Homeland Security

Biodefense Knowledge Center
Rapid Response

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INQUIRY STATEMENT:

Please provide additional analysis of the potential impact of an accidental release of foot-and-mouth disease (FMD) from each of the proposed locations for the National Biological and Agricultural Defense Facility (NBAF).

EXECUTIVE SUMMARY

We conducted both a qualitative analysis of an aerosol release from the six proposed National Biological and Agricultural Defense (NBAF) sites as well as analyzed seven scenarios related to the potential impact of an accidental foot and mouth disease virus (FMDV) release in the vicinity of each of the six candidate sites. The qualitative assessment of the impact of an aerosol release from each site determined that an aerosol release from New York and Kansas would have the lowest and greatest impacts, respectively. Our epidemiological analysis indicated that for scenarios involving a single initial (index) case, outbreak durations were comparable across all proposed site locations, lasting between 44 to 51 days on average. Based on the number of animals infected, simulated outbreaks initiated in Kansas and North Carolina were the largest and outbreaks initiated in New York were the smallest. Based on the number of herds inflected, Kansas had larger outbreaks and New York and Texas had smaller outbreaks.

The average overall economic impact of the single-introduction outbreaks evaluated was slightly lower for New York, but was not dramatically different for the remaining sites. **Table 1** summarizes the estimated total economic impacts, calculated as the sum of lost foreign trade, industry disruption, and direct cost to government. Key findings and points related to the economic impact analysis are as follows:

- Because simulated outbreaks were relatively small and of short duration, loss of foreign trade dominates the economic impacts calculated for the six candidate National Biological and Agricultural Defense Facility sites.

- A procedure to regionalize the country in the area around an outbreak to enable foreign trade to continue in non-affected areas, is likely to be more feasible for an island location. However, the ease with which it may be established for the other sites was not considered for this analysis. This is likely to be an important factor impacting the indirect costs and value of lost foreign trade.

- Losses due to industry disruption (indirect costs) are an order of magnitude smaller than foreign trade, but are larger for states with the largest livestock industries (Kansas and Texas), assuming the implementation of state wide movement restrictions upon confirmation of foot and mouth disease virus within the state.

- The economic and epidemiological analysis presented here assumes an accidental release results in infection of at least one livestock premises. It does not consider the likelihood of an accidental release at each site, nor does it consider the likelihood of a least one animal becoming infected given that a release occurred. Addressing both of these factors will lead to more accurate overall conclusions on the potential economic impact.

Table 1. Average estimated economic impact from a single random introduction of FMDV in each of the counties proposing to host the NBAF.

Site	Duration of surveillance (days)	Duration of foreign trade bans (days)	Value of foreign trade lost ($million)	Industry disruption loss ($million)	Direct cost to government ($million)	Total cost ($million)
GA	47	185	3,100	154	94	3,350
KS	51	189	3,100	1001	97	4,200
MS	47	185	3,100	216	94	3,400
NC	47	185	3,000	430	95	3,500
NY	44	182	2,700	31	93	2,800
TX	46	184	3,100	940	93	4,100

ANALYSIS:

Qualitative Assessment of the Potential Impact of an Aerosol Release

A qualitative analysis of an aerosol release of FMDV from the six proposed NBAF sites was conducted based on two criteria: 1) the likelihood of an infection to appear in proximal livestock premises and 2) the likelihood that a major outbreak could result from this introduction. Based on the likelihood of an airborne FMDV release to cause infection or cause a major outbreak in the vicinity of each site, we assess that an aerosol release at Plum Island, NY would have the lowest impact, while a release at the Manhattan, KS location would have the greatest impact. The current, limited qualitative analysis was not able to distinguish between the impacts of the other four proposed sites.

Key assumptions and limitations of the qualitative aerosol release analysis include:

- An aerosolized release of FMD has occurred. As such, this document does not characterize the probability of such an occurrence.
- A serotype and subtype of FMDV with a propensity for aerosol transmission is associated with the release. The likelihood that an FMDV isolate is involved in aerosol dissemination varies greatly by subtype.
- The probability of downwind infections due to aerosolized FMD is assumed to:
    - Decrease with distance from the release site,
    - Be non-zero (although not necessarily large) up to 100 km downwind of the release site,
    - Be significantly greater for cattle than for pigs or sheep,
    - Be greater in regions of high animal density, and
    - Be significantly greater for large farms (>500 animals) compared to small farms.

