# Transforming Survey Data to APEX Model Input Files

March 2009

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## Chapter 1. INTRODUCTION

### 1. Overview

This document provides an overview of the procedures used to edit, augment, and transform the CEAP cropland survey data into APEX (Williams and Izaurralde, 2005; Williams et al., 2006) simulation model data sets, one data set for each survey sample point. Also included is a discussion of the procedures used to set up the APEX simulations for simulating long term vegetative conservation cover for the 2003 NRI points classified as CRP.

Extensive editing of the CEAP cropland survey data was required to develop the APEX simulation model input data sets for each sample. After the data was edited it was processed further with a Visual Basic program (Run Builder) to produce an Access database formatted for the I_APEX (Siemers, 2007) multiple run management software. This document describes those processes.

In this Introduction and Overview section, only a brief discussion of various data edits and transformation processes covered in the remainder of the document are given. The following list is an introduction to the issues that led to the need for extensive editing of the survey data in order to setup the APEX simulations:

1) Apparent data recording and computer input errors as the survey data was collected and processed;

2) Apparent mis-interpretation of quantity units and other calculation errors;

3) Reporting of fertilizer and manure in a variety of quantity and nutrient content formats;

4) Evidence that the “three year snapshot” of management activities collected by the survey was clearly a point in time for a 2-year, or longer crop rotation;

5) Reporting of replanting for failed crops, farm fields split with two or more crops in some years but not others, and other cases of multiple crops per field or differing management on parts of a field in one or more years;

6) Lack of collection of the “day” date component of management activities in the 2003 survey;

7) Reporting of general crop labels such as “all wheat” or “grass seed” rather than specific labels such as “winter wheat” or “orchard grass seed”;

8) Requirement of editing of reported field operations, or insertion of extra field operations for representation of complex harvest and other tillage situations correctly in APEX, such as pre- and post harvest grazing and/or straw removal; linked, tandem, or combination equipment normally used in multi-pass single operations; and other complex crop management techniques;

9) Reporting of days and/or number of cows for pre- and post harvest grazing, but not the grazing start and stop dates, the use of supplemental feed, indication or grazing of weed growth rather than crop biomass, or the proportion of the field grazed; and

10) The need to account for site specific and weather variation information in setting up irrigation simulations, including estimates of conveyance and application efficiency losses, percolation, salt leaching, and runoff;

The following simulation data components are addressed in other documents and are only briefly reviewed in this document:

1) Reported crop resolution with the NRI land uses and/or other criteria for sample disqualification procedures;

2) Weather data set development;

3) Soil dataset development;

4) Estimates of atmospheric nitrogen deposition;

5) Simulation of structural conservation practices;

6) Pesticide quantity and application method standardization;

7) APEX model parameterization required for calibration and validation; and

8) Setup of the no-practice, enhanced nutrient management and other scenarios.

The CEAP cropland survey data was also subjected to earlier quality checks by USDA-NASS prior to digitization and by USDA-NRCS while analyzing the reported data for use in the CEAP reports and prior to the beginning of the edits described in this document. Resolution of some crop identification labels, non-reporting or missing data sections, and split field issues were accomplished in an iterative fashion to maintain consistency between the datasets developed for APEX simulation and the survey data used for analysis of original survey results. Examination of the original paper survey forms and consultation with state or regional level technical specialists was often required to determine exactly what crop management or technology was being applied for a particular situation and how to best represent it in the APEX simulations.

The largest source of apparent recording and input errors was due to the process of hand recording of numeric codes on the paper survey forms rather than the recording of the actual names of the machine, crop, chemicals and other entities, e.g., recording of “112” instead of “121” (implying use of a “Lister-bedder” for corn harvest rather than a “Small Grain Combine”). Also frequent errors appeared to be due to the procedure of recording the management data for the most recent crop year first, and then working backwards, to the earlier years, without insuring consistency across years. For example, the reporting of fall plowing on September 15, 2002 for the 2003 crop year, and then on a subsequent data sheet recording a grain harvest on October 21, 2002 for the 2002 crop year. Similar date issues arose from our procedure of treating the reported 3-year snapshot of management data as if it were a repeated 3-year rotation over the 47-year simulation period. For example, if winter wheat, soybeans, and corn were reported for 2001, 2002, and 2003 with the pre-plant tillage of the winter wheat starting July 1, 2000, then the implication is at least a 4-year rotation with the 2000 crop year being either idle or, for a 3-year rotation, have had the corn crop harvested prior to July 1; obviously, corn could not have been the crop for 2000.

The most frequent interpretation and calculation errors were in the area of unit and quantity reporting for fertilizer applications. This was partly due to the respondents having the option of reporting either 1) the elemental analysis formula (e.g., 18-46-0) along with total quantity of fertilizer material applied, or 2) pounds of actual nutrients. If pounds of actual nutrients were reported, an indicator box should have been checked and the total quantity box left blank. There were numerous reports of high yielding corn with low N fertilizer where an error was obvious, such as, 18 lbs of N, 46 lbs of P205 and 0 lbs of K reported as actual pounds nutrients rather than as elemental analysis (18-46-0 is a common fertilizer grade). More difficult to address were numerous cases of N fertilizer levels in the range of one-third to two-thirds of the level required to sustain yields. Another frequent type of error involved conversions when the fertilizer type was liquid and the units were gallons or where fertilizer was applied with irrigation water. The logic behind other apparent fertilizer reporting errors was often not clear.

An extreme example of these kinds of errors can be seen in the comparison of two samples reporting carrot production in California on similar soils. The first sample reported harvest of 1000 lbs per acre of carrots in the month of April for each of the years 2002, 2003, and 2004, along with application of 12, 33, and 48 lbs per acre of N fertilizer nutrients in the three years, respectively. The second sample, reporting only the 2004 crop year, reported harvest in April of 40 tons of carrots per acre followed by 18 tons of onions per acre in June, with 12 separate fertilizer applications (10 of them with irrigation water) between September 2003 and April 2004 for a total annual application of 1872.8 lbs per acre of N fertilizer nutrients. Carrot yields reported in the Agricultural Statistics for California for 2001 and 2002 averaged 290 cwt (14.5 tons) per acre, indicating that yields reported for these two samples might also be suspect.

There were other situations where the fertilizer reported for the three surveyed years may have been correctly reported, yet too low to sustain yields over a 47 year simulation. For example, one Colorado sample with irrigated corn reported nearly 200 bushels per acre for two years, and then another crop in the third year, with only a minimal amount of starter fertilizer applied at planting each year. A check of the NRI data for this sample showed that previous to the two years of corn, the field had been in irrigated Alfalfa hay for at least 4 years, which would have possibly generated sufficient carryover nitrogen to produce those corn yields. Since the CEAP survey did not collect information on management prior to the three year survey yield, the fertilizer had to be supplemented as explained in Chapter 5.

Many date and year adjustments were required to set up the three-year survey “snapshot” of reported crop history data as a rotation repeated over time in the 47-year duration APEX simulations. These adjustments were also required prior to analyzing the basic findings of the survey, e.g., prevalence of tillage system types. Since the respondents were required to report all management actions for each of the 3-crop years, many primary tillage operations and chemical and animal waste applications were reported for the fall of the calendar year prior to the earliest survey period crop year, e.g., plowing for the 2001 crop year in the fall of 2000 when the survey covered crop years 2001, 2002, and 2003. In this example, the calendar year of the fall 2000 operations was changed to 2003 so that they occurred after harvest of the 2003 crop, implying a repeated 3-year rotation. For numerous cases, the additional edits of moving the 2003 harvest a few days earlier and the after-harvest tillage a few days later were required to avoid overlap.

The most frequent crop rotation related edit was to exclude one of the reported years of data when the management system was obviously that of a two year crop rotation. A check of the 1997 NRI showed that 40.3 percent of survey points reporting one or more years of corn or soybean production in 1994, 1995, 1996, or 1997 had years of corn and soybeans in rotation in the ratio of 1:1. Another 10 percent of those points reported continuous corn and 4.5 percent reported continuous soybeans, while 10.5 percent had corn and soybeans in the ratio of 3:1 or 1:3. Since the NRI reported exactly four years of crop history, it was not possible to calculate the frequency of 2:1 or 1:2 ratios of corn and soybean years in the rotation. Example, for a commonly reported three year sequence of soybeans-corn-soybeans, in most cases the 1$^{st}$ year of data was excluded so that the simulated rotation would be corn-soybeans. In the 2005 and 2006 surveys nearly every sample reported the intended rotation while in the 2003 and 2004 surveys only a portion of the samples, generally those reporting use of conservation crop rotations, reported their intended rotation. The decision to exclude the first or last year of reported data to reduce the management to a 2-year rotation was complicated for cases where the management differed between the 1$^{st}$ and 3$^{rd}$ years. For several hundred samples the solution was to replicate and re-label the reported middle year as a new first year, extending the rotation to 4-years, with differing management in the 2$^{nd}$ and 4$^{th}$ years. The resolution of those cases in discussed in more detail in a later section of the paper

Similar to the reduction of the 3-year system to a 2-year rotation, for cases where identical three years of management were reported (mono-cropping), the first two years were excluded and only the final year was used for the simulation data set.

Many harvest operations had to be marked “exclude” and then replaced with an APEX field operation with appropriate coefficients. For example, reported “hand harvest” operations were replaced with crop specie specific harvest operations. Grain combines followed by straw balers had to be replaced with alternatively defined combine and baler operations depending on whether or not the combine was followed by some type of mower or rake (implying a larger quantity of removed straw). An extreme example of harvest machine replacement is the case of sweet potato harvest involving three operations: a chopper or shredder, a mold board plow, and then hand harvesting. In APEX the plow would kill the crop and there would be no live biomass left for harvest. Therefore, the plow was excluded and the hand harvest replace with a “harv swt pot” operation having soil disturbance characteristics similar to the plow. Similarly, various other forage harvest preparation machines such as windrowers, rakes, mowers, tedders, and bale wagons were excluded. In APEX the choppers, mowers, and windrowers have a cutting height and so convert the standing biomass to flat dead residue which is then not part of the harvestable biomass pool to be removed the later standard combine, silage chopper, or baler. Tedders, rakes, and bale wagons have no effect on biomass, nutrients or soil disturbance. For a comprehensive agriculture energy assessment these various machines would need to be accounted for. However, the survey respondents were inconsistent in their inclusion of trucks, wagons, rakes, etc., implying the need for data checking and consistency edits if the energy assessment were to be done.

Within the survey data were other more complex cases where some of the simple adjustments noted in the previous paragraphs were not sufficient. Some of those complex cases involved the following issues:

1) Apparent abnormal management reported for one or more of the survey years due to drought or other abnormal pest infestation or weather conditions; this situation also confounded the decision of excluding the first or last year to reduce the reported data to a two year rotation;

2) Changing management over the three year period, e.g., adoption of notill or reversion to moldboard plowing, so that if simulated as reported, adoption of conservation tillage would switch back and forth every 2 or 3 years during the course of the 47 year simulation;

3) For samples where the decision was to reduce to a two year rotation, the use of a sub-soiler or similar operation in the first or last of the three years, requiring a judgment to be made about the intended frequency of use of that operation in a repeated rotation over a longer time span;

4) Crop failure, followed by the replanting of the same or another crop, with additional tillage and chemical operations reported for the 2nd and/or 3rd crop;

5) Absence of a harvest activity or reported yield with no clear indication of whether the crop was abandoned, used as a cover crop, or grazed (this was more of a problem for the 2003 survey since the later surveys collected the intended use of the crop and an indicator of abandonment);

6) Data reported for only 1 or 2 years with no indication of why the other years were omitted, e.g., possible ownership or management change;

7) One, two, or three years of harvest reported for a perennial crop, with or without indication of an establishment year or data, and with or without an indication of other crops included in the longer rotation;

8) Reporting of a single planting operation (equipment pass) to plant two crops, such as barley and alfalfa;

9) Lack of harvest and fall tillage operations for the final survey crop year where apparently the survey data was collected prior to the occurrence of those activities and possible exclusion or fall tillage operations for the calendar year prior to the first survey crop year;

10) Inconsistency in the reporting of trucks, wagons, trailers, and non-field traversing equipment;

11) Apparent confusion over machine definition, such as the reporting in the South of multiple passes with a "disk plow" when the appropriate choice would have been multiple passes of the machine labeled "tandem disk – plowing";

12) Differing management on parts of the field, such as all corn the first year, but split into oats and soybeans the second year, or part of the corn harvested for grain and part for silage, or reporting of the management of hay on a small portion of a corn or soybeans field.

13) Situations of mint, sugar cane, and other horticulture crops where the survey respondent was unable to relate his management activities to the list of reporting options, e.g., most Louisiana sugar cane samples reported two spring disk operations and a fall small grain combine harvest for each of three years of cane cultivation;

14) Samples with manure where up to 34 annual applications were reported several days or weeks apart and where each was labeled as covering the entire field although it seemed clear that each was applied to, e.g., 1/34th of the field; and, finally,

15) Lack of clarity on the specific crop being grown, e.g., "Sorghum – all" (grain or forage?) or "other hay" or "vegetable seed".

In the edit process, to the extent possible, the original data was retained. This was accomplished in some cases by adding replicate columns to hold altered data, e.g., all crop and machine identification labels were saved in replicate columns prior to any editing. In other cases, indicator variables were added where alpha-numeric codes could be used to track data rows having certain characteristics, such as rows added to expand the hay rotations. For fertilizer and manure data rows added to the dataset by the edit process, a unique “method of application” code was added so that they could be tracked throughout both the input and output data analysis processes. Where efficiently possible no data was deleted, but rather marked with an “exclude” indicator so that it would not be used in the APEX simulation or in analysis of the basic survey data.

Six general types of procedures were applied to edit the data.

- First, there were some changes that could be automated and applied to the database as a first step prior to visual inspection and manual editing of the data, such as re-labeling of Pima and Upland cotton as Picker or Stripper cotton according to the type of reported harvest machines.
- Second, a “display and edit” program was developed where, along with numerical codes, the crop and machine names, were displayed on a single computer screen for an entire sample, along with other supporting data, including crop history information from the National Resource Inventory (NRI) and a calculated STIR value for each crop in each crop year. The display and edit program also included a link to a “CEAP Track Status” table where a narrative log of all edits and the status of each sample was updated each time any edit was performed on a sample. Each sample was displayed and edited as needed with this program.
- Third, some data was downloaded, analyzed, and transformed and/or compiled with supplementary data and then reloaded, e.g., calculation of supplemental nitrogen fertilizer applications for samples with obviously missing or recording error cases.
- Fourth, additional queries were developed to check for and fix specific issues that may have been overlooked in the previous visual inspection procedures, e.g., harvest date before planting date.
- Fifth, a Run Builder program was developed to transform the edited CEAP survey data into an actual I_APEX database and this program also incorporated a variety of data assumptions. Except for the insertion of the day components of the dates for the 2003 survey (discussed in more detail below), the Run Builder procedures did not alter the survey data, but rather transformed it with the output being the I_APEX database.
- Finally, the output of the APEX simulations were carefully analyzed for abnormalities which pointed to further input data edits. Despite the comprehensiveness of the above five classes of procedures, when the actual APEX simulations were made, additional problems were found with subtle date errors and other issues.

In all of these edit procedures specific rules and guidelines were developed for identifying and fixing obvious errors. The procedures for all data edits, supplements, and exclusions were reviewed and approved by an NRCS team consisting of an Agronomist, Agricultural Economist, and Soil Scientist, all with Ph.D.’s in their respective fields, all with a background of actual farm experience, and all with 20+ years of experience working with NRCS programs and crop management data. However, with so many widely diverse and complex situations, professional judgment was often required to supplement or over ride the guidelines.

A “CEAP Track Status” table was added to the survey database and used to classify the status of each sample throughout the various phases of editing and analysis, to keep a permanent record of edits, and to classify the sample in various ways, e.g., continuous hay. Once a sample was examined with the Display/Edit program it was categorized as “ok”, “done”, “fix”, or “bad”. A status of “fix” indicated that the team anticipated that the sample could be successfully edited, but that extensive additional analysis was required. The status classification of each sample is subject to change over time and will not be finalized until the actual APEX simulation output is analyzed. In the preliminary stages of data review it was not possible to recognize how many of the complex crop and operation sequences would have to be altered in order for the APEX simulations to be properly built and executed. Consequently, additional edit checks and procedures were added, and will continue to be added, up until the simulations are performed for the final report. Consequently, over time the status of some samples may continue to change as additional checks and edits are performed. Most samples move “up” over time, into the “ok” or “done” categories, but unfortunately, some also move downwards into the “fix” and “bad” categories. Some samples with otherwise complete data have been disqualified due a determined inconsistency between reported information and the basic site information from the NRI.

## 2. Initial Data Preparation

### Various Date Fixes

For the 2004, 2005, and 2006 surveys all field operations and chemical and manure applications were reported with dates in the “mm/dd/yyyy” format; for the 2003 survey only the months and years were reported. APEX requires the month, day, and year parts of the date to be in separate variables, as did the Display/Edit program for sorting and indexing purposes. Additional variables were added to the appropriate tables and queries were implemented to populate those variables. The day components of the dates for the 2003 survey were added to the database with a special version of the Run Builder program according to a complex decision tree.

### Backup of Original Crop and Machine ID’s

As noted above, and described in later sections of this document, for several reasons the crop identification codes were changed on some samples. In order to maintain consistency within the database and with data updates over time, the original crop codes were saved. This was accomplished by adding and populating [crop code old] columns with values from [crop code] prior to any crop code edits in the following tables:

commfertilizer (application events for commercial fertilizer)
crophistoryi (crop, acres, purpose, yield, etc., for each year and crop)
fieldoperations (schedule of all tillage and other machine operations)
manure_events (application events for animal waste)
pesticide_events (application events for pesticides).

Also, since the identification codes for some field operations needed to be changed, a column “MachineCodeOrig” was added to the field operations table and populated with the original “Machine Code” values prior to any visual inspection and manual or query editing of the data.

### Assignment of Cotton as Picker or Stripper Type

In the standard APEX crop growth parameter table there is no distinction between Pima and Upland cotton. However, for the model to operate properly, that parameter table contains different crop coefficients for cotton according to whether it is harvested with a picker or a stripper. Consequently, each occurrence of either Pima or Upland cotton was relabeled as Picker or Stripper cotton with the following procedures:

1) Make a table [cotton type] that shows the original cotton type for each case of crop year in a sample and includes a column for the new assigned type;

2) Run the "Cotton Type 401" query that sets cotton type to "401 stripper cotton" in [cotton type] if a cotton stripper is present;

3) Run the "Cotton Type 402" query that sets cotton type to 402 if still null in [cotton type]; note that this results in assignment to picker cotton if either a picker is present or if no harvester is reported, such as in the case of an abandoned crop; and

4) Use the results in [cotton type] to change cotton crop label to 401 or 402 in the following tables:
    commfertilizer
    crophistoryi
    fieldoperations
    manure_events
    pesticide

**Re-Assign Field Cultivators versus Row Cultivators by Season**

As described in a later section of this document, all cases of a field cultivator reported for the period between planting and harvesting was changed to a row cultivator (unless apparently used to cover broadcast seed). Most instances of this edit were found and performed with a Visual Basic program:

C:\CEAP project\CEAP program\CEAP.exe with the option
"Replace MC 21 and 26 with 24"

Before running the program the "unique" index was added to "CEAP Track Status". The index included the fips and psu_id variables. (the "fips" is a standard county ID from the Federal Information Processing Standard and the "psu_id" is the unique point ID for an NRI point within a county).

The program also added the letter "j" to the "ChangeNo" field of the "CEAP Track Status" table (see section 3. below).

**Add Omitted Dates for Tandem Operations**

When two or more operations occurred on the same day, particularly if done in tandem, the enumerators often recorded the same sequence number for all the operations, but left the date blank for other than the first operation. The following procedures and queries were set up to identify and fill in these dates as follows (the visual examination and edit process provided a further check on this issue):

1) Make a copy of the field operations table with a temporary name.
2) Develop a "right outer join" query between the temporary field operations table and the original with the joins on fips, psu_id, crop, cropyear, machine code and sequence number and restrict to query selection to rows where the [OpMthdayYr] variable is present in the temporary table but absent in the original.
    a) Adjust and apply this query to make a table with unique list of samples to be fixed.
    b) Apply this query to set the missing [OpMthdayYr] variable in original field operations table to the existing [OpMthdayYr] variable in the temporary field operations table.
3) Develop an additional query to use the list of affected samples to add "n" to the "ChangeNo" column in the [CEAP Track Status] table (see section 3. below).
4) Run queries to split the date into month, day, and year components.

