**Table 3-11**
**Human Age Categories, Equivalent Cattle Age Categories, and Age-Specific Human Sporadic CJD Rates[a]**

| Human Age Category (years) | Equivalent Cattle Age Category (years) | Annual Clinical CJD Incidence Rate (per million) | Annual Pre-Clinical BSE Incidence Rate (per million) |
|---|---|---|---|
| 0 to 4 | 0.0 to 1.0 | <0.01 | 0[b] |
| 5 to 9 | 1.3 to 2.4 | 0 | < 0.01 |
| 10 to 14 | 2.6 to 3.7 | 0 | <0.01 |
| 15 to 19 | 4.0 to 5.0 | 0 | 0.04 |
| 20 to 24 | 5.3 to 6.4 | <0.01 | 0.08 |
| 25 to 29 | 6.6 to 7.7 | <0.01 | 0.16 |
| 30 to 34 | 8.0 to 9.07 | 0.04 | 0.45 |
| 35 to 39 | 9.3 to 10.4 | 0.08 | 0.99 |
| 40 to 44 | 10.6 to11.7 | 0.16 | 2.14 |
| 45 to 49 | 12.0 to13.0 | 0.45 | 3.55 |
| 50 to 54 | 13.3 to14.4 | 0.99 | 5.03 |
| 55 to 59 | 14.6 to15.7 | 2.14 | 5.75 |
| 60 to 64 | 16.0 to17.0 | 3.55 | 5.6 |
| 65 to 69 | 17.3 to18.4 | 5.03 | 3.94 |
| 70 to 74 | 18.6 to19.7 | 5.75 | 2.42 |
| 75 to 79 | 20.0 to21.0 | 5.6 | 2.42[c] |
| 80 to 84 | 21.3 to22.4 | 3.94 | 2.42[c] |
| 85 + | 22.6 + | 2.42 | 2.42[c] |

*Notes:*

*a. Adapted from (Holman et al., 1995, anonymous, 1996)*

*b. We assume that the spontaneous CJD case observed in a young child was erroneous.*

*c. We assume that the spontaneous rate for BSE remains unchanged at ages beyond what can be inferred from the corresponding spontaneous CJD data.*

### 3.3.2 Importation of Infected Cattle

Because APHIS has banned the import of cattle from countries in which the presence of native BSE has been documented (see Section 2.3.2), the import of even a single infected animal is not likely. Given that even in the UK, the prevalence of BSE is relatively small, it is implausible that a large number of animals infected with BSE might be imported into the United States.

Nonetheless, in order to evaluate the robustness of the U.S. cattle population against the introduction of infected animals, we have simulated the introduction of 1, 5, 20, 50, 200, and 500

animals into the U.S. We assume that the imported animals are 12-month old female dairy cattle that have just become infected.

### 3.3.3 Domestic Scrapie

The transmission of scrapie from sheep to cattle is one of the primary hypotheses for the origin of BSE (Horn et al., 2001). Moreover, scrapie is present in the United States. Although no North American strain of scrapie has been successfully transmitted to cattle exposed orally to the agent (Cutlip et al., 2001), we evaluate the impact of assuming that such transmission is possible. In particular, if such transmission is possible, we estimate that the rendering of scrapie-infected sheep could expose the U.S. cattle population to 1 cattle oral $ID_{50}$ in feed each month. The derivation of this estimate is based on the assumption that the number of cattle oral $ID_{50}$s administered to cattle is equal to the product of 1) the number of scrapie-infected sheep rendered each year, 2) the number of sheep oral $ID_{50}$s per infected animal, 3) the inverse of the cattle-sheep species barrier, and 4) the proportion of infectivity sent to rendering that survives rendering and is ultimately administered to cattle.