- The probability of a wide-scale outbreak would be significantly greater if:

- A large number of swine were infected as a result of the release (swine emit large quantities of viable FMD aerosols into the air which can cause spread the disease)
- Animals at a livestock market became infected (the infected animals are assumed to be widely distributed before the disease was detected).

We assessed the likelihood that an aerosol release would result in a downwind infection using two metrics: 1) the total number of susceptible animals and 2) the number of large cattle facilities (>500 head) (see **Table 2**). We assessed the likelihood that an aerosol release would result in a major outbreak using two additional metrics (see **Table 3**): 1) the total number of markets and 2) the number of large swine herds (> 500 head). All metrics were compiled for the immediate area (i.e., the county in which the facility was located) and for animals housed in counties within 50 and 100 km rings about the facility. This approach likely overestimates the number of animals within a 50 and 100 km radius, particularly for counties win only a small portion within the specified range, but was adopted as the precise animal locations were not available. While the impact of a national scale FMD outbreak can be effectively assessed utilizing the county level data, the exact herd locations in proximity to the proposed NBAF sites would be needed to perform a more detailed quantitative assessment of the impact of an aerosol release from each site.

Table 2. Infection metrics

		Proposed Site					
	Number [a] of	NY	MS	GA	NC	TX	KS
Within same county	Total Animals	650	20,000	7,500	17,000	59,000	47,000
	Large Cattle Farms	0	5	2	1	8	4
Counties within 50 km	Total Animals	18,000	92,000	330,000	190,000	390,000	540,000
	Large Cattle Farms	2	14	24	11	59	120
Counties within 100 km	Total Animals	69,000	330,000	570,000	1,200,000	1,200,200	1,700,000
	Large Cattle Farms	6	53	51	46	200	320

Table 3: Major outbreak metrics

		Proposed Site					
	Number [a] of	NY	MS	GA	NC	TX	KS
lWithin same county	Markets	0	2	1	1	0	1
	Large Pig Farms	0	0	1	1	0	3
Counties within 50 km	Markets	2	2	4	4	0	7
	Large Pig Farms	0	0	21	10	0	34
Counties within 100 km	Markets	3	13	14	14	0	23
	Large Pig Farms	0	2	27	520	2	130

[a] The precise herd and market locations were not available. The animal, herd, and market numbers presented here represent all animals within a county for which at least a portion is within 50 or 100 km of the proposed release site. Reported values have been rounded to two significant figures.

Based on the numbers in tables 2 and 3, we judge that an aerosol release from the Plum Island location is least likely to produce a significant off-site impact. This conclusion was driven by the low numbers and densities of animals in the regions surrounding the proposed site. In contrast, an aerosol release from the proposed Manhattan, KS facility was judged to be most likely to produce the significant off-site impacts. This conclusion was driven by the high numbers and densities of animals in the counties surrounding the proposed site. In particular, the proposed Manhattan, KS facility had the highest number of susceptible animals in both the local and extended regions and the highest number of markets and large swine facilities (e.g. there are 19 markets and 120 large swine facilities within 100 km of the proposed site).

Aerosol releases from the other four proposed sites will likely produce intermediate impacts and a more detailed meteorological and dispersion model analysis is recommended to quantify the relative ranking of potential impacts.

Multiscale Epidemiological/Economic Simulation and Analysis Evaluation of an Accidental release: Scenario Descriptions and Modeling Assumptions

As accidental releases of FMDV from a research facility could occur via fomites (e.g., personnel, equipment, effluent, waste or air), direct contact (e.g., escape of an infected animal) or during a natural disaster or accident (earthquake, explosion, fire, etc.). For the purposes of this report, no analysis was conducted to determine the most likely mechanism for an accidental release, nor the amount of FMDV released during such an event. An assessment of the likelihood of plausible routes of viral escape and the amount/quantity of FMDV associated with each release would allow for a more comprehensive assessment of the potential impacts.