**Exclude Non-modeled Field Operations**

Some surveys included operations such as backhoe, bull dozer, grain cart, tractor, truck, etc. which do not disturb the soil nor affect the biomass on the field. These were removed from the field operations table and saved in a separate table. Various hauling and pre- or post-harvest commodity handling equipment were also marked "exclude", since they had no effect on the simulations; examples included, hay rakes, straw wagons, etc. Some enumerators excluded these types of operations from the data collection, while others did not.

## 3. Common Edit List

When the process of examining each individual survey with the Data View and Edit program was initiated, it quickly became apparent that some common edits would be repeated for many samples. Rather than describe each of these common edits for each sample in the edit log, a list of the common edits was developed with assigned identification codes and only the edit codes were recorded in the "ChangeNo" column of the "CEAP Track Status" log table. Any particular sample could have none, one, or many of these common edits. Note that the letter code for the presence of an edit was only recorded once regardless of how many times it was applied in the sample, e.g., if four instances of field cultivator were changed to row cultivator, the letter "j" would be added to the "ChangeNo" string only once. An additional benefit of the "ChangeNo" column is that it allows easy summarizing of the frequency of samples being edited for various reasons. Table 1-1 shows a count of the samples having one or more of the frequent edits. The types of edit performed on the most samples were a and b, the changing of the event year for fall tillage in the year prior to the survey period and the reduction of the 3-year data to a 2-year rotation.

a. Change the calendar year of isolated after-harvest tillage operations occurring in the year previous to the 1$^{st}$ crop year simulated to follow the harvest of the last year simulated, or delete them if identical after-harvest operations already exist after the harvest of that last year. For example, if the crop years are 2002 and 2003, then a fall tillage operation reported for November of 2001 must be changed to November of 2003.

b. For cases of three years of reported data for what is obviously a two-year rotation (1$^{st}$ and 3$^{rd}$ years identical), mark as exclude the 1$^{st}$ year crop history, field operations, fertilizer, and manure rows. Check carefully for cases of differing management in 1$^{st}$ and 3$^{rd}$ years. One or more of the years may involve double cropping or a cover crop. This rule was supplemented later with rules "i", "l", "m", "q", and "r" for situations with different management in the 1$^{st}$

and 3rd year. See also rule "h". For selected crops (peanuts, watermelons, etc.) no back to back repeat cropping unless the field operation schedule explicitly shows it.

c. For cases of continuous cropping with 2 or 3 years of identical reported data, mark to exclude the data of the first 1 or 2 years. (One or more years may involve double cropping or a cover crop.) This rule was supplemented later with rules "i", "l", "m", "q", and "r" for situations with different management in the reported years. See also rule "h".

d. For a crop year reported as "#318 idle" or "#333 fallow", there must be at least one field operation occurring in that year for APEX to simulate the year. If there were no field operations reported for the idle or fallow year, which may correspond to cases of chemical fallow or allowance of vegetative growth, then operation "#450 Idle Fallow Placeholder" was added for that year.

e. For fall applications of fertilizer and manure, and if the year of application was prior to the calendar year of the first crop year to be simulation, it was necessary to set the operation year to the year preceding the crop year (in 2003 the survey only recorded the crop year, not the fertilizer application year; for all survey years samples sometimes needed to be edited for the same reason as "a." above). For example, a corn crop year with large N application reported in the preceding November.

f. If one or more years of any non-annual hay, pasture, or grass seed, whether other crops are present or not, or for cases where the only crops reported were fallow or idle, the samples were set aside for later analysis and rotation development (see detailed discussion of Hay and Idle). Note, if 3 years of idle or fallow were reported the sample was marked "bad".

g. Severely incomplete, inconsistent, or mixed up operations – include this note if the sample is so bad that repair seems unlikely.

h. Exclude the later rather than the earlier years (cases b. and c. above) in some situations where the early years are reported completely, but for the final year, data is incomplete. Need to be aware of situations where the survey may have been collected prior to completion of harvest and so no harvest operations or yield were reported for the final year.

i. Not reduced from 3 year to 2 year or to continuous cropping since tillage is different in 1st and 3rd year or across the years of continuous cropping. However, if the sets of operations are different, but the annual STIR value is nearly the same, then treat the sets of operations as if they were the same. (See later section of the document for STIR values in more detail, including ranges for each tillage system classification and note "m" below).

j. Change operation #21 "field cultivator" in after-plant situations (for weed control, irrigation furrow building, or root crop hilling) to operation #24 "row-disk, sweep, shovel". In some cases, make the reverse change where #24 was reported used for primary or secondary tillage.

k. Exclude non-field traversing and other machines not affecting the simulation; trucks, trailers, and carts; and various fertilizer and chemical applicators (fertilizer and pest application operations – machines - will be added by the simulation builder program, Run Builder).

l. The reported three-year sequence of management data was not reduced to a two year rotation due to the reported intended rotation, e.g., intended rotation is corn-corn-soybeans.

m. Where the three-year sequence would be reduced to two years, but the management, primarily tillage or fertilizer, is definitely different in the 1st and 3rd years, e.g., every other corn year (every 4th year) perform a deep ripper. For these cases copy, replicate, and label the middle year as a 4th year prior to the first year, e.g., corn-soybeans-corn, becomes soybeans-corn-soybeans-corn. This procedure was implanted only for the 2005 and 2006 surveys; at some point it would be useful to re-examine the 2003 and 2004 samples with regard to this.

n. Add operation dates for later operations performed in tandem on the same day (will have the same sequence number as 1st operation). The survey instructions allowed recorder to omit the dates for the tandem operations occurring on same day.

o. Grazing and/or combine operation added for grain crop situations with no yield reported and grazing either reported or determined to have been likely to have occurred according to criteria developed by the team. In some cases a harvest date earlier than May might have been recorded while the yield was left blank. The 2004, 2005, and 2006 surveys included explicit information on grazing and on the intended purpose of the crop.

p. Split field, or split management of same crop in a field, often indicated by two or more crops have the same, or significantly overlapping, seasons in one or more years, or where acreages differ across years. The criteria for addressing these cases are discussed in a separate section later in the document.

q. Not reduced from 3 year to 2 year or to continuous crop since the manure application differs across years (see note “m” above).

r. Not reduced from 3 year to 2 year or to continuous crop since fertilizer application differs across years. However, note the following: 1) if the fertilizer difference for the years is only for K, then ignore the difference since the environmental impacts of K are not being analyzed; 2) If the only difference is that the later year has fertilizer data for corn and the earlier crop does not, then exclude the earlier year since lack of fertilizer data is an error; and 3) in general ignore N differences of less than XX lbs and P205 differences of less than XX lbs (see note “m” above).

s. Samples with reported perennial forage or grass seed in rotation where the crops reported included all of those in the 5-year NRI crop history (1999 to 2003). For perennial hay, the reported years were replicated and adjusted to fill out the 5-year NRI sequence. For grass seed, the sample was set up as continuous grass seed production by excluding the other crops and replicating/adjusting the reported grass seed years as needed.

t. Samples with reported perennial forage in rotation, but where the 5-year NRI crop history included no years with forage. These samples were set up to simulate as reported, with needed adjustments, such as adding primary tillage and planting in the appropriate season for the forage crop.

u. Adjustment of application year relative to crop year for pesticides, to correspond to notes a. and e. above for tillage, fertilizer, and manure.

y. Corrected something in an operation or application date. This note was applied for cases where a later consistency check query showed that changes were needed. The detail is described in the “Other Consistency Checks” section of this document.

z. Notation that team discussion and decision of complex samples was completed.

## 4. Missing Data

### NASS Edit Codes

Edit codes were added by NASS to indicate missing or incomplete pesticide, fertilizer, manure, and field operation sections of the survey reports (see Chapter 2 for complete discussion of this aspect of the survey). These codes indicate that for a variety of reasons (refusals, missing historical records, not farmed that year, etc.), the form was not filled out completely. This "missing" determination could have been made by the enumerator or by the NASS editors prior to digitization of the data. Many of the samples not classified as "missing" were missing data to the same or a greater extent, the difference being that the respondent apparently did not fill out the form completely without indicating it was incomplete, as opposed to saying that he would not or could not. Even with missing sections, some of the samples could be prepared for analysis and simulation, depending on which sections were missing and whether or not the deficiency could be overcome according to the application of procedures described in this document. An important point to note is that even if the data looked complete even though marked incomplete, there was no way to know what may have been omitted, e.g., another instance of disking, or another application of fertilizer. For some samples, the data deficiencies were so large that the samples were disqualified prior to the editing procedures discussed in this document (see Chapter 2).

For the 2005 and 2006 survey data, the samples were screened and in some cases disqualified prior to the start of the edit procedures discussed in this document. However, for the 2003 and 2004 survey data, most of the procedures in this document were applied initially without consideration of the NASS Edit "missing" codes. Consequently, it was necessary to then re-evaluate the 2003-2004 samples and determine if the applied edits needed to be modified or if the samples needed to be disqualified. The re-evaluation procedures were based on the following principles:

1. If missing only fertilizer, keep and model anyway since procedures will be applied to adjust for missing and low fertilizer rates;

2. If missing only manure, model anyway without adjustment;

3. If missing only pesticides, model anyway without adjustment, unless missing all three years, in which case the sample was disqualified;

4. If missing any combination of the above, model anyway; and

5. If missing Field Operations for one or more years, exclude the sample, except for the special case of reported type of No-till. In the case of No-till, simply add a planter and harvester. (Note that for the 2003 data, the NASS Edit "missing" code was not available for the field operations portion of the survey data.) However, if 1$^{st}$ or 3$^{rd}$ year was missing data and the sample would have been reduced to a two year rotation, keep sample and set up as a two year rotation with the two complete years.

A summary of the outcome of that analysis is shown in Table 1-2 for the 20303 and 2004 samples that had initially been edited without regard to the NASS Edit Missing code. (The summary in Table 1-2 was as of 15 September 2007 and additional edit procedures after that period may have changed the status of some of the samples).

### 5. Date Completion in the 2003 Survey Data

The survey data collected in 2003 did not record the calendar year of application for the fertilizer and manure applications; only the month of application and the crop year to which it belonged. Consequently, it was obvious, for example, that with a crop year of 2002 for corn and a fertilizer application in the month of November, that that application must have been done the previous fall. Therefore “Fert Year” and “Man Year” columns were added to the fertilizer and manure application tables. Initially a query was implemented to set these years equal to crop year if the application month was between one and seven and to crop year minus one if the month was greater than seven. However, each sample was then examined with the data edit and display program and corrections were made as appropriate, especially to correct for the cases of the query having set the application year to a year previous to that of the first crop year (as described in the “Fall Tillage in Year Prior” section above.)

For the 2003 CEAP survey data only the month and year were reported for field operations; application of fertilizer, manure, and pesticides; and planting and harvesting dates. Rules for assigning a specific date within the month were required for building the APEX simulations. Initially those rules were implemented only in the Run Builder program as the APEX datasets were created and were not reflected in the edited CEAP Survey data. Since each survey year’s data varied slightly, each was handled independently, in its own database, own display/edit program, and own Run Builder version. However, after most of the editing was complete for all four survey years a decision was made to combine all 4-years of survey data into a common database. To accomplish that the 2003 Run Builder was augmented so that it could be run one time set to determine the day components of dates for the 2003 samples and insert those dates permanently into the survey database making those samples consistent with the other survey years.

In general the rules followed the following criteria. Within each month, the fertilizer, manure, and pesticide applications and field operations were ordered according to standard agronomic guidelines, e.g., incorporated fertilizer prior to tillage, tillage prior to planting, and planting prior to cultivation for weed control. The collected survey data included sequence numbers for the field operations showing the order in which the farmer performed them.

Note that the APEX model includes an option for varying the exact date of operations from year to year according to weather conditions. For that option the earliest allowable date for an operation is specified in the APEX dataset along with a requirement of how many heat units should have accumulated prior to the operation. APEX will not perform the operation until both the minimum date and minimum accumulation of heat units have occurred. Also, certain operations will not be performed on a given day if precipitation events occur of if the soil moisture content is not above a specified level. Also, for a planting operation to occur the temperature in the second soil layer must be at least two degrees above the base temperature of the crop. APEX evaluates these conditions each year based on the weather input data sets for the simulation.

## 6. Other Consistency Checks

After the analyses described above and the visual examination of each sample with the Data Display/Edit program had been completed, a variety of queries were set up to check for the issues listed below. This was necessary due to the sheer magnitude of the data involved. The data tables for the set of final samples includes some 47,812 individual crop history rows, 179,795 field operations, and 50,992 fertilizer applications (as of 18 April 2008). With this magnitude of data it is possible that additional subtle date and quantity errors will continue to be discovered. Fortunately, in the trial run stage of the analysis serious errors will either cause the APEX simulation to fail or else to produce obviously erroneous output, highlighting the specific need for further editing of some samples. Consequently, it is expected that the dataset will continue to be edited until frozen for the simulations for the final analysis. A sample of the special queries used to check for errors included the following:

1. Various queries to check the consistency of planting and harvest dates, including match of year of operations, growing season length, count of planters versus harvesters, etc., and match of harvest and plant dates and machines with crops.

   a) Check for interval between plant and harvest and visually evaluate small and large cases.

   b) Harvest month earlier than July except for winter wheat, oats, barley, forage, vegetables, and some small grains planted in fall or winter as exception.

   c) Use of planter (machine ID #101 … 116) in the place of a grain combine (machine ID #121 … 126) or vice versa.

   d) Planting operations (machine ID #101 … 116) after month 7 for crops planted in the spring in the U.S. (crop Nos. 5, 6, 16, 25, 26, 98, 153, 163, 164, 401, 402 …). (Crops 163 and 164 were found to sometimes legitimately be planted fall or winter for AZ and CA.)

   e) Combine operation (machine ID #121 … 126) before month 7 for crops listed in 4. above, except for AZ and CA.

2. Check if the count of each specific operation by sample, crop code, crop year, and sequence number was greater than one (in the case of legitimate multiple use of an operation such as a disk or a hay harvester, each operation would have a different sequence number).

3. Check if the count of operations by sample, crop code, crop year, crop machine ID was greater than one for selected operations such as primary tillage with a mold board plow, for planter, for grain combines, etc.

4. Check crop year versus calendar year for the added "idle fallow placeholder".

5. Check various counts of type of operations, such as count of planters or harvesters or fallow place holder occurring in a single month.

6. For a each sample and crop check use of more than one planter (#101 … 116) or one combine (#121 … 127).

7. Get the plant date (month) and harvest month for each sample and crop code for operation year = crop year and see if harvest month < (plant month + 2).

8. Check that calendar year not equal to crop year for a fertilizer operation if the month was less than August and the same for manure events. Some samples had fertilizer applied during the spring or summer of the fallow year of a wheat operation and those seemed legitimate.

9. Manure application month can't be after plant month unless irrigation applied, although an exception was made for a couple of rice rotations.

# Chapter 2. SAMPLE QUALIFICATION AND CROPPING SYSTEM CLASSIFICATION

## 1. NASS Edit Codes

Edit codes were added by NASS to indicate missing or incomplete pesticide, fertilizer, manure, and field operation sections of the survey reports. These codes indicate that for a variety of reasons (refusals, missing historical records, not farmed that year, etc.), the form was not filled out completely. This "missing" determination could have been made by the enumerator or by the NASS editors prior to digitization of the data. Many of the samples not classified as "missing" were missing data to the same or a greater extent, the difference being that the respondent apparently did not fill out the form completely without indicating it was incomplete, as opposed to saying that he would not or could not. Even with missing sections, some of the samples could be prepared for analysis and simulation, depending on which sections were missing and whether or not the deficiency could be overcome according to the application of procedures described in this document. An important point to note is that even if the data looked complete even though marked incomplete, there was no way to know what may have been omitted, e.g., another instance of disking, or another application of fertilizer.

There were 806 samples (see Table 1-2) in the 2003-04 set of 11,504 potentially model-able 2003 and 2004 points that have one or more missing/incomplete sections (pesticides, fertilizer, manure, field operations) according to the NASS edit codes. Here is a summary of the extent of missing information in these samples:

- 145 samples have missing/incomplete pesticide records in every year reported. In all cases, there was evidence in the survey that pesticides had been used (either the pesticide use field was "yes" or incompletes were coded for each year in the NASS edit codes). 72 of these samples have other missing sections as well—68 have missing/incomplete fertilizer records for one or more crops/years, 24 have one or more missing field operations data, and 12 have missing manure application data. None were included in the 9,417 samples comprising the interim/preliminary sample set. 16 have multiple crops. 98 of these sample points were initially identified as "bad" in the initial data editing process and set aside.

- Of the remaining 661 samples, 328 had one or more missing pesticide sections (but never for all years reported), 136 samples had missing field operations data, 358 had missing fertilizer data, and 62 had missing manure data. Some samples had more than one type of missing/incomplete section. 370 of these 661 sample points were included in the Interim/Preliminary 2003-04 sample set. 54 sample points have multiple crops. The vast majority of these have at least one good year.

These sample points present a problem for us because the original model set up was done without using the information in the NASS edit codes. Information includes not only which sections are missing/incomplete, but also documents legitimate "zeros"—instances of no applications. In the majority of cases with missing/incomplete sections, samples will have complete records for one year—usually the most recent year—and show "missing/incompletes" in subsequent years. Our initial plan was to "fill" the missing data using a statistically appropriate imputation procedure, such as "borrowing" data from similar "donor points."

It is likely, however, that many—maybe half—of these samples already reflect the best representation of what was done, and do not need to be "filled." Over half of the samples have been reduced to 2-year rotations or 1-year rotations, using only 1-2 of the 3 years reported in the survey. When this was done, crops without missing data were selected. In cases with multiple crops, the missing data could have been for a crop not selected to represent the sample point. Missing field operations can probably best be "filled" using information on the tillage type reported in the Cropping History section of the questionnaire and expert judgment based on general practices found in the completed surveys in the same geographic area, rather than using donor points.

In addition, it is almost impossible to fill in pesticide data, as it depends critically on the pest problems unique to each field. Filling in manure data using donor points is also problematic without information on the source of manure (livestock type). Manure applications vary greatly, and geographic proximity or other factors cannot be used to identify suitable donor sample points.

Here are suggestions for how to deal with the missing sections in the 2003-04 dataset:

1. Identify the worst of the worse and exclude the samples. It is reasonable that, with survey data, a small subset will be unusable for modeling. I suggest the 145 samples with missing pesticide data in all reported years, as it is essentially impossible to use statistical imputation to fill missing pesticide data in a reliable manner.
2. For all remaining samples, protocols in selecting the crop years for defining the crop rotation should include avoiding use of crop years that have missing data when that is possible.
3. For missing field operations data, use information on other crops reported in the survey and the tillage type reported in the Cropping History section to derive--using expert judgment--an appropriate tillage schedule, guided by general practices for the same crops in other samples from the region. In cases where a judgment on the tillage type/intensity cannot be made, use frequency of occurrence information for the region and choose using a probability method (so as not to skew the tillage results with these missing-sample data points).
4. For manure missing sections, model the sample point without any manure application. No data fill. There is no acceptable data fill procedure for manure. (Missing manure sections have a low frequency—62 samples out of 11,504.) Report in our documentation the extent to which this occurred. This will result in our understating manure applications by a small, unknown amount. Since the accuracy of our manure applications is not high anyway, this small under-reporting will be of no real consequence.
5. For fertilizer missing sections, the procedure developed to augment N fertilizer applications can be used for the N application rate. For phosphorus, a state-crop average can be used for the rate. Method of application and time of application can be either: 1) derived from data for other crops/crop years reported in the same survey, or 2) based on frequencies of occurrence by state and crop and selecting method and timing and form probabilistically (random according the probabilities as estimated by the frequency of occurrence data).
6. For pesticides, the only feasible approach is to first try to construct the likely pesticide application regime based on data for other crops/crop years reported in the same survey. If that is not possible, model the sample point without pesticide applications and report the extent to which this was done in the methods.
7. Special case of reported type of No-till. In that case simply add a planter and harvester.

