry.
- Be administratively feasible.
- Have payment rates and procedures that can be implemented within required time limits.
- Be economically sound in terms of appropriate cost-minimization criteria.
- Be socially and politically acceptable.
- Be flexible enough to allow for modification as the situation warrants.

Under current regulations, indemnity payments cover only the direct costs of animals and materials destroyed. It has been well documented, however, that the economic losses may exceed by several times the costs covered by the indemnity payments, as a consequence of trade disruptions (Berentsen et al., 1990). These “consequential losses” may be incurred not only by livestock producers but also by all industries linked directly and indirectly. It is impossible, however, to define and quantify consequential losses with any degree of accuracy. Therefore, they should be addressed by other measures such as those used to provide relief from natural disasters—low cost loans, tax relief, special unemployment payments, etc.

Given the expected magnitude of the consequential losses, it may be difficult for the livestock and dairy industries to return to business after the lifting of the quarantines. The industry should study the creation of a self insurance scheme to cover the indemnification of consequential losses. The basis could be a fund that would be invested in the financial markets until needed. Because of the low probability of an outbreak, the initial investment could be relatively small and constituted over a number of years.

Appraisal procedures

All animals, products and materials to be destroyed because of exposure or contamination by FMD virus must be appraised prior to the beginning of depopulation procedures. Appraisals must reflect the interests of both the owner and the state and the federal governments, and also must be consistent with market values. Owners or their representatives should participate in the appraisal process (APHIS, 1991).

In setting the indemnity payments, three problems must be considered: (1) the payments should not be so low that producers' participation is discouraged, (2) the payments should not be so high that they encourage producers to introduce susceptible animals into the quarantine areas, and (3) the payments should induce producers to maintain their animals in the premises until depopulation can be started (Aulaqui and Sundquist, 1979).

There are several methods for appraising livestock but most fall into two broad classifications: market value method and productivity method. Current legislation calls for compensation of destroyed animals and animal products on the basis of "fair market value," but this value is not defined in the legislation. At least two prices can be used in the appraisal process: prices quoted in national exchange markets for products of similar quality and grade, or local prices for other products. Since it is expected that markets and pricing mechanisms would be seriously disrupted by a FMD outbreak, prices immediately prior to the outbreak should be used.

The productivity method basically involves calculation of the discounted stream of net revenues generated by an asset. This method should be used when market prices are not readily available or markets were out of equilibrium prior to the outbreak. Since this method is more arbitrary than the market value method, the latter should be used whenever possible.

Quarantine procedures

Federal and state quarantines are one of the most effective measures for stopping the spread of highly contagious livestock diseases. When FMD is suspected, a farm quarantine should be issued by the investigating veterinarian or foreign animal disease diagnostician. When FMD is confirmed, the premises must be quarantined or, if previously in effect, the quarantine must be amended to indicate the specific disease and number of species and animals involved.

Monitoring measures should be instituted to ensure day and night compliance with the terms of the quarantine until disposal of the animals is complete and the contaminated portions of the premises have received a thorough cleaning and soaking with an approved disinfectant (APHIS, 1991). Enforcement of the quarantine would require the presence of law enforcement agents at the farm gates and at all checkpoints.

Security checkpoints should be located on all rural roads where they enter the quarantine zone. At these checkpoints, all vehicles suspected of containing farm-related products, materials, or animals should be stopped. Movements within the quarantine zone are allowed. Farm products from premises within the quarantine area but not known to contain infected or exposed animals may be marketed on a permit basis. Checkpoints should be manned 24 hours a day, and maintained for 30 days after the last infected animal is depopulated—or until the situation indicates they are no longer needed.

As soon as the first case of FMD is confirmed, every effort should be made to stop the movement of

all susceptible livestock from and within a large area. Until the extent and distribution of the outbreak can be determined, this area may include one or more states. Within seven to 14 days and after movements of all possible exposed animals have been traced, the size of the quarantine area may be reduced to an area with a radius 10 to 25 miles from the affected premises, or other distance as determined necessary (APHIS, 1991).

Such a large effort could probably exceed the resources available from local enforcement agencies and most probably would require collaboration from the National Guard. Even though the quarantines could be in place within 48 hours of mobilizing the National Guard, it is expected that three more days would be required to train the law enforcement personnel on the procedures of the quarantine. Until that time enforcement will rely on local agencies. The effectiveness of the quarantines also will depend on the availability of resources.

For further surveillance, control, and eradication, the quarantine area would be subdivided into: (1) a high-risk zone extending three to five miles beyond all known infected herds, and (2) a buffer zone extending from the periphery of the high-risk zone to the outer perimeter of the quarantine area—about 10 to 25 miles from the affected premises. Animals moving out of the buffer zone would be subject to the same restrictions as those in the high-risk zone, except for a seven to 14 day quarantine and observation period before they are allowed into non-infected areas. (APHIS, 1991).

These quarantine areas are similar to those used in other countries (Garner, 1992; Moutou and Durand, 1994; Maragon et al., 1994). In the EU two restricted areas are minimally required. The smallest area, the protection zone, has a minimum radius of 3 km around the infected premises; the surrounding area, the surveillance zone, has a minimum of 10 km (Nielen et al., 1996). In New Zealand, the high risk area—where a complete cessation of animal movements is enforced—should have a radius of 3 km while the infected area should have a radius of at least 25 km, and should include enough meat and dairy processing capacity to process all animal products originating in the area. A recent study, however, claims that the buffer zone should be expanded. Sanson et al. (1993) argue that an infected area with a radius of at least 25 km would not contain the majority of all high risk contacts in New Zealand. The information collected for this study indicates that this could also be the case in the South Valley.

Definition of the size of the high risk and the buffer zones involves a crucial trade-off. If these areas are too small, infected animals may be allowed to move to less controlled areas; however, an expansion of the controlled areas increases the manpower required to monitor all premises, and multiplies the disruption to economic activities.

In the high-risk area, security would be accomplished primarily by patrols which should stop all vehicles that might contain farm-related products, materials or animals. These patrols should be maintained on a 24 hour basis for 30 days, or for such period as deemed necessary (APHIS, 1991). Daily inspections of all non-infected herds in the high-risk zone would continue for 30 days follow-

ing depopulation of the last affected herd. Weekly inspections would then be conducted until the quarantine is released. The quarantine may be lifted from the area after the last affected premise is ready for quarantine release—120 days after its cleaning and disinfection—and all other eradication measures have been completed (APHIS, 1991). Meanwhile, animals in the buffer zone should be inspected at least twice weekly.