The DHS-sponsored Multiscale Epidemiological/Economic Simulation and Analysis (MESA) decision support system was utilized to evaluate the potential impact of an accidental release of foot and mouth disease virus (FMDV) from each candidate National Biological and Agricultural Defense (NBAF) site. For each of the six locations, seven scenarios were evaluated (42 scenarios total) and 400 epidemic realizations were simulated per scenario (16,800 epidemics). The scenarios evaluated included outbreaks beginning in the county of the proposed NBAF site (Clarke County [Georgia]; Riley County [Kansas]; Madison County [Mississippi]; Suffolk County [New York]; Granville County [North Carolina]; and Bexar County [Texas]) or this county and surrounding counties (those within ~20 kilometers [km] of its borders). The seven scenarios are grouped into one of three categories:

- An initial single, random introduction represents an outbreak resulting from the successful introduction of FMDV into a randomly selected livestock premises in the county proposing to host the NBAF. Sales yards were excluded from introduction but were allowed to spread the disease.

- To evaluate the potential impact by type of species initially infected, four scenarios represented FMDV introduction randomly occurring in cattle, swine, sheep, and goat premises. Following the initial introduction, the disease was allowed to spread to all other premises types. These scenarios may represent what might be expected to be associated with a fomite release.

- To provide a basic assessment of the potential impact of an aerosol release into the county of the proposed NBAF site and surrounding counties, two additional scenarios were evaluated. A weighting factor was used to ensure that the farm where the initial infection occurs is proportional to the number of animals on each farm. This is because a farm with a higher animal density is more likely to become infected. In the first scenario, the introduction was limited to one farm, while in the second scenario, five farms were initially infected. The latter scenario may correspond to a larger aerosol release. No consideration was taken with respect to the relative susceptibility of the various animal species at risk nor was any consideration given to animals being housed indoors. These considerations, in addition to the exact premises locations, information on the FMDV source term (numbers and species shedding virus at the time of release by serotype), meteorological conditions,

and virus decay rate in the environment, would be needed to provide a more quantitative estimate of the potential impacts of various aerosol release scenarios.

The national dataset available for use by MESA is the 2002 National Agricultural Statistical Survey (NASS) data. This does not include exact herd locations within a given county.

Spread methods accounted for in the epidemiological model include direct contact animal movement, high and low risk indirect contact (fomite transmission), and interstate transportation of live animals. Inter-herd aerosol transmission is not a spread method accounted for in the epidemiological model.

Disease transmission parameters and detection parameters are based on the characteristics of a "generic" type O FMDV. As each serotype and subtype of FMDV possesses differing transmission and clinical characteristics, simulations for other FMDV subtypes will vary.

For each simulation, when the first case of FMD is detected and confirmed, a set of response and control measures consistent with the MESA '07 FMD baseline response[1] was implemented. These baseline assumptions are consistent with the U.S. Department of Agriculture (USDA) FMD Response Plan (Draft)[2] and informed by expert opinion. It is important to note that the USDA FMD Response Plan (Draft) provides general guidance on the implementation of a FMD response. According to this response plan, the exact actions taken (and the geographical range for each control measure) at the time of confirmation of FMD in the U.S. will be consistent with and informed by the available situational awareness at the time of the actual event. In our simulations, all control measures were fully implemented without constraining the quantity of available human or financial resources.

The control measures are summarized as follows:

- Contact reductions (as would be accomplished via biosecurity and movement restrictions) for direct and indirect (high risk and low risk) contacts into and out of designated control zones (quarantine zone, infected zone, and buffer surveillance zone) are implemented. Note: the size of the buffer surveillance zone is the entire state which is impacted. This translates into statewide biosecurity/movement restrictions, resulting in a greater indirect economic impact in states with larger livestock populations (even if not in proximity to the NBAF candidate site).
- Stoppage of all interstate livestock movement out of the affected states
- Closing of all sales yards within the buffer surveillance zone
- Trace-back and trace-forward of direct contacts for one generation
- Slaughter of confirmed infected herds after a species-dependent delay
- No preemptive depopulation of non-infected herds
- No vaccination
- Minimal time to obtain freedom from disease following the last case is three incubation periods (42 days).

