An Improved Processed Based Ammonia Emission Model for Agricultural Sources Emission Estimates

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University of California at Davis
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Outline

- Introduction
- Model Development/Coding
- Data Requirements & Sources
- Model Results

NH3 Model Development Team

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  - Sponsoring/Funding Agency

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Processes Involved in Ammonia Emissions

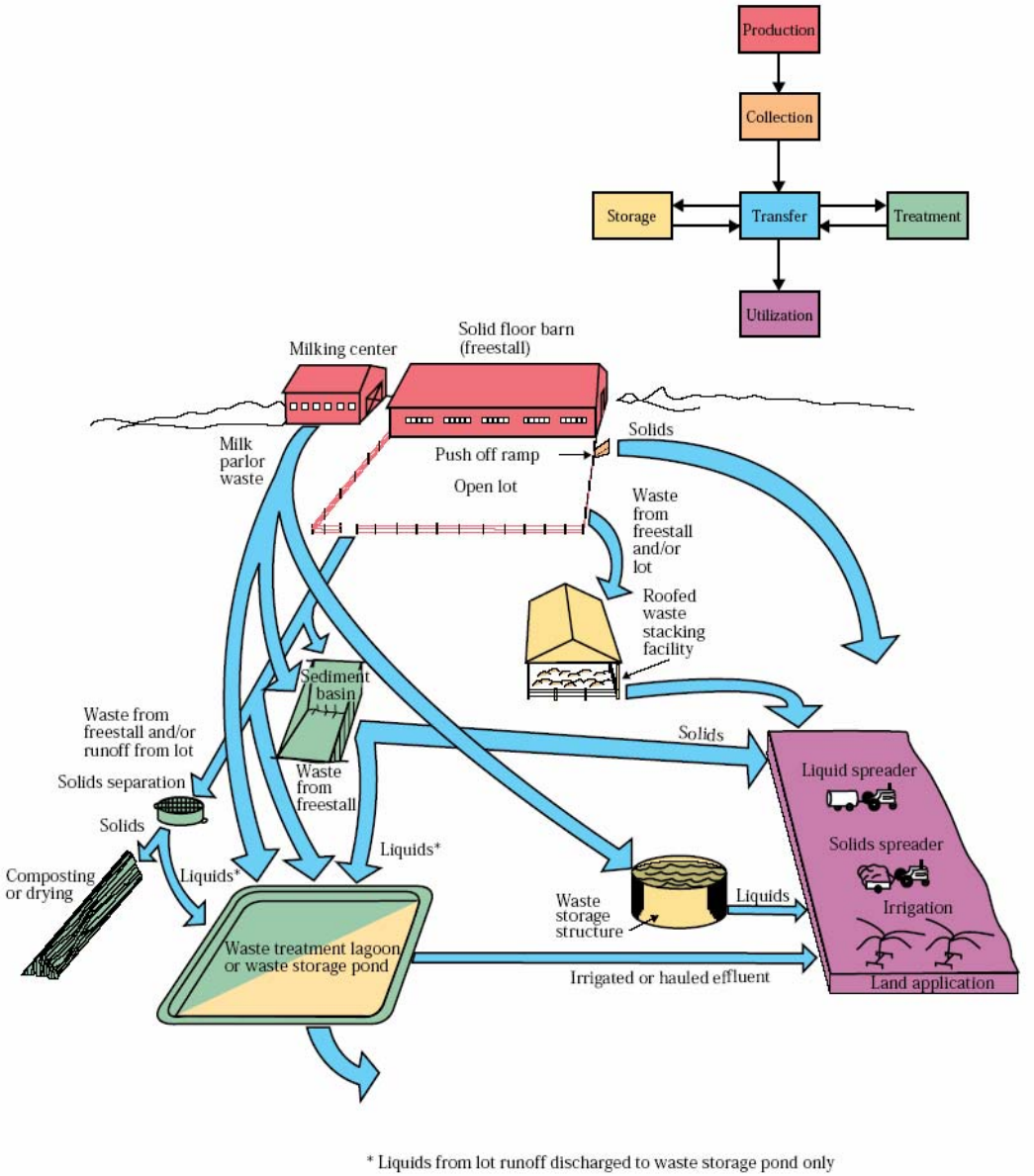
- **Ammonia generation**
  - Urea hydrolysis via enzymes
  - Organic nitrogen mineralization via bacteria
  - Aqueous chemical reactions
- **Ammonia transfer from water phase to air phase**
  - Diffusion
  - Convection mass transfer

Process-based Scientific Approach

- **Consider and analyze all physical, chemical and biochemical processes and reactions that take place and influence ammonia emission rate,**
- **Employ processed based mechanistic and empirical models (new and existing),**
- **Keep mass balances for the flow of nitrogen through each component of an animal waste management system.**

Manure Management Train (MMT)

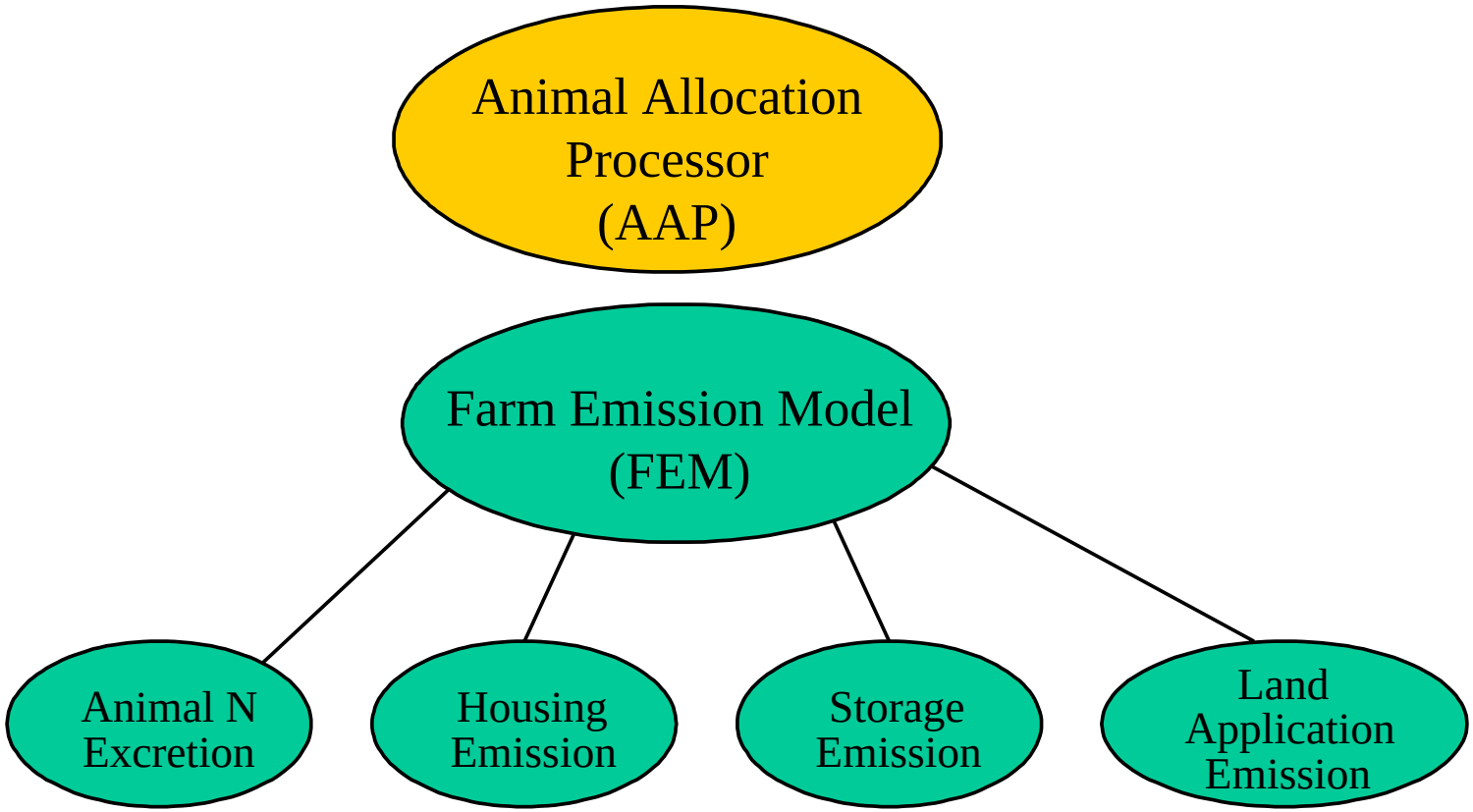
Animal Housing and Management Practices



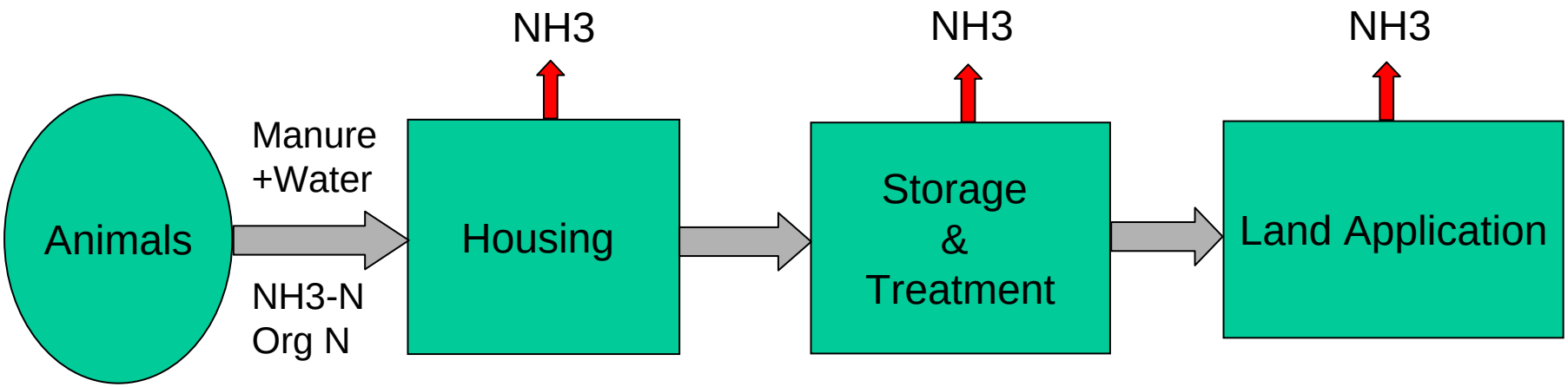
Processed Based NH3 Model w/ Commercial Fertilizers