When FMD-suspicious animals are found, the inspection veterinarian should not visit other premises for 48 hours (APHIS, 1991). Premises adjacent to affected sites are considered exposed, and animals are considered exposed when there has been direct contact—such as over a fence, or location downwind at a distance such that airborne transmission is possible—during the preceding 10 days, or longer if circumstances dictate. Contact premises must be handled in the same manner as affected premises. Animals moved from affected premises to other premises during the 10 days preceding the onset of the disease—longer if circumstances dictate—constitute a direct contact exposure. The receiving premises must be handled in the same manner as affected premises. Premises receiving animals from affected premises 11 days to 3 weeks before the onset of the disease should be placed under quarantine and inspected daily for 21 days.

Affected premises should remain free of all susceptible animals for at least 30 days. Following this period, a few susceptible animals should be placed on the premises. If no FMD is observed after a 30 day trial period, then the quarantine may be released.

All stockyards, auction markets, sales, fairs, assembly points and other livestock points of concentration, both in the quarantine and surrounding areas as determined by an evaluation of livestock movements, should be immediately closed by state authorities.

Slaughterhouses in the quarantine area would be allowed to continue operating, but all animals on the premises should be inspected antemortem and postmortem. If FMD is confirmed in the slaughterhouse, it should cease operations immediately. After being cleaned and disinfected the plant may resume operations, but pens that contained infected animals will remain under seal for 90 days.

Controls on animal products

Animals exposed to the FMD virus but which are clinically healthy may be directed to slaughter for protein utilization, according to the APHIS plan. The feasibility of this procedure will depend on the availability of secure transport vehicles, properly located slaughter plants, and adequate processing and storage capacities. Fresh, chilled and frozen de-boned meat and meat products from normal cattle, swine, sheep, and goats—even those considered exposed to FMD virus but not showing signs of infection—can be marketed for human consumption, but only within the region under FMD quarantine. FMD virus contained in the muscle of susceptible animals is inactivated by the formation of lactic acid after death, provided the meat is not chilled or frozen immediately after slaughter. The virus, however, is not inactivated in lymph node tissue or bone marrow (APHIS, 1991). The EU

started importing South American beef treated in this manner (i.e., deboned and matured) after the 1967 epidemic in the United Kingdom, and no outbreaks have been traced to these imports in the last three decades.

The FMD virus is well protected within certain cellular components of milk. Milk from normal lactating cows, except those known to be infected with the FMD virus, may be transported from the quarantine area to officially designated processing plants. Milk marketing should be in non-livestock areas, and restricted to the quarantine area. The FMD virus is inactivated by ultra-high temperature (UHT) pasteurization (2.5 seconds at 148 degrees Celsius; 298 degrees Fahrenheit). Only one plant in the Los Angeles basin is equipped for UHT of relatively large volumes of milk. Some plants in the South Valley have a small capacity for UHT. Because of this reduced capacity, UHT is not an option unless the Chino Valley is included in the quarantine area. When UHT is not possible, regular pasteurization should help reduce virus concentration. Fluid milk from the South Valley would be allowed into the Los Angeles basin only if the outbreak included this area. Even though the volume of milk to be processed would be significantly larger, the combined capacity of the plants in both areas should be enough to process all the milk produced in the region.

Every effort should be made to avoid using milk as livestock feed. Milk from known infected cows should be treated before disposal (APHIS, 1991). Milk from adjacent dairies in the quarantine area may be moved to officially designated plants. Since the FMD virus is present in the milk before the onset of clinical signs, trucks should be cleaned and disinfected before entering and after leaving every premise in the quarantine area. Even if enough washing capacity is available, the hauling cost could increase by up to 20% due to the additional time required for C&D.

Production of certain types of cheeses such as mozzarella and cheddar in the quarantine area may continue because the virus is destroyed by the acid produced naturally in the cheese making process. Cheese manufacturing plants should be approved based on the type of process used. Marketing should also be limited to the states or regions under FMD quarantine. Cheese production absorbed 41.3% of the total milk fat produced in 1995 in the state; cheddar and mozzarella represented more than 95% of this output. Presently there is a large idle capacity for cheese production in the South Valley—over 30% of the total capacity. This excess capacity would not be enough to process the milk that cannot be used for other products such as dry milk.

The FMD virus survives in other dairy products for various periods between two weeks and six months. Continued production of these products could be allowed if they can be stored until the virus is inactivated. Availability of this option would depend on storage capacity and storage cost. (Evaluation of this alternative exceeds the scope of this study; consequently in the model it is assumed that production of all these dairy products will be halted.)

Skins of infected animals must be destroyed. Skins of exposed animals may be utilized provided they are handled in accordance with the existing regulations. The skins must be transported to an

approved establishment in a leak-proof airtight sealed container. The skins may be placed in an approved soak, or moved under supervision to a tannery for supervised processing. However, there are no such establishments in the western part of the U.S. and there might be only a couple on the East Coast. Currently, most of the hides are exported to Korea and Japan, which are expected to restrict importation in the event of a FMD outbreak. The most viable alternative would be to export the hides to plants in countries that would accept them.

CHAPTER 7

MODELING A FMD OUTBREAK IN TULARE COUNTY

The value of animal health surveillance and monitoring services equals the expected losses they prevent. Even though catastrophic losses can be caused by a number of exotic animal diseases, in this study the losses arise exclusively from an assumed FMD outbreak that starts in the South Valley and, eventually, involves the entire San Joaquin and Chino Valleys. Hence, the estimated value should be considered a lower bound of the true economic value of animal health surveillance and monitoring services.

These expected losses are defined as the estimated cost of the outbreak times the probability of occurrence. The FMD virus could be introduced into California through a number of routes (the most important are travelers, uncooked garbage, economic terrorism, and imports of animals and animal products). Since the risk involved in each of these routes varies over time due to changes in regulations and technical change, there are no up-to-date estimates of risk levels. Estimation of the true risk levels is important because they provide valuable information to update trade regulations and target surveillance activities. However, such estimation effort would require resources in excess of those available for this research. To increase the efficiency of monitoring and surveillance services, estimation of the risk of introduction of FMD virus through alternative routes should be considered.