For additional details on the specific control measures and their efficacy please see the Defensive Architecture Analysis: Assessment of Countermeasures for the Intentional Introduction of a Foreign Animal Disease (October 2006).[3]

Multiscale Epidemiological/Economic Simulation and Analysis Epidemiological Results

For all seven scenarios, the key factor that influenced the overall impact was the density of livestock in proximity to each site. For scenarios that initiated in a single index case, outbreaks initiated in swine and sheep were larger based the number of animals infected. Outbreaks initiated in sheep premises resulted in the largest outbreaks based on number of herds infected, except in Mississippi. In sheep, clinical disease is difficult to detect and disease spreads slowly within the flock. Therefore, "silent spread"(disease spread prior to confirmation) is longer when sheep are the index case, because they will remain undetected and the disease will have a longer time to spread prior to confirmation and implementation of control and response

measures (as in the U.K. 2001 outbreak). In addition, sheep have direct contact with other sheep premises over greater distances than other premises types which may also result in larger geographic distribution of outbreaks. The larger outbreaks (based on number of animals) in Kansas and North Carolina are mainly due to swine being infected. Swine premises frequently have large numbers of animals per premises. Simulated outbreaks in New York are small due to the low number of animals and herds in Suffolk and surrounding counties. Although Texas has the largest number of animals and herds in the county of the proposed NBAF site, the premises are primarily small stocker cattle and cow/calf operations and disease spread is limited in these facility types. The overall size (based on number of herds) of the outbreaks are comparable for Texas and New York.

For the last two scenarios, as animal facilities were weighted by the number of animals on the premises to more accurately represent successful FMD introduction by aerosol, larger facilities had a higher likelihood of being infected, resulting in larger outbreaks. It is important to note that for these scenarios aerosol release is assumed to be equally successful in infecting all species; however, sheep, goats, and pigs would have much lower probabilities of successful infection by this route versus cattle.

Multiscale Epidemiological/Economic Simulation and Analysis Economic Impact Discussion

The overall economic impact for each scenario includes estimates of foreign trade loss (due to trade ban durations), industry disruption (indirect costs) and direct cost to government to control the outbreak (Table 1). The duration of foreign trade bans was assumed to be six months post detection of the last case of FMD. This time frame is variable, based on the epidemic and the effectiveness of the response, but is the primary driver for the economic impact of these smaller scale epidemics. The annual value of foreign trade was taken to be the 2007 value of U.S. red meat exports of $6.4 billion. Temporary trade loss due to an outbreak was calculated by pro-rating the annual total by the duration of the foreign trade ban.

Industry disruption associated with disease control and response measures lead to indirect losses to producers who are impacted by the movement and biosecurity controls. Animal movement controls were assumed to include a statewide movement ban from first confirmation of disease in the state until 42 days (approximately 3 incubation periods) after the last detection in the state. Industry disruption losses were calculated by multiplying the number of animals under livestock controls on each day by a unit cost, and summing over days under control. Unit costs for animals under livestock movement controls were derived based on lost revenue, added costs, and cost savings to livestock producers who are prevented from moving animals during an outbreak. Assumed losses to the cattle industries include loss of bull dairy calves, and lost throughput to beef stockers, feedlots, and slaughter plants. In addition, cow-calf farms are assumed to lose the value of calves that reach normal shipment age during the outbreak and cannot be sent to stockers or feedlots for further feeding. This conservative assumption is intended to account for the likely price impact to primary producers who are left holding a backlog of cattle in the aftermath of an outbreak. Assumed losses to the swine industry include loss of feeder pigs that cannot be moved to grow-out barns, and resultant loss of throughput to swine nurseries, finishers, and slaughter plants.

Key observations and caveats on industry disruption losses include:

- While foreign trade loss scales with outbreak duration, industry disruption loss is determined by a combination of outbreak duration and the local composition (density and premises type) of livestock.

- Industry disruption loss reduces supplies, and therefore would tend to mitigate the surplus supply problem created by loss of foreign trade. However, in these cases, the supply impact was negligible compared to the volume of foreign trade.