- **NH3 Animal Allocation Processor**
- **NH3 Farm Emissions Model:**
  - Animal excretion model
  - Housing emissions model
  - Feedlot emissions model
  - Storage emissions model, and
  - Land emissions model
- **Animal species considered:**
  - Dairy cows
  - Beef cattle
  - Swine
  - Poultry (layers, broilers, and turkeys)
- **Commercial Fertilizers**

Process-based NH3 Model Flow Diagram



Farm Emissions Model



Dairy
Beef cattle
Swine
Layers
Broilers
Turkeys

Confinement
(Mechanically ventilated
or Naturally ventilated)
Open Feedlot

Under-floor pit
Outside storage
(liquid, solid)

Surface Application

Animal Allocation Processor

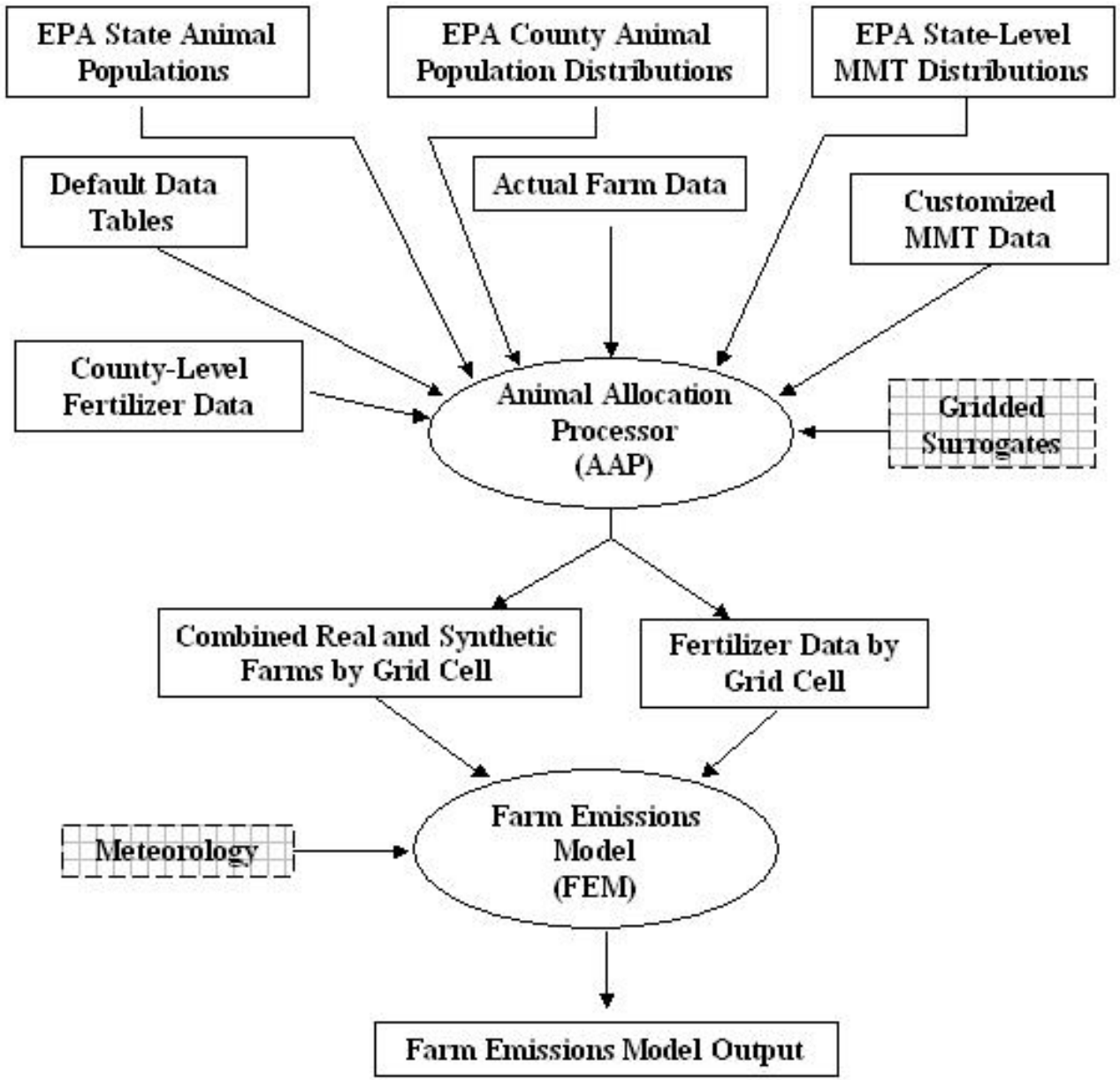
- Distribute county-level animal head counts to defined Manure Management Trains (MMTs)
- Spatially allocate MMTs to grid cells using gridded surrogates (agricultural land)
- Format input data for Farm Emission Model (FEM)
- Actual Farm Data
- Commercial Fertilizers

NH3 Emissions Calculation in FEM

- **FEM computes NH3 emissions with animal numbers by each Manure Management Train (MMT) for each grid cell:**
  - Reads in ascii outputs from AAP
  - Reads in meteorology file from CONCEPT met tables
  - Run Animal Excretion Model
  - Based upon MMTID:
    - Run Housing Emissions Model
    - Run Storage/Feedlot Emissions Model
    - Run Land Emissions Model
  - Output total NH3 based on animal type & MMTID
  - Output commercial fertilizer NH3 emissions estimates

Commercial Fertilizer Emissions

- Default (Placeholder) Approach
- Fertilizer Amounts by County
- Spatial Allocation Using Gridded Surrogates
- Processed through FEM in anticipation of improved estimation methodologies dependent on meteorology and environmental parameters


EPA State Animal Populations
EPA County Animal Population Distributions
EPA State-Level MMT Distributions
Default Data Tables
Actual Farm Data
Customized MMT Data
County-Level Fertilizer Data
Animal Allocation Processor (AAP)
Gridded Surrogates
Combined Real and Synthetic Farms by Grid Cell
Fertilizer Data by Grid Cell
Meteorology
Farm Emissions Model (FEM)
Farm Emissions Model Output

AAP/FEM Coding Specs

- **Code written as part of the CONCEPT Framework**
- **Conform to CONCEPT coding specs.**
- **Could also be run as a stand-alone model**
- **Languages used include:**
  - PostgreSQL (& plpgsql)
  - Perl

FEM Input/Output

- **Input Data**
  - AAP ASCII outputs
  - Meteorological Data
    - Lat/Lon Coordinates
    - Wind velocity and direction
    - Relative Humidity, Rain,
    - Frictional velocity, etc.
- **Output Data**
  - Based upon animal type & MMTID
  - Format:
    - CONCEPT ready format
    - NIF 3.0 format
    - ASCII csv format

AAP Input Data Sources

- **Livestock Data**
  - 2002 and 1997 Census of Agriculture Data
  - EPA MMT Distributions
  - Revised MMT by ISU for Midwest states
  - FEM Defaults from UCD and ISU
  - EPA Animal Population Category → FEM Categories from UCD and ISU
- **Commercial Fertilizers**
  - Carnegie Mellon University (CMU) NH3 Model
  - County-level fertilizer application rates by month for 2002

EPA MMT

AnimalType	MMTID	SCC	SCC Description	MMT Description	Animal	RptFig#
Swine	1	2805039	Swine production - operations with lagoons (unspecified animal age)	Swine House with Lagoon Systems and no Solids Separation	Swine	1
Swine	4	2805039	Swine production - operations with lagoons (unspecified animal age)	Swine House with Lagoon Systems and Solids Separation	Swine	1
Swine	2	2805047	Swine production - deep-pit house operations (unspecified animal age)	Swine House with Deep Pit System	Swine	2
Swine	3	2805053	Swine production - outdoor operations (unspecified animal age)	Swine Outdoor Confinement	Swine	3
Poultry	1	2805007	Poultry production - layers with dry manure management systems	Poultry- dry layers	Layers	12
Poultry	2	2805008	Poultry production - layers with wet manure management systems	Poultry- wet layers	Layers	13
Poultry	1	2805009	Poultry production - broilers	Broiler house	Broilers	14
Poultry	2	2805009	Poultry production - broilers	Broiler outdoor confinement area	Broilers	16
Poultry	1	2805010	Poultry production - turkeys	Turkey house	Turkeys	15
Poultry	2	2805010	Poultry production - turkeys	Turkey Outdoor Confinement Area	Turkeys	16
Beef	1	2805001	Beef cattle - finishing operations on feedlots (drylots)	Beef Feedlot with Storage Pond, no Settling Basin	Beef	17
Beef	2	2805001	Beef cattle - finishing operations on feedlots (drylots)	Beef Feedlot with Storage Pond and Settling Basin	Beef	17
Beef	3	2805001	Beef cattle - finishing operations on feedlots (drylots)	Beef Feedlot with no Storage Pond or SettlingBasin	Beef	17
Beef	4	2805003	Beef cattle - finishing operations on pasture/range	Beef Operations on Pastures	Beef	18
Dairy	1	2805019	Dairy cattle - flush dairy	Flush Dairy with Solids Separation	Milking	4
Dairy	2	2805019	Dairy cattle - flush dairy	Flush Dairy without Solids Separation	Milking	4
Dairy	3	2805021	Dairy cattle - scrape dairy	Scrape Dairy without Soilds Separation	Milking	5
Dairy	4	2805021	Dairy cattle - scrape dairy	Scrape Dairy with Soilds Separation	Milking	5
Dairy	6	2805021	Dairy cattle - scrape dairy	Scrape Dairy- Daily Spread	Milking	7
Dairy	9	2805021	Dairy cattle - scrape dairy	Scrape Dairy- Slurry	Milking	9
Dairy	8	2805021	Dairy cattle - scrape dairy	Scrape Dairy- Solid Storage	Milking	10
Dairy	7	2805022	Dairy cattle - deep pit dairy	Dairy Barn with Deep Pit	Milking	8
Dairy	5	2805023	Dairy cattle - drylot/pasture dairy	Dairy Outdoor Confinement Area	Milking	11
Dairy	10	2805023	Dairy cattle - drylot/pasture dairy	Dairy Heifer and Dry cow drylot	Dry Cows	6