# Chapter 3. CROP HISTORY

## 1. Crop Identification Labeling

Several crops were not adequately identified in the CEAP survey data for environmental analysis and simulation, e.g., “all wheat” or “other hay”, or “other vegetable seeds”. Similar cases included crops reported according to purpose rather than specie, e.g., “small grain hay” rather than “winter wheat”. The appropriate assignment of a specie or type was required for the APEX simulation and was accomplished by inspection of the crop history, reported yield values and units, and dates of field operations. Agronomic information sources were consulted for assignment of crop species, e.g., Brome grass for "other hay" in some regions.

**Cotton Harvest Type**

For environmental analysis purposes cotton must be identified according to harvest method, either picker or stripper, rather than by the type of cotton, Pima or Upland, as reported in the survey data. In the 2003 survey data only 0.6% of the samples were identified as Pima and the APEX model crop model growth parameters do not differentiate between Pima and Upland cotton types. The harvest machines were checked in each sample to determine if the cotton was harvested by picker or stripper method and new crop IDs of 401 (stripper) and 402 (picker) were assigned, according to the following list. Where the harvest type could not be determined from the recorded harvest machines, the default assignment was picker.

| Picker | Stripper |
|---|---|
| 214 Picker – mounted | 219 Stripper – self propelled |
| 215 Picker – self propelled | 218 Stripper – Pull type |
| | 217 Stripper – mounted |

If the only harvest machine listed was "Gleaner" or "Rood" (a frequent occurrence), the crop type was assigned as picker since those machines are used only following a primary harvest operation for cleaning up cotton missed in the previous harvest operations.

**Grass Seed Label Issues**

The survey data from the Pacific Northwest included samples with crop "#136 Ryegrass Seed" that appeared to be produced as an annual crop in some cases, and as a perennial in other cases. There were other cases of #138 "Grass Seed Other" with similar issues. In some cases it was possible to assign the crop as annual or perennial according to the listed field operations. Annual cases of Ryegrass were modeled with the APEX crop growth parameters pertaining to Rye grain.

**Specie for Other Hay, Forage, Haylage, Silage, and Pasture**

For "other hay" and similar non-specified forages such as "haylage" the listed field operations and the crop history were used to determine if the crop was cultivated as an annual or a perennial. If an annual, the assigned specie was Rye or Winter Wheat if planted in the fall and Oats or Spring Wheat if planted in the spring, with the exact choice depending on local prevailing practices. The specie assignments for perennial "other hay" and non-specified forage species by region are given in Table 3-1. The following CEAP crops required this assignment of "other hay" specie:

| | |
|---|---|
| 11 | Hay other |
| 10 | Forage and green chop |
| 23 | Silage and haylage |
| 138 | Grass seed other |
| 225 | Hay wild |
| 226 | Grass silage |
| 311 | Grass other than clover & Sudan |
| 316 | Pasture in rotation |

In some exceptional cases, the reported data could be interpreted to indicate that the specie should be a small grain, corn, sorghum, etc., rather than requiring the specie assignment as indicated above. For the cases where the listed survey crop was “217 Hay small grain”, rye or winter wheat was used if fall planted and spring wheat or oats if spring planted, with the choice depending generally on the crops reported in other rotations for the same of adjacent counties.

### Wheat Type

The CEAP survey includes the crops “134 Wheat all” and “172 Wheat all for seed”. These two crops were re-labeled as either “164 Spring wheat other” or “165 Winter wheat” according to information in the field operations and crop history. If the planting date was in January through July, the crop was assigned as Spring Wheat and if between August and December, Winter Wheat.

### Assigning Silage or Grain for “Corn All” and “Sorghum All”

Cases of reported “Corn – All”, “Sorghum – All” and “Sorghum - Sudan Crosses” were assigned as forage or grain according to the type of reported harvest operation. In other samples the crop label was changed from grain to silage or vice versa depending on the harvest machine, crop yield, and crop yield units reported. In a few cases, grazing was assigned as the harvest operation according to the methods given in the section “Crop Abandonment, Cover Crop, Failure or Grazing.”

### Specie Assignment for Other Special Cases

Other crops for which a crop label needed to be assigned included various clovers, grasses, forages, “Peas all other”, vegetable seeds, etc. In most cases whether or not the crop was a winter or summer type and whether or not it was a perennial or an annual was determined according to the reported field operation dates. Note that for the clovers, grasses, and forages, the specie assignment varied by region.

## 2. Replanting, Abandonment, Cover Crop, Failure and Grazing

### Replanting to Same or Different Crop

A number of samples, mostly in the Southern Great Plains, reported two or more sets of pre-plant and planting operations occurring sequentially through the spring and early summer months, with the second or third sets either being for the same crop or a different crop. In most cases, the data edit team made the decision that the first crop planted was the intended crop and the data was edited accordingly, including deleting the succeeding tillage and planting operations and editing the harvest operation, and in some cases the fertilizer and pesticide applications. However, note that it was not possible to account for any later fertilizer, pesticide, and other field operations that the producer might have applied if the first crop planted would have continued to maturity. In a few cases the determination was made that the later crop was the more commonly used crop and the data was adjusted accordingly. In a few cases it was impossible to determine which crop should be simulated and/or how to edit the datasets – these cases were given a status of “bad” and were not simulated.

### Disposition of Small Grains Lacking Harvest Equipment

The 2004, 2005, and 2006 survey data included a variable denoting the intended purpose of the crop: Dual Use, Harvest Grain, Grazing Only, Cover Crop, and Other and also an indication of how many acres of the field were abandoned. The 2003 survey data did not have the intended purpose or the abandoned acreage variables. Even in the 2004 - 2006 data there were cases where reported harvest operations and/or yields were either not listed or were inconsistent with the listed purpose. For 2003 each individual crop year in each sample for which no harvest or yield was listed was examined and where possible a determination was made as to the crop purpose (see grazing section below). In many cases, particularly for 2003, it appeared that the harvest operation was simply not listed, and so a suitable harvest operation was added. In a few cases the data reported for conservation practices could be examined to determine if a cover crop was being listed as part of a management plan. In general, a small grain crop planted in the fall, followed by spring tillage for the subsequent crop, was assumed to be a cover crop and no harvester was added. The procedures for determination of a grazing purpose for the crop are given in the next paragraph. However, there were still unresolved cases where it was not possible to determine the farmer's intent. These were marked as "fix" or "bad" and saved for further analysis.

## 3. Reduction to 2-Year Crop Rotation or Mono-cropping

### Overview

The survey collected a three-year point-in-time snapshot of management information. However, many cropping systems consist of a single crop grown repeatedly over time, two crops grown repeatedly in sequence over time, or longer more elaborate rotations such as that involving alfalfa hay. For three years of data reported for a two year crop rotation sequence, if those sequences were simulated directly as 3-year rotations, repeated 14 times over the 42 year simulation, the resulting sequence would have double the correct frequency for the $1^{st}$ and $3^{rd}$ year reported crops. For example if the reported corn-soybeans-corn sequence was repeated, the simulation would have corn-soybeans-corn-corn-soybeans-corn and so on. The NRI shows that the vast majority of corn-soybean acreage is actually managed as a two-year corn-soybean rotation (14.1, 5.6, and 14.3 million acres in 1997 for IL, IN, and IA). According to NRI data the sequences with the next largest acreage after corn-soybeans in that region are things like corn-corn-soybeans-soybeans, corn-corn-soybeans, soybeans-soybeans-corn, and then followed by continuous corn (continuous soybeans has much smaller acreages). Similar patterns for two crops grown repeatedly in sequence are shown by the NRI for other regions and crops.

Some samples indicated continuous mono-cropping, with the report showing only one crop regardless of the number of years reported. Where the management data was identical for the reported years, all but one year was excluded to avoid needless replication of data in the APEX simulation. A more difficult situation was where only one year of data was reported. As noted above, these cases likely resulted from ownership or management change during the years surveyed. For cases where continuous cropping was thought to be possible, such as for corn, sorghum, wheat, and similar crops, the sample was used as reported. However, for cases such as potatoes or sugar beets, the samples were marked for analysis with the perennial crops, i.e., the NRI was consulted for additional crop rotation information.

For the 2005 and 2006 surveys the respondents reported their intended rotations and most of those showed crops for at least 4 years even if only two crops were being repeated in sequence. However, for the 2003 and 2004 surveys only a few respondents, primarily those reporting use of "conservation crop rotation" practices, reported their intended rotation. The reported management data, the intended rotation, and in selected cases, the NRI crop history, for each sample was examined and one of the following actions taken:

1) If 1st and 3rd year crops were identical, with essentially the same management, and a two-year rotation was indicated, exclude the 1st year of data (or, in select cases exclude the 3rd year if it appeared to be incomplete);
2) If 1st and 3rd crops were identical and two-year rotation, but with different management, do one of the following (more detail following this list);
   a) Exclude 1st or 3rd year of data;
   b) Keep all 3 years of data;
   c) Replicate middle year and label as year prior to 1st survey year (follow-up edits, including the 2003-2004 samples, resulted in this choice for 673 samples (Table1-1);
3) If all 3 year's crops were identical, exclude all but 1 year of data;
4) If all 3 year's crops were identical, but with different management, keep all three years;
5) If operations of 1st year extend back through the summer of previous year, add a "previous" year as an idle or fallow year, extending the rotation to 4 years;
6) If sugarcane, follow specialized procedures (outlined in another section); and
7) If perennial crop not managed as an annual or bi-annual, set sample aside for specialized procedures for development of rotation.

The following sub-sections provide more detail on the decision processes listed above. However, in many cases, the team evaluated the reported data and made a decision not easily categorized into the cases described here.

**No "Back-to-Back" of Selected Crops**

For selected crops and situations, the team made the technical decision that back-to-back cropping was not feasible, e.g., peanuts after peanuts in reported peanuts-oats-peanuts rotation, was not feasible, and therefore the editing priority was to reduce it to a two year rotation, based on guidelines in the above section}. For these cases, regardless of other considerations noted above or below, unless the 3-years of reported data included specifically the crop grown in two consecutive years or the intended rotation showed the crop grown in two consecutive years, and adjustment was made.

**Replication of Middle Year and Extension to a 4-Year Rotation**

There were cases where it was difficult to reduce 3-year to the 2-year rotation because the management in the 1st and 3rd years was different. For the 2003 and 2004 surveys, rarely was information included on the intended rotation. For the 2005 and 2006 data nearly all samples reported an intended rotation, and most of them reported 4 years (5 years in some cases).

For the 2004-04 survey where the rotation was 2-years but the 1st and 3rd year management were different, some detailed guidelines like the following were applied: (see discussion in the next sub-section):

- if the difference is only in K2O then ignore
- if difference in STIR less than 40 then ignore
- Notill or mulch tillage has clearly been adopted

For the 2005-06 data an enhanced procedure was developed, based on the reported intended rotations. That procedure was to replicate the middle year rather than trying to decide whether to drop 1st or 3rd year. For example, the reported corn-soybeans-corn for 2003-2004-2005 becomes soybeans-corn-soybeans-corn for 2002-2003-2004-2005 with 2004 data replicated for 2002. This was for cases where for example, in every other occurrence of corn in the rotation, a deep ripper would be used.

The "middle year replication" procedure is better than that followed for the 2003-04 data because all the data is preserved and the intended rotation is also matched. Most cases of difference were due to tillage differences. But there have also been cases where in 1rst year all fertilizer applied in spring while in 3rd year it is injected in the fall.

There were 673 samples for which the middle year was replicated are marked with "m" in the "ChangeNo" column for frequent edits as of 2 March 2008 (see Table 1-1).

**Criteria for Keeping All Reported Years**

There were many samples where inspection of the data indicated the reported three years of data should be reduced to a two-year rotation (or three years to one year for continuous cropping) but, however, that decision was difficult because of different management in the 1$^{st}$ and 3$^{rd}$ years of data. Therefore a decision had to be made of reducing to 2-years or keeping all the data as reported. The following guidelines were developed as the 2003 and 2004 survey data was initially being edited. At a later date, some of these samples were changed to conform to the protocol developed for the 2005-2005 survey data of replicating the middle year to make the system a 4-year rotation as described in the previous sub-section. For samples with intended rotations reported, it was often clear that even though the reported data was, e.g., corn-soybeans-corn, the intended rotation was corn-corn-soybeans.

<u>Difference in 1$^{st}$ and 3$^{rd}$ Year Management is in Tillage.</u>

1. If the only difference was the use of one or two after-plant cultivations (for weed control, furrow building, etc., the difference was ignored, and the 1$^{st}$ year was excluded (1$^{st}$ two years were excluded for samples with continuous cropping).

2. The STIR rating for each year was examined (*and the year that seems to be closest in tillage intensity to the middle year was kept or the year was kept that is more intensive since the respondent would have been more likely to have forgotten to record an a tillage operation as opposed to recording an extra operation*).

> a. The STIR range for Mulch tillage is 30 to 100. So if the STIR for both years was between 30 and 100 and if the difference was less than about 20, ignore the difference, and exclude the early years.
>
> b. If both STIR were less than 30, ignore the difference, and exclude the early years.
>
> c. If both STIR were between 100 and 200, ignore differences of less than 40, and exclude the early years.
>
> d. If both STIR are over 200, ignore differences, and exclude the early years.

3. If for continuous cropping it appears that tillage is about the same, but every 2nd or 3rd year there is a deep ripper or similar "special" operation that under normal conditions is customarily used less frequently than every year, then keep all years.

4. If the sample appeared to convert to less intensive tillage, it was assumed that adaptation has occurred and drop the earlier more intensively tilled years if one of the following conditions was met:

a. If reduced tillage or residue management was listed as a conservation practice.
b. If the last two consecutive years were both mulch till or notill, adoption was implied.

Difference in 1st and 3rd Year is in Fertilizer.

1. If the only difference was in the use of K, then ignored the difference, and dropped the earlier years since the environmental effects of K are not included in the scope of the CEAP study.

2. For corn, a year was dropped if one of the following conditions occurred:

a. The year had no N fertilizer at all or if the difference was only in P and the P difference was less than 60 lbs per acre (years with no N or exceptionally low N fertilizer would have N fertilizer added prior to the simulation anyway).

b. If the lbs of N fertilizer were less than 80% of the corn yield expressed in bushels (case of too small of N and it would be adjusted if kept).

c. If both (or three years of continuous corn) have zero or low N as defined in above 2.b., then drop the years with the fewer numbers or types of applications.

3. For soybeans, often one year will have fertilizer but not the other and most often the difference was in the P application.

a. If N was less than 25 lbs per acre and P was less than 60 lbs for the year with the higher values, keep the higher year.

b. If P was greater than 60 (perhaps up to 100) and if then it appeared that for every other soybean year a large application is made, replicate the corn year, making the sample a 4-year rotation.

4. For all years with "reasonable" but different fertilizer applications in the samples with continuous crops, use the middle year or keep all years.

5. If a very "large" application of N for soybeans where soybeans are in rotation with corn, wheat, cotton, sorghum, rice, etc., and those other crops have "low" fertilizer amounts, then need to change crop label and/or year of the "large" N application to assign it to the other crop.

Difference is in Manure.

The cases with differing manure could not be treated according to the fertilizer rules because much of the manure applications might not be applied according to crop nutrient needs. Consequently, in most cases all three years of data were kept or the rotation was expanded to 4 years by replicating the middle year.

**Situations where a Fourth Year of Data was Required**

There were samples where a straightforward edit was to augment the survey by completing an implied fourth year of data. This most commonly occurred where two different crops were being alternated with summer fallow, or where one crop was alternated with fallow, but with different management in the 1st and 3rd years. For instance, a sequence of winter wheat-fallow-sorghum might show the sorghum being harvested in September of 2003, along with fall tillage for the 2001 winter wheat crop starting in June or July of 2000, implying that the winter wheat was preceded by fallow rather than sorghum, and so implying a 4-year rotation of fallow-wheat-fallow-sorghum. In that case, all that was required was to explicitly add identification to the data so that the APEX simulation would recognize that four years of data were involved, e.g., that the year 2000 was a fallow year. More difficult cases were where the fourth year was implied, but reporting of tillage and other data was apparently incomplete. Those cases required judgments about what additional operations to add.

## 5. Split Fields

For some NRI- CEAP samples the crop history section of the survey form showed multiple crops for one or more years, often with each crop accounting for only a portion of the total acreage of the field. Careful inspection of these cases was required to determine which of the following situations was being reported:

1) The field was physically divided for two or more crops;

2) A single crop was harvested in two or more ways, e.g., partially as silage and partially as grain;

3) A crop was abandoned and the field was replanted with the same or a different crop;

4) A separate crop history entry was reported for each of several harvest events, including multiple harvests of a forage crop or harvesting part of the field on different dates;

5) Repeated or overlapping crops within a year, nurse crop for hay establishment, and/or intercropping; and

6) Cultivation of a cover crop during part of the season.

The following detailed discussion applies to required decisions about which crop to model for the cases of physical division of the field and/or replanting after an abandoned crop. Cases of double, triple, and even quadruple (vegetables) cropping, inter-cropping, and cover crops were simulated as reported. For cases of a single crop with split management, e.g., part grain and part silage, the dominant part was usually chosen and setup for the simulation.

For some NRI-CEAP samples, the field identified by the operator was split into sub-fields, each with a different crop growing simultaneously (not double cropped)--different crops grown in different parts of the field. Often, a very small portion of a field was reported to have hay or grass production. It is likely that those portions corresponded to grassed waterways or other similar areas of the field. Sometimes this case existed for only 1 of the 3 years, sometimes for all 3 years. In 2003, enumerators attempted to collect information on all of the crops grown in the field. In 2004, 2005, and 2006 enumerators were asked to NOT report all crops grown on the field to reduce the respondent burden; they were asked to choose the sub-field with the most acres to maximize the likelihood of coinciding with the NRI crop history. Nevertheless, there are a few hundred samples that include these multiple crops in the 2004 survey database, and a lesser number in the 2005 and 2006 survey databases.

Since the NRI sample point is linked to specific geographical spot in the field, we had to make judgments about which crops to use from the survey to represent the NRI point for these samples with "multiple crops." The objective was to choose the crop from among those reported for each year that conformed the closest to the crop history reported for the sample point in the NRI.

The survey reports crops for three years—2001, 2002, and 2003 in the case of the 2003 survey. Double crops and cover crops are included. The NRI crop history has "primary" crop information for four years—2003, 2002, 2001, and 2000. (For the 2005 and 2006 surveys a preliminary determination of the NRI 2005 and 2004 land use was also available. The NRI also has, for a few sample points, information on a "secondary" crop, such as a double crop or cover crop for each year. Exact matches between the NRI and the 2003 CEAP samples could thus only be made for two specific years—2002 and 2003. The crop information for the CEAP sample is very specific, including information on the use of the crop (grain versus silage, grazing only, etc.), whereas the crop information in the NRI is more generalized and includes crop groups such as "other row crops" and "other close grown crops."

Every sample with more than one crop reported in one or more years was initially considered to be a potential candidate for a "multiple crop" sample. Many of these, however, were samples with double crops or cover crops, and did not require a crop selection procedure. Closer examination also showed other samples reporting multiple crops in the crop history section to be cases of crop failure followed by replanting to a different crop or two different types of harvest, e.g., silage in June but hay in August, or x acres of silage and y acres of grain. Resolution of the crop failure/replanting and multiple harvest type cases are discussed in other sections of this document.

Programming rules were used to identify potential multiple crop samples, which were then examined to determine which crops best represented the NRI sample point.

**Identification of Samples with Multiple Crops**

1. Identify all samples with two or more crops reported for one or more years. It was determined for each of these samples whether the crops were grown sequentially (double and cover crops) or simultaneously (multiple crops).

2. Identify the subset with 3 or more crops in one or more years. Nearly all of these samples were multiple crop situations.