- The assumption of statewide movement ban may be overly conservative for larger states (Texas), which may seek to apply movement bans on a more localized, regional basis more consistent with natural geographic barriers and livestock production patterns within the state. For example, in Texas, outbreaks occurring in the San Antonio region are likely to impact the cow-calf industry and

lead to small outbreaks which have lower probabilities of migrating north into the Panhandle where large feedlots and swine operations exist. Hence, response agencies may be inclined to limit the initial movement bans to a more limited geographic extent around San Antonio vs. the entire state.

Direct cost to government includes compensation payments paid to producers for infected animals that are destroyed and costs to complete the "3 D's" (depopulation, disposal, and disinfection). Compensation payments were taken to be $602 per head for beef cattle, $2,000 per head for dairy cows, and $120 per head for swine. Other organization costs to complete the eradication campaign were taken to be $440 per head, which was the estimated cost to the U.K. government to respond to the 2001 FMD outbreak. Government cost was also assumed to include a fixed cost for surveillance and freedom of disease testing which will have to be completed even for a very small outbreak. The fixed cost was taken to be $92.8 million which was the cost to the U.K. government to deal with the much smaller 2007 FMD outbreak.[4]

Additional details and supporting documentation related to the economic analysis are available in a LLNL-developed report for DHS/S&T titled "Defensive Architecture Analysis: Assessment of Countermeasures for the Intentional Introduction of a Foreign Animal Disease (October 2006).

Recommendations for Additional Analysis

This analysis provides additional insight into the potential impacts of accidental FMDV releases for the six proposed NBAF sites. Based on the preliminary and follow-on analysis completed to date and the level of detail required, we recommend additional analysis in the following areas:

- *Additional scenarios*. Ideally more time and resources would be devoted to evaluate the consequences of the scenarios (hazards) identified in the environmental impact statement (EIS). These may include FMDV introductions that occur a significant distance from the proposed NBAF site and in patterns which were not accounted for in this assessment. These consequence estimates could be coupled with the likelihood estimates for each scenario to provide a more accurate estimate of the total risk (and probable impact) of an accidental release at each site.
- *Aerosol dispersion modeling*. The analysis described in this document represents a rapid, qualitative estimate of the potential impacts associated with an aerosol release of viable FMDV from each of the six proposed NBAF sites. A quantitative impact and risk model would require a more detailed release scenario (including source term information such as the amount of material released), regional meteorological characterization, more precise locations and degree of clustering present in the animal populations, and advanced dispersion models.[*] This effort would be even more beneficial if it includes a tighter coupling between the airborne dispersion and animal spread models.

[*] For example, given the location of the proposed sites, the likely range of release scenarios, and distances to be considered, a simple straight-line Gaussian model may be insufficient to characterize the downwind impacts of an FMDV aerosol release.

Appendix: Detailed results by proposed site location

The mean and 95th percentile (95% confidence intervals [CI]) for the number of herds infected (**Table A1**), number of animals infected (**Table A2**), epidemic duration (**Table A3**), direct economic costs (**Table A4**), and indirect economic costs (**Table A5**) are summarized by site for each of the seven scenarios. Values highlighted in red and shaded are the highest values for each row (multiple values are highlighted when the highest values are not statically significant) and in highlighted in green and shaded for the lowest (low values which are not statically significant are both shaded in green for a given row).

Table A1: Mean and 95th Percentile of Herds Infected for Each Scenario by State.