*Number of scrapie-infected sheep rendered*: We estimate the number of clinical sheep and the number of pre-clinical sheep separately. A total of approximately 180,000 federally inspected mature sheep are slaughtered each year in the U.S. (USDA-FSIS, 1998). Assuming that the prevalence of scrapie is the same in the U.S. as it is in the UK (11%) (Simmons et al., 2000), there are approximately 20,000 sheep with scrapie slaughtered each year. Although sheep with clinical signs would ordinarily be detected at AM inspection and directed to incineration, we assume that they are rendered. We assume that 1% of the infected sheep fall into this category, suggesting that approximately 200 sheep with clinical signs are slaughtered each year. Note that these estimates are likely to be conservative because the true prevalence of scrapie in the U.S. is probably less than it is in the UK.

*Number of sheep oral $ID_{50}$s per clinical scrapie case*: For sheep with clinical scrapie, we assume that this quantity is 10,000, *i.e.*, the same as the number of cattle oral $ID_{50}$s per clinical case of BSE. In order to estimate the amount of infectivity in sheep that are not yet showing clinical signs of disease, we assume that the infectivity load for scrapie follows the same temporal pattern as BSE does in cattle (see Figure 3-6). As a result, we estimate the average number of $ID_{50}$s in a sheep to equal the time-averaged $ID_{50}$ burden in cattle over the period prior to the

development of clinical signs, or approximately 600 $ID_{50}$s. Note that this estimate is likely to overstate the true average culling and slaughter ensure that the number of older sheep (and hence the number of sheep that have been infected with scrapie for a long period of time) is less than the number of sheep that are younger (and hence are likely to have been infected for a shorter period of time).

*The cattle-sheep species barrier*: We assume that the species barrier between sheep and cattle is 1,000, *i.e.*, 1 sheep oral $ID_{50}$ is equivalent to 0.001 cattle oral $ID_{50}$s. This assumption is based on an evaluation of the relative transmissibilty of BSE from cattle to mice (Bradley, 1999) and on results from *in vitro* conversion studies (Raymond et al., 1997). The true species barrier is unknown and may be substantially higher. For example, no North American strain of scrapie has been successfully transmitted to cattle exposed orally to the agent (Cutlip et al., 2001).

*Proportion of infectivity surviving rendering and administered to cattle*: We used the simulation model, along with the base case assumptions to estimate the proportion of infectivity in prohibited material that is ultimately administered to cattle. In particular, we repeatedly simulated the rendering of a bovine with 1 $ID_{50}$ using the base case assumptions. Based on 1,000 runs of this simulation, we estimate that under the conditions described the base case, the average number of $ID_{50}$s administered to cattle amounted to $8 \times 10^{-4}$, *i.e.*, a little less than 0.1% of the infectivity in prohibited material survives rendering and is ultimately administered to cattle.

*Total infectivity to cattle*: For sheep with clinical scrapie, the product of the four quantities just described is approximately 2 cattle oral $ID_{50}$s per year. For sheep not yet showing clinical signs of disease, the product is approximately 10 cattle oral $ID_{50}$s per year. The total amounts to 12 cattle oral $ID_{50}$s annually, or 1 cattle oral $ID_{50}$ per month. Note that this estimate probably overstates actual cattle exposure for two reasons. First, it is likely that the true species barrier is greater than the value of 1,000 used here. Second, the prevalence of scrapie in the U.S. is probably less than the UK prevalence rates adopted here.

### 3.3.4 Chronic Wasting Disease: Oral Exposure

The FDA feed ban prohibits the use of rendered material derived from cervids in the production of feed to be administered to cattle. However, because the ban is not completely effective, cattle may be exposed to cervid-derived protein and hence to CWD. This section

describes our estimate of an upper bound on this exposure. Annual cattle exposure to CWD attributable to consumption of cervid-derived protein is the product of the 1) number of diseased animals harvested, 2) the number of cervid $ID_{50}$s per slaughtered case, 3) the fraction of animals rendered, 4) the inverse of the species barrier, and 5) the proportion of infectivity surviving rendering and administered to cattle. As described below, we estimate that present-day exposures to CWD among the U.S. cattle population could be as high as 2 cattle oral $ID_{50}$s per year, although the true value is likely to be substantially lower and could be zero.