The model assumes that all susceptible species in the South Valley are affected by the outbreak. In regions where FMD is endemic, outbreaks occur irregularly in time and magnitude, making it very difficult to derive general properties and predictive values. Even among fully susceptible populations, some animals are not infected.⁹ Also, it is impossible to know beforehand whether any particular strain of FMD would affect all susceptible species or only some. However, considering the high density production conditions in the South Valley, all susceptible animals should be considered at risk.

The dissemination of the disease depends on a number of factors: weather patterns, animal densities both on farms and at the regional level, production practices, direct contacts between susceptible animals, indirect contacts (e.g., through humans, non-susceptible wildlife or materials such as feed trucks), and control policies (stamping out was the only control analyzed in this study).

⁹ As was the case in the 1977 outbreak in Taiwan which affected exclusively pigs and not other susceptible species (Dunn and Donaldson, 1997; Shieh, 1997).

This chapter reviews the construction of the model used to estimate potential losses—in other words, to evaluate the losses that could be avoided or reduced by the action of monitoring and surveillance services. The chapter includes a description of:

- Physical characteristics of the South Valley that may affect the spread of a FMD outbreak—weather patterns, roads and other geographic circumstances, etc.
- The risk factors identified in the study.
- The simulation model and its two components: an epidemiological model and an economic model (the two models are described in detail in Appendices B and C).

Physical characteristics

Large hog facilities, feedlots and dairies in the study area are located in several clusters with high concentrations of susceptible animals. Under these conditions airborne diffusion of FMD becomes a major concern, and weather is a major influence on airborne diffusion. The virus cannot survive when relative humidity is below 60% or temperature is high (Moutou and Durand, 1994). Donaldson and Ferris (1975) showed that, provided relative humidity was higher than 60%, neither daylight nor other environmental factors greatly influenced virus survival. Relative humidity in the South Valley is above 60% during daylight hours most days except in the summer and almost every night throughout the year.

Winds in the San Joaquin Valley have a clear seasonal pattern. April, May and June each average about three days of moderate winds, above 7.2 km/h. April, May, June and July each have between two to three weeks of slow winds, faster than 3.6 km/h and slower than 7.2 km/h. Finally, a slow breeze of less than 3.6 km/h predominates—more than three weeks per month—between September and February. The wind direction also presents a clear seasonal pattern. Northern winds are more common between October and December—between six and nine days per month. Northwesterly winds predominate between April and August—between 12 and 17 days per month—while southern or southeastern winds predominate in September and October.

In summary, weather conditions in the South Valley would allow airborne diffusion all year. During the summer months, the spread would occur during the night hours when humidity is higher and the temperature lower. In other seasons, conditions could be suitable for airborne diffusion all day.

There are no major geographic features in the South Valley that could hinder airborne diffusion of the virus. A few dairies are surrounded by orchards, but the trees are relatively low and would not be an efficient barrier to massive movement of aerosols. Most of the dairies are surrounded by open spaces with pastures or annual crops.

Two major north-south highways—Highways 5 and 99—cross the South Valley. Neither could be completely closed to enforce quarantines because of disruption to other economic and social activi-

ties. Control on these roads could only be partial, blocking the movement of large animals. Also, it would be impossible to completely control the movement of small animals or farmers and other people in close contact with susceptible animals.

Risk factors

Factors affecting the spread of a FMD outbreak in the South Valley can be categorized as high and low risk.

High risk factors are:

- Climatic conditions in the San Joaquin Valley, which allow airborne spread all year round.
- High density of susceptible animals within premises as well as in the whole region. Very large dairies (above 3,000 cows) and hog operations (above 1,000 animals) present a particularly high risk.
- Lack of awareness about FMD, which could lead to a wrong diagnosis of the first cases.
- Difficulty in reconstructing all movements in and out of farms during the days prior to diagnosis of the outbreak.
- Lack of available funds for timely depopulation of infected premises.
- Difficulty in completely enforcing the quarantine along the two major highways that cross the South Valley.
- Movement of people, neighbor dairymen in particular, to other premises with susceptible animals.
- Animal movements between premises—from dairy to dairy, from dairy to calf ranch, from dairy to stocker operation.
- Backyard operations with no animal health control where people also work in a commercial operation with susceptible animals.
- Services entering several farms on the same route without proper sanitary controls.
- Milk movements, mainly from farm to plant, with milk trucks stopping in several dairies during the same trip.
- Movement of cull cows to other dairies.
- Culling of sick cows without proper veterinary diagnosis.
- Movement of hogs from slaughterhouses to hog farms.
- Use of rejected milk as animal feed.

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- Wildlife population in close contact with livestock in the Valley, in particular rodents, birds and stray dogs.

Low-risk factors are:

- Milk movements, mainly from farm to plant, with milk trucks stopping in one dairy in each trip.
- Services visiting several farms in the same route without proper sanitary controls (if they do not enter the premises).
- Reduced use of emergency veterinary services, and faster culling of sick cows.
- Use of uncooked garbage as animal feed.
- Control of run off water.
- Backyard operations with no animal health control (if the owner does not work in a commercial operation with susceptible animals).
- Inadequate sanitary inspection of animals entering fairs and shows.
- Environmental regulations that may delay depopulation of infected premises.
- Employees in several premises (saleyards, dairies, etc.) coming into contact with susceptible animals away from their employment.
- Wildlife population in close contact with livestock in the foothills.
- Court orders that may delay depopulation procedures.
- Negative publicity and action by animal rights activists that may delay depopulation procedures.

The importance of all these factors in the South Valley is increasing due to (1) expansion of the dairy industry and decline of the beef industry, leading to higher on-farm and regional animal densities, (2) new technologies with strong economies of scale that give an economic advantage to large facilities, (3) more hog farms in the area, (4) more use of separate facilities to raise replacement heifers, (5) more interstate movement of cattle, and (6) more interaction between farms in the South Valley and the foothills.

The model: two components

The dairy and livestock industries are linked forward and backwards to a number of industries, i.e., input suppliers, service providers, and milk and livestock buyers. A serious disruption of the dairy and livestock industries would also affect the linked industries. These are the indirect effects of the outbreak. The reduced economic activity would also reduce employment, sales and consumption throughout the economy; these are the induced effects.