Mapping of Animal Subcategories

- **Dairy**
  - exact match (lactating, dry, heifer)
- **Beef**
  - EPA: not on feed heifers and steers, on feed heifers and steers, bulls, calves, beef cow
  - FEM: finishing, cow-calf pair, maintenance
- **Poultry & Layers**
  - EPA: broilers, turkeys, hens, pullets, chickens
  - FEM: broilers, male turkeys, female turkeys, layers
- **Swine**
  - EPA: swine 60, swine 60-119, swine 120-179, swine 180, swine breeding
  - FEM: finishing, weaning, gestating, lactating

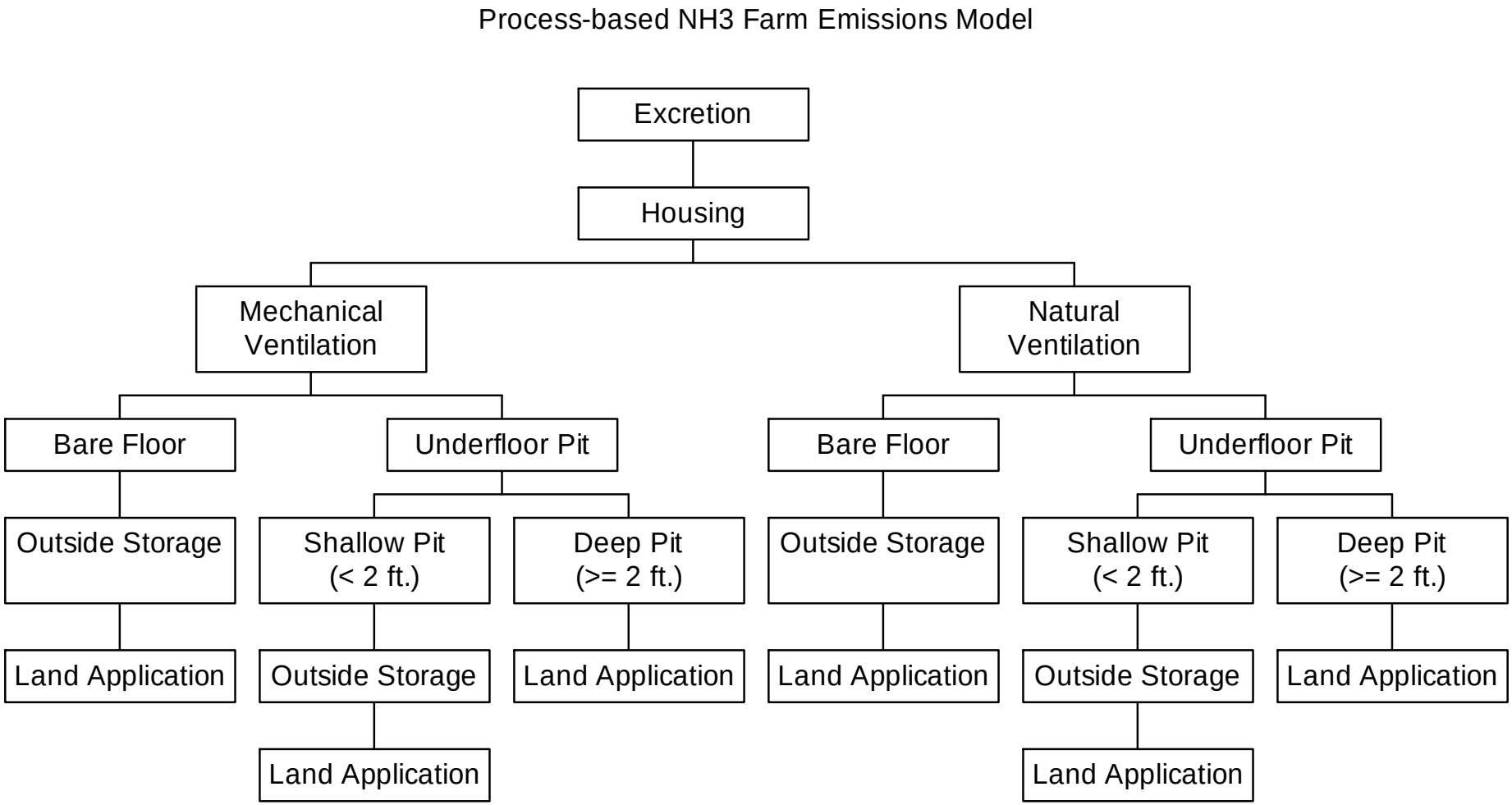
Animal Category Mappings

- **Beef:**
  - cow-calf pairs = 0.8*(205/365)*(beef cow)
  - maintenance = (1 - 0.8)*(205/365)*(beef cow) + +(160/365)*(beef cow) + bulls + (beef NOF heifer) + (beef NOF steer)
  - finishing = (beef OF heifer) + (beef OF steer)
- **Poultry:**
  - broilers = broilers
  - male turkey = 0.5*turkeys
  - female turkey = 0.5*turkeys
  - layers = hens + chickens + pullets

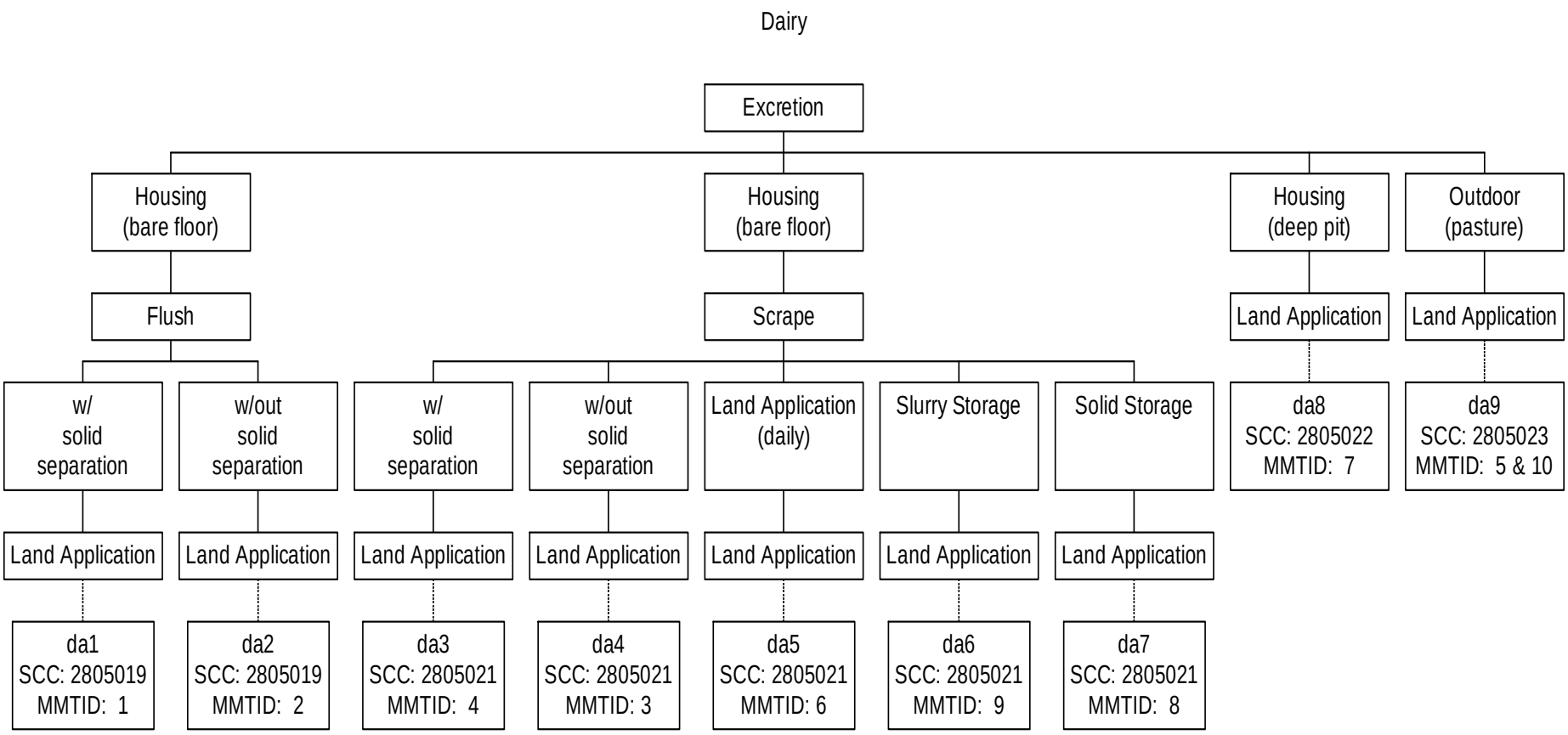
Animal Category Mappings

- **Dairy:**
  - lactating = dairy milk cow
  - dry = dairy dry cow
  - heifer = dairy heifer
- **Swine:**
  - finishing = (2/3)*(swine60 + swine60_119 + swine120_179 + swine180)
  - weaning = (1/3)*(swine60 + swine60_119 + swine120_179 + swine180)
  - lactating = (1/6)*(swine breeding)
  - gestating = (5/6)*(swine breeding)