3. The remaining subset consisted of samples with 2 crops grown in one or more years. These samples were further divided into 4 subsets:

    a. **Exempt**: samples with crops reported that were determined unambiguously to be only double crops or cover crops. This was determined by demonstrating that the plant date for the second crop follows the harvest date of the first crop, or demonstrating that the intended use of one or both crops was either: 1) cover crop, or 2) graze only. Crops with "cover crop" or "graze only" intended uses have plant dates but no harvest date.

b. **Rule 1**: samples with acres planted for one or both crops that was less than the total cropped acres reported for the field—partial fields. For this rule, the survey data item "P17" is used as the total cropped acres, which is the total acres in the field that was cropped in the first year of the survey.

c. **Rule 2**: same as Rule 1, but include in the total acres calculation the acres reported for the first year of the survey as "idle, fallow, or rotational pasture"—P19. Sometimes these acres were cropped in one of the other years. Total acres were thus represented as the sum of P17 and P19 for this rule. The bulk of potential multiple crops were identified by Rule 1, but a small number were only identified with this additional rule.

d. **Residual**: remaining samples consisted of a variety of cases not covered in the above rules, such as missing plant or harvest dates, abandoned and replanted crops, multiple hay cuttings, and "inter-cropping" cases where both crops have the same plant date. Very few of these were multiple crop samples.

Notes:

1. In some cases, the enumerator chose the field parcel for reporting. When double crops and cover crops were involved, these are usually included in the Rule 1 and Rule 2 subsets as "false positives."
2. Cases where the entire field was abandoned and replanted with a second crop are treated the same as double crops and cover crops—both crops were retained and used in the crop sequence used to characterize the sample point for purposes of categorizing the cropping system. However, for the APEX simulations, in most cases a determination of "intended crop" was made and the sample edited accordingly (described in another section of this document.
3. Some cover crops and some crops planted for "grazing only" have all acres reported as "abandoned."
4. Partial field re-plantings produce the same problem that multiple crops do, and require that a choice be made based on the best correspondence with the NRI crop history. These cases are included in the multiple crop adjustment.
5. Hay is a perennial crop, and can be recorded multiple times throughout a year if repeated for each cutting. The plant date is often not recorded for hay.
6. Hay is sometimes planted along with a small grain crop, which serves as a "nurse crop" for the hay but which also produces a harvest. Both have the same plant date (usually) but different harvest dates.
7. In a very few cases, a second crop is planted before the first crop is harvested. For example, soybeans is sometimes planted into wheat or other small grain crops a week or two prior to the harvest of the wheat. Another example is where a small grain crop or cover crop is planted into standing hay early in the spring.
8. Some samples have plantings only for the purpose of providing forage for pastured livestock; these do not have harvest dates and may be planted more than once per year.

As an example of the procedures followed, a summary of sample counts for the 2004 CEAP-NRI survey is presented in table 3-2. There were 898 samples with 2 or more crops in one or more years in the 2004 survey. Of these, 397 had multiple crops that require selection of crops that best represent the NRI sample point. The rules identified all but 2 of these multiple crop samples (one of which was actually an erroneous data entry error); 37 samples were "false positives." A total of 348 samples were identified as double/cover crops using programming routines. Another 149 samples were determined not to be multiple crop samples by inspection.

**Selection of Crops That Best Represent the NRI Sample Point**

The following rules were established for use with the **2004 NRI-CEAP sample**. Similar rules apply to other survey years.

1. Cases where the field has clearly been divided into fixed sub-fields, indicated by parcels that have the exact same acreage planted in every year.
    a. Cases where the 2003 crop matches the 2003 NRI crop.
        i. Choose the 2003 crop that matches the 2003 NRI crop, either the primary or secondary crop.
        ii. Choose crops for 2004 and 2002 from this same parcel, regardless of whether the 2002 selection matches the 2002 NRI crop.
    b. Cases where the 2003 crop does not match the 2003 NRI crop.
        i. Choose the 2002 crop that matches the 2002 NRI crop and crops for other years from this same parcel.
        ii. If the 2002 crop has no match, choose the parcel with 2003 and 2002 crops that best reflects the crop mix in the four years of NRI crop history.
        iii. If none of the crops match any of the crops in the NRI crop history, choose the parcel with the most acres planted or, in the case of re-plantings, the most acres harvested.
        iv. If none of the crops match any of the crops in the NRI crop history and acres are exactly equal, use a randomization approach (random numbers drawn for each possibility) to chose the parcel.

2. Cases where the sub-field acreage is parceled for 2 years but not the third year. Follow the rules above for the years the field is parceled. For the remaining year:
        i. Choose the crop that best reflects the crop mix in the four years of NRI crop history.
        ii. If none of the crops match any of the crops in the NRI crop history, choose the crop with the most acres planted or, in the case of re-plantings, the most acres harvested.
        iii. If two choices are equally good, use a randomization approach (random numbers drawn for each possibility) to chose the crop.

3. Cases where the sub-field acreage varies from year to year.
        i. Choose crops that match the 2002 and 2003 NRI if possible; if no matches or 2004 crop, choose crops that best represent the four-year NRI crop mix.
        ii. If none of the crops match any of the crops in the NRI crop history, choose the crop for each year based on the most acres planted.
        iii. If none of the crops match any of the crops in the NRI crop history and acres are exactly equal in one or more years, use a randomization approach (random numbers drawn for each possibility) to chose the crop.

Notes:

1. Double crops and cover crops may also be listed, often for the full acreage of the field. Be sure to include these crops if there is evidence that they applied to the sub-field selected.

2. Where there is not a match with the NRI crops or crop mix, avoid choosing the crops that will result in the sample being discarded because of modeling issues—strawberries, mint, peppermint, asparagus, and CRP.

3. Whenever faced with two choices that seem to both qualify and not covered by the above protocols, use a randomization approach (random numbers drawn for each possibility) to chose the crop.

4. Since hay is a perennial crop, special consideration should be given to how hay acres are selected, maintaining a logical sequence of crops over the years if hay is in the selected sub-field.

5. Where the CEAP cropping history and the NRI cropping history indicate a strong crop rotation pattern, maintain the crop rotation where the rules allow for choices.
6. In the case of abandoned and replanted crops (whole field), multiple hay cuttings, "nurse" crops planted with hay, and other "inter-cropping" cases, retain all crops except those for which a reasonable case can be made that they were not planted sequentially in the same subfield or parcel.

7. Hay can be recorded multiple times throughout a year if repeated for each cutting. These records are retained.

**Split Management for Single Crop within a Field**

Some samples used different harvest methods for the field, either on portions of the acreage or at different times of the years. Examples are parts of the field as corn silage and corn grain, or an early harvest reported as silage followed by a later hay or grain harvest. For these cases, generally the dominant type was chosen as dominant. At a future date it would be possible to set up replicate runs for the field, each run representing one of the reported sequences of management. Another example was primary tillage operations for the entire field, but separate plant and harvest operations for the same or different crops on parts of the field (multiple operations with different dates).

## 5. Fallow and Idle Crop Years (and within-Year Periods)

The CEAP survey data included two "crops", #333 Fallow, and #318 Idle, with the distinction being that fallow was generally part of a repetitive management plan, such as for winter wheat and rice, while idle was most often simply abandoning the land for one or more years. In most cases the fallow years involved some management activities while the idle years did not. Note that in the 2004 survey definitions, #318 was initially listed as "short rotation woody crop" and consequently shows up with that description in the unedited crop labels; however, NASS staff provided guidance that the intended and actual use of #318 was for idle situations.

Considerable discussion and various proposals were considered for addressing a fundamental question about simulation of fallow and idle crop years: What vegetation would have been growing during that period and how would it be managed, i.e., how to simulate what was actually happening on the land during that period? Initially it was determined that for every fallow and idle year a vegetative “generic weed” would be planted. In the APEX simulations the weed would have grown until killed by a chemical or tillage operation. However, the next step in the discussion process realized that in the real world, those operations may kill all or only part of the weed, reduce its population only partly, or just convert some of its vegetative biomass from “standing live” condition to “dead residue”. Also, new populations of the weed would germinate and grow after the control event. Even though it would be possible in APEX to add sets of operations for replanting the weed after each control operation, or only partly reducing its population or its growing biomass, two other considerations were noted. First, the required agronomic information for setting up those operations to grow and reduce the weed in the wide variety of situations being simulated across the U.S. was far beyond the scope of the CEAP project. Secondly, if weed growth were addressed for these idle and fallow samples in that manner, then for consistency for the samples not involving idle or fallow years, there would also need to be periods of weed growth and subsequent reduction which the study was also not addressing. In fact, in some cases, the system with an idle or fallow year might have a weed growth period of only a month or two while non-fallow systems often would have several late summer, fall, or spring months without tillage or chemical application in which weeds would be growing. The final decision was to exclude from consideration the weed growth issue, both for the idle – fallow systems and for the others. It was recognized that the management of the weeds would have an impact on soil carbon, nutrient and water balances, and other environmental out comes, however, addressing those issues is beyond the scope of CEAP at this time.

Other than consistency edits for issues similar to those addressed in crop producing years, the main edit performed for idle/fallow years was to check to see if at least one field operation, soil disturbing or not, was included in the calendar year matching the idle or fallow crop year. If there were no operations present, then a newly defined, non-soil disturbing, operation “#450 Idle Fallow Placeholder” was added to occur on April 15 of that year (on other dates in some cases). Without at least one operation for the calendar year APEX would exclude that year, resulting in, e.g., continuous repeating of the one year of wheat operations rather than repeating of the two years of wheat-fallow operations. This placeholder operation was defined to have no soil disturbing or vegetation impacting properties.

There were more difficult and complex situations. For example, in Colorado many of the wheat fallow samples listed all of the operations except the harvest with the fallow “crop” label rather than the wheat crop. To the extent possible the crop label was changed on those operations so that at least the planting and fertilizer operations were identified as belonging to wheat rather than fallow. For classifying the tillage type of the rotation, to which crop a plow or disk was assigned did not matter. However, for classifying the tillage type by crop year, it would be incorrect to have all of the tillage operations labeled as “fallow”. However, other for the planting, fertilizer, and harvesting, the crop label operations were not changed for this issue.

**Placeholders for Non-reported Idle/Fallow Years**

For approximately 50 of the 2003-2004 samples where no data was reported for one of the three years in the survey period other sample information indicated that the respondent did control the land that year. However, since nothing was done with the land, nothing was reported. For these cases an idle year was added to the rotation by making an entry to the crop history section of the data and adding one instance of the “#450 Idle Fallow Placeholder” operation.

# Chapter 4. FIELD OPERATIONS

## 1. Overview of CEAP Field Operations

There were approximately 230 different machines (field operations) reported in the CEAP surveys, identified by "CodeID" of less than 401 in the database table ***"def Machines"***. In addition a variety of additional operations were defined as described in theses sections in order to properly setup the APEX simulations (most cases of "CodeID" greater than 400 are for operations defined and added by the APEX modeling team).

There were some specific cases of machines being miss-coded in the surveys and some other cases where machine IDs were changed for consistency and/or modeling purposes. For example, in the 2004 survey documentation materials, machine #108 was labeled as a "spring planter" rather than "sprig planter" and was reported used in 448 instances. Those cases were relabeled as #113 "Min/No Till planter "for tillage types 1 – 3 (None, Mulch, and Ridge) and to #114 "Conventional Planter" for tillage type 4 (conventional). There were also cases where machine #158 "Stack Mover", had erroneously been listed in documentation as "Stack Mower", and then chosen for forage harvest (mowing) operations. In those cases, another forage mower was added in place of "Stack Mower". Other sections of this chapter cover cases of machine definition edits for grain harvest with and without stubble removal, alternative depths of machines, multiple harvest operations, and specific harvest for specific vegetables versus hand harvest.

For winter wheat used as a cover crop, the wheat would often be reported as planted, and then a few months later have a plowing operation. The crop label for that plowing operation was changed to correspond to the subsequent crop for APEX and Run Builder to function properly.

To the list of CEAP machines, additional machines (or "operations" according to the APEX terminology) were added for nine purposes, each of which is discussed below in greater detail:

1) Separate operations were specified for each type of fertilizer, manure, and pesticide application, e.g., "broadcast incorporated" or "aerial application", each with its own APEX technical coefficients;

2) Specialized harvest machines were needed for various crops such as the "402 Potato Combine" and the "411 harvest vegetable greens" for which the CEAP survey reported a generic operation such as "hand harvest" or "root crop harvest";

3) For cases of grazing of small grains, for removal of straw or stover after harvest, and multiple harvests such as once for seeds and then for forage, additional operations had to be defined and added so that the biomass removal would be treated correctly in the APEX simulations;

4) In the 2005 and 2006 surveys a number of instances of two planters were reported, one being a regular planter with a depth of generally 6 – 12 inches, followed immediately by a No-till planter; consultation with technical experts revealed that reporting was to reflect the use of a No-till In-Row Subs oiler Planter operation. Consequently, a new planter was defined with those characteristics and used in place of the original two planters;

5) For cases where no tillage operation was included for terminating a cover crop, an artificial mower/chopper/kill operation was inserted;

6) A single machine was often reported in different surveys to be operated at a wide range of depths; this was particularly true for primary tillage operations. However, the team noted that some named machines, such as a tandem disk or a field cultivator might be operated at different depths on the same field at different times for other purposes;

7) Grazing start and stop operations were defined and added (see Chapter 7);

8) Fertilizer augmentation operations were added to account for low and missing fertilizer applications (see Chapter 5);

9) Irrigation operations were added to define uniquely the efficiency, runoff, and leaching of each situation (see Chapter 10);

## 2. Technical Specification of Field Operations in APEX

In APEX, Field Operations are used to represent tillage, planting, harvesting, chemical and manure application. They are also used to specify starting and stopping of irrigation and grazing and to kill or terminate growth of a crop. Each field operation is defined with the following technical coefficients in the APEX ***"Operations"*** table:

- IHC code (type of operation, see list in Williams et al., 2006)
- Tillage depth (use negative values for height above ground of harvest cut)
- Harvest/Pesticide efficiency
- Over-ride harvest coefficient
- Surface residue mixing efficiency
- Surface random roughness
- Surface ridge interval and height
- Fraction of area compacted
- Fraction of plant population reduced

The "Harvest/Pesticide" efficiency coefficient specifies the percent of "harvestable" portion of biomass removed from field by an operation or the proportion of pests eliminated by a pesticide operation. For example, corn for grain typically has a "Harvest Index" of 50 percent, e.g., 50 percent of above-ground biomass is the harvestable portion. Then a grain combine typically has a "Harvest Efficiency" value of 0.95, meaning that it removes 95 percent of the 50 percent of the above-ground corn biomass that is the harvestable portion. The "Over-ride harvest coefficient" is used for operations that remove a portion of the biomass without regard to whether it is counted as harvestable according to the crop Harvest Index, e.g., a silage harvester with the "Over-ride harvest coefficient" set at 0.95 removes 95 percent of all above ground biomass of the corn crop. For root crops the indices apply to the appropriate portion of the below-ground biomass. The proportion of biomass removed is independent of the cutting height of the operation. If the cutting height is non-zero, then all biomass above the level of the cutting height that is not removed by the harvest is converted from standing dead residue to flat dead residue.

For crops typically involving multiple machines used to prepare a single harvest, only one of the machines should have its coefficients set with a cutting height and to remove biomass. Traditionally the hay baler has been used in APEX to remove biomass, with the various mowers, rakes, wagons, etc., not actually interacting with the biomass. Usually the baler is set to harvest without killing since a separate "kill" operation is usually included in the field operation schedule. For the "override harvest index" no distinction is made between, for example, the corn grain and other parts of the corn plant. For grazing such an operation might occur each month, whether or not the plant had matured to the point of producing the normal grain or a harvestable portion of biomass. Repeated hay or grazing harvests can be simulated by having the machine remove a specified portion of available biomass on each harvest date, or by scheduling them to each occur when a certain portion of the Heat Units required for maturity have accumulated.

For cropping systems having a primary product harvest followed by stubble, vine, or other residue harvest, additional considerations are required. The first harvest operation converts all remaining non-harvested biomass above the cutting height (below for root crops) from standing live biomass to flat dead residue, regardless of the quantity of biomass harvested. Flat dead residue is not "harvestable" by any subsequent (stubble) harvest. Therefore, the cutting height for the first harvest operation must be left blank or zero. The second operation will then remove the specified portion of remaining above ground biomass left after the first operation. To facilitate this it was necessary to define and use alternative grain combines for the cases followed by stubble removal or grazing.

A specific "crop terminate" operation is required for each crop in order to kill it, generally the day of harvest for annual crops, or on the day of the first tillage of succeeding crops for perennials.

**Reserved Operation Labels in APEX**

The APEX software reserves certain Operation Id (machine ID) for specified management activities. Consequently, a few of the CEAP survey Machine ID labels had to be re-assigned in the survey data according to the following definitions:

| APEX Reserved | CEAP Original | Re-assigned CEAP |
|---|---|---|
| 261 DryFtrlr | 261 Tying Machine | 416 Tying Machine |
| 265 LqdFtrlr | 265 Topper Tobacco | 417 Topper Tobacco |
| 266 ManSpder | na | |
| 268 Animal | 268 Transplanter Carousel | 435 Transplanter Carousel |
| 401 Crop Kill | na | |
| 500 Cntr Pvt | na | |

## 3. Exclusion of Non-simulated Field Operations

The samples were inconsistent in inclusion of trucks, trailers, and wagons, ranging from no inclusion, to the other extreme of the reporting of one truck operation for each load of material hauled to or from the field. Since soil compaction was not explicitly simulated in the model, there was no need to account for even truck intensive operations, e.g., potato harvesting where the truck drives along side the harvester as the field is harvested.

The soil disturbance of fertilizer and pesticide application operations were included in the specific chemical application operations written by the Run Builder program (see explanation above), consequently, machines for these purposes were excluded for the cases where they were reported in the survey.

The field operation schedules contain a variety of machines and equipment that actually perform a function at the edge of the field, exterior to the field, or to a limited extent within the field. Examples include head-ditch cleaners, back hoes, and bull dozers for various irrigation delivery system construction and maintenance, vehicles such as trucks, trailers, and wagons for delivering materials to or from the field (but not traversing within the field), and other equipment that does not traverse the field. These machines were identified and removed from the field operation schedules. In some complex cases it is possible that the presence of these machines will need to be accounted for in the APEX sub-basin and conservation practice specification.

Interest has been expressed in using the CEAP data to conduct energy use analysis. Since the survey was inconsistent in the reporting of the operations discussed here, even using the ones reported would give distorted results. Therefore, from the survey, only "partial" analysis can be conducted. For example, the energy differential between two samples can be calculated, such as for comparing tillage energy use across different tillage systems.

## 4. Tillage Depth

The need to re-label selected primary tillage operations according to depth is described in a later section of this document. The re-labeling was accomplished by opening the "CEAP Cmn Def Data" database and linking to the field operations table where the changes are desired. The definition table and the two queries used to accomplish the task are:

Def machine depth range
Update mach replicates for depth
Update mach replicates for depth null

A wide range of depth of tillage was reported in the survey for each primary tillage machine. However, a large number of cases did not report a depth and in other cases the reported value was outside the range of reasonable expectations, e.g., seven inch depth for aerial seeding, or 28 inch depth for tandem disking. An APEX analysis with representative simulation data sets showed that for major classes of soil disturbing machines some model simulation outcomes were sensitive to tillage depth. Also, it was recognized that many machines might vary in design and/or be operated at different depths for different management purposes. Consequently, a decision was made to define two or three replicates for the seven primary tillage machines as shown in Table 4-1 (the "6i", "12i", "18i",…, indicates assigned replicate depth and was appended to the original name). The frequency of use of those machines reported in the 2003 survey data is also shown in Table 4-1. For cases where the original depth was left blank, the new replicate with the shallowest depth was assigned. After these replicate machine definitions were determined, queries were used to update the machine IDs in the survey Field Operation tables.

## 5. Chemical and Nutrient Application Operations

Initially it was determined to check for consistency between listing of tillage equipment (type and date of use), chemical and nutrient application equipment, and listed method of application. However, it quickly became clear that various inconsistent interpretations and reporting guidelines were involved, particularly with regard to the listing (inclusion or not) of equipment for chemical and nutrient application (mostly not listed). Consequently, it was determined to exclude any reported application equipment for chemicals and nutrients and instead, define and include a separate APEX operation for each method of application. Those newly defined APEX operations were defined to have appropriate soil disturbing properties, e.g., the operation to broadcast and incorporate manure would have soil disturbing properties similar to a light disking. There may be a few cases where the samples already had such a light disking and in those cases the soil disturbance may be slightly exaggerated for the sample. In addition, replicate application operations were defined for all cases where the team added fertilizer or manure so that those additions could be clearly tracked and analyzed throughout the simulation process (also allowing easy decisions of inclusion or exclusion of those extra applications for scenario analysis). Table 4-2 shows the defined machines or operations for fertilizer and pesticide application. Machines were defined similarly for pesticides.