The total estimated cost of the outbreak—including direct, indirect and induced effects—is calculated in this study by a model with two components: an epidemiologic module that simulates the diffusion of the outbreak, and an economic module that estimates the economic impact.

The epidemiologic module is built as a state-transition model representing the spread of FMD in California susceptible animal populations. It is a random state-transition model developed from a Markov chain. Similar models have been used by several authors to simulate FMD outbreaks (Miller, 1979; Dijkhuizen, 1989; Berentsen et al., 1992b; Garner and Lack, 1995).

Because the potential behavior of FMD under current conditions in California is unknown, the model used to generate the scenarios was based on (1) a review of production conditions in the South Valley, (2) overseas experiences and (3) expert opinions.

Chance has been postulated as a major factor affecting the magnitude of an outbreak (Carpenter, 1988a; Garner and Lack, 1995). Therefore, a stochastic model was constructed. All dissemination rates are allowed to change randomly in both directions up to a maximum of 30%. The mean and standard deviations of the number of animals in each state (susceptible, infected, etc.) are estimated after 100 runs.

Even though there is evidence that some strains of the FMD virus have developed specific infectivity for particular species, in this study it is assumed that all susceptible animals in the quarantine area can be infected. This is because, in the particular conditions of the South Valley, the potential for an extremely fast spread of the infection is so great that it becomes too risky to delay depopulation until completion of the tests to determine whether the strain has specific infectivity.

Only premises with cattle or pigs are included in the model. Since all other susceptible animals—sheep, goats, llamas, wild animals, etc.—are not important from an economic perspective or in the logistics of depopulation, the only role of these animals is as vectors. Their role in the epidemic is considered in the estimation of the dissemination rates.

The basic scenario is constructed on the assumption that the infection starts in a backyard pig operation. (No assumptions were made as to how the virus arrived there.) The epidemiological model simulates the spread of FMD in five different types of premises: large dairies (2,000 head average), small dairies (500 head average), feedlots (15,000 head average), and commercial hog facilities (500 head average) as well as backyard pig operations (one pig). The unit of analysis is the herd.

The state-transition model has two components: states and transition probabilities. The states are the different categories in which herds can be, e.g., susceptible to the disease, latent, infected with the disease, or dead as a result of the disease.¹⁰ The number of susceptible, latent and depopulated herds in each period depends on the control strategies.

¹⁰ If vaccination was considered or the disease was allowed to run its course, a fifth category would be immune.

The transition probabilities represent the probability that an individual will move to state j in the next period when it is presently in state i . The probabilities depend on production and environmental conditions, and on control strategies. Consequently, transition probabilities adequate to the particular production conditions and geographical distribution of herds in the South Valley were used.

The state-transition model used in this study has the following characteristics:

- States and transitions are discrete (e.g., one every half week).
- There is a finite number of states.
- Transitions depend only on the current state, not on prior states. In other words, the whole history of the process is contained in the current state.
- Some transition probabilities are a function of the state of the system in the current period.
- Within each herd, there is a random mixing of susceptible and infected individuals.
- The infectious period is short and has constant length.
- The disease does not spread outside of California.
- The affected regions return to their pre-outbreak situation in terms of the number and composition of livestock enterprises and establishments.

The model estimates the numbers of latent infections as well as infectious premises. Since it is expected that depopulation of dangerous contacts will be a major constraint in the eradication of an outbreak in California, the transition *latent to infectious* was introduced to explicitly explore the consequences of starting depopulation at different stages of the epidemic. Different intervention dates are considered, and the costs associated with the disease are calculated for each date. The only eradication policy analyzed is stamping-out.

This approach differs from similar previous studies which analyzed the eradication of incubating herds by reducing the transition *susceptible to infectious* and increasing the transition *susceptible to depopulated*. When modeled in this way, the probability of eradicating dangerous contacts does not depend directly on the number of exposed premises, and the outcome of the policy thus depends on simultaneous changes to two transitions. The combination of these effects impairs the tracing of efficiency of eradication policies.

In order to account for the possible additional state (latent), the time unit used in this study is a half week. This interval is only half as long as those reported in the literature, in particular for the infectious state. The model shows that even with this shorter interval the outbreak of FMD spreads extremely rapidly due to the intensive production conditions and to the regional high density of animals. Increasing the length of the infectious period would increase the rate of spread. This model,

therefore, provides a conservative estimate of the behavior of the infection.

Key disease parameters for the model are (1) incubation and latent period, (2) infectious period, (3) immune period, and (4) dissemination rate. Dissemination rates were set to reflect the intensive production practices and environmental conditions prevailing in the South Valley. These key disease parameters, dissemination rates in particular (including the assumed role of airborne diffusion), are described in detail in Appendix B.

Epidemiological assumptions

Three major assumptions of this report are that:

- The outbreak is successfully contained within California's borders. Thus trade restrictions are the only consequences felt by livestock industries outside California.
- The disease is eradicated in a limited period of time; in other words, it does not become endemic.
- The outbreak is a one-time event; in other words, the disease is completely eradicated after the outbreak.

The first assumption is very unlikely. Considering the animal movements between California and other states, it is highly probable that the outbreak will spread to other states even before it is diagnosed in California. However, a complete modeling of the U.S. livestock industry is beyond the scope of this study. The second assumption has higher probability. The high costs resulting from FMD becoming endemic and the feasibility of controlling animal movements make eradication the preferred option for almost every level of output prices and spread of the disease. The third assumption is an optimistic scenario because it supposes that C&D efforts can be 100% effective in eliminating the virus from all infected premises. The recent experience in Taiwan showed the extreme difficulty in eradicating the virus in a massive outbreak.

The extent and duration of the epidemic depend on (1) the delay before the disease is recognized, (2) the type of control strategy applied, (3) the availability of human and financial resources, and (4) the effectiveness of animal health authorities in executing the eradication policies. In the U.S. and California, the preferred option in dealing with a FMD outbreak is stamping-out. This would involve prompt and rigid control of the movements of animals and animal products, vehicles, equipment and people; prompt depopulation of infected or exposed premises; intense surveillance of suspected herds; and C&D of infected premises. The efficiency of this policy depends on the timely availability of sufficient human, physical and financial resources. If the policy cannot be implemented with a high degree of efficiency from the first moments, the final eradication cost may be higher than if alternative policies are implemented. Study of alternative policies, however, is beyond the scope of this project.