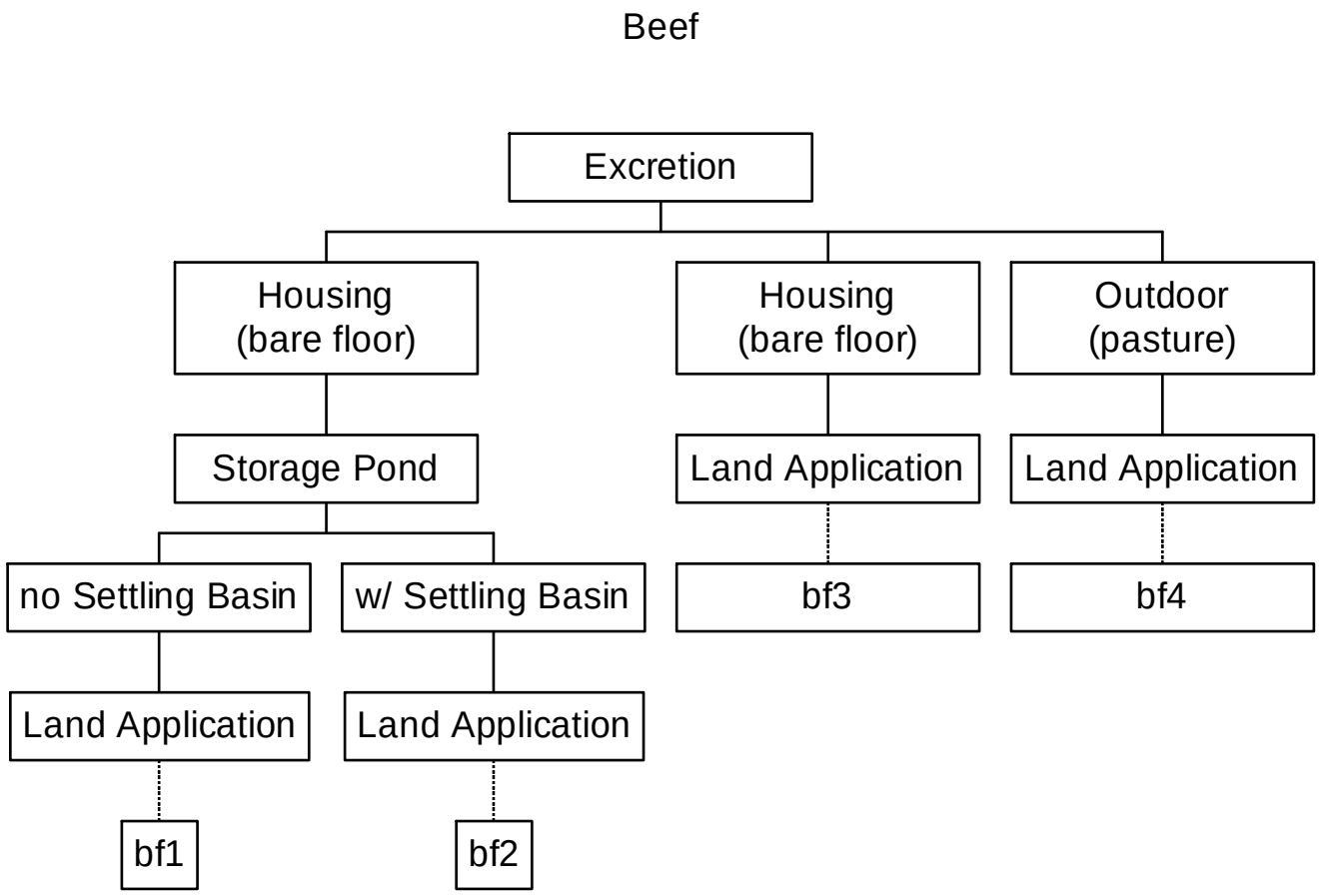
Process Flow Chart & Decision Tree



MMT – Dairy

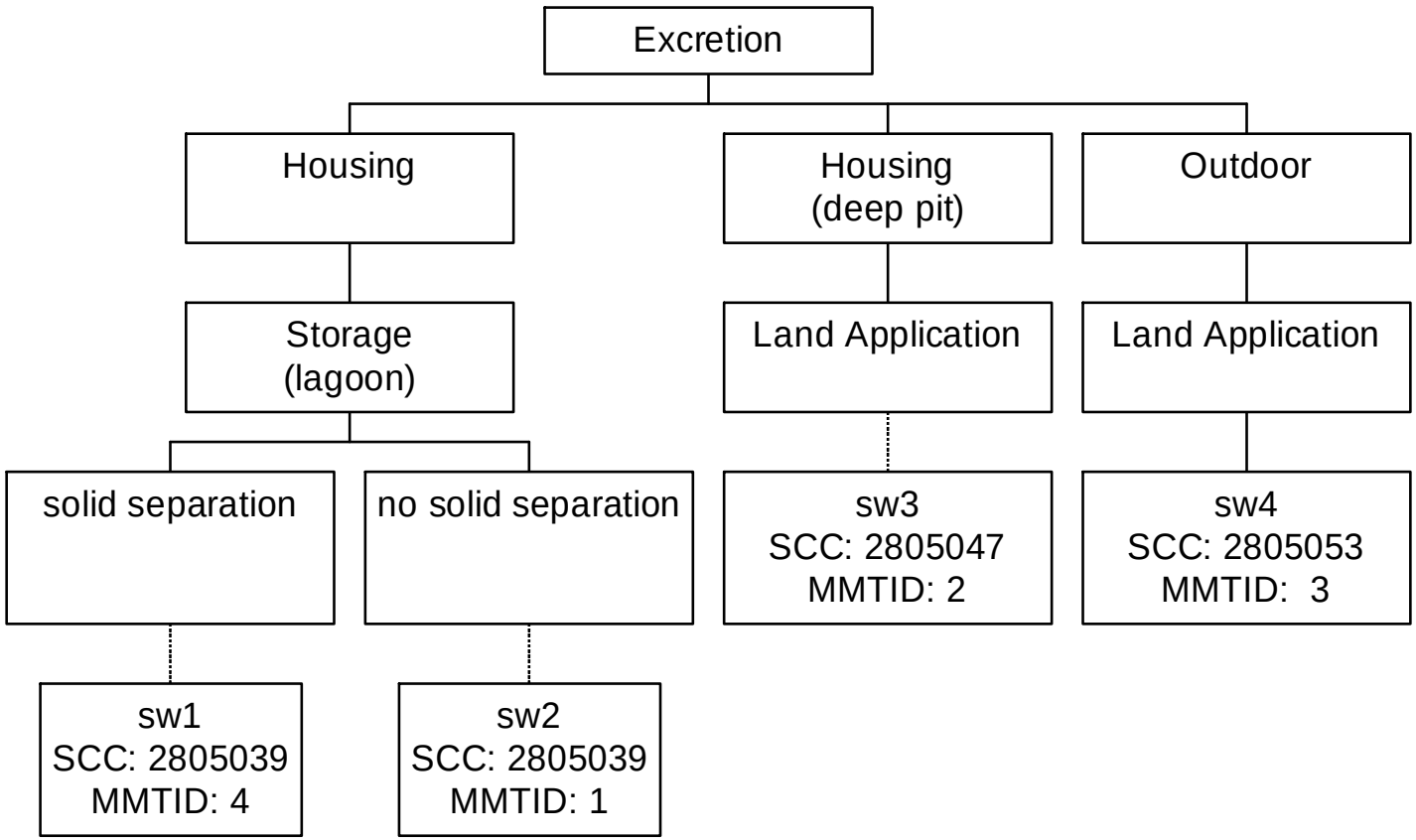

Dairy
Excretion
Housing (bare floor)
Housing (bare floor)
Housing (deep pit)
Outdoor (pasture)
Flush
Scrape
Land Application
Land Application
w/ solid separation
w/out solid separation
w/ solid separation
w/out solid separation
Land Application (daily)
Slurry Storage
Solid Storage
da8 SCC: 2805022 MMTID: 7
da9 SCC: 2805023 MMTID: 5 & 10
Land Application
Land Application
Land Application
Land Application
Land Application
Land Application
Land Application
da1 SCC: 2805019 MMTID: 1
da2 SCC: 2805019 MMTID: 2
da3 SCC: 2805021 MMTID: 4
da4 SCC: 2805021 MMTID: 3
da5 SCC: 2805021 MMTID: 6
da6 SCC: 2805021 MMTID: 9
da7 SCC: 2805021 MMTID: 8

MMT – Beef


Beef
Excretion
Housing (bare floor)
Housing (bare floor)
Outdoor (pasture)
Storage Pond
Land Application
Land Application
no Settling Basin
w/ Settling Basin
bf3
bf4
Land Application
Land Application
bf1
bf2