Mean **Herds** Infected [95% CI]	**GA**	**KS**	**MS**	**NC**	**NY**	**TX**
random[a]	3.3 [2.6, 3.9]	**6.9** [5.3, 8.4]	2.6 [2.2, 3]	3.1 [2.5, 3.7]	**1.5** [1.2, 1.8]	2 [1.8, 2.2]
cattle[b]	3.9 [3.1, 4.6]	**5.8** [4.2, 7.3]	2.6 [2.1, 3.1]	3.8 [2.9, 4.7]	**1.5** [1.1, 1.8]	1.9 [1.7, 2.1]
goat[c]	2.2 [1.7, 2.6]	**3.1** [2.4, 3.8]	2.1 [1.7, 2.5]	2.6 [1.9, 3.3]	**1.1** [1, 1.1]	1.7 [1.5, 1.9]
swine[d]	5.3 [4.2, 6.3]	**7.1** [5.5, 8.8]	2.8 [2.3, 3.3]	4 [3.2, 4.9]	**1.7** [1.3, 2]	2.9 [2, 3.8]
sheep[e]	9.8 [8.5, 11]	**14** [12, 16]	3.4 [2.9, 3.8]	10 [8.6, 12]	**2.1** [1.7, 2.6]	6.2 [5.5, 6.8]
random single index cnty & srnd.[f]	5.6 [4.7, 6.6]	**7.7** [6.1, 9.2]	2.5 [2.2, 2.9]	4.3 [3.4, 5.1]	4 [3.4, 4.7]	**2.5** [2.2, 2.9]
random 5 index, cnty & srnd.[g]	**17** [16, 19]	**17** [15, 19]	11 [10, 12]	14 [13, 15]	13 [12, 14]	**8.9** [8.4, 9.4]
95th percentile **Herds** Infected	**GA**	**KS**	**MS**	**NC**	**NY**	**TX**
random[a]	11 [8, 21]	**40** [27, 64]	10 [7.5, 14]	13 [10, 23]	**2** [2, 4]	5 [4, 7.6]
cattle[b]	17 [13, 22]	**27** [17, 47]	9.1 [7, 13]	14 [11, 25]	**2** [1, 2]	5 [5, 6]
goat[c]	7 [5, 12]	**13** [12, 21]	9 [4, 14]	9.1 [7, 15]	**1** [1, 1]	4 [3, 6]
swine[d]	21 [16, 35]	**34** [26, 53]	13 [10, 16]	19 [12, 31]	**2** [1, 7.1]	7 [5, 9]
sheep[e]	31 [27, 41]	**64** [56, 77]	11 [10, 15]	44 [36, 52]	**8** [4.5, 14]	19 [17, 24]
random single index cnty & srnd.[f]	23 [20, 30]	**44** [34, 65]	9 [7, 12]	15 [13, 21]	14 [11, 20]	**7** [5, 11]
random 5 index, cnty & srnd.[g]	**51** [43, 60]	**56** [44, 78]	29 [24, 38]	39 [32, 46]	29 [25, 35]	**17** [15, 20]

[a]a single random introduction into any premises type in the immediate county

[b]a single random introduction into any cattle premises (dairy or beef) in the immediate county

[c]a single random introduction into any goat premises in the immediate county

[d]a single random introduction into any swine premises in the immediate county

[e]a single random introduction into any sheep premises in the immediate county

[f]a single random introduction into any livestock premises in the immediate and surrounding counties weighted by animal density on each premises

[g]five random introductions into any livestock premises in the immediate and surrounding counties weighted by animal density on each premises

Table A2: Mean and 95th Percentile for Animals Infected for Each Scenario by State.