*Number of diseased animals harvested*: Table 3-12 details the disease prevalence rate, population size, and annual harvest rate for the three species suspected of harboring CWD. In one respect, these estimates are likely to overstate the true values because they assume the prevalence rate for the endemic area applies to the entire population. On the other hand, because monitoring of CWD is limited to post mortem evaluation of brain tissue, it is possible that surveillance fails to detect animals with less advanced disease.

**Table 3-12**
**Annual Number of CWD-Infected Animals Harvested**

| Species | Disease Prevalence[a] | Population Size[b] | Annual Harvest Rate[b] | Infected Animals Harvested per Year[c] |
|---|---|---|---|---|
| Mule deer | 4.9% | $2 \times 10^6$ | 20-25% | 24,500 |
| White tail deer | 2.1% | $3.2 \times 10^7$ | 25% | 168,000 |
| Rocky Mountain Elk | 0.5% | $1.0 \times 10^6$ | 15-20% | 1,000 |
| **Total** | | | | 194,000 |

*Notes:*

a. *Refers to the estimated prevalence of CWD among animals harvested from the CWD endemic areas of north central Colorado and southeastern Wyoming* (Miller et al., 2000)

b. *Source (Rocky Mountain Elk Foundation, 1997); Lloyd Floyd, personal communication; Quality Deer Management Association's*

c. *Computed using the upper bound annual harvest rate in the fourth column from the left.*

*Number of cervid $ID_{50}$s per case*: Because the prevalence rate has been estimated on the basis of post mortem evaluation of brain tissue, they may reflect only those animals that have advanced disease. We assume that there are 10,000 cervid oral $ID_{50}$s per case of disease.

*Fraction of animals rendered*: Only a small portion of cervids harvested for human consumption are likely to be rendered at all. Those that are rendered are most often processed by an independent facility that handles only prohibited rendered material (Don Franco, personal communication). We assume that 10% of the harvested cervids are rendered.

*The species barrier*: As noted in Section 2.3.4, the species barrier for the transmission of CWD from cervids to cattle appears to be between $10^5$ and $10^{12}$. We conservatively assume that the species barrier value is $10^5$.

*Proportion of infectivity surviving rendering and administered to cattle*: As described in Section 3.3.2, under present-day conditions (*i.e.*, with the adoption of the feed ban), total cattle population exposure to infectivity is approximately 0.1% as great as the amount of infectivity in animals sent to rendering.

*Total Cattle Population Exposure*: Under present-day conditions, total exposure to CWD is estimated to amount to no more than 2 cattle oral $ID_{50}$s per year, or approximately 0.2 cattle oral $ID_{50}$s per month. As noted above, this estimates reflects several assumptions that are potentially very conservative. The true level of exposure is perhaps much lower.

### 3.3.5 Chronic Wasting Disease: Lateral Transmission

Because this source is insignificant (see Section 2.3.5), we do not quantitatively model its impact on the prevalence of BSE in the U.S. cattle population or its contribution to contamination of the U.S. food supply.

### 3.3.6 Mink

As is the case with cervids, FDA regulations prohibit the administration to cattle of feed fortified with proteins derived from mink. However, it is possible that this ban fails to completely halt such exposures. This section describes our development of an upper bound estimate on this exposure, which we estimate to be on the order of 1 cattle oral $ID_{50}$ annually. The true value is likely to be substantially lower, and could be zero. Our methodology is similar to that used for CWD. Annual cattle exposure to TME attributable to consumption of mink-derived protein is the product of the 1) number of diseased animals harvested, 2) the number of mink $ID_{50}$s per animal

slaughtered, 3) the fraction of animals rendered, 4) the inverse of the species barrier, and 5) the proportion of infectivity surviving rendering and administered to cattle.