The economic model

The economic model, which is discussed in detail in Appendix C, has three components:

- The first calculates the direct cost of depopulation, C&D and quarantine enforcement.
- The second uses an input-output model of the California economy to estimate the value of the direct, indirect and induced losses caused by the outbreak.¹¹
- The third economic component estimates the losses caused by trade restrictions.

The first component includes both direct costs of eradicating the outbreak and production losses in the quarantine area in cattle, dairy, pigs, and related industries. Losses in other livestock industries, in wildlife and in outdoor activities are not included.

Depopulation costs are calculated for an individual animal; the total depopulation cost is then obtained by multiplying the cost per head by the average number of animals in each farm type and the number of premises in the category. Depopulation costs include compensation payments, the cost of killing the animals, and the cost of disposing of the carcasses; the latter can be heavy (see Appendix C). The cost of C&D per premise is estimated as the cost per representative premise times the number of infected premises in the category. Finally, the cost of quarantine enforcement is estimated on a regional basis. Production losses in the quarantine area arise from depopulation of infected premises and close contacts, and from the idle time until repopulation is allowed. The lost output for these premises is calculated as the average production per week times the number of weeks that the premises cannot be repopulated. It includes the value of the various products marketed, including beef from culled dairy cows. All costs were estimated with the collaboration of Veterinary Services (APHIS) and Animal Health Branch (CDFA) following the guidelines set by APHIS (1991).

The second component of the economic module—direct, indirect and induced losses in the state due to the reduced livestock and dairy output (estimated output losses)—is obtained by multiplying the estimated direct loss by the output multipliers in the input-output model. An input-output model for the state of California developed by M.I.G. Inc. was used (See Appendix C). Economic data used in the model for the dairy, beef cattle, swine and sheep industries are listed in Appendix A.

The third component, trade losses due to international trade restrictions, is estimated under the assumption that the U.S. will be able to export only in the FMD-endemic market for at least two years after the eradication of the last outbreak. The prices drop by 50%, but the volume exported is maintained. This is an unlikely scenario, since exports are likely to fall because of trade restrictions and output reductions. However, given the assumption that the outbreak is contained in California and the fact that California is a net beef importer, the volume of meat available for export from other states is assumed to remain unaffected.

¹¹ It is expected that the outbreak would spread very rapidly over several counties, making estimation of single-county costs almost meaningless.

CHAPTER 8

ESTIMATION OF THE OUTBREAK COST

Due to uncertainty about the dissemination rate and the large disparity from previously published simulations of FMD, seven scenarios reflecting different assumptions about dissemination rates and intervention policies were constructed. Scenarios 1 through 4 use high dissemination rates that reflect the information collected in the South Valley for this study, while scenarios 5 through 7 use the highest dissemination rates published in the literature—which are low by comparison.

All dissemination rates were allowed to change randomly up to 30% in any direction. The model was run one hundred times, and the means and variances for each scenario were calculated.

The seven scenarios are:

1. High dissemination rates, no depopulation of latent infections, and 90% of infectious herds eliminated each week.
2. High dissemination rates, 90% depopulation of latent infections starting in the third week, and 90% of infectious herds eliminated each week.
3. High dissemination rates, 95% depopulation of latent infections starting in the second half of second week, and 95% of infectious herds eliminated each week.
4. High dissemination rates, 95% depopulation of latent infections starting in the first half of second week, and 95% of infectious herds eliminated each week.
5. Low dissemination rates, no depopulation of latent infections, and 90% of infectious herds eliminated starting in the third week.
6. Low dissemination rates, 90% depopulation of latent infections starting in the first half of third week and 95% of infectious herds eliminated each week.
7. Low dissemination rates, no depopulation of latent infections, and 50% of infectious herds eliminated each week.

Table 3 shows results of the simulations in average numbers of herds destroyed or surviving. Scenario 1 represents the worst possible case considered in this study. However, it still is substantially more favorable than what is considered the most probable outcome in case of an outbreak. This is because the simulated depopulation is faster than could be expected with the limited financial resources presently available to respond to an animal health emergency. Initially the scenario 1 outbreak spreads slowly but explodes in the second half of the third week. By the end of the fourth

week all susceptible herds have been infected, and depopulation ends in the first half of the sixth week. The standard deviation of the number of herds in all states at the end of the sixth week is 0.

In scenario 2, depopulation of 90% of all infectious and exposed herds starts at the beginning of the third week. The epidemic ends in the first half of the sixth week, and only 7.5% of the dairies, 7% of the feedlots, 8.7% of the commercial hog operations and 7.2% of the backyard operations survive the outbreak. The standard deviation is equal to 19% of the surviving herds. Even though elimination of infected herds proceeds faster than in scenario 1, the epidemic has the same duration because complete depopulation of latent infections requires an additional half week. If the efficiency in depopulation of latent and infectious herds increases to 95% from the beginning of the third week, about 13% of the herds survive. This scenario is not reported in Table 3.

In scenario 3, the intervention starts in the second half of the second week and the efficiency in depopulating latent infections and infectious herds is 95%. At the end of the epidemic 76% of the dairies, 73% of the feedlots, 74% of the commercial hog operations and 76% of the backyard operations survive the outbreak. The standard deviation is equal to 19% of the surviving herds.

Scenario 4 is similar to scenario 3 except that the intervention starts a half week earlier, during the first half of the second week. The outbreak has two peaks, at the beginning of weeks two and three, and 81.5% of the dairies, 80% of the feedlots, 82.7% of the commercial hog operations and 81.7% of the backyard operations survive the outbreak. The standard deviation is equal to 22% of the surviving herds.

Scenario 5 is similar to scenario 1 but with lower dissemination rates. The epidemic lasts 67 days and approximately 13% of the premises are not depopulated. The standard deviation is equal to 13% of the surviving herds.

In scenario 6, depopulation starts at the beginning of the third week, with 10% of latent and 5% of infectious herds remaining. Depopulation ends at the beginning of the sixth week, and by this time about 74% of the herds remain susceptible. The standard deviation is equal to 7.6% of surviving herds.