### 6. Beaters, Choppers Mowers, Rakes, Windrowers, Etc.

Due to the way that APEX simulates harvest and/or biomass removal, it was necessary to check carefully the consistency between the listed machines used for forage and grain harvest and the attributes of those machines in the APEX Operation definition table. The baler has generally been chosen by APEX modelers as the single forage harvest machine with a non-zero "override harvest index" coefficients so as to remove the biomass. Mowers or windrowers were reported in the survey data for not only forage harvest, but also for a pre-combine operation on grain crops, presumably to enable drying of the crop. If those operations had been specified to have a cutting height, then all biomass above that height would have been converted to dead residue and so not be available for the subsequent baler or combine. One approach to this issue would have been set the APEX coefficients for those machines so as to not interact with the biomass of the growing crop. However, there were other samples where these machines were used, e.g., cover crop, without a subsequent harvest operation. Also, since those machines was neither interacting with the growing crop nor disturbing the soil surface, they would have no impact on simulated environmental outcomes. The decision was therefore to exclude those operations from the simulation. Consequently, the grain and forage crop samples were checked only for the presence of a combine or baler harvest operation (note the exception for grazing explained in other sections and in Chapter 7).

Additional complications occur with grass seed production in places such as Oregon. In some cases the grass may be grazed or harvested as hay early in the season, then allowed to reach maturity so seed can be harvested, and then finally, the remaining residue is grazed or harvested as hay or straw. Careful editing of the listed operations was required to insure that biomass removals were properly reflected in the simulations.

Machine number 149 "Rotary Mower-cutter, Chopper, Bush Hog" was reported used in a variety of very different situations, ranging from harvesting of a forage crop as silage to chopping of cotton stalks after harvest to cutting of wheat stubble after a combine but before a baler. For the APEX machine definition file, a machine used for harvesting a forage crop requires different coefficients than a machine used for mowing or shredding stalks. In the APEX definition file, the coefficients for machine number #149 were set for shredding, chopping, and mowing, and not for harvesting. In all situations where machine number 149 was used for a harvesting purpose (e.g., a silage chopper), it was replaced with machine number 204 "Silage chopper".

### 7. Harvest of Vegetable and Other Specialty Crops

Table 4-3 shows the list of operations were defined and used in place of the reported harvest operation (usually a hand harvest, but in some cases nothing was reported). Each of these machines is defined in terms of soil disturbing attributes and harvest efficiency for the specific crop noted.

For tobacco, the variety of hand harvest, multi-pass mechanical, priming aid, etc., were all changed to a once over mechanical harvest for consistency.

## 8. Stubble Harvest

As explained above, as the APEX harvest operation passes through the field, all of the biomass above the cutting height that is not removed as harvested yield is converted from standing live plant material to flat dead residue (quantity of biomass converted to flat dead residue depends on the cutting height and proportion of biomass not removed by the harvest). Any subsequent harvest operations can only remove any remaining standing live plant material, i.e., not the portion converted to dead residue by the previous operation. So even though the cutting height has no effect on the harvest quantity, which is a fixed portion of harvestable yield, the cutting height does convert some portion of total above ground biomass to dead residue (or below ground biomass to dead in the case of root crops). To simulate grain harvest followed by stubble or straw harvest it was necessary to define an alternate grain combine with a zero cutting height. The zero cutting height caused APEX to not cut the biomass, i.e., not convert it from standing live to flat dead biomass. The same thing could have been accomplished by setting the cutting height higher than the crop height. This alternate combine removes the specified portion of harvestable biomass but does not convert the un-removed biomass to flat dead residue. Then it was necessary to define a single machine for the stubble harvest, a baler, with an “override harvest index” value set at the proportion of remaining biomass to be removed from the field. But in some cases a mower and/or rake preceded or followed the combine, implying an even lower cut and therefore more straw removed by the subsequent baler operation. For those cases it was necessary to define an alternate baler with an appropriately larger “override harvest index”. In all cases, other harvest machines, such as mower, rake, or windrower, had neither a cutting height nor a biomass removal coefficient. These newly defined machines are listed in Table 4-3.

The following edits were made in the survey data Field Operation tables:

- If no straw harvest, then the grain combine was used as originally specified.

- If straw harvest directly after the grain combine with no additional mowing, then “#432 Hrv Combine for Straw” was used, followed by “#433 Baler Med Residue”, “override harvest index” set at 0.60, cutting height of 125 mm.

- If a mower was used after the combine, then “#432 Hrv Combine for Straw” was used, followed by “#434 Baler Hi Residue”, “override harvest index” set at 0.8, and cutting height of 125 mm.

- If the crop was Peanuts or Soybeans, then the“#432 Hrv Combine for Straw” was used, followed by “#449 Baler Low Residue”, “override harvest index” set at 0.4, and cutting height of 125 mm.

Note that there were residue removal operations (balers, rakes, etc.) and grazing operations for listed for some crops where typically there would not be sufficient residues for such a thing to be practical. In those cases, the operations were used as reported and setup as specified here, but the actual removal of biomass of the specified crop may be very small. It is likely that the reported operations were targeting weed biomass. However, in Wisconsin, several samples reported the baling of soybean residue, presumably for bedding material, and in the Southeast, there were a few instances of baling or grazing of peanut vines. Since the peanut harvest targets below ground biomass and the baling or grazing targets above ground biomass, the baler removed the specified portion of the above ground biomass, regardless of the yield of peanuts. Similarly was the simulation outcome for cases of sugar beet harvest followed by cattle grazing of the beet tops.

## 9. Non-harvested Cover Crops

In APEX a special operation is required to terminate the growth of each crop at the end of the crop's life. The Run Builder program inserted these operations automatically, based generally on the harvest operations. For crops commonly grown as cover crops special rules were developed so that Run Builder could insert the termination operation even if no harvest. However, a few samples used a mower (such as #149) at the end of the growing season for a crop not commonly grown as a cover crop (e.g., corn), but with no other harvest operations or reported yield. To adequately simulate this it was necessary to define a new machine, #466 "Mow Chop Kill noharv", which converts standing live residue to flat dead residue, and triggers the insertion of the termination operation, without removing biomass from the field (Table 4-3).

## 10. Other Harvest Machine Issues

In this section a few other harvest operation issues and edits are discussed.

For potatoes and sugar beets a mechanical beater or topper is often used to kill and detach the above ground vegetation prior to harvest. The machines listed for these operations were also used for mowing/chopping operations on other crops and so had a cutting height. The effect of the cutting height was to convert the live biomass to dead residue resulting in the harvest operation having a yield of zero. Rather than change the cutting height on the machines, we chose to exclude them from the beet and potato systems since they really had no model effect on soil disturbance or biomass fate. The following machines all had their tillage depth (cutting height) values set equal to zero so that the subsequent harvest operations would be effective:

202 Flail Shredder (height a problem if used for potato vines or beet tops prior to harvest)
203 Rotary Shredder "
231 Beater – beet harvest
236 Thinner Beet Mechanical Electric
237 Thinner Beet Mechanical Random
239 Topper – beet

<u>Cotton.</u> Every sample needed to have either a Stripper or a Picker as the main harvest machine. The Picker or Stripper can be followed by a Rood or Gleaner, however, if the Rood or Gleaner was the only machine, then a Stripper or Picker was added. In the APEX Operations definition table, the Picker and Strippers had their coefficients set to harvest the biomass, while the Rood and Gleaners were treated as described above for the various forage rakes, windrowers, wagons, etc. Some samples reported use of Boll Buggies and most, but not all, the use of Module Builders. However, these were routinely marked for exclusion since they don't interact with the biomass or disturb the soil.

<u>Peanuts</u>. For peanuts the peanut combine was designated as the harvest machine removing biomass and so all samples were checked for its inclusion. Typically the samples reported use of a digger with a shaker or inverter followed by a combine. Note the discussion regarding vine harvest in the last paragraph of the previous section.

Rice. A few samples reported production of a second rice harvest in a single year (rattoon production). However, the APEX model is not set up to simulate two grain harvests that way, so the second harvest was marked for exclusion.

Tobacco. There was a wide variation in listing of harvest machines for tobacco. Cases of hand harvest were changed to once over machine harvest so that the biomass removal would be done correctly.

## 11. In-Row Sub-Soiler for Notill Planter

A number of samples had two planters listed for one crop, often on the same day, or within a few weeks of each other, with the first planter having a deep depth (10 – 16 inches) and the second planter having either zero or very shallow depth. Also, the second planter was usually a Notill planter. In the Respondent Booklet in parentheses under machine "113 No-till, Minimum Till" Planter was listed a "Ripper Planter". After consulting the original survey forms it was determined that these situations could best be handled by excluding one of the planters and replacing the other with a newly defined machine "117 No-till Planter In-Row Sub-Soiler" (Table 4-3). This new machine has the same APEX coefficients as "8 Sub-soiler" with the exceptions that the STIR value and the mixing efficiency are reduced by 50 percent (to values of 22.5 and 12). A count shows 54 instances of this technology.

## 12. Fall Tillage in Year Prior to First Simulated Year

Since the survey respondents were asked to record all of the field operations pertaining to each crop year reported, it was common for tillage, fertilizer, and manure operations for the crop performed in the preceding fall to be recorded. For instance if the crop years for 2001, 2002, and 2003 were corn, corn, soybeans, the survey might report fall tillage in 2000 for the 2001 crop year. If this data were not edited, in the APEX simulation there would be four years of cropping sequence with every fourth year having only those few fall tillage operations reported for 2000. Since each operation had recorded both the crop year and the calendar year in which the operation occurred the standard edit was to change the calendar year for the fall 2000 operations to 2003, so that as the three-year sequence of crops was repeated over time, the fall operations for the 2001 crop would consistently occur in the fall of the previous year simulated. However, in some cases, other adjustments were required. One such adjustment was where the month and or day of that fall tillage operation reported for 2000 was slightly earlier than the month and or day reported for the 2003 harvest; this is discussed in the next section. Another situation sometimes seen was where the tillage operations for the 2001 crop year performed in the fall of 2000 were very inconsistent with the reported 2003 crop, such as summer fallow or idle cultivation performed during the May – August period. In most cases those situations could be fixed by adding operations to fill out completely a 2000 crop year, transforming the sample into a four-year rotation (discussed two sections below). In other cases a 4$^{th}$ year was added to the rotation as described in the previous chapter.

## 13. Tillage Overlap with Harvest of Preceding Crop

The order of data reporting was to first fill out the form for the most recent crop year and then work backwards. There were some cases where it seemed apparent that after the data sheet for the most recent year was filled out and set aside, that data was not checked for consistency with data then entered for the earlier years. As an example, in some cases the fall tillage of the most recent year was reported as preceding the harvest of the next most recent year. This most often occurred with winter wheat where fall tillage and planting was listed as occurring before the harvest of the preceding crop. This situation seemed to be more common in the 2004 data where the actual day of operation was listed than in the 2003 data that included only the month of operation. However, many of the 2004 cases involved overlaps of 10 days or less. Where the overlap was less than three weeks, the difference was generally split, moving the harvest forward and the first tillage backwards in time. For longer cases, the data was checked more carefully, including the planned rotation and the tillage, planting, and harvesting dates of the other crop years in the sample.

Across the samples in general, it appeared that the harvest dates were more variable from year to year within a sample than were the planting dates. For example, a sample having 2 or 3 years of corn might show as much as six weeks difference between the earliest and latest reported corn harvest dates. Those differences were likely due to weather, and as explained in the "Day Specification" section above, the Heat Unit scheduling option of APEX will adjust the operation dates according to weather events. Where the overlap was more than 5 or 6 weeks the samples were either marked as unusable (very few) or if adjustments to the schedule could not feasibly be made, the rotation was extended to four years.

A similar issue also occurred in some cases for a spring planted crop following winter wheat, where the survey would list the tillage and planting of the next crop prior to the harvest of the preceding winter wheat crop. For example, winter wheat harvested late in June, but soybeans planted in May or early June.

## 14. Seeding Rates

The CEAP survey collected seeding rate data. However, that data was reported in a variety of units, such as cwt, lbs, bushels, entities, 50-lb bags, seeds per foot of row (row width was not reported), etc. An initial attempt was made to convert the reported seeding rates to the required plant population values needed for the APEX simulations. The results were very inconsistent, due to unknown values such as seed size, germination rates, seedling mortality, etc. The team determined that for the majority of the samples, the seeding rate is not part of any conservation plan. Consequently, it was determined that use of the inconsistently reported seeding rate data would have introduced excessive and unwarranted variation in the APEX plant population values which would have then resulted in similar variation in biomass production and environmental outcomes.

Alfalfa is probably the best example of the difficulty of translating seeding rates into plant population values. For Alfalfa the two points on the APEX growth curve are 22 plants at 50% and 40 plants at 70%. An agronomic reference (Heath, Metcalfe and Barnes) state that "A goal of 135 – 270 plants/$m^2$ is desirable for maximizing seeding year yields and assuring good stands for extended periods. Since only 20-50% of the planted seed produce plants with present establishment practices, high seeding rates are recommended." Assuming 30% of planted seed survive in the 1$^{st}$ year's stand, the CEAP seeding rate data imply about 284 plants/$m^2$.

The final decision was to use the APEX model default plant population values. Consequently, the seeding rate data in the CEAP surveys was not edited nor used.

In the APEX model for each crop there is an S-curve function defined that relates plant population to proportion of Maximum Leaf Area Index. For each crop the APEX Crops table includes two points on the S-curve. For example, for winter wheat the first point has 125 plants per square meter associated with 60 percent of Maximum Leaf Area and the second point has 250 plants per square meter associated with 95 percent of Maximum Leaf Area (MLAI). At the upper end of the APEX S-curve, where the Leaf Area Index approaches or equals 1, the model biomass production and other outputs becomes insensitive to increasing plant population. Therefore specifying a very high plant population, even a multiple of the 90% MLAI, simply results in maximum leaf area index and biomass production not limited in that regard, but still subject to other biological limits specified in the crop data set. Therefore, APEX was augmented to set the plant population at the 95% point on that S-curve if plant population was not in the data set.

## Chapter 5. FERTILIZER

The database table "***commfertilizer***" holds the survey fertilizer application data. Each row of data is for one application event. For each instance of a crop in a year in a sample there may be multiple applications, with some of the applications occurring in the previous calendar year. The data involved the following complications or issues that were addressed:

1) The quantity of N applied was often insufficient to produce a crop, even if an obvious unit or reporting error was not present;

2) For the 2003 survey, the year was recorded as the crop year rather than the calendar year, leading to some cases where it appeared that fall applications for a given crop that actually happened in the previous fall, appear in the report after harvest of the crop;

3) For the 2003 survey, only the year and month of fertilizer applications was recorded, not the day;

4) For the 2003 survey, a "time" of application was recorded, either "Fall", Spring Pre-Plant", "At Plant", and "After Plant" and in some cases these designations seemed to conflict with either the month of application of the planting date of the crop;

5) A method of application (see Table 5-2) was recorded, which in some cases conflicted with the other listed field operations;

6) The standard percent analysis formula (grade) for more than one-half of the application events could not be determined, due in many cases to apparent custom mixtures or blends of materials containing N, P, and K; and

7) Other.

### 1. Application Year versus Crop Year for 2003 Data

Since the original '***commfertilizer***' table for the 2003 survey data had only a crop year variable, an additional variable was added for "fertilizer year", corresponding to the calendar year when the fertilizer was applied. The data was edited, to some extent with automated queries, but mostly with manual edits, to set the calendar year variable to one year earlier than the crop year for applications made in the fall for a crop harvested during the following year. After the adjustments described for issue 1) were applied, 2,895 (22.6%) of the 12,814 total fertilizer application events occurred in the months of August to December.

## 2. Day and Method of Application

Since the 2003 samples lacked the day component of the application date, rules were developed for specifying the date (Table 5-1). For "Fall" applications of fertilizer, the last day of the month was chosen except for Winter Wheat, where a date 7 days prior to planting, was assigned. All "Pre-Plant" applications were set to occur 7 days prior to planting and all "After" applications were set to occur 21 days after planting, except for Winter Wheat, in which case the "After" applications were on the 15$^{th}$ day of the month in which the fertilizer was applied. The explanation of the determination of the planting dates is given in other documentation.

The survey reported fertilizer applied by one of eight methods. Rather than depend on the presence of the appropriate application machine in the "***fieldoperations***" table part of the survey, specific operations were developed for each method as shown, with their required APEX coefficient (Table 5-2). The standard APEX operation for Anhydrous Ammonia Application was assigned for all applications that were knifed or injected in (only a portion of those could be specifically identified as Anhydrous Ammonia material as explained in the next section). The "Broadcast Incorporated" operation was assumed to have the same soil disturbance effect as a light disking.

## 3. Fertilizer Grade

An initial attempt was made to assign the fertilizer from every application event to a specific common fertilizer composition, e.g., 18-46-0, and to calculate a total quantity applied of the composite fertilizer material. Such an assignment would have allowed a very precise tracing of the proportion of the applied N material that was in Ammonium or Anhydrous or other forms. That would have in turn allowed analysis of the option of changing form as a conservation practice. However, the assignment could not be made in about one-half of the cases, mostly due to apparent use of custom mixes or the reporting in a single application of multiple materials. This was likely due to the combined reporting of a mix of several composite materials. Consequently, it was determined to isolate the application events that appeared to be Anhydrous Ammonia and apply that material in that form, while applying all other materials in elemental N and P forms. All applications including N where the percent analysis N was between 80 and 84 while P and K were zero were assigned to Anhydrous Ammonia. Note that survey values are in lbs/acre and P is in terms of P2O5 while for APEX quantities are kg/ha and P is in terms of elemental P, so conversions are performed in the program. For Anhydrous Ammonia, the quantity applied is equal to reported lbs of N divided by 0.82.

## 4. Rounding up of Small Values

It was found that excessively small fertilizer application values were rounding to zero in APEX and causing some interpretation issues in the results. Consequently, 131 application values for N that were less than 0.5 lbs/acre were rounded up to 1.0 lbs/acre. Similarly for a small number of P applications.

## 5. Reconciling Low and Missing Fertilizer Values

Many samples had no fertilizer applications, N fertilizer levels so low as to be obviously inconsistent with crop yields, or apparent inconsistency between reported composite fertilizer formulation, total applied quantity, and/or actual lbs of nutrients applied. Other samples had apparent inconsistent use of quantity units and/or calculations at some level prior to data entry to the computer files, e.g., conversion of fertilizer concentration in irrigation water. In a few cases, examination of the original hard copies of the survey instruments indicated that the data was initially reported correctly, but then changed to an erroneous state at a later editing. In other cases it appeared that simple data entry errors had occurred. Some examples of these issues with the N fertilizer data included the following:

- A large number of actual nutrient applications of 18 lbs of N, 46 lbs of P2O5, and 0 lbs of K2O for cases of corn yields of over 150 bushels, or 32 lbs or 82 lbs of N with 0 lbs of P205 and K20 (note that Diammonium Phosphate, Ammonium Nitrate, and Anhydrous Ammonia have N-p205-K20 nutrient concentrations of 18-46-0, 32-0-0, and 82-0-0, respectively);

- Data input errors such as for a sample reporting three years of corn, where for the first two years 127.6 lbs of N is applied, but in the third year only 12.7 lbs;

- Cases where the first two years might report actual lbs of N, P, and K as 160, 50, and 0 and then the third year reports 0, 160, and 50; and

- Samples with apparent calculation errors, e.g., with irrigation application, where the values seemed to be off by an order of magnitude, such as 1760 lbs of N when 176 lbs (or something close to that) would be more reasonable.

There were many other cases where the values were just too low to be reasonable, and where a straightforward explanation of the error, such as for one of the above cases, was not possible to derive. Since the reported CEAP crop rotation and management are repeated over a 47 year simulation, for most samples estimated crop yields decrease over the duration of the simulation if N application is not at least equal to crop uptake and removal. Also, estimates of nutrient losses from the soil profile will be lower, resulting in a smaller apparent benefit from conservation practices.