*Number of diseased animals harvested*: A total of 2.6 million mink are harvested in the U.S. annually (USDA, 2001). The prevalence of disease is unknown. We assume that the prevalence of clinical and pre-clinical disease are both similar to the corresponding rates for scrapie, or approximately 0.1% and 10%, respectively. Hence, we estimate that there are 2,600 clinical animals and 260,000 pre-clinical animals slaughtered each year.

*Number of mink $ID_{50}$s per case*: As we estimated for scrapie, we assume that pre-clinical animals harbor an average of 600 mink $ID_{50}$s, whereas clinical animals harbor 10,000 mink $ID_{50}$s.

*Fraction of animals rendered*: We estimate that 60% of slaughtered mink are rendered (based on information provided by Teresa Platt, Executive Director-Fur Commission USA).

*The species barrier*: Experimental transmission of TME from the Stetsonville outbreak to cattle via i.c. inoculation resulted in animals developing a fatal spongiform encephalopathy (Marsh et al., 1991), although it appeared to be distinct from BSE. As with CWD, we assume that the species barrier for TME transmitted to cattle is $10^5$.

*Proportion of infectivity surviving rendering and administered to cattle*: As in the case of CWD, we assume that this value is now 0.1%.

*Total infectivity reaching cattle*: Total infectivity reaching cattle from clinical TME cases amounts to 0.2 cattle oral $ID_{50}$s annually, while the corresponding value for pre-clinical animals is 0.9 cattle oral $ID_{50}$s. The total amounts to 1 cattle oral $ID_{50}$ per year, or approximately 0.1 cattle oral $ID_{50}$s per month. Because this source exposes cattle to substantially less infectivity than does scrapie (as modeled in Section 3.3.3), we do not quantitatively model its impact on the prevalence of BSE in the U.S. cattle population or its contribution to contamination of the U.S. food supply.

### 3.3.7 Pigs

Because this source is insignificant (see Section 2.3.7), we do not quantitatively model its impact on the prevalence of BSE in the U.S. cattle population or its contribution to contamination of the U.S. food supply.

### 3.3.8 Poultry

Because this source is insignificant (see Section 2.3.8), we do not quantitatively model its impact on the prevalence of BSE in the U.S. cattle population or its contribution to contamination of the U.S. food supply.

### 3.3.9 Recycled Waste

Because this source is insignificant (see Section 2.3.9), we do not quantitatively model its impact on the prevalence of BSE in the U.S. cattle population or its contribution to contamination of the U.S. food supply.

## 3.4 Alternative Scenarios Evaluated Using the Simulation Model

The alternative scenarios evaluated using the simulation model fall into three categories. First, we evaluated the plausibility of the model's output by comparing the predicted number of clinical BSE cases to the observed number of clinical BSE cases between 1985 and 2000 in Switzerland (Section 3.4.1). Second, we evaluated the potential for two sources of infectivity (spontaneous disease and cattle imported from the UK during the 1980s) to have introduced BSE into the U.S. prior to the implementation of regulations meant to limit its spread (Sections 3.4.2 and 3.4.3). Finally, we evaluated the extent to which additional risk management action (implementation of a UK-style specified risk material ban, or a ban on rendering cattle that die on the farm) reduces the potential spread of BSE and potential human exposure (Sections 3.4.4 and 3.4.5).

### 3.4.1 Switzerland

Because there has never been a controlled experiment to quantify the impact of introducing BSE into a country, a true validation of the simulation model described in this report is not possible. Instead, this section describes an evaluation of the model's plausibility that

involves modeling the small BSE outbreak observed in Switzerland following the introduction of BSE infectivity from the UK. Working with experts in Switzerland, we identified appropriate parameter values in order to characterize the herd population dynamics, conditions, practices, and procedures in that country. The Switzerland scenario reflects changing conditions over time. In addition to specifying conditions at the beginning of the simulation (1986), the scenario also reflects changes to these conditions in 1990, 1993, 1996, 1998, and 1999.