In scenario 7 the intervention starts in the first half of the third week and the efficiency in depopulating infectious herds is only 50%, but 10% of the latent infections become infectious. The outbreak ends after 77 days, and about 2.5% of the herds remain susceptible at the end of the epidemic. The standard deviation is equal to 4% of the surviving herds.

The simulations show that even when the dissemination rates are high, early intervention combined with high efficiency in identifying latent infections and depopulating can substantially reduce the magnitude of the epidemic. Increasing the efficiency of depopulating latent infections and infectious herds from 90 to 95% has only a minor impact; the key factor is the early beginning of depopulation.

Table 3: Simulation Results Herds Destroyed and Surviving In the South Valley

Scenario		Large Dairies	Small Dairies	Feedlots	Large Pigs	Backyard Pigs	Processing Plants	Duration (in days)
1	destroyed	175	441	15	23	1,001	27	35
	st.d.	0	0	0	0	0		
	survived	0	0	0	0	0		
	st.d.	0	0	0	0	0		
2	destroyed	162	409	14	21	929	25	35
	st.d.	2.48	6.24	0.21	0.34	14.17		
	survived	13	32	1	2	72		
	st.d.	2.48	6.24	0.21	0.33	14.15		
3	destroyed	42	106	4	6	241	6	35
	st.d.	3	8	0	0	18		
	survived	133	335	11	17	760		
	st.d.	3	8	0	0	18		
4	destroyed	32	80	3	4	183	5	35
	st.d.	4	10	0	1	17		
	survived	143	361	12	19	818		
	st.d.	4	10	0	1	22		
5	destroyed	151	381	13	20	866	23	67
	st.d.	2	4	0	0	10		
	survived	24	60	2	3	135		
	st.d.	2	4	0	0	10		
6	destroyed	45	114	4	6	260	7	35
	st.d.	4	10	0	1	22		
	survived	130	327	11	17	741		
	st.d.	4	10	0	1	22		
7	destroyed	170	430	15	23	975	26	72
	st.d.	0	1	0	0	2		
	survived	4	11	0	0	25		
	st.d.	0	1	0	0	2		

However, the opportunity for decisive intervention lasts only one week. If eradication starts in the third week of the outbreak, about 13% of the herds survive the epidemic compared to about 81% when eradication starts in the second week—assuming the same efficiency in depopulation.

Comparing scenarios 5, 6 and 7, it is clear that even with low dissemination rates, containment of the epidemic requires depopulation of dangerous contacts. An increase in the depopulation rate of infectious herds from 50% (scenario 7) to 90% (scenario 5, when latent infections are not removed) increases the proportion of surviving herds from about 2.2% to only about 13%. However, when latent infections are removed as well as a high proportion of infectious herds (scenario 6), the proportion of surviving herds increases to about 74%.

A key factor affecting the planning of eradication policies is the actual value of the dissemination rates. If the dissemination rates are low the stamping-out policy can be started later in the outbreak. If the dissemination rates are high—which is more likely—and depopulation starts late, the stamping-out policy may require depopulation of all herds in the affected region. In that case, ring vaccination combined with a slower depopulation rate may result in a lower economic loss. In any case, it is

clear from the simulations that, regardless of the dissemination rates, a high degree of preparedness and timely availability of financial resources are necessary conditions for containment of the epidemic.

Costs of the outbreak

Table 4 shows the total C&D costs, including compensation for destroyed animals and materials, and the quarantine cost for the different scenarios. The figures result from multiplying the number of depopulated premises in each scenario by the C&D costs.

In this table and the following four there is an added second-phase scenario, designated as Scenario 8. All scenarios except this one are for the South Valley—Fresno, Kern, Kings and Tulare counties. Scenario 8, however, replicates scenario 1 (high dissemination rates, no depopulation of latent infections, and 90% of infectious herds eliminated each week) under the assumption that the outbreak affects the entire San Joaquin Valley and the Chino Valley.

Table 4: Cost of C&D, depopulation and quarantine (millions of \$)

Scenario	Large Dairies	Small Dairies	Feedlots	Large Pig Operations	Backyard Operations	Processing Plants	Quarantine	Total Cost
1	542	361	218	4	32	11	260	1,428
2	502	335	204	4	30	10	260	1,345
3	130	87	58	1	8	3	258	545
4	99	66	44	1	6	2	258	476
5	468	312	189	3	28	9	311	1,320
6	139	93	58	1	8	3	258	560
7	527	352	218	4	32	10	319	1,462
8 (San Joaquin & Chino Valleys)	1,759	1,586	338	9	65	23	1,039	4,819

Table 5 shows the direct production losses caused by the outbreak. These are estimated as the average daily production in the region times the proportion of infected premises times the number of days the premises cannot sell their output. The calculations are based on the following assumptions: (1) the quarantines are lifted 120 days after depopulation of the last infected or exposed premise; (2) depopulated farms return to production 60 days after depopulation of the last infected or exposed premise; (3) the supply of animals outside the infected region is large enough to repopulate the quarantined premises in a short period of time, (4) the price of cattle remains at the levels prevailing before the outbreak; (5) dairies start selling milk immediately after the quarantines are lifted; (6) dairies that are not depopulated sell milk in the quarantine area without interruption at the same prices they received before the outbreak, (7) feedlots need 130 days after being repopulated to bring

the animals to slaughter weight; and (8) hog facilities finish their animals in 40 days after the lifting of the quarantines.

Table 5: Direct production losses (in million dollars)

Scenario	Milk	Beef	Pork	Total
1	281	268	9	558
2	260	251	8	519
3	67	72	2	141
4	51	54	2	107
5	324	266	9	599
6	72	72	2	146
7	380	313	11	704
8 (San Joaquin & Chino Valleys)	710	746	12	1,468

The direct output losses induce additional losses that affect the entire state economy. These losses, shown in Table 6, were estimated as the direct output loss multiplied by the corresponding output multipliers from the IMPLAN model.

Table 6: Direct, indirect and induced output losses in California (in million dollars)

Scenario	Milk	Beef	Pork	Total
1	455	518	17	990
2	421	484	15	920
3	109	138	4	251
4	83	104	3	190
5	525	513	18	1,056
6	117	138	4	259
7	615	603	21	1,239
8 (San Joaquin & Chino Valleys)	1,150	1,439	24	2,613

In addition to the output losses, a FMD outbreak would trigger trade losses to both California and the U.S.; given the difficulties in estimating the beef exports originating in California, only the losses for the U.S. were estimated. These losses, shown in Table 7, are the result of restrictions imposed by the major current U.S. customers, forcing the U.S. to sell its animal products in markets willing to accept them.