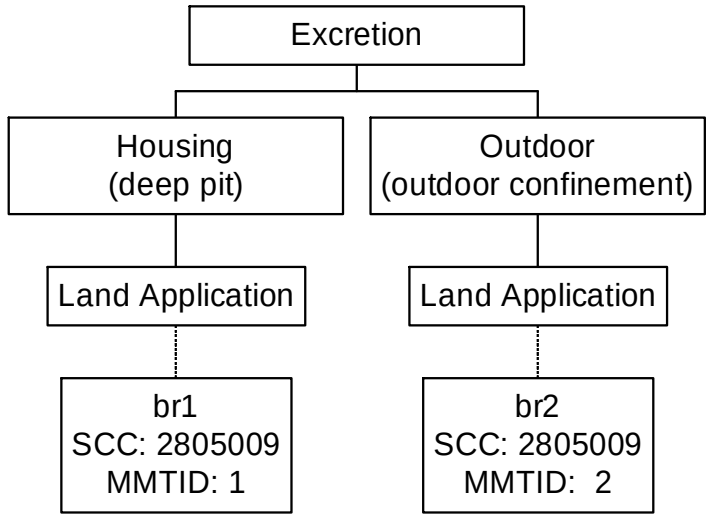
MMT – Swine

Swine

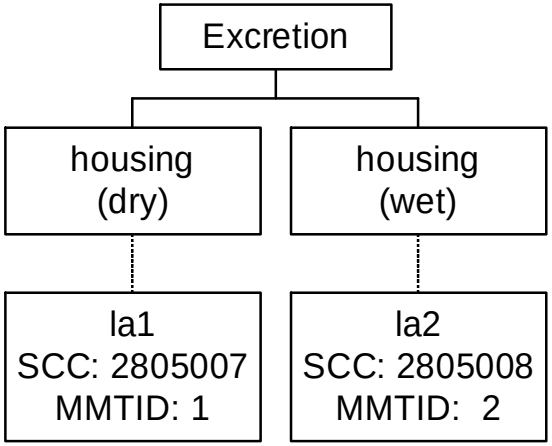


MMT – Poultry

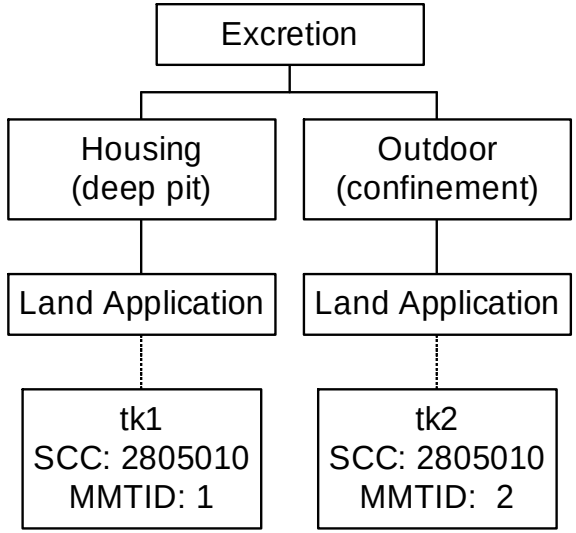
Broilers



Layers



Turkey



AAP Input File Name: Post-excretion Storage - Beef

Emission Unit	TblNH3Post
Element	**Element Description**
RECORD TYPE	**A code that identifies the type of record (SB)**
COUNTRY_CODE	**The name of the country**
FIPS	**The FIPS code for the state and county**
AJC	**Alternate Jurisdiction Code.**
START DATE	**Start date of the period**
END DATE	**End date of the period**
OpenFeedlotManure	Proportion of Manure collected on open feedlot (corrals)
StorageLiquidManure	Proportion of Manure collected into liquid storage
SurfaceArea	Surface area of open feedlot (corrals)
SolidManure	Proportion of manure collected in solid form
LiquidManure	Proportion of manure collected in liquid form
StoragePeriod	Total manure storage period before storage is emptied
StorageType	Manure storage type, cumulating volume vs. constant volume
StorageGeometry	Manure storage geometry (cylindrical, rectangle, or pond)
Diameter	Diameter of storage if it is circular
BottomLength	Bottom length of storage if it is a rectangular pond
BottomWidth	Bottom width of storage if it is a rectangular pond
BottomDiameter	Bottom diameter of storage if it is a cicular pond
SideSlope	Side slope of storage if it is a rectangular or circular pond
ManureMoisture	Manure moisture
ManurePH	Manure pH
VolumeEmptied	Volume emptied from the storage during the time step
TimeStep	Time step (1 hour)
MineralizationRate	Organic nitrogen mineralization rate at 20°C
TempCoeff	Temperature coefficient used in the mineralization rate eqn

AAP Input File Name: Post-excretion Storage - Poultry

Emission Unit	TblNH3Post
Element	**Element Description**
RECORD TYPE	**A code that identifies the type of record (SP)**
COUNTRY_CODE	**The name of the country**
FIPS	**The FIPS code for the state and county**
AJC	**Alternate Jurisdiction Code.**
START DATE	**Start date of the period**
END DATE	**End date of the period**
SolidManure	Proportion of manure collected in solid form
storageLiquidManure	Proportion of manure collected in liquid form
StoragePeriod	Total manure storage operiod before storage is emptied
StorageType	Manure storage type, cumulating volume vs. constant volume
StorageGeometry	Manure storage geometry (cylindrical, rectangle, or lagoon)
Diameter	Diameter of storage if it is circular
BottomLength	Bottom length of storage if it is a rectangular pond
BottomWidth	Bottom width of storage if it is a rectangular pond
BottomDiameter	Bottom diameter of storage if it is a cicular pond
SideSlope	Side slope of storage if it is a rectangular or circular pond
ManureMoisture	Manure moisture
ManurePH	Manure pH
VolumeEmptied	Volume emptied from the storage during the time step
TimeStep	Time step
MineralizationRate	Organic nitrogen mineralization rate at 20°C
TempCoeff	Temperature coefficient used in the mineralization rate eqn

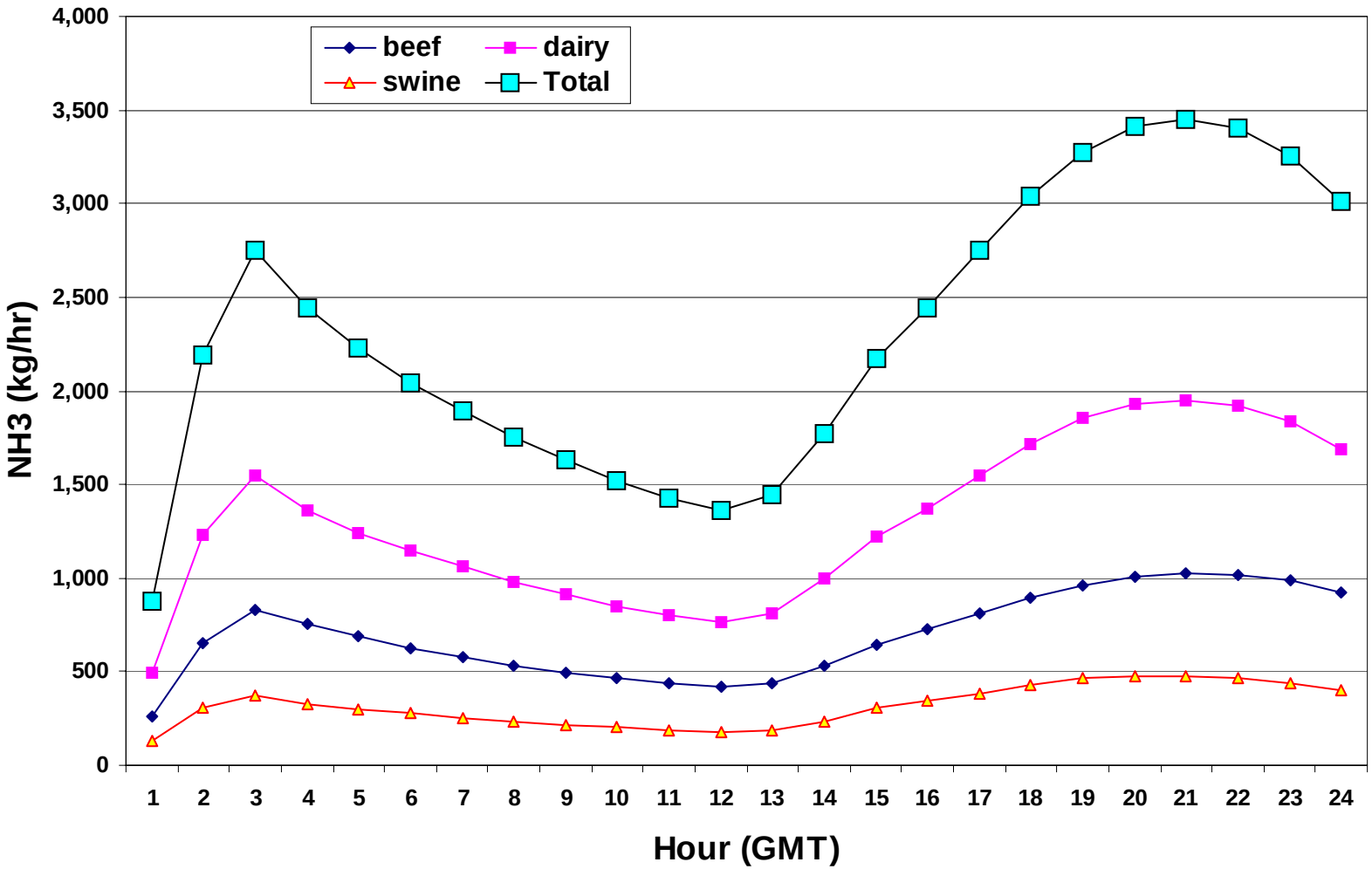
AAP Input File Name: Post-excretion Land Application - Dairy

Emission Unit	TblNH3Post
Element	**Element Description**
RECORD TYPE	**A code that identifies the type of record (LD)**
COUNTRY_CODE	**The name of the country**
FIPS	**The FIPS code for the state and county**
AJC	**Alternate Jurisdiction Code.**
START DATE	**Start date of the period**
END DATE	**End date of the period**
NPH	Manure - pH
Mdensity	Manure Density (g)
CropType	Crop type
Grain	N Uptake -corn (grain, 150 bu per ac)
Silage	N uptake-corn (silage, 16 tons per ac)
Soybean	N Uptake -Soybean (50 bu per ac.)
Wheat	N Uptake-Wheat (60 bu. Per ac)
Alfalfa	N Uptake -Alfalfa (4 tons per ac.)
Bermuda	N Uptake - Bermuda grass (4 tons per ac.)
Soil_application	soil infiltration rate
	Crop or weed canopy height (h)
	Height above ground where friction velocity is calculated
DryMineralizationRate	Mineralization rate (k)for dry soil
WetMineralizationRate	Mineralization rate (k) for wet soil