*1986:* The Switzerland scenario begins in 1986, the year we assume that 67 newly infected female dairy cattle were incubating BSE (Doherr et al., 1999). Thirty of these cattle are assumed to be 25 months of age and the remaining 37 are assumed to be 26 months of age.

At the same time, the Switzerland scenario assumes that feed containing 4000 cattle oral $ID_{50}$s was imported. The assumption is based on information that three tons of MBM were imported from the UK between 1985 and 1989. We assume that during that period, MBM from Britain was contaminated with BSE. In particular, we assume that the three tons of MBM imported from Britain represented rendered protein from three cattle, each of which harbored between 800 and 2,000 cattle oral $ID_{50}$s. We assume that the 3 tons of MBM were used to supplement feed at a concentration of 5% and was therefore distributed as part of a total of 60 tons of feed. Assuming that cattle consume 30 pounds of feed a day (3% of their weight) and that farms purchase feed in lots sufficient to last them 30 days, the 60 tons (120,000 pounds) of feed would be divided among 133 cattle (*i.e.*, 120,000 pounds ÷ (30 pounds/cow-day × 30 days)).

Differences between the base case and the Switzerland scenario in 1986 include the following. First, the misfeeding rate is assumed to be 15%, considerably higher than the 1.6% misfeeding rate in the base case. The assumption of a substantially higher misfeeding rate is based on the observation that a substantial proportion of the farms in Switzerland raise both livestock that can consume prohibited feed and livestock that are restricted to non-prohibited feed. For example, nearly 67% of the poultry in Switzerland are raised on farms that also raise cattle (Switzerland farm Structure census: farms with cattle and chicken, 1999). For hogs, the corresponding proportion is 59% (Switzerland farm Structure census: farms with cattle and pigs, 1999).

Second, the Switzerland scenario assumes that most rendering systems in use in 1986 in Switzerland used batch processing technology, which normally reduces infectivity by a factor of

1,000 (*i.e.*, 3 logs). However, because use in Switzerland typically did not conform the 133°C/20 minutes/3 bars of pressure minimum treatment standard, we assume that the majority of rendering facilities achieved only 2 logs of infectivity inactivation.

Finally, the Switzerland scenario reflects the absence of a feed ban in 1986.

*1990:* In 1990, Switzerland enacted a feed ban. However, the structure of the MBM and feed production industries provided opportunities for failures to this ban. In particular, a substantial portion of the prohibited feed was produced by mixed feed producers. We assume that these producers mislabeled or failed to properly label 10% of their prohibited feed and that contamination occurred during production of 20% of the prohibited feed. We also note that increased efforts to keep specified risk materials (SRM) out of the human supply increased the flow of this material into MBM and ultimately into animal feed.

*1993*: By 1993, rendering practices improved. We assume that at that time, all renderers complied with the 133°C/20 minutes/3 bars of pressure standard, and hence that all rendering achieved a 3.1 logs of infectivity reduction (a factor of approximately 1,260).

*1996*: Further changes came around 1996, when Switzerland enacted a ban on the rendering or use as human food of SRM, including brain, spinal cord, dorsal root ganglia, gut, lung, eyes, and AMR meat. Changes in farming practices also helped reduce the spread of BSE infectivity. These changes included reduced misfeeding of prohibited rations to cattle (we assume this rate was 0.1%) and the elimination of rendering cattle that had died on the farm.

*1998*: In 1998, slaughter facility practices further improved with an increased effort to remove spinal cords after splitting. We assume the spinal cord was removed 99.9% of the time.

*1999*: Finally, in the 1999-2000 time period, Switzerland outlawed the practice of feeding MBM to <u>any</u> farm animal. This move essentially eliminated the possibility of misfeeding animals. In addition, Switzerland prohibited the feeding of blood meal to cattle .