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Table 7: Trade losses (in million dollars)

Scenario	Beef	Milk	Pork	Skins	Total
1	2,992	703	843	1,560	6,098
2	2,992	703	844	1,562	6,101
3	2,992	703	846	1,566	6,107
4	2,992	703	845	1,564	6,104
5	3,108	730	847	1,568	6,253
6	2,992	703	848	1,570	6,113
7	3,126	734	849	1,572	6,282
8 (San Joaquin & Chino Valleys)	2,992	703	843	1,560	6,098

It is assumed that the products subject to trade restrictions are sold in the FMD-endemic market where prices are 50% lower than in the FMD-free market. Since most of the exports subject to restrictions are currently shipped to Japan and Korea, which do not recognize the regionalization principle, the outbreak would affect not only exports originating in California but all U.S. exports. The model assumed that the restrictions are lifted two years after depopulation of the last infected or exposed herd, and that U.S. exporters can regain the market share in the FMD-free market immediately. This is a very optimistic scenario because it assumes that the C&D efforts would be 100% effective in eliminating the virus from all infected premises, and that other exporters would not permanently capture a portion of the U.S. share of the FMD-free market.

The trade losses arise exclusively from a lower export price. It is assumed that exporters in other states are able to maintain the volume of exports they shipped before the outbreak. This assumption is very unlikely, but follows the basic assumption that the outbreak is restricted to the South Valley. It is also assumed that California does not export any pork meat, and that trade restrictions on pork meat are applied only by Japan and Korea.

The total cost due to the FMD outbreak in California is equal to the direct, indirect and induced output losses, plus the cost of C&D and enforcing the quarantine, plus the losses due to trade restrictions. Table 8 shows the total cost of the outbreak, including the effect on all meats, skins and dairy products originating in any state in the U.S. If the dissemination rates are high, a half week delay in the start of depopulation increases the loss by \$132 million (compare scenarios 3 and 4, column 7). A delay of seven days increases the loss by \$1,754 million (scenarios 1 and 4, column 7). If the outbreak spreads to the entire San Joaquin Valley and the Chino Valley, the loss increases by \$6,770 million over even the most optimistic of the South Valley scenarios (scenarios 4 and 8, column 7)

Even in the most optimistic case (scenario 4), public animal health services would need \$475 million during weeks two to six of the epidemic to eradicate the outbreak. However, under present legisla-

Table 8: Total cost (in million dollars)

Scenario	C&D	Quarantine	Direct, Indirect and Induced Output Lost			Trade from California	Total (with Cal. trade)	Trade from U.S.	Total (with U.S. trade)
			Dairy	Beef	Pork				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	1,169	260	455	518	17	1,871	4,289	6,098	8,516
2	1,084	260	421	484	15	1,871	4,135	6,101	8,365
3	287	258	109	138	4	1,871	2,667	6,107	6,903
4	217	258	83	104	3	1,871	2,535	6,104	6,768
5	1,010	311	525	513	18	1,969	4,345	6,253	8,630
6	303	258	117	138	4	1,871	2,692	6,113	6,934
7	1,143	319	615	603	21	1,984	4,686	6,282	8,983
8 (San Joaquin, Chino & Valleys)	3,781	1,039	1,150	1,439	24	1,871	9,305	6,098	13,531

tion only \$12 million would be immediately available, and appropriation of additional resources would require legislative intervention which could delay the start of eradication more than one week. In this same scenario, eradication of the outbreak would require depopulation and disposal of 149,000 cows and 2,183 pigs in the first two weeks of the eradication campaign. Past experiences—in Italy and Taiwan, for example—indicate that this is almost impossible. The simulations suggest that the most probable outcome in the case of a FMD outbreak would be a rapid spread over California and other states with large livestock industries. Therefore, the estimates in Table 8 including Scenario 8 must be considered as the lower bound of the true cost of an outbreak.

It also must be noted that the cost estimates are based on very optimistic assumptions about:

- The efficiency of the eradication policy, in particular the feasibility of imposing a 100% efficient quarantine and achieving 100% efficiency in C&D of depopulated premises.
- The containment of the outbreak in California.
- The time frame in which the markets return to a situation similar to the one prevailing before the outbreak.

CHAPTER 9

SUMMARY AND RECOMMENDATIONS

Exotic animal diseases could cause major economic losses to the U.S. and California livestock and dairy industries, to consumers and to governments. Among all exotic animal diseases, FMD has the potential for the highest losses.

The U.S. operates a two-tier system of defense against highly contagious exotic animal diseases. The first tier involves trade restrictions to minimize the probability of infected animals or animal products being shipped to the U.S., as well as border controls to monitor the entrance of travelers and imports from infected countries. However, risk of virus introduction is increasing and border controls have not evolved enough to face this new challenge.

The second tier of defense consists of public federal and state monitoring and surveillance services. In case of an outbreak, these services are also responsible for control and eradication campaigns. These policies cannot succeed without strong cooperation from other agents who are required to provide support at different stages of implementation. The agents include, among others, farmers, private practitioners, processing industries, law enforcement agents, and policy makers.

In the case of a FMD outbreak, Veterinary Services (APHIS) and Animal Health Services (CDFA) would follow a stamping-out policy. The major components of this policy involve:

- Establishment of a quarantine area where all animal movements are restricted for at least 60 days after depopulation of the last infected premise.
- Slaughter and burning or burial of all infected and exposed (even though asymptomatic) susceptible animals.
- Close monitoring of all remaining susceptible animals.
- Cleaning and disinfection of infected premises in the area, including farms, saleyards, slaughterhouses and milk processing facilities.

The chief conclusion of this study is that it is highly likely that implementation of the stamping-out policy would face enormous problems which would seriously compromise its chances of success. The most important of these problems are:

- Producers might not be aware of the urgent need to report vesicular diseases. Additionally, under current regulations, they have incentives not to do so.