There were other situations where the fertilizer reported for the three surveyed years may have been correctly reported, yet too low to sustain yields over a 47 year simulation. For example, one Colorado sample with irrigated corn reported nearly 200 bushels per acre for two years, and then another crop in the third year, with only a minimal amount of starter fertilizer applied at planting each year. A check of the NRI data for this sample showed that previous to the two years of corn, the field had been in irrigated Alfalfa hay for at least 4 years, which would have possibly generated sufficient carryover nitrogen to produce those corn yields. Since the CEAP survey did not collect information on management prior to the three year survey yield, the fertilizer had to be supplemented as explained in Chapter 5.

The fertilizer evaluation and adjustment procedures are based on completed APEX simulations. Consequently, as of March 2009, only the adjustments for the Upper Mississippi River Basin (UMRB) can be discussed. However, similar procedures will be applied to all regions.

**Nitrogen in the UMRB**

In the NRI-CEAP Cropland Survey, farm operators were asked to provide information on nitrogen application rates for all crops grown on the sample field for the previous 3 years. Preliminary APEX model runs revealed, however, that the reported nitrogen fertilizer levels were often insufficient to meet agronomic needs over the 47 years in the model simulation. This not only resulted in crop yields significantly below those reported in the survey but also produced inflated estimates of soil erosion and sediment loss because of the lack of crop growth and canopy cover that normally protects the soil from the forces of wind and water during the crop growing period. To obtain appropriate estimates of the effects of conservation practices, it was necessary to add additional nitrogen when the reported levels were insufficient to support reasonable crop yields in model simulations.

Overall, about half of the non-legume crops in the UMRB had inadequate amounts of nitrogen reported to support crop yields (Table 5-3). Only a small amount of additional nitrogen was needed for some samples, whereas nearly all the nitrogen required was added in other samples. Some of the cases were determined to be data entry errors, which were corrected when the intended response was clear; such errors could not be corrected in all cases. In a few cases, the explanation could be that residual soil fertility levels had been built up in years prior to the survey period and only modest amounts of nitrogen were added during the years reported in the survey. Nitrogen applications during drought years or other conditions indicative of impending crop failures would also be expected to be less than agronomic requirements.

The following discussion outlines the procedure used to add sufficient nitrogen for adequate growth. The goal of the adjustment procedure was to raise the nutrient application rates of questionable reports to levels similar to those that appear to supply an adequate amount for agronomic production. The auto-fertilization option in the APEX model supplies plant-available nitrogen automatically when the plant requires nitrogen that is not available from other sources. The result obtained using auto-fertilization is essentially the optimal yield and nitrogen rate specific to the crop grown in the reported rotation under the conditions specific to management activities, conservation practices, weather, and soil properties for a sample point. It accounts for all sources of plant-available nitrogen associated with the specific crop at the specific sample point—the reported amount of nitrogen fertilizer or manure applied, the time of application, the method of application, atmospheric deposition of plant available nitrogen, and soil nitrogen, which includes nitrogen from previously planted legume crops and any plant-available nitrogen from decomposition of organic material and crop residue.

Soil-specific “probable yields” for each crop in each sample were obtained from the soil survey database (USDA-NRCS 1994). Crop yields simulated in the current condition scenario that were within 90% of the soil survey database yields were considered to be probable yields.

Rates of total nitrogen applied to the set of probable yields were compared with the rates supplied to that crop using auto-fertilization. After grouping by crop (or crop groups when sample size was insufficient), a statistical test was used to determine the percent rate difference between the auto-fertilization rate and the rate supplied to achieve the probable yield. The amount of additional nitrogen added to points with questionable reported rates was determined by reducing the auto-fertilization application rate for that crop by the average percent difference with the “probable rate” by crop or crop group. The average difference between auto-fertilized rate and the probable rate was 18 percent for corn and 33 percent for wheat. A pooled average of 24 percent was obtained for the other crop groups. The adjustment procedure was conservative in guarding against over application, and average adjusted nitrogen rates were lower than reported rates of unadjusted crops.

The auto-fertilization procedure was used to identify the points that would need additional nitrogen applied and the amount needed to obtain an optimal yield. The amount of nitrogen added was adjusted to support a yield that was lower than optimal yield but represented a reasonable or probable yield for the given conditions.

The nitrogen adjustment was made for each crop by applying a percentage to all reported applications. If there were no nitrogen applications, a single nitrogen application was added in the spring before planting. The effect of these procedures was to add sufficient nitrogen to samples needing adjustment to bring the yield up to the same percent of potential yield as observed in the samples not needing adjustment. To maintain integrity of the database, the original survey application events were preserved. Replicate events were inserted for the added fertilizer. This allowed tracking of the added fertilizer in both the input and output data sets. For example, if a crop in a sample originally had 3 applications with 50, 10 and 50 lbs of N, and the adjustment procedure called for adding 75 more lbs of N, three additional applications were added having the same date and method as the original, with rates of 34.1, 6.8, and 34.1 lbs, respectively.

**Phosphorus**

A similar adjustment was made for low phosphorus applications, including acres that did not receive phosphorus applications according to the NRI-CEAP Cropland Survey. In the APEX model, lack of sufficient phosphorus does not inhibit potential crop growth. Nevertheless, a minimum amount of phosphorus is required agronomically to grow a crop. In actual practice, phosphorus applications would be made every few years when soil tests indicated that the level of soil phosphorus has fallen below a critical level for good yield performance. In order to realistically simulate crop growth over the 47-year simulation, it was necessary to add phosphorus for crops that did not receive adequate amounts based on the survey.

The first step in this phosphorus fertilizer adjustment process was to determine the crop harvest removal levels of phosphorus for each crop in each crop year of each sample, based on model simulation results. That level of phosphorus was compared to the application of phosphorus to determine if application rates were too low. If rates were less than the uptake and removal of phosphorus at harvest, additional phosphorus was added at the amount needed to bring the total annual phosphorus application up to the amount removed with the crop at harvest under the assumption that farmers would realistically apply at least as much phosphorus on average as was being removed from the field.

Three different cases of low or zero phosphorus application were addressed. (1) If no phosphorus was applied from either manure or fertilizer, a single application equal to harvest removal was added at planting time as a surface broadcast. (2) If only manure phosphorus was reported with no fertilizer, a single application of commercial phosphorus was made at planting time, surface broadcast. If the amount of manure phosphorus applied was adequate for crop growth, no additional phosphorus was applied. (3) If one or more commercial fertilizers were applied, the required additional phosphorus was spread proportionally across the reported phosphorus fertilizer applications, thus preserving the reported timing and methods.

In summary, 25.5 million acres (43.8 percent of UMRB cultivated cropland) received a phosphorus adjustment (Table 5-4). The median adjustment was 8.7 pounds per acre per year; 25 percent of the acres required less than 3.1 pounds per acre per year and 25 percent required more than 26.7 pounds per acre per year.. Of the 10.3 million acres that received manure, 3.8 million acres had low levels of manure application and required the application of additional phosphorus fertilizer to meet crop growth requirements.

## 6. Other

In the 2003 CEAP ***"fieldoperations"*** table there were only seven instances of use of soil incorporating fertilizer application equipment, and those were distributed among four samples. In the ***"comfertilizer"*** table there were 14,845 instances of fertilizer application of which 3,060 were "broadcast with ground incorporation", "2,507 are knifed or injected in", and 1,437 were "banded or side dressed in or over the row" (distinct from the 1,306 in seed furrow cases). A brief sample of data shows many cases where the date of fertilizer application, whether or not it was incorporated or left on the surface, occurred several months prior to any other tillage operation. Consequently, the decision was made to define specific operations for each method, and have those operations do any required action, such as incorporation and mixing of surface residue. This was in place of the option of adding an additional tillage operation for incorporation, or changing reported dates so that existing tillage operations appropriately followed fertilizer applications having incorporation (see Table 5-2).

In the 2003 survey the crop year and the month of application were listed, along with the season of application. In many cases, as an example, the crop year was 2002, the crop was corn with all the field operations occurring in 2002. But the month of fertilizer application was 10 or 11. So the fertilizer was actually applied in 2001. However, there are approximately 330 cases where the time of application is listed was “Fall”, but the month of application is between January and July. Those cases, plus other cases of inconsistency with dates and application method were analyzed and a corrective edit applied.

# Chapter 6. ANIMAL MANURE

## 1. Representation of Animal Waste Application in APEX

To achieve consistent APEX representation of the manure application events, some transformations were required in both the Application Event data and the representation of the composite manure material in the APEX fertilizer definition table.

Simulating manure application with APEX requires data entry in two APEX input data tables. First, each “unique composite manure material” must be represented as a row in the APEX Fertilizer definition table. Second, each manure application event must have an entry in the APEX Field Operations table. The Field Operations table includes a manure application event (data row) specifying the quantity of composite manure material and date of application, method of application, and machine used for each application event reported in the CEAP survey data. Applications in APEX are specified in terms of kg/hectare of composite material and are linked to a specific ID (row) in the Fertilizer table (the survey data and all analysis of the data are in English quantity units, however, APEX operates in metric units and data are converted with the Run Builder program as it builds the input data sets). However, as explained below the mass of composite material was re-specified to include only the N, P, K, and C elements, eliminating, water and other inert elements.

The data required in the APEX Fertilizer definition table for each unique composite manure material includes the following:

- Assigned unique fertilizer material ID
- Assigned name
- Proportion of material as mineral N
- Proportion of material as mineral P
- Proportion of material as organic N
- Proportion of material as organic P
- Proportion of the mineral N in ammonia form
- Proportion of material as organic C
- Proportion of material as mineral K (default is zero in current version)

APEX allows the specification of fertilizer and other nutrient materials in a variety of formats such as "as excreted wet from animal", "dry weight basis", "elemental nutrient basis", etc. However, for each application event in the Field Operations table, the quantity measurement unit must be consistent with the associated nutrient content definition row for the material in the Fertilizer definition table.

There are some implications to certain material specifications. For example, one CEAP sample reported a very dilute liquid animal waste material applied at a rate of 330 tons per acre per year with an irrigation system. In that case, the proportions of material as mineral N and organic N were only 0.00005 and 0.00003, resulting in an annual application rate of 52.8 lbs of N, and an "irrigation" rate of about 3 acre-inches. If that application were specified and simulated directly as reported with APEX, the simulation results would be incorrect for two reasons. First, the APEX model assigns a soil erosion reduction value to the inert material, without considering whether the inert material is water or other materials. Secondly, the portion of the inert material that is water is not considered in the APEX soil water balance accounting. Consequently, for the CEAP analysis, manure applications were specified in terms of elemental N, P, and C, with other portions of the composite manure materials ignored. In the entire national survey there were only a few manure application events where the implied irrigation water amounted to one-half inch or more, so water content of the manure was ignored. Also, in cases such as these, irrigation water applied with the manure is normally a minor component of the water budget.

Three general steps were used to convert the manure data to a form that excluded consideration of inert materials:

1) Calculate the total nutrient proportion of the material (NPKC Fraction) as the sum of the mineral and organic proportions of N and P plus the organic C;

2) For each original composite manure row re-define the nutrient proportion in the APEX fertilizer definition table by dividing them by the NPKC Fraction; and

3) For each application event, assign the appropriate revised manure ID from the APEX fertilizer definition table and multiply the application event quantity by the corresponding NPKC proportion.

As an example, suppose that a very bulky manure material contained 1.0, 1.0, 1, 1.0, and 3.0 percent Organic N, Mineral N, Organic P, Mineral P, and Organic C, respectively. Then "NPKC Fraction" would be 7 percent. The new APEX fertilizer coefficients would be 0.1429 (e.g., 1/7) for each of the Organic and Mineral N and P components and 0.4286 (3/7) for the Organic C component. An application event of 8 tons of the original material would now be entered in the Field Operation table with an amount of 0.56 tons (8*0.07). It follows that for this application event the organic N application is 160 lbs, which is either 1 percent of 8 tons of the original material or 14.29 percent of 0.56 tons of the total nutrient material only.

Note that in a similar fashion to steps 1) to 3) above, the water content of the manure could also be applied as a separate irrigation application, if desired, but was not done for the CEAP applications, since irrigation is handled with the auto-irrigate routines.

The major tasks for setting up the simulations for samples with manure were the following:

1) Preparing the "Application Events" data table for the Run Builder program that writes the APEX "Field Operations" table.

2) Augmenting and formatting the supplemental “Manure Coefficients” table (see Table 6-1 and supporting documentation, “Manure Nutrient Content for CEAP Questionnaires”) with columns corresponding to the data requirements of the APEX fertilizer definition table and adding these rows to the APEX fertilizer definition table.

3) Augmenting the APEX fertilizer definition table with rows defining additional unique composite manure materials beyond the basic 43 from the “Manure Coefficients” table (Table 6-1) (requirements for these composite material definitions is explained later in the section).

4) Calculating application quantities for approximately 200 cases where neither the quantity of nutrients nor the quantity of composite material was reported.

## 2. Manure Coefficients for CEAP Analysis

Much of the national assessment portion of the Conservation Effects Assessment Project (CEAP) depends on the results of a survey questionnaire completed for cropland fields corresponding to sample points of the National Resource Inventory. A part of the questionnaire deals with manure applications to the field, if any. The surveys were conducted by the National Agricultural Statistical Service (NASS).

Ideally the operator would have had an analysis of the manure applied, and that with subsequent questions dealing with the amount of manure applied per acre (such as tons, gallons, etc) and application methodology would provide a fairly good picture of the actual nutrients applied to the field. Unfortunately either the land owner didn’t have a manure analysis readily at hand, or none has actually been made. For whatever reason, the analysis was not recorded on many questionnaires. In these cases some other means of determining manure nutrients applied must be formulated. For the discussion that follows, we assumed that the operator didn’t have a manure analysis. This discussion and the spreadsheet it supports was originally authored in the 2004 and 2005 time frame and revised with better information in the fall of 2007.

Information available from the survey/questionnaire included the amount of manure applied per acre as already mentioned, the consistency of the manure, application method, and a question about the type of storage used. In addition, there was a question as to whether the manure was composted, and a question whether bedding was included with the manure. Unfortunately the latter two pieces of information tend to confuse the issue rather than help – and they are dealt with when appropriate.

The application method is important because of ammonia nitrogen losses during the application process. This loss takes place *after* the manure is collected and stored/treated and is usually handled as a percentage loss of the nitrogen at the time the manure is applied. Table 6-2 estimates the amount of nitrogen lost with various application strategies.

The original Table 6-2 values were themselves estimates based on material from NRCS, The Ohio State University, and the University of Missouri. The term ‘incorporation’ is not defined in the NASS questionnaire, so there is no reason to expect consistency in the answers as to what is incorporated. Most agree if the manure is not incorporated within hours to days, much of the advantage of incorporation is lost.

An interesting paper, Agronomy Facts 55, "Estimating Manure Application Rates," College of Agricultural Science, Pennsylvania State University, further distinguishes between the nitrogen availability for poultry manure as compared to all other manure. To illustrate, the paper shows for spring applied poultry litter and incorporated the same day, 75 percent of the N is available. If incorporation is delayed seven days or longer, the availability of N is only 15 percent. With other manure, the paper shows 50 percent of the N available if incorporated the first day, and 20 percent of the N available if incorporated after seven or more days. The differences are a result of much of the nitrogen in poultry manure being in the ammonia form as compared to other manure, and ammonia is volatilized when not incorporated. The bottom line seems to be the poultry litter when not incorporated loses more Nitrogen than does other manure.

On the other hand, there is currently a body of information that suggests the values shown in Table 6-2 for dry broadcast (solids) are too high. A paper from Manitoba and a paper from Purdue (Table 4 in Agronomy Guide, AY 277, Purdue University Cooperative Extension, Purdue) suggests unincorporated losses of N with dry broadcast manure at 15 – 35 percent, with no explanation of the ranges. In addition, the Purdue reference and one from Iowa State suggests both dry and liquid broadcast manures, if incorporated, had nitrogen losses of less than 5 percent.

In light of the more recent Canadian and American research, it might be concluded the NRCS in Chapter 11 of the Agricultural Waste Management Handbook has over-estimated the losses of unincorporated manure with the exception of poultry litter, and with poultry litter they have under estimated the nitrogen losses. However, since incorporation in the survey isn't defined as discussed above, incorporation could be hours or days after broadcast, so the line between incorporated and unincorporated manure becomes blurred. The values suggested by Iowa State for incorporated manure are similar to what they suggest for injected manure, which would imply immediate incorporation, which is unlikely. With all this in mind, we've concluded the values in Table 6-2 are more representative of what respondents would consider incorporated and unincorporated broadcast manure, than are those suggested by Iowa State and the other American literature. It is our understanding Table 6-2 losses are estimated by the EPIC/APEX model, but the discussion above and Table 6-2 are included to fully document the manure application coefficients.

**Indirect Estimate of Manure Nutrient Content**

Assuming we had no information about the nutrient content of the specific manure applied, the following strategy was used to estimate nitrogen and phosphorus content of the manure before application losses as discussed above. What we do have from the survey is the source of the manure in broad general categories such as beef, dairy, and swine, but also includes bio-solids, 'other,' and 'don't know.' We know manure characteristics vary considerably within broad categories as the animal goes through its life cycle, however the information in the survey does not lend themselves to that fine of detail. The survey also records the appropriate units for the manure application quantity which generally speaks to the consistency of the manure, and finally a single question that describes the manure storage/treatment system grouped by manure consistency.

An EXCEL spreadsheet was developed with the manure storage/treatment options displayed against the broad sources of manure. The spreadsheet is summarized as Table 6-3, "N and P values for manure from the basic CEAP systems." Nutrients in the table are recorded as Total Nitrogen or Total Phosphorus. $P_2O_5$ values were converted to TP, and TKN and TN values were assumed equal because manure contains very little NO+ forms. The values on the spreadsheet are in pounds of N or P per ton of manure. Liquid and slurry manure are more commonly reported as pounds per 1000 gallons or pounds per acre inch, but we will leave it to the user of Table 6-3 to make necessary unit conversions assuming 60 pounds per cu ft.

Over the years there have been hundreds if not thousands of site specific studies providing data on the composition of manure at the time of application. Some have attempted to capture the data in the form of 'national' level data bases. Two that we chose to use with the 2005 version of the spreadsheet were the "Livestock Manure Characterization Values From North Carolina Database," assembled by Dr. James Barker, and the "As Removed Manure Production and Characteristics," included with the recent revision of ASABE Standard D384.2, "Manure Production and Characteristics." The NC State database as originally used was a massive file converted to paper by SCS (NRCS) in the early 1990s. In recent times the data is now available on-line at http://www.bae.ncsu.edu/programs/extension/manure/awm/program/barker/a&pmp&c/table_of_content.htm. Some of the values have changed from the original, and additional data added.

The NC State data base is dated, but still cited in recent publications. The EXCEL spreadsheet was altered to reflect the web based data set. The as-removed values from ASABE were assembled by Dr. Jeff Lorimer of Iowa State University. On the original spreadsheet for each nutrient, we listed ASABE and NC State values where available, and took the average of the two. For the category, 'sheep,' only the North Carolina State University had data available.

In the 2007 revision process, other viable sources of characteristic data were found through the internet. These sites, some of which are cited in the text, are included at the end of this discussion. Where this data tended to improve the estimates of N and P already made, these additional data were included on the spreadsheet, and averaged with the ASABE and NC State data. In one or two cases the data reported in these other data sets was significantly different than that from ASABE and NC State. Those are noted, but no adjustment made in the average value for that particular item.

The as-removed data is quite variable. While the ASABE data and the data sources discovered during revision lists a single value for each variable, the NC data lists the range, mean, and standard deviation of the values. The variability in the data can be illustrated using beef feedlot manure. The NC reference notes TKN as ranging from 5 to 58 pounds per ton of manure, or a range of more than a thousand percent from low to high, with a mean of 27 pounds per ton. This is typical of all the manure data bases, because little has ever been done to specifically identify true outliers in the data. The variability in the data can also be explained in part because of the change in moisture content of the manure during collection and storage/treatment which can be both a management factor and a climate factor. P in particular is proportionally related to the Total Solids (TS) content of the manure (which is another way of expressing moisture content). Nitrogen tends to be less in proportion to TS because often the same processes that promote moisture change also impact N volatilization and concentration.