Mean **Animals** Infected [95% CI]	GA	KS	MS	NC	NY	TX
random[a]	1701 [596, 2807]	**5410** [3840, 6981]	1438 [797, 2079]	3865 [2153, 5577]	177 [41, 312]	**168** [60, 275]
cattle[b]	1263 [534, 1992]	4059 [2444, 5674]	1503 [622, 2384]	**7293** [4047, 10540]	**119** [24, 215]	315 [38, 592]
goat[c]	351 [89, 613]	2812 [1305, 4318]	542 [228, 857]	**3013** [1331, 4696]	**25** [2, 49]	170 [151, 189]
swine[d]	3631 [2694, 4568]	8550 [6277, 10823]	642 [370, 914]	**9046** [5845, 12247]	**228** [87, 369]	2334 [1017, 3651]
sheep[e]	3301 [2342, 4259]	11823 [9100, 14546]	656 [338, 974]	**24248** [18727, 29769]	**300** [151, 449]	677 [293, 1061]
random single index cnty & srnd.[f]	5022 [3523, 6521]	10486 [8358, 12614]	1491 [899, 2082]	**13435** [9902, 16968]	**1430** [227, 2633]	3280 [2608, 3953]
random 5 index, cnty & srnd.[g]	20608 [18138, 23078]	30628 [27001, 34256]	6787 [5513, 8060]	**47484** [43007, 51962]	**2788** [2508, 3067]	12337 [11230, 13444]
95th percentile **Animals** Infected [95% CI]	**GA**	**KS**	**MS**	**NC**	**NY**	**TX**
random[a]	4645 [2393, 8965]	**37014** [23055, 54784]	5811 [2947, 13574]	17483 [6967, 49137]	**133** [92, 250]	343 [216, 736]
cattle[b]	3105 [2141, 5135]	20458 [10507, 48540]	2879 [1469, 9140]	**35656** [12222, 79048]	**68** [68, 210]	194 [156, 336]
goat[c]	937 [437, 3081]	**11238** [5894, 22356]	971 [407, 2581]	8154 [938, 26147]	**5** [5, 5]	378 [351, 443]
swine[d]	15048 [10714, 28875]	**44840** [29944, 73931]	2819 [1286, 6963]	42214 [23079, 115378]	**132** [132, 409]	6792 [2901, 23462]
sheep[e]	14539 [9371, 26511]	63525 [52578, 78752]	**1286** [999, 2725]	**139077** [114108, 188802]	1515 [402, 3183]	1882 [1458, 2273]
random single index cnty & srnd.[f]	27221 [16438, 37063]	55209 [35239, 67365]	5771 [2204, 17514]	**55412** [40307, 73232]	**3439** [2694, 4820]	14550 [14497, 14768]
random 5 index, cnty & srnd.[g]	74610 [62062, 92252]	105921 [83776, 131674]	37342 [29002, 47287]	**133325** [111617, 148672]	**7097** [5899, 9533]	30861 [29631, 40481]

[a]a single random introduction into any premises type in the immediate county
[b]a single random introduction into any cattle premises (dairy or beef) in the immediate county
[c]a single random introduction into any goat premises in the immediate county
[d]a single random introduction into any swine premises in the immediate county
[e]a single random introduction into any sheep premises in the immediate county
[f]a single random introduction into any livestock premises in the immediate and surrounding counties weighted by animal density on each premises
[g]five random introductions into any livestock premises in the immediate and surrounding counties weighted by animal density on each premises

Table A3: Mean and 95th Percentile for Epidemic Duration for Each Scenario by State.

Mean **Duration** of Epidemic	**GA**	**KS**	**MS**	**NC**	**NY**	**TX**
random[a]	47	51	47	47	44	46
cattle[b]	49	49	46	48	43	45
goat[c]	46	49	45	47	42	47
swine[d]	50	50	47	48	44	46
sheep[e]	57	59	49	56	46	62
random single index cnty & srnd.[f]	52	52	47	51	50	48
random 5 index, cnty & srnd.[g]	65	64	59	64	64	60
95th percentile **Duration** of Epidemic	**GA**	**KS**	**MS**	**NC**	**NY**	**TX**
random[a]	67	78	64	69	61	62
cattle[b]	70	74	63	72	51	59
goat[c]	64	70	60	66	44	70
swine[d]	70	79	66	71	61	62
sheep[e]	76	84	64	80	71	87
random single index cnty & srnd.[f]	75	76	62	73	70	69
random 5 index, cnty & srnd.[g]	83	83	76	84	82	80

[a]a single random introduction into any premises type in the immediate county
[b]a single random introduction into any cattle premises (dairy or beef) in the immediate county
[c]a single random introduction into any goat premises in the immediate county
[d]a single random introduction into any swine premises in the immediate county
[e]a single random introduction into any sheep premises in the immediate county
[f]a single random introduction into any livestock premises in the immediate and surrounding counties weighted by animal density on each premises
[g]five random introductions into any livestock premises in the immediate and surrounding counties weighted by animal density on each premises

Table A4: Mean and 95th Percentile of Direct Economic Costs (government costs) by Scenario for Each State.