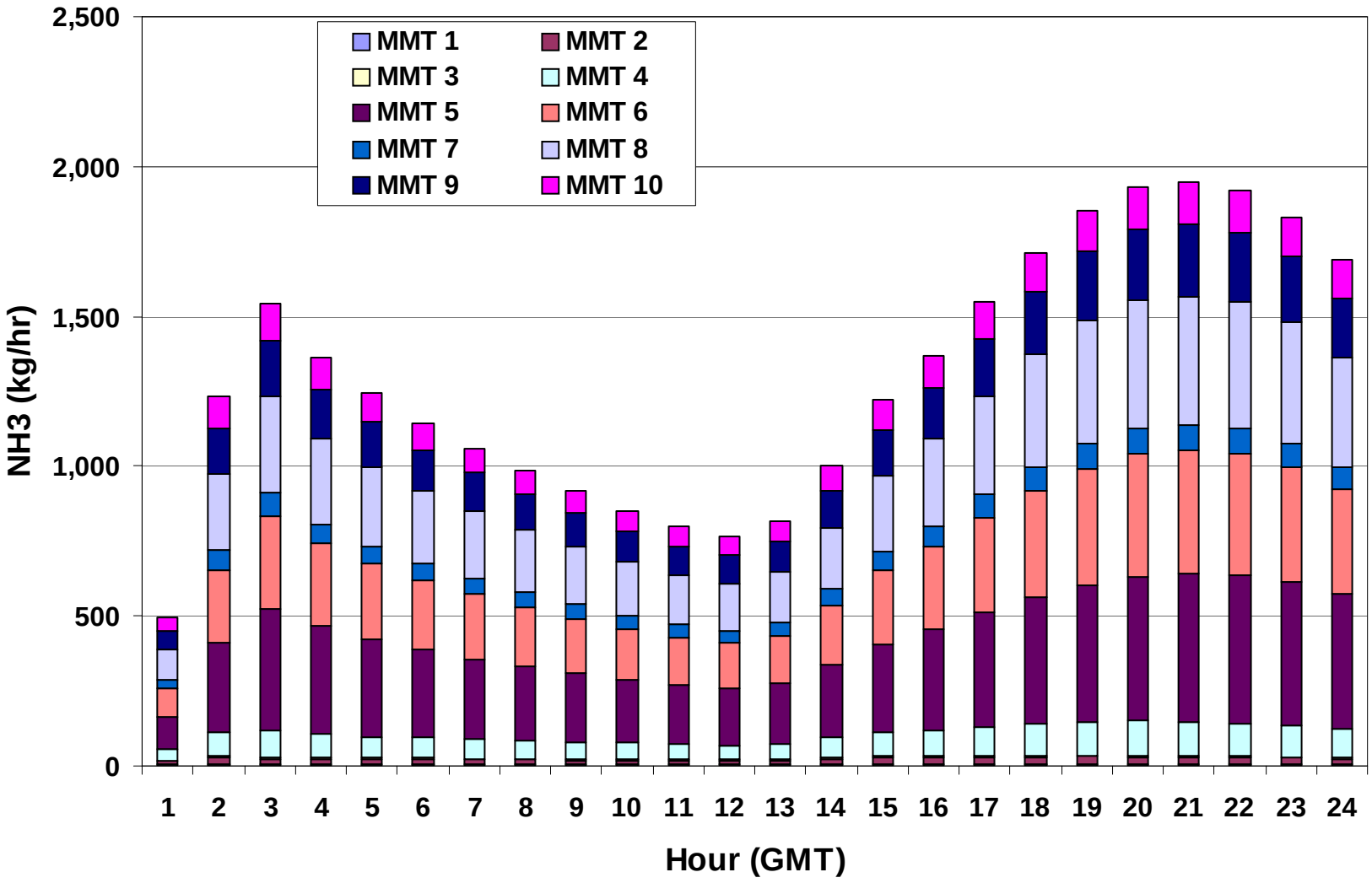
Preliminary Model Results

- Model run for State of Kentucky
- Results for July 6, 2002
- Housing and Storage Only
- Hourly, county-level NH3 Emissions by animal species, MMT
- Comparison w/ WRAP LU-based NH3 Emission Model

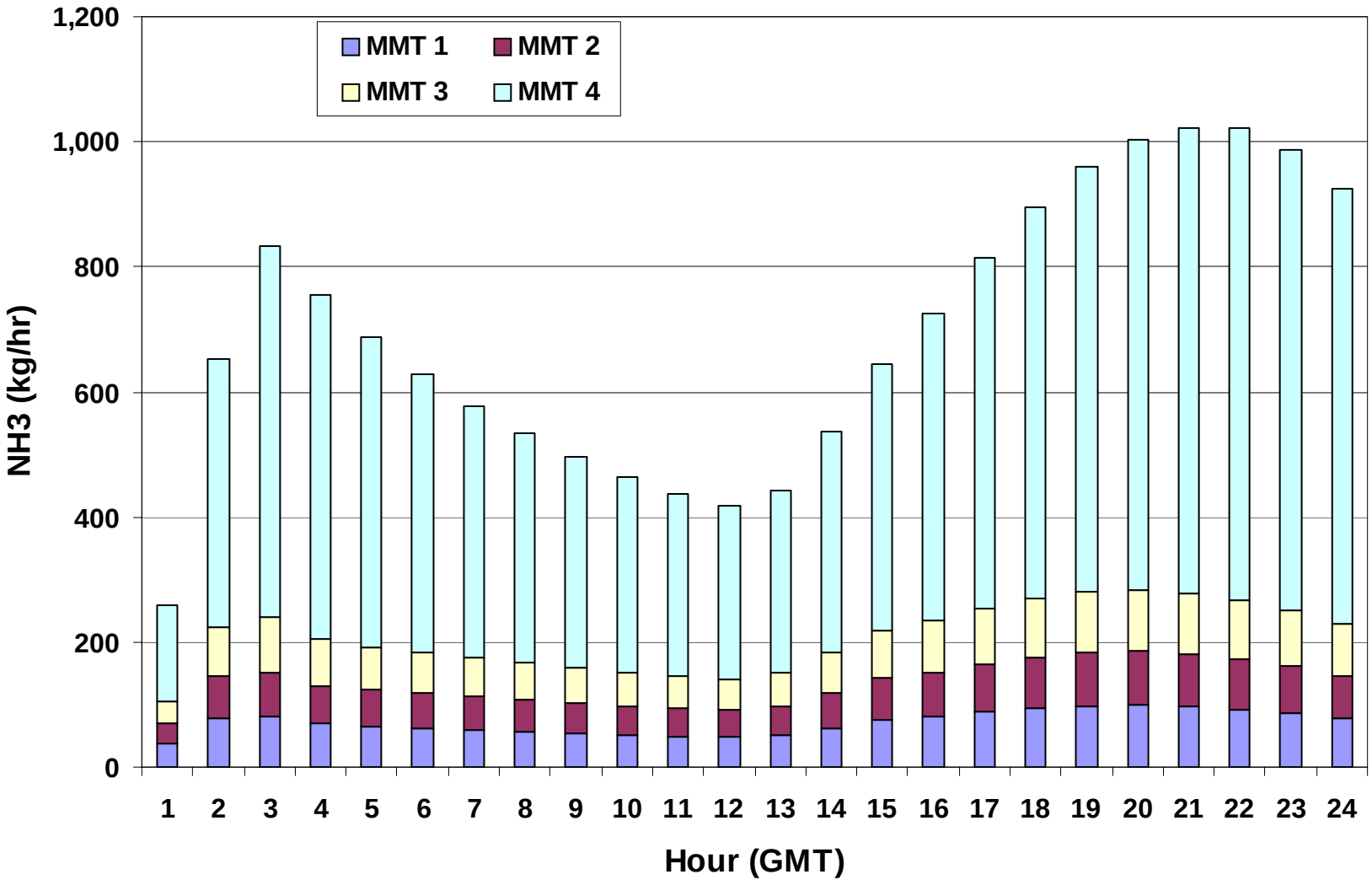
Hourly NH3 Emissions for Kentucky
Housing & Storage Only