As mentioned above, the questions in the survey dealing with compost and bedding tended to confuse the understanding of other parts of the survey. For example, much dairy and poultry manure contains some amount of bedding as well as spilled feed. These items get incorporated into the manure stream, are collected and stored/treated, and are land applied along with the manure. The characteristics of the as-removed manure usually include some bedding and spilled feed. There are no reasonable methods using the available data bases to give credit for a positive response to the bedding question on the survey.

The question on compost in the survey implies there was an expectation there would be some additional 'corrections' applied to waste characteristics to account for the composting process.

Roughly 20 percent of the survey respondents stated their manure was composted. This value is much higher than the number of operators actually composting. In reality, if allowed to stand in an aerated state, composting does occur to some extent, but normally not to the extent where the material's characteristics are altered. Finished compost (does not continue to compost when allowed to stand under conditions where composting occurs), like manure, varies widely in characteristics. This in part can be accounted for by animal types and manure management, but can be equally influenced by bulking agents used, amount of soil mixed with the compost, etc. The nutrient content of finished manure based compost is often identified in relationship to the starting Carbon to Nitrogen ratio of the compost mix. Since C:N ratios of compost depend on manure characteristics AND the type and amount of bulking agent, and the unreasonable number of operators reporting compost, we chose to ignore the survey note that the manure is composted. The discussion of compost N and P values below are to be used where the survey indicates the material applied was compost, not manure per se.

BEEF

The ASABE reference had a single listing for beef earthen feedlots. The NC reference had a listing for earth lots as well, plus a listing for scraped paved lots. There were no listings for most of the options in the 'solids' category in the survey. Did notice there seemed to be a fairly good correlation between nutrient content and solid content for the two listings for earth lots and the single listing for paved lots. Using some estimated TS contents for stacking pads and barns, we estimated an N and P content for each of the 'solids' options. The reasoning for the assumed TS numbers were the uncovered slab would tend to dry, but would also accumulate rainfall. The bulk of the stack would tend to hold in moisture as compared to the relatively thin manure pack on the earth lots. This, of course, would also be dependent on when the manure was collected from the earth lots (wet vs dry season), and whether the scraped manure was stored on site or taken directly to the field. The stack that is covered would hold in moisture, but would not receive precipitation which would tend to make the manure dryer than in uncovered stacks in higher rainfall areas. One could argue a cover would have little \influence on manure moisture in more arid areas; i.e. there would be little rainfall to impact uncovered stacking facilities. .

The barn, shed, or house category would provide less opportunity for the manure to dry if it is pulled to one corner. Often some amount of bedding would be added to 'solidify' the manure, but the bedding wouldn't add significant weight or nutrients to the mix. These numbers agree closely with the publication, "Best Management Practices Land Application of Manure," AGF 208-95, The Ohio State University, adjusted for solids content. Not certain what the 'other' option might include, but did add a value for nutrients at a TS content of something less than a stack, but more than what would accumulate in a building.

The NC reference also had a category for both beef slurry and beef lagoon. Neither of these options are common in the experience of NRCS, but may show up on a survey. We used the NC value for slurry for all the slurry options, and used the NC value for lagoon for both the single and two stage lagoon options. The characteristics are for the lagoon effluent only. Neither reference had an option for a runoff only pond, so we borrowed information from Table 4-10, Chapter 4, Agricultural Waste Management Field Handbook (AWMFH), Natural Resources Conservation Service, United State Department of Agriculture, to fill in the blank.

The N and P values for the 'no storage' option were based on as excreted manure with some reduction in the N portion to account for volatilization after excretion and before application. A slurry consistency was assumed.

DAIRY

As with beef, there were a limited number of options available to determine characteristics. The value available in both ASABE and NC State was for Scraped Concrete, with no distinction between outside paved and inside paved – both are common in dairy situations. The solids content given is typical of inside scraped manure with minor amounts of bedding and spilled feed added. The value from the data sets were used for “Barn, Shed, or House.” There were no values for manure packs that would be common in the Southwest, but the ASABE data set had a value for as-removed “scraped earthen lots” that was used to represent the manure pack situation. This may tend to overestimate the N and underestimate the P values for earth lots in the Southwestern states.. The limited amount of data was expanded to the ‘solids’ options as was done for beef. The assumed solids content for the different options are shown on the spreadsheet, and are ‘wetter’ than beef manure” for other than manure pack, which tends to be about the same as beef, particularly in the Southwest.

The single values for slurry and liquid systems were expanded as for beef, and the runoff pond value was used as if it was beef. The ‘no storage’ option assumed ‘as excreted’ manure characteristics for lactating cows with a 10 percent reduction for N volatilization.

There was no way to differentiate any of the dairy category by groups such as heifers, dry cows, milking string, etc. The survey did not provide any clues that would allow one to make that differentiation. A simplifying assumption could be that manure from all groups contributed to the applied manure. This may well be the case, but also may not. In many instances the heifers and dry cows are confined (if they are confined) in dryer areas on the property where the manure most likely would be solid. The milking string is often confined on concrete where the manure would be more of a slurry consistency, or if mixed with water from the milking parlor, would tend to be more liquid.

SWINE

The ASABE reference had no entry for solid manure. The NC reference did have an entry for scraped pavement, which we’ve used in the spreadsheet for both covered and uncovered slabs. In fact, very few modern systems of any size use a solids collection option, so while here and available, we do not expect these options to occur except rarely. We did not include a value for either the manure pack or the ‘building’ option. Two more recent data sources; one from Ohio State University and the other from the 2000 MWPS-18 suggested P concentrations in solid manure at 3.5 to 3.9 pounds per ton of manure. We are inclined to believe these two sources as probably more reliable than the NC State data because of the concerted effort to reduce P in the diet of swine. Since the data is to be used in a simulation spanning some 40 years, We decided to average the recent and older data for P.

Single values for slurry and lagoon effluent were available from both ASABE and NC State, and these were used for similar options for slurry and liquid categories, except there is not a ‘runoff’ option for swine. We did include nutrient values for daily haul (no storage), although we doubt if that option exists any more.

SHEEP

There is little information on the nutrient content of stored/treated sheep manure. The NC reference did contain information in pounds per ton as excreted, but no indication of the impact of the lot. Looking at some typical moisture changes for beef manure as related to N and P content, and assuming similar drying for sheep manure we estimated a value for a manure pack and for a 'building' option with solid manure. The Purdue reference also had values for sheep manure with and without bedding. The phosphorus values and nitrogen content for the 'barn' option were similar to those from NC State, but the lot value was considerably higher. The two data sources were averaged.

All the other options aren't realistic alternatives.

POULTRY

Of all the livestock related sources, poultry was the most problematic because there are so many very distinct manures from the various poultry types, and none of the 'solids' data matched the storage systems used in the survey. What we did was assume the category, 'covered slab' in the survey was the same as 'stockpiled litter' in the NC reference. We assumed the survey category, 'barn, shed, or house-pit,' was the same as the NC reference category, 'Layer, unpaved deep pit storage.' We used the 'other' category in the survey to represent the range of litters described in both the ASABE and NC reference. This includes pullets raised in house, turkey (both sexes), and broilers.

The NC reference also had values for layer related slurry and layer related lagoon effluent. We do not believe the slurry option actually exists any more, but did include the values. There are lagoons associated with layers still in use.

There has been a discussion of runoff ponds associated with turkeys grown outside, but no data. We declined to put in a value. If the survey indicated we could enter the value for beef or dairy runoff.

EQUINE

There was a single reference for solid horse manure in both references and almost identical information. We used the value for all the solid manure options and the 'no storage' option. This will underestimate the nutrient content in some cases, and over estimate the content in others.

BIOSOLIDS

Biosolids are occasionally applied to cropland and almost always accompanied (by law) with a chemical analysis. Neither the ASABE nor the NC reference included biosolids, so we went to the WWW for answers. There seems to be a large body of dated literature that supports a relatively consistent set of characteristics for septage and a sludge with slurry consistency; in fact, these all appear to be the same set of data. There is also a smaller body of literature supporting dewatered or dried sludge. We used three different references to back into the nitrogen and phosphorus content of biosolids. The first is out of Oklahoma, http://www.deq.state.ok.us/factsheets/water/NutrientsSludge.pdf . The values in the Oklahoma reference is supported by those in a Canadian publication http://www.omafra.gov.on.ca/english/nm/nasm/info/brochure.htm#6 and Table 3.2, "Handbook of Organic Waste Conversion," M.W.M. Bewick, Van Nostrand Reibhold Environmental Engineering Series (1980). Assumed a slurry with 10 percent total solids and a solid with 30 percent total solids. By and large the biosolids characteristics are reported as a percent of dried material or as concentration in parts per million. Probably the drying process isn't as common now as a couple of decades ago, but we included values for both the slurry and the solid. We also included the 'slurry' value for the 'no storage' category, rationalizing the drying process for a solid cake implies some storage.

COMPOST

There are numerous references and web sites discussing compost; both making compost and the use of the finished compost. As one might imagine, the nutrient composition widely varies between livestock types, manure management techniques, and bulking agents introduced to the waste stream. Some of the sites used here are http://www.ianr.unl.edu/ianr/csas/IF/compost.htm , http://www.thedairysite.com/articles/1221/characteristics-and-fertilizer-value-of-compost-dairy-barn-manure and http://www.compost.org/pdf/Certifica.PDF. The spreadsheet reflects less than 1 % nitrogen, and phosphorus content a few tenths of a point less. One of the important variables is the moisture content of the finished compost. The results used here reflect a moisture content of approximately 50 percent which is common in many non-commercial composting scenarios.

OTHER and DON'T KNOW

These are relatively nebulous categories, and from the survey data sets examined to date, appear to be rarely used. Often a farm may have multiple livestock and multiple storage facilities. May well be the operator may not remember which manure was applied to a particular field. We added a single N and P number for each category similar to a solid manure for beef or dairy.

**Coefficients for APEX from Manure Characteristics**

A second step was needed to transform the basic manure nutrient data to the data to be used by the EPIC/APEX model as shown as Table 6-1. The discussion below documents an intermediate step in preparing Table 6-1. This intermediate step is shown as Table 6-4.

Table 6-4 displays the 43 'confined' systems developed to estimate applied manure characteristics where the CEAP surveys did not provide the amount of nutrients applied. A decision was made early on not to use all the possible combinations of systems shown in Table 6-3. The 43 systems included here were judged to be the most likely to occur, and were very similar to systems not included. To summarize, the table shows the estimated N and P per ton of manure, the fraction of N and P that are organic (compared to inorganic or mineral), and the estimated carbon content of the manure in lbs per ton. In addition, the table also displays the ammonia fraction of the N component as well as the ammonia fraction of the mineral N fraction. Also shown are the proportion of the total manure application that is organic carbon. These values are used as inputs to the fertilizer component of the EPIC/APEX model.

Carbon content of manures can be estimated using published carbon content numbers or carbon nitrogen ratios (C:N) of typical manures. Carbon content data is not readily available, but when found, it is shown as the sum of Total Organic Carbon (TOC) and Inorganic Carbon (IOC), where IOC is a fraction of the Total Carbon. The North Carolina State University manure characteristics data lists TOC and IOC for swine and layer manure, but no other animal types. Carbon can also be estimated if the ash content of the manure is known. The ash is the residue remaining after the manure is heated and is related to fixed solids, but not necessarily the same. With all the uncertainties and lack of information on total carbon data, the decision was made to rely on published C:N ratios to calculate carbon content from known or estimated nitrogen values.

There are many different sources of C:N available over the internet, and to a great extent they all agree. Robert Kellogg prepared the original version of Table 6-4, and the carbon data was from an unknown source and appeared somewhat suspect for the more liquid manures. The Kellogg version of Table 6-4 was updated with revised N and P values, and further modified by adding columns for C:N ratios, N fraction, and ammonia fraction. The first C:N column was calculated using the carbon and N content from the earlier Kellogg work The second column contains values from various tables in the NRCS Agricultural Waste Management Field Handbook (AWMFH), Chapter 4, as well as Table 10-6, AWMFH. The third column contains values from many different sites found using a Google search. The fourth column contains values from the *On-Farm Composting Handbook,* NRAES-54, Natural Resource, Agriculture, and Engineering Service, Cornell University.

Where the collected set of C:N ratios were somewhat consistent with those on the Kellogg sheet, the original values were maintained. Where the values differed, the *On-Farm Composting Handbook* value or one close to it was used. Most of the values in all the references were for manure solids, which is expected because the C:N values are most commonly used when composting. The AWMFH and one or two other references included an occasional reference to C:N ratios for slurry and liquid manure, but not for all animal types. The available values were expanded to each of the slurry and liquid systems as seemed appropriate. The *On-Farm Composting Handbook* suggested a C:N value of 6 – 10 for municipal sludge and night soil. A C:N of 10 was used for bio-solids slurry and a somewhat greater value for solids and a lesser value for liquid bio-solids. The adjusted C:N values were used to compute a new carbon content, which was transferred to Table 6-4.

The original Kellogg spreadsheet used a simplifying assumption that 100 percent of the carbon in manure was in the organic form. As previously mentioned, the NC State data contained a value for inorganic carbon for both swine (20 percent of total) and layer (10 percent of total) manure, and one can assume there is an inorganic carbon fraction for other waste materials. In Table 6-4 it was assumed 85 percent of the carbon is organic.

The North Carolina State University manure characteristics data base used as a major source of N and P information, also provides substantial information about the inorganic and organic fraction of the manure. The data base provided TKN as the measure of organic N and gave values of ammonia in terms of % TKN and nitrate as pounds per ton. The calculation for the organic N fraction was one minus the sum of the percent ammonia and nitrate (inorganic portion) divided by the percent nitrate plus TKN at 100 percent (which is Total Nitrogen). The NC State data source consists of a compilation of many data samples from across the country and is used as the best source of information for the organic and inorganic fraction of N.

We also documented the organic phosphorus fractions shown on the spreadsheet. There are several references accessible from the internet with vague references to organic phosphorus ranging from 30 to 75 percent of total manure phosphorus – most less than 50 percent. One reference used in the past is the documentation of the nutrient component of the EPIC model, and it appears this was the reference for the organic P fractions shown on the original Kellogg spreadsheet. Since we could not find significantly 'better' values, those to be used are the same as on the Kellogg work. We are concerned about the singular reference to a 75 percent organic P fraction, since this would be twice the values being used, but without confirmation, the lower values will be used.

Table 6-1 does not contain coefficients for manure from grazing livestock. These are needed in situations where cropped fields are grazed as part of the crop rotations. The documentation for coefficients for grazing livestock will be described in the following section.

**Manure Left on Cropland from Grazing Animals**

It has long been recognized grazing animals drop manure as they graze, and to a large extent, the nutrients in feed intake are returned to the field. Many estimate only twenty percent or less of the nutrients are retained by the animal. Unfortunately grazing doesn't result in even manure distribution across the field. The animals tend to congregate near water or shady areas, and over time these areas receive much more grazing pressure and a disproportionate share of manure. Good grazing management will result in the animals being more evenly spread across the field and a more uniform manure application, but still not as effective as most manure application equipment. For the purpose of the CEAP/APEX analysis we are assuming a uniform manure distribution across the area grazed. The discussion that follows documents the development of the values shown for grazing animals in Table 6-5. Nitrogen and Phosphorus from Grazed Animals and, supporting Tables 6-6 and 6-7. Additional information on specification of grazing is included in the next major section of this document.

The characteristics of manure dropped during the grazing process (as-excreted manure) are dissimilar to manures subject to collection, storage, and/or land application as we have considered in the rest of the analysis. These manures are initially richer in nutrients, and by and large have a higher moisture content than stored manure not diluted with rainfall or other outside water. The nutrients in any manure dropped during grazing will depend on the quality and quantity of the crops grazed. The ASABE reference (ASABE, 2005) contains equations to relate the nutrients in the feed to the nutrients in the manure, however this seems beyond the scope of this particular effort. With the availability of the ASABE material, that from Penn State (Rotz et al) cited below, and other efforts such as at Texas A&M (Norman, 2008), to tie forage quality and manure, it would seem possible to actually embed a routine in EPIC/APEX to estimate manure constituencies for various levels of grazing intensity. Again, this would be beyond the scope of the current CEAP effort, but something to consider for future efforts.

Much of the information on manure characteristics is in terms of 1000 pound animal units or their metric equivalents. To calculate nutrients, an assumption must be made of the average weight of all the animals contributing to the manure. There are no clear choices for the average or typical weight of any of the animal types. Looking at many different sources there seemed to a grouping of animal sizes for grazing cattle (beef or dairy), horses and sheep. These are shown on Table 6-6. The CEAP survey data also contained entries for grazed swine, and there was no data available. We assumed a value of 150 lbs which is the mid-range for the grower-finisher category.

Several texts and references have values for characteristics of as-excreted manure, and to maintain consistency, the NRCS (NRCS, 1992), NC State (Barker, 2001), and American Society of Agricultural and Biological Engineers (ASABE, 2005) were used as references. Each of the references provided estimates of the daily manure production and nutrient content of the manure. In addition, the NRCS reference provided carbon to nitrogen (C:N) ratios, and the NC State reference included details of the nitrogen content, carbon information, and a differentiation between the quantity of urine and feces. There were no data on carbon content for horse manure in these three references, so the carbon-nitrogen ratio available from the *On-Farm Composting Handbook* (NRAES, 1992) was used. These values are displayed in Table 6-6.

As with manure applied from confined operations, the manure dropped by grazing animals is subject to losses at the 'time of application.' The rule of thumb currently used by Extension is 85 percent of the N in manure from grazing is available for plant use (Gamroth, 2008), which translates to a 15 percent loss in 'application.' In the same communication, Gamroth stated they are finding grazed pastures are becoming deficient in N, and are assuming their rule of thumb does not capture all the N losses. Another reference from Penn State (Rotz et al) states; "The main nutrient contained in urine is nitrogen. Urine accounts for about 70% of the nitrogen returned to a pasture by grazing livestock. According to Dr. Barker, one urine patch can have a nitrogen application rate equivalent to about 1000 pounds/acre. This is too much nitrogen to be effectively used by grass growing in the area, so there are high nitrogen losses. Leaching losses, where nitrogen moves down through the soil and out of the rooting zone, account for nearly 50% of the nitrogen in a urine patch according to a German study cited by Dr. Barker. Another 22% of the nitrogen is lost to the air by volatilization as ammonia." The leaching loss described here would probably not happen at time of application, most likely over time, and will be simulated by the sub-routines in EPIC/APEX. Earlier we assumed unincorporated manure applied as a liquid (slurry) would lose approximately 30 percent of N due to volatilization. As-excreted manure contains less ammonia fraction than would the stored slurry or liquid, but over-all more total nitrogen. The assumption of a 30 percent N loss to volatilization seems valid. **These losses are addressed in the modeling elsewhere, as they are not included in the application rate estimates estimated using the EPIC/APEX coefficients.**

As-excreted manure is relatively low in solids, and it follows, lower in carbon content than many stored manures. There is relatively little information about manure characteristics specific to grazing animals where total manure is captured, so the more common C:N values from NRCS in Chapter 4 of the AWMFH (USDA, 1992) were examined. These were checked against other data sources such as the NC State (Barker, 2001) data. The NC State data also included a value for Total Organic Carbon (TOC) for each as-excreted manure type, and for swine, also included a value for Inorganic Carbon (IOC). All the C:N ratios available were within ranges as discussed in the literature, but no two sets of data agreed on a single number. For land applied manure we assumed a ratio of organic carbon to total carbon of 85 percent. Looking at the IOC plus TOC for swine in the NC State data, the organic fraction computed to 86 percent. Going back to the assumption TOC is 85 percent of total carbon, and using the NC State data for TOC, the pounds of carbon per ton of manure was calculated. The resulting values when used to re-compute C:N ratios provide lower values than contained in the NRCS data, but still within published ranges, how-be-it at the lower end. For horse manure, the NRAES C:N value was used to compute carbon content. All this is displayed on Table 6-5

The survey data did not differentiate between dairy and beef for grazed bovines, but simply lumped both together in the category, 'Cattle." The survey data was consulted, and where dairy manure had been applied to the field, and the livestock grazing the field was identified as cattle, it was assumed the livestock type was dairy. Similarly, if beef manure was applied and cattle were the grazing livestock, it was assumed the livestock type was beef. In addition, if another manure other than beef or dairy was applied, the grazed animals were also assumed to be beef.