Mean **Direct Cost** ($M)	**GA**	**KS**	**MS**	**NC**	**NY**	**TX**
random[a]	94	97	94	95	93	93
cattle[b]	94	96	94	97	93	93
goat[c]	93	95	93	95	93	93
swine[d]	95	98	93	98	93	94
sheep[e]	95	101	93	107	93	93
random single index cnty & srnd.[f]	96	100	95	101	94	96
random 5 index, cnty & srnd.[g]	106	114	100	120	98	106
95th percentile **Direct Cost** ($M)	**GA**	**KS**	**MS**	**NC**	**NY**	**TX**
random[a]	96	117	99	104	93	93
cattle[b]	96	110	97	114	93	93
goat[c]	94	102	94	98	93	93
swine[d]	104	122	96	121	93	97
sheep[e]	105	137	94	172	94	94
random single index cnty & srnd.[f]	109	129	97	124	99	108
random 5 index, cnty & srnd.[g]	137	159	131	168	104	125

[a]a single random introduction into any premises type in the immediate county
[b]a single random introduction into any cattle premises (dairy or beef) in the immediate county
[c]a single random introduction into any goat premises in the immediate county
[d]a single random introduction into any swine premises in the immediate county
[e]a single random introduction into any sheep premises in the immediate county
[f]a single random introduction into any livestock premises in the immediate and surrounding counties weighted by animal density on each premises
[g]five random introductions into any livestock premises in the immediate and surrounding counties weighted by animal density on each premises

Table A5: Mean and 95th Percentile of Indirect Economic Costs (Industry losses) by Scenario for Each State.

Mean **Indirect Cost** ($M) [95% CI]	GA	KS	MS	NC	NY	TX
random[a]	154 [128,179]	**1001** [918,1083]	216 [176,257]	430 [413,447]	**31** [29.34]	940 [924,956]
cattle[b]	170 [137,202]	850 [778,922]	211 [168,252]	451 [428,475]	**29** [26,31]	**932** [915,950]
goat[c]	117 [100,134]	897 [826,968]	132 [108,156]	440 [418,462]	**26** [24,27]	**947** [927,968]
swine[d]	288 [245,330]	988 [908,1067]	153 [123,184]	486 [456,517]	**36** [31,42]	**1029** [984,1074]
sheep[e]	322 [286,358]	**1589** [1491,1686]	150 [128,172]	610 [563,658]	**40** [36,43]	1282 [1247,1317]
random single index cnty & srnd.[f]	268 [224,312]	**1128** [1052,1204]	240 [199,282]	526 [487,565]	**40** [34,46]	985 [962,1009]
random 5 index, cnty & srnd.[g]	672 [603,740]	1708 [1631,1786]	595 [528,662]	810 [763,857]	**59** [53,64]	1269 [1242,1295]
95th percentile **Indirect Cost** ($M) [95% CI]	**GA**	**KS**	**MS**	**NC**	**NY**	**TX**
random[a]	619 [521,896]	**3293** [2704,3453]	1079 [898,1680]	656 [567,877]	**108** [30,141]	1275 [1200,1410]
cattle[b]	666 [513,910]	**2625** [2312,3338]	1214 [1049,1511]	657 [599,1129]	**28** [24,102]	1204 [1184,1282]
goat[c]	461 [328,668]	**2443** [2289,2974]	627 [259,1125]	712 [557,1459]	**25** [24,102]	1430 [1264,1631]
swine[d]	1098 [966,1478]	2907 [2580,3164]	841 [288,1278]	1209 [707,1564]	**122** [29,193]	2029 [1747,2721]
sheep[e]	1004 [883,1434]	**3276** [3079,3951]	531 [319,1002]	1639 [1374,2135]	**129** [118,148]	1806 [1726,1894]
random single index cnty & srnd.[f]	1253 [1003,1598]	**3068** [2762,3310]	1257 [1076,1481]	1433 [1245,1646]	**118** [107,156]	1480 [1361,1606]
random 5 index, cnty & srnd.[g]	2063 [1800,2445]	**3356** [3060,3525]	1962 [1766,2376]	1786 [1643,2005]	**175** [150,209]	1863 [1729,1006]

[a]a single random introduction into any premises type in the immediate county
[b]a single random introduction into any cattle premises (dairy or beef) in the immediate county
[c]a single random introduction into any goat premises in the immediate county
[d]a single random introduction into any swine premises in the immediate county
[e]a single random introduction into any sheep premises in the immediate county
[f]a single random introduction into any livestock premises in the immediate and surrounding counties weighted by animal density on each premises
[g]five random introductions into any livestock premises in the immediate and surrounding counties weighted by animal density on each premises

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