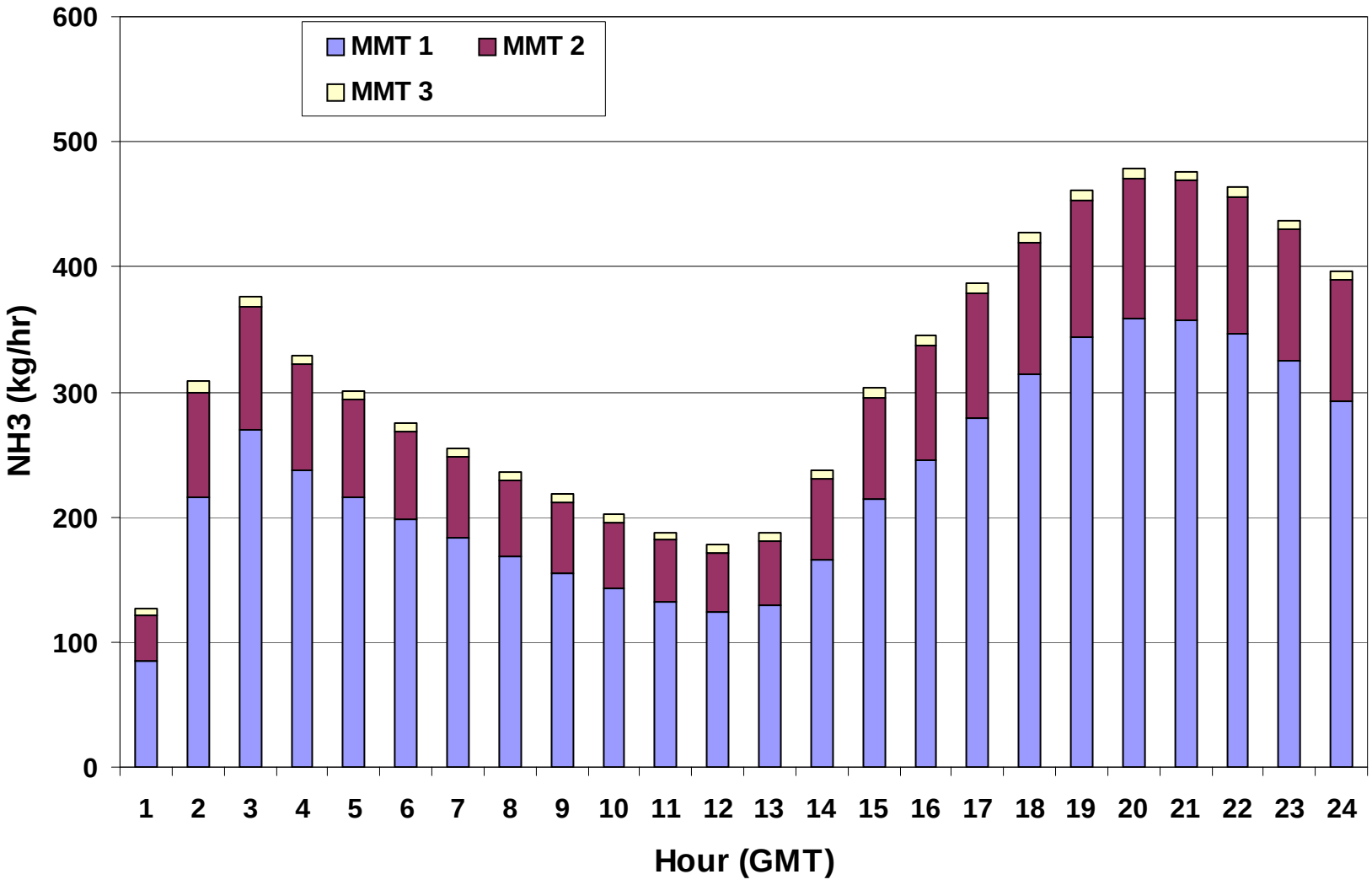
Dairy NH3 Emissions by MMT



Beef NH3 Emissions by MMT



Swine NH3 Emissions by MMT



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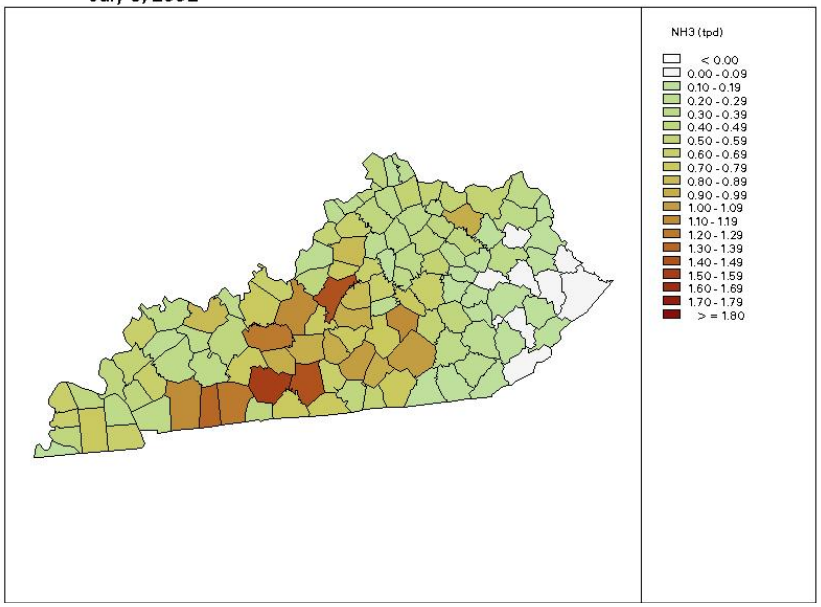
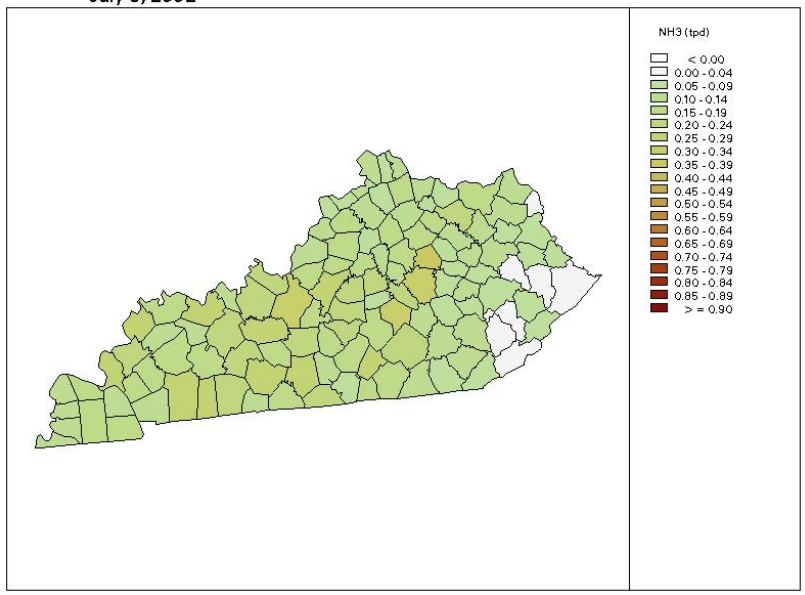
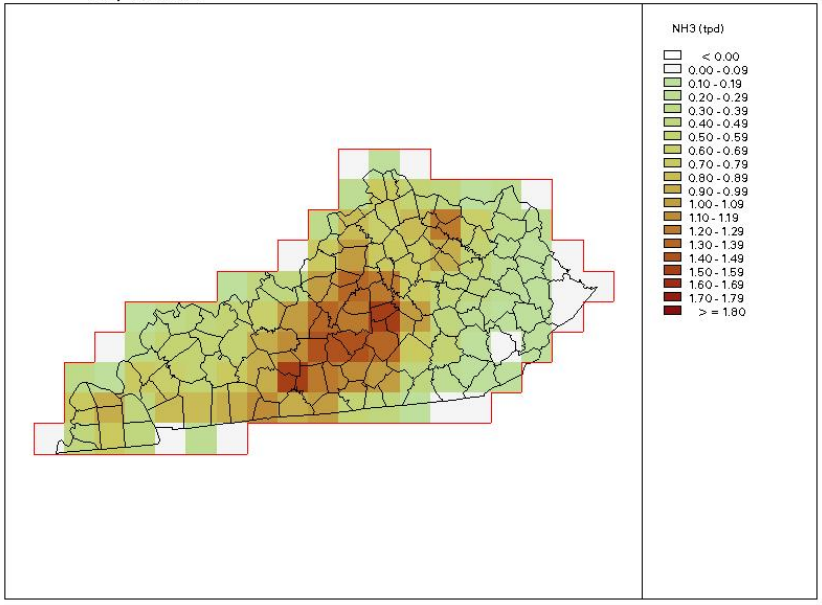
County-level Livestock NH3 Emissions
July 6, 2002



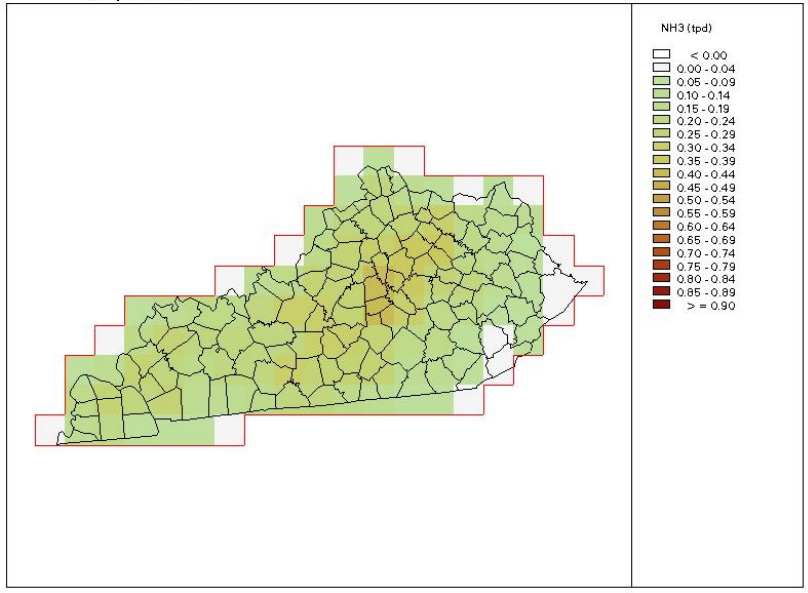
County-level Beef NH3 Emissions
July 6, 2002



Gridded Livestock NH3 Emissions
July 6, 2002



Gridded Beef NH3 Emissions
July 6, 2002



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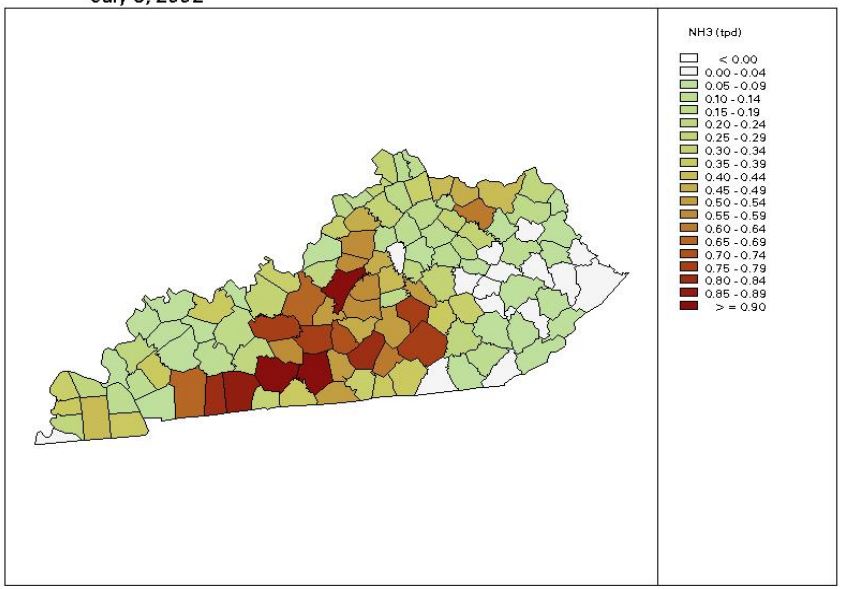
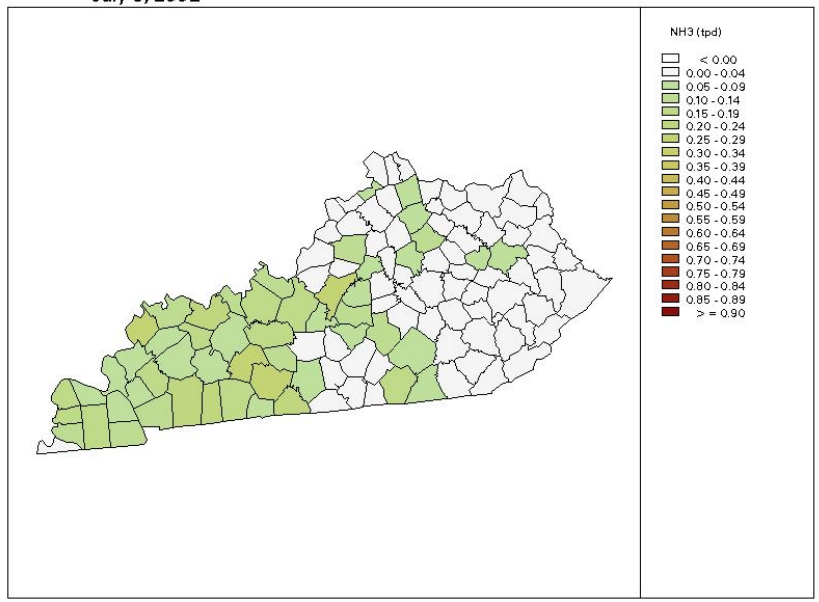
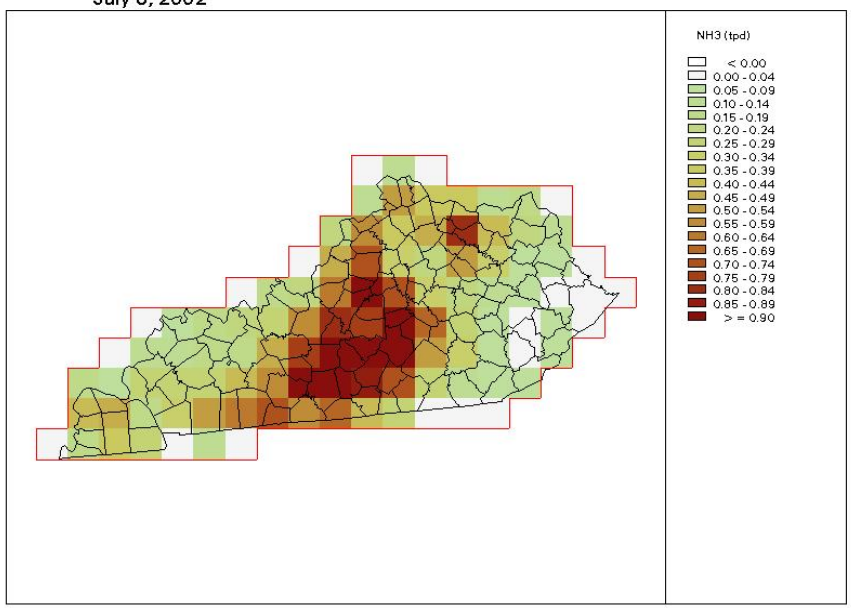
County-level Dairy NH3 Emissions
July 6, 2002