### 3.4.2 Spontaneous Disease as a Potential Source of Infectivity in the U.S.

This scenario is the same as the spontaneous disease scenario described in Section 2.3.1 except that it also assumes the absence of the 1997 feed ban. We assume that prior to the adoption of the 1997 feed ban, 65% of the MBM produced by renderers that processed cattle went to animal feed manufacturers, while the remaining 35% was either exported or otherwise allocated to some other use that posed no risk of exposing cattle to BSE infectivity. We further assume that 98% of the feed produced by feed manufacturers was sent to farms and that only 2% was allocated to uses that posed no exposure risk to cattle.

### 3.4.3 Cattle Imported into the U.S. from the UK During the 1980s

This scenario evaluates the potential consequences of U.S. imports of cattle from the UK during the 1980's prior to the imposition of an import ban in 1989. Of particular concern has been the import 334 cattle from the UK and 162 cattle from the Republic of Ireland during that period because those animals may have been infected with BSE. The vast majority of the cattle imported from Ireland were regarded as a negligible challenge to the US system because they were imported before 1985 (SSC, 2000c). Of the animals imported from UK, USDA has determined that 161 were disposed of in a manner that eliminates the possibility that they could have either contaminated the human food supply or lead to the exposure of additional animals in the U.S. to BSE. However, USDA has not been able to conclusively determine that the other 173 animals posed no risk to either human food or animal feed. This scenario characterizes the potential impact these cattle may have had on the presence of BSE in the U.S.

For each of the 173 animals that may have posed an exposure risk, USDA has determined from Department records and from interviews year of birth, animal type (beef or dairy), gender, age when exported to the U.S., and age when last seen. Using this information, we have computed the probability that the animal was infected and the distribution of values for the animal's total infectivity load. Probabilistically summing these distributions over all 173 cattle yielded a distribution of $ID_{50}$s imported into the U.S. For this scenario, we assume that all infectivity was imported in 1980. Section1.1 in Appendix 2 describes our methodology for developing the imported infectivity distribution.

To determine the impact of these imports, we simulated the introduction of various amounts of infectivity in cattle feed. Amounts simulated were 0.1, 1.0, 5.0, 10.0, and 50.0 cattle

oral $ID_{50}$s. The simulation started in the year 1980 and ran through the year 2010. The following assumptions were made for each time period over that 30-year duration.

*1980*: At the beginning of the simulation, there is no feed ban in place. In addition, we assume that for cattle between the ages of 12 and 23 months, mis-splits occur with 5% probability, AMR is used 20% of the time, and spinal cords are removed with 50% probability (regardless of AMR usage). The same assumptions apply to animals 24 months of age and older, except for the mis-split probability, which is assumed to be 8%. The fraction of spinal cord and DRG that contaminate AMR meat also differs somewhat from the baseline assumptions (see Appendix 2 for details). Finally, we assume that air-injected pneumatic stunning is used for 15% of all animals.

*1993*: We assume that in 1993, the proportion of animals processed in plants using AMR increases from 20% to 40%.

*1997*: The simulation reflects implementation of the feed ban in 1997. However, we assume that at this time, the mislabeling rate for prohibited and mixed renderers is 10% (instead of the base case value of 5%). We also assume that the contamination rate for mixed renderers is 28% (instead of the base case value of 14%). For prohibited and mixed feed producers, we assume that the mislabeling rate is 10% (instead of the base case value of 5%). The probability of contamination for mixed feed producers is assumed to be 32% (instead of the base case value of 16%).

*1999*: We assume conditions return to those reflected by the base case assumptions.

### 3.4.4 Risk Management: Specified Risk Materials (SRM) Ban

The SRM ban eliminates the potential for the following tissues to contaminate either human food or rendered material that might be used as feed: brain, spinal cord, gut, eyes, and AMR meat products. The SRM ban also eliminates the practice of rendering animals that die on the farm.

### 3.4.5 Risk Management: A Ban on Rendering Animals that Die on the Farm

Animals that die on the farm are not rendered. We assume that any infectivity in these animals will not contaminate either human food or rendered material that may be used as animal feed.