- Because the U.S. has been free from FMD for seven decades, it is probable that the first cases will be misdiagnosed.
- The high intensity of production practices in dairies and feedlots, including large herds and considerable movements of services and products, favors rapid spread of the disease.
- The high density of animals within herds and high density of herds in the region facilitates airborne diffusion.
- Enforcing the quarantines would be difficult because of the disruption of activities and extremely high costs imposed on other farmers and sectors of society.
- Depopulation and carcass disposal would face serious difficulties—timely availability of sufficient human, physical and financial resources, availability of burning materials, lack of knowledge of the cost imposed on different social groups by alternative carcass disposal methods, environmental and legal issues, etc.
- The cost of C&D and depopulation of the large production units typical of the South Valley would exceed the financial resources immediately available to face an animal health emergency, and appropriation of additional resources would require legislative action that could cause excessive delays in implementation.
- There is likely to be resistance by producers, politicians and society to the killing of apparently healthy animals, as happens with exposed herds.

The simulations conducted for this study show that a successful stamping-out program in the South Valley would require: (1) depopulation of both exposed and infectious herds, and (2) eradication starting no later than the end of the second week of the outbreak. In that context, “success” is defined as eradication of the outbreak while depopulating less than 40% of the premises in the quarantine area. This study, however, indicates that—given the production conditions of the South Valley, and the limited availability of financial, human and material resources—it is possible that more than 80% of the susceptible animal population in the San Joaquin and Chino Valleys would be infected or exposed even before the first premise is depopulated.

The cost of the stamping-out policy would explode with the number of depopulated premises. Therefore, other policies could become more cost effective when a large number of premises must be depopulated. The alternative policy of vaccination could reduce the number of animals destroyed but would delay the return of the U.S. to the FMD-free market. However, the number of destroyed animals at which stamping-out ceases to be the optimal policy is unknown.

Recommendations

The probability of an outbreak depends on the efficiency of border controls and the bio-security measures implemented by livestock producers. Changes in the travel and trade environment are

modifying the risk posed by the various potential routes of introduction of the FMD virus. Studies should be conducted to elicit the actual risk levels posed by each potential route, in order to prioritize surveillance and control efforts.

The bio-security measures implemented by farmers depend on their awareness of the indications and consequences of a FMD outbreak, and the incentives to take adequate prevention measures. Programs targeted to producers, private practitioners and related industries are needed to increase awareness of the probability of an outbreak, and to reduce the disincentives to report vesicular diseases.

Advanced gathering of information to be used in an animal health emergency can accelerate both implementation of the quarantines, and identification of the movements of infected animals. Programs to collect critical information and make it immediately available should be identified.

The eradication effort would require large financial resources. Waiting until such resources are appropriated would delay the beginning of depopulation, and increase the cost of the epidemic. Alternative policies to speed up the appropriation process should be studied. Contributions of the federal and state governments, producers and industry should be explicitly considered.

Finally, additional studies are needed to determine the economic and societal costs of alternative eradication policies.

A complete list of recommendations to increase preparedness to deal with a FMD outbreak follows.

**ADDITIONAL SUGGESTIONS FOR DEALING
WITH THE THREAT OF FMD**

Implementation of the recommendations of this report, and preparedness in general for an outbreak of FMD, will require a complex mix of specific actions, as indicated by these suggestions:

- Compare the efficiency of maintaining the present U.S. vaccine bank versus the option of joining a larger international bank.
- Identify and create the databases that could help in increasing the efficiency of the first response to an outbreak (e.g., an animal identification and information system to trace animal movements, or a list of trucking companies that may help in following cattle movements).
- Study animal movements in and out of California to assess the resources required to enforce state and federal quarantines.
- Study typical movements in and out of premises with livestock to determine the optimal size of the high risk and buffer zones.
- Study bio-security practices among livestock producers and industries in California to identify the best actions (regulatory changes, education, extension, etc.) aimed at reducing the probability of an outbreak, minimizing risk factors and facilitating eradication.
- Develop a model of airborne diffusion calibrated to the different agroecological areas of the state.
- Develop an expert system to be used in the management of an animal health emergency.
- Analyze the process of resource mobilization in case of an epidemic to identify potential bottlenecks.
- Increase participation of farmers and farm organizations in diffusion of information.
- Create a program to increase participation of private practitioners in developing contingency plans and transfer of information to producers and allied industries.
- Implement an information campaign aimed at elected officials on the value of animal health emergency services and the importance of prompt response.
- Analyze alternative procedures to speed access to emergency public funds.
- Design a self insurance mechanism financed by the dairy and livestock industries to partially

cover the losses caused by a FMD outbreak. This insurance could speed the recovery and reduce the need for public disaster assistance.

- Create a state interagency committee to coordinate the emergency response. The committee should include at least representatives of CDFA, the state EPA, officers of state emergency services, the University of California, National Guard, California Veterinary Medical Association, law enforcement agencies, the Governor's office, the state legislature, the livestock industry and APHIS. Conduct periodic meetings to evaluate preparedness, probably every two years.
- Analyze the cost benefit ratio of alternative methods for carcass disposal to determine the optimal investment in disposal capacity. Evaluate the possibility of developing joint programs with other states, such as portable incinerators owned jointly by several states or the federal government. Particular attention should be given to the cost imposed on farms, processors and counties by each disposal method.
- Increase interaction with animal health services in other states and countries to exchange experiences.
- Designate one or two professionals to follow developments in monitoring and control of FMD in other countries.
- Evaluate the efficiency of present activities conducted by Animal Health Branch and APHIS in California. Activities with low impact and high cost, such as control of low risk garbage feeding operations, should be eliminated.
- Ban garbage feeding in the state.
- Increase control of high risk concentration places, such as fairs, shows and auctions of small animals. The control could be enforced either by the public or private sector.
- Target information campaigns to backyard operators, such as 4H members.
- Prepare cleaning and disinfection plans for complex cases such as milk processing plants and slaughterhouses. Contingency plans also should be developed to deal with non-agricultural carriers, such as urban populations and vehicles.
- Estimate the cost of outbreaks of other reportable diseases. This information should be shared with the industry and contingency plans should be evaluated.
- Discuss with local authorities the possibility of including in applications for new livestock facilities a requirement for a contingency plan for rapid depopulation of the premises—identification of burial sites, determination of groundwater depth, etc.
- Establish minimum standards of an exotic disease emergency preparedness program in California.

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