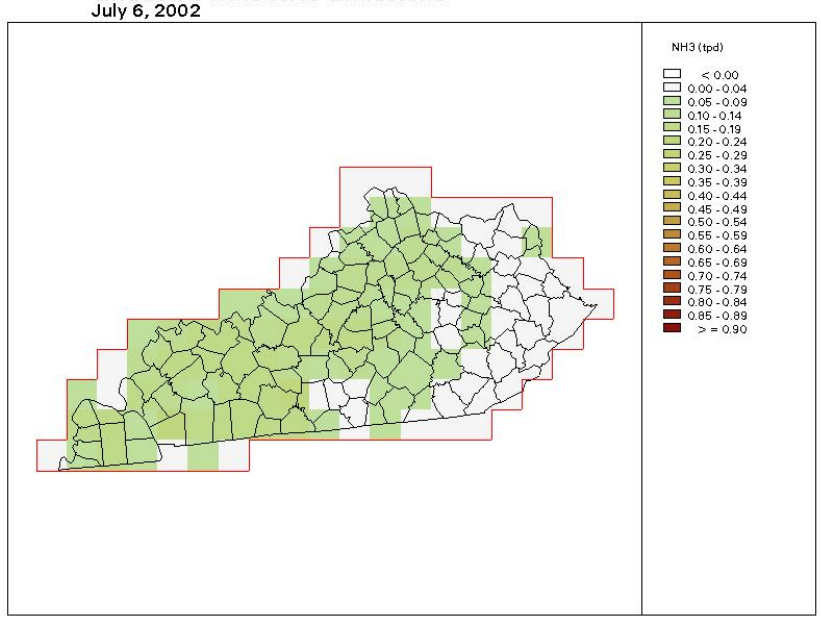
County-level Swine NH3 Emissions
July 6, 2002

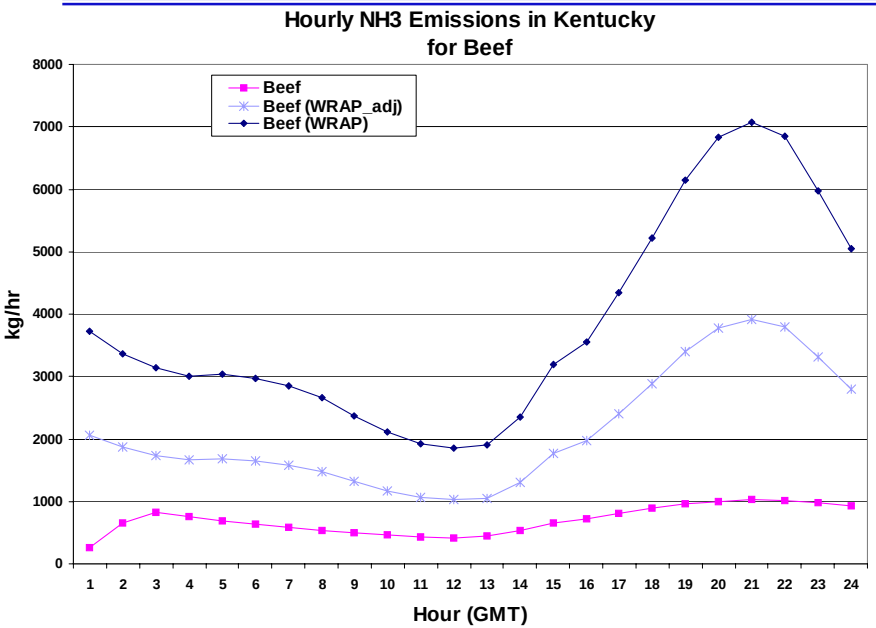


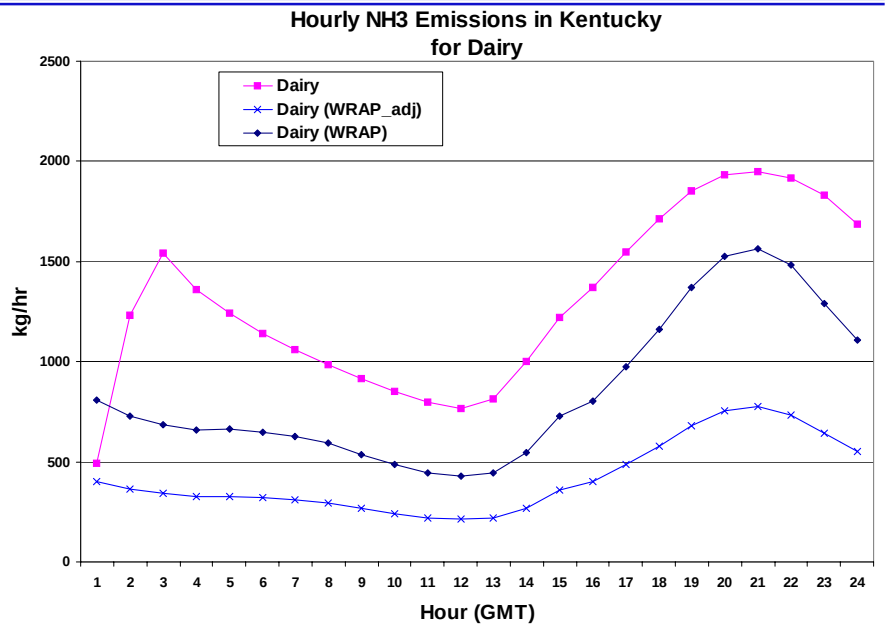
Gridded Dairy NH3 Emissions
July 6, 2002

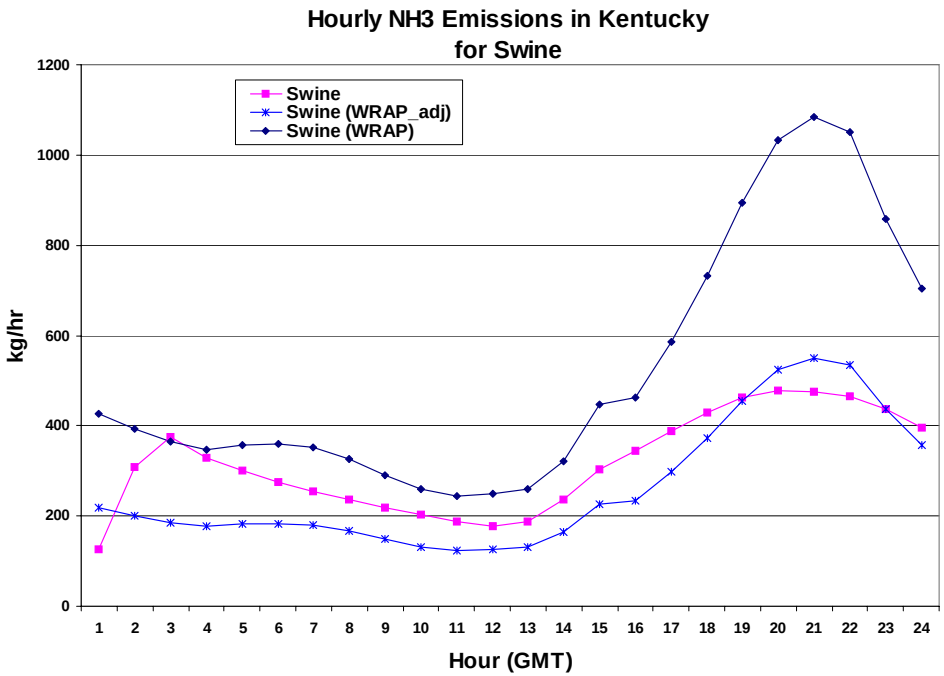


Gridded Swine NH3 Emissions
July 6, 2002




Hourly NH3 Emissions in Kentucky for Beef
Beef
Beef (WRAP_adj)
Beef (WRAP)
kg/hr
Hour (GMT)


Hourly NH3 Emissions in Kentucky for Dairy
Dairy
Dairy (WRAP_adj)
Dairy (WRAP)
kg/hr
Hour (GMT)


Hourly NH3 Emissions in Kentucky for Swine
Swine
Swine (WRAP_adj)
Swine (WRAP)
kg/hr
Hour (GMT)