In the large majority of cases, there were no clues as to whether cattle meant beef or dairy. The following procedure was used to develop APEX coefficients for the category, Cattle, where no other information was available. See Table 6-7.

1. The country was divided by state into ten commonly recognized regions such as Appalachia, Cornbelt, Delta States, Lake States, etc. These are shown on Table 6-7.
2. The number of farms with cattle for each state for the year 2002 was determined from the Agricultural Census (USDA, 2004) as was the number of farms with milking cows (dairy). It was assumed the number of farms with cattle minus the number of farms with dairy equals the number of beef farms.
3. The ratio of beef cattle farms to dairy farms was computed for each state, and averaged for each region.
4. The regional ratio calculated in 3 was used to weight the APEX coefficients for beef and dairy to arrive at a regional cattle coefficient.

The coefficients for the nitrogen components and organic phosphorus were determined as previously described in the section, Documentation for Manure Coefficients Used With EPIC/APEX, and are displayed in Table 6-5.

**References Specific to Manure From Grazing Animals**

American Society of Agricultural and Biological Engineers, ASAE D384.2, *Manure Production and Characteristics*, ASABE, St. Joseph, MI, March 2005

Barker, James C., Animal *and Poultry Production and Characterization*, Biological and Agricultural Engineering, North Carolina State University, Raleigh, North Carolina, Revised 2001

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Natural Resource, Agriculture, and Engineering Service (NRAES). *On-Farm Composting Handbook*, NRAES-54, 1992

Rotz, C.A., D. R. Buckmaster and J. W. Comerford, *A beef herd model for simulating feed intake, animal performance, and manure excretion in farm systems,* ARS-USDA, Pasture Systems and Watershed Management Research Unit; and Agricultural and Biological Engineering and Dairy and Animal Science Departments, The Pennsylvania State University, University Park PA

United States Department of Agriculture, National Agricultural Statistics Service, *2002 Census of Agriculture, United States Volume 1, Geographical Area Series, Part 51*, Table 11, USDA, Washington, DC, June 2004

United States Department of Agriculture, Natural Resources Conservation Service, Part 651, *Agricultural Waste Management Field Handbook,* Chapter 4 and associated tables, Washington, DC, 1992

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**Manure Characteristic Web Sites Used to Develop CEAP APEX Manure Coefficients**

http://www.nrcs.usda.gov/technical/land/pubs/nlapp1b.html This site is the NRCS location of manure characteristic data we put together early in the 1990's. Probably not a lot of value because not tied to particular systems. Nutrients in lbs/ton could be of use in filling in missing data for surveys

http://cetulare.ucdavis.edu/pubdairy/Sampling.htm Fairly general, a little solids/nutrient data, but not much.

http://www.bae.ncsu.edu/programs/extension/manure/awm/program/barker/a&pmp&c/table_of_content.htm This is what we have in book form, and provides a general public access to the data. Has statistics attached to numeric data.

http://www.lpes.org/Lessons/Lesson21/21_Sizing_Storages.html Charles Fulhage work. May give some idea for solids content, but nutrients tied to lbs/day/1000 lb animal unit

http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/pou3606 Poultry data from Canada

http://www.kimberly.uidaho.edu/AgWaste/beefprograms/BeefManure.htm beef data from Idaho.

http://www.ianrpubs.unl.edu/epublic/live/g1315/build/g1315.pdf Some general data that could come in handy

http://www.asas.org/abstracts/2002abs/jnabs58.pdf Mainly abstract type data – doesn't appear to be a lot of help.

http://www.ces.purdue.edu/extmedia/AY/AY-277.html Some data on solids and nutrients for liquid stuff

http://extension.oregonstate.edu/catalog/html/em/em8597/#anchor1012012 Basically the NRCS way of computing manure nutrients

http://www.abe.iastate.edu/fileadmin/www.abe.iastate.edu/extension/wastemgmt/CNMP_Curriculum/Manure_Characterisitcs_MWPS18-1.pdf Appears to be fairly decent site with quite a bit of data that will give a check to ASABE and NC State data
http://asae.frymulti.com/request.asp?JID=2&AID=19432&CID=s2000&T=2 This is text of ASABE Standard D384.2 Click on title when page comes up

http://ohioline.osu.edu/agf-fact/0208.html Good reference with usable data on nutrient content resulting from storage and treatment.

http://cropsoil.psu.edu/extension/facts/agfact55.pdf Paper from Penn State that discusses application losses and has some other good data for our purposes.

http://www.deq.state.ok.us/factsheets/water/NutrientsSludge.pdf This is the site of the original data on dewatered bio-solids

http://www.omafra.gov.on.ca/english/nm/nasm/info/brochure.htm#6 Sludge site with info used in spreadsheet for dewatered sludge

http://www.ianr.unl.edu/ianr/csas/IF/compost.htm Compost characteristics

http://www.thedairysite.com/articles/1221/characteristics-and-fertilizer-value-of-compost-dairy-barn-manure Compost characteristics

http://www.compost.org/pdf/Certifica.PDF Compost characteristics

## 3. Using Manure Coefficients to Determine Applied Nutrients

Surveys conducted in the years 2003 – 2006 indicated which fields received manure, and as previously discussed, contained various amounts of information about the manure application. The discussion that follows references the years the survey was conducted. Much of the activity was duplicated for survey data year after year, and the documentation will be the same. For clarity, the documentation repeats material previously discussed and includes documentation that relates to a specific year. Some of the documentation of the data is contained in other sections, and will be referenced at the appropriate time. Names were included in the initial drafting of the documentation and are continued here for clarity. At some point the names could be removed from the documentation.

**Application data for 2003 and 2004**

The process for estimating manure application rates for CEAP sample points and dealing with partial treatment records is described below:

1. David Moffitt, NRCS agricultural engineer and currently with Texas A&M Agrilife Research, provided a methodology for calculating approximate manure N and P application rate on the basis of the information provided in the CEAP survey for cases where only the animal type was known. This has been discussed in Section 2 immediately above and the coefficients included as Table 6-1.

2. Kevin Ingram provided a listing of the relevant survey variables for the 2003 and 2004 CEAP samples that had data on manure applications.

3. Bob Kellogg expanded the list of variables from 2. to include pounds of N and pounds of P (elemental P) applied, as well as other variables needed to make this calculation. **All original variable fields from the survey were retained without making any edits.** Comments about needed edits or additional assumptions made to make the application rate calculations are noted in a "comment" field.

4. Each record was categorized into one of four possible categories:
   i. Only the animal type and quantity applied were available. David Moffitt's coefficients were used to calculate application rates.
   ii. Percent analysis results were reported. Application rates were calculated using the reported percent of the quantity per acre applied. As a check, the implied pounds of N and P per ton of manure was calculated based on Moffitt's coefficients. Designated 'Unique Fertilizer.'
   iii. Actual pounds applied were reported (associated with a code of 19 in the units column). In these cases, the quantity applied was NOT reported in the survey. The implied quantity of manure applied (tons/acre) was estimated using Moffitt's coefficients. Designated 'Unique Fertilizer.'
   iv. No information on quantity of manure or quantity of N and P applied was provided in the survey. The decision was made to estimate a manure application for each of these situations. The process used for the 2003 data is described in Section 8 below. The process used to fill in missing data for the 2004 year applications is as follows. Typical yields and N and P requirements for that yield were taken from Table 6-6, Agricultural Waste Management Field Handbook. It was assumed manure was applied to meet an N standard unless the survey specifically showed a P standard was to be used. When using

an N standard, the application was increased by 80 percent to account for nitrogen losses to leaching and de-nitrification and for less than complete mineralization of the manure nutrients. No adjustments were made for commercial fertilizers. The value, tons of manure applied, was calculated by dividing the appropriate Moffitt coefficient for either N or P per ton of manure into the total required N or P (whether N Rate or P Rate). Where the manure was applied to a legume, it was assumed only half of the N standard would be applied to the crop. If the manure application was to idle land, an application of 100 pounds per acre N was assumed. Designated 'Unique Fertilizer.'

5. The survey reports quantity of manure in three units—pounds, gallons, and tons per acre. These were all converted to tons per acre, since the manure coefficients were in terms of pounds of N or P per ton of manure applied. Gallons were converted to tons assuming approximately 270 gallons per ton, a conversion factor used by engineers for slurry and liquid animal waste. (Strictly speaking, this implies that the percent analysis reported on the survey for liquid applications is percent by weight and not by volume, but NASS was never specific about this in their directions, and it is unlikely that enumerators ever made this distinction.)

6. Using information on the method of application and the primary manure storage type for on-farm livestock operations, the manure consistency was identified as solids, slurry, or liquid. This was necessary as the manure coefficients varied in some cases depending on the consistency of the manure. Occasionally there was a conflict between the method of application code and the primary storage type. The method of application was used to define the consistency in most of these cases. Where the method of application did not distinguish dry from liquid, an assumption was made on the basis of the storage type and usually noted in the comments.

7. In many cases, the reported application was for only part of the sample field, most often applied at different times. (Sometimes these multiple applications on part of the field also differed by animal type and method of application.) In some situations, it is inappropriate to model all of these applications as multiple applications at the NRI point. It is equally inappropriate to average the application over the entire field since we are modeling points and not fields. The following assumptions and rules were used:

- If only part of the field received manure and there were no multiple applications within a crop year, it was assumed that the NRI point received the manure application.
    a. There is one exception—samples where the sum of acres receiving manure over all the years was less than the total acres in the field. In these cases, it is possible that the operator was distributing manure over different parts of the field in each year (a sound manure management practice). For these cases, the year with the largest acres applied was selected. If equal acres were applied in all years, a random number was used to select the application record.
- If there were multiple applications within a crop year and each was applied to 50 percent or more of the acres, it was assumed that the NRI point received all manure applications.
- If there were multiple applications within a crop year that summed to less than or equal to the total acres in the field, it was assumed that each application covered a different portion of the field. In these cases, it is appropriate to model only one of the applications, as the NRI point on the field would have received only one manure application. The selected application was chosen as the record with the highest acreage, or, if equal acreage, chosen randomly using a random number generator.

8. Some samples had reported manure applications with quantities that appeared to be unreasonably low or high, or produced application rate estimates that seemed unreasonably low or high. Records with less than 1 ton per acre of solids applied or less than 2000 gallons per acre of manure applied will be examined more closely to see if there are apparent coding errors. **These records were excluded from the cleared manure dataset sent to Temple in November, 2007. The original surveys were examined, where available, and many were included in the final data set.**

**Application data for 2005**

The process for estimating manure application rates for CEAP sample points and dealing with partial treatment records for the 2005 dada set is described below, and is very similar to the documentation for the 2003 and 2004 data set documented by B. Kellogg as shown above.

1. David Moffitt, NRCS agricultural engineer, and currently with Texas A&M Agrilife Research, provided a methodology for calculating approximate manure N and P application rate on the basis of the information provided in the CEAP survey for cases where only the animal type was known. This has been discussed in Section 2 immediately above and the coefficients included as Table 6-1.

2. Kevin Ingram provided a listing of the relevant survey variables for the 2005 CEAP samples that had data on manure application.

3. David Moffitt expanded the list of variables to include pounds of N and pounds of P (elemental P) applied per acre, as well as other variables needed to make this calculation. The variables added were the same as Bob Kellogg added for the 2003 data with the exception an additional column was added, "Final Application Code." In reviewing the reported survey information, some applications showed a discrepancy between the consistency of the manure and the method of application. The added column reflects changes in application method to be consistent with other survey data. **<u>All original variable fields from the survey were retained without making any edits.</u>** Comments about needed edits or additional assumptions made to make the application rate calculations are noted in a "comment" field.

4. The records were often incomplete or provided conflicting data. Where possible, the original survey document was found and examined for clues. It was noted that in many cases the omission of data or addition of conflicting data occurred during the NASS review process. For 2005, **110 survey documents** were examined and approximately 50 percent provided some clue as to how to proceed. The comment field was used to record information from the survey document that did not appear on the original spreadsheet.

5. Each record was categorized into one of four possible categories:
   i. <u>Only the animal type and quantity applied were available</u>. Moffitt's coefficients were used to calculate application rates.
   ii. <u>Percent analysis results were reported</u>. Application rates were calculated using the reported percent of the quantity per acre applied. As a check, the implied pounds of N and P per ton of manure was calculated based on Moffitt's coefficients. <u>Note: This option was not used for the 2005 survey data.</u>
   v. <u>Manure analysis provided.</u> The manure analysis was provided in terms of pound of N and P per unit weight (volume), or total pounds of N and P applied per acre. As in 2003,

it was assumed all reported P values were in terms of $P_2O_5$ rather than elemental P. Where the actual pounds applied were reported (associated with a code of 19 in the units column), and the quantity applied was NOT reported in the survey. The implied quantity of manure applied (tons/acre) was estimated using Moffitt's coefficients. In other cases, either N or P was reported, but not both. The ratio of N:P from Moffitt's coefficients were used to calculate the missing value. Designated 'Unique Fertilizer.'

vi. No information on quantity of manure or quantity of N and P applied was provided in the survey. The decision was made to estimate a manure application for each of these situations. The process was to identify the crop receiving the manure. Typical yields and N and P requirements for that yield were taken from Table 6-6, Agricultural Waste Management Field handbook. It was assumed manure was applied to meet an N standard unless the survey specifically showed a P standard was to be used. When using an N standard, the application was increased by 80 percent to account for nitrogen losses to leaching and de-nitrification and for less than complete mineralization of the manure nutrients. No adjustments were made for commercial fertilizers. The tons of manure applied was calculated by dividing the appropriate Moffitt coefficient for either N or P per ton of manure into the total required N or P (whether N Rate or P Rate). Where the manure was applied to a legume, it was assumed only half of the N standard would be applied to the crop. If the manure application was to idle land, an application of 100 pounds per acre N was assumed. Designated 'Unique Fertilizer.'

6. The survey reports quantity of manure in three units—pounds, gallons, and tons per acre. These were all converted to tons per acre, since the manure coefficients were in terms of pounds of N or P per ton of manure applied. Gallons were converted to tons assuming 267 gallons per ton or 4.16 Tons per 1000 gallons, conversion factors used by engineers for slurry and liquid animal waste. (Strictly speaking, this implies that the percent analysis reported on the survey for liquid applications is percent by weight and not by volume, but NASS was never specific about this in their directions, and it is unlikely that enumerators ever made this distinction.)

7. Using information on the method of application and the primary manure storage type for on-farm livestock operations, the manure consistency was identified as solids, slurry, or liquid. This was necessary as the manure coefficients varied depending on the consistency of the manure. Occasionally there was a conflict between the method of application code and the primary storage type as previously mentioned. The method of application was used to define the consistency in many of these cases. Where the method of application did not distinguish slurry from liquid and the storage type was not noted, an assumption was made the manure was slurry if the material was injected or knifed in during the application process.

8. In many cases, the reported application was for only part of the sample field, most often applied at different times. (Sometimes these multiple applications on part of the field also differed by animal type and method of application.) In some situations, it is inappropriate to model all of these applications as multiple applications at the NRI point. It is equally inappropriate to average the application over the entire field since we are modeling points and not fields. In some cases the actual cropped acres in the field were not noted. In those cases the field area was assumed to be the cropped area. The following assumptions and rules were used:
   - If only part of the field received manure and there were no multiple applications within a crop year, it was assumed that the NRI point received the manure application.

a. There is one exception—samples where the sum of acres receiving manure over all the years was less than the total acres in the field. In these cases, it is possible that the operator was distributing manure over different parts of the field in each year (a sound manure management practice). For these cases, the year with the largest acres applied was selected. If equal acres were applied in all years, a random number was used to select the application record.

- If there were multiple applications within a crop year and each was applied to 50 percent or more of the acres, it was assumed that the NRI point received all manure applications.
- If there were multiple applications within a crop year that summed to less than or equal to the total acres in the field, it was assumed that each application covered a different portion of the field. In these cases, it is appropriate to model only one of the applications, as the NRI point on the field would have received only one manure application. The selected application was chosen as the record with the highest acreage, or, if equal acreage, chosen randomly using a random number generator.

9. Some samples had reported manure applications with quantities that appeared to be unreasonably low or high, or produced application rate estimates that seemed unreasonably low or high. The following criteria was used to determine low applications: Records with less than 1/2 ton per acre of solid poultry manure or 1 ton per acre other solid manure; and 1000 gallons or less slurry manure or 2000 gallons liquid manure. A note was made in the comment field. The survey reports for those applications deemed high were examined, and all applications were as reported. **These records are all included in the 2005 data set.**

**Application data for 2006**

The process for estimating manure application rates for CEAP sample points and dealing with partial treatment records for the 2006 data set is described below, and is very similar to the documentation for the 2005 data set, and the 2003 and 2004 data sets documented by R. Kellogg.

1. David Moffitt, NRCS agricultural engineer and currently with Texas A&M Agrilife Research, provided a methodology for calculating approximate manure N and P application rate on the basis of the information provided in the CEAP survey for cases where only the animal type was known. This has been discussed in Section 2 immediately above and the coefficients included as Table 6-1.

2. Kevin Ingram provided a listing of the relevant survey variables for the 2006 CEAP samples that had data on manure applications.

3. David Moffitt expanded the list of variables to include pounds of N and pounds of P (elemental P) applied per acre, as well as other variables needed to make this calculation. The variables added were the same as Bob Kellogg added for the 2003 and 2004 data with the exception an additional column was added, "Final Application Code." In reviewing the reported survey information, some applications showed a discrepancy between the consistency of the manure and the method of application. **The added column reflects changes in application method to be consistent with other survey data. All original variable fields**

**<u>from the survey were retained without making any edits.</u>** Comments about needed edits or additional assumptions made to make the application rate calculations are noted in a “comment” field.

4. The records were often incomplete or provided conflicting data. Where possible, the original survey document was found and examined for clues. It was noted that in many cases the omission of data or addition of conflicting data occurred during the NASS review process. For 2006, **73 survey documents** were examined and approximately 50 percent provided some clue as to how to proceed. The comment field was used to record information from the survey document that did not appear on the original spreadsheet.

5. Each record was categorized into one of four possible categories:
   i. <u>Only the animal type and quantity applied were available</u>. Moffitt’s coefficients were used to calculate application rates.
   ii. <u>Percent analysis results were reported</u>. Application rates were calculated using the reported percent of the quantity per acre applied. As a check, the implied pounds of N and P per ton of manure was calculated based on Moffitt’s coefficients. Designated ‘Unique Fertilizer.’
   iii. <u>Manure analysis provided.</u> The manure analysis was provided in terms of pound of N and P per unit weight (volume), or total pounds of N and P applied per acre. As in 2003, it was assumed all reported P values were in terms of $P_2O_5$ rather than elemental P. Where the actual pounds applied were reported (associated with a code of 19 in the units column), and the quantity applied was NOT reported in the survey. The implied quantity of manure applied (tons/acre) was estimated using Moffitt’s coefficients. In other cases, either N or P was reported, but not both. The ratio of N:P from Moffitt’s coefficients were used to calculate the missing value.
   **iv.** <u>No information on quantity of manure or quantity of N and P applied was provided in the survey.</u> The decision was made to estimate a manure application for each of these situations. The process was to identify the crop receiving the manure. Typical yields and N and P requirements for that yield were taken from Table 6-6, Agricultural Waste Management Field Handbook. It was assumed manure was applied to meet an N standard unless the survey specifically showed a P standard was to be used. When using an N standard, the application was increased by 80 percent to account for nitrogen losses to leaching and de-nitrification and for less than complete mineralization of the manure nutrients. No adjustments were made for commercial fertilizers. The tons of manure applied was calculated by dividing the appropriate Moffitt coefficient for either N or P per ton of manure into the total required N or P (whether N Rate or P Rate). Where the survey document indicated a yield of half or less typical yields, no factor was used. Where the manure was applied to a legume, it was assumed only half of the N standard would be applied to the crop. If the manure application was to idle land, an application of 100 pounds per acre N was

assumed. Where manure was applied multiple times to the same field to a single crop, it was assumed only a portion of the crop needs were supplied in each application.

6. The survey reports quantity of manure in three units—pounds, gallons, and tons per acre. These were all converted to tons per acre, since the manure coefficients were in terms of pounds of N or P per ton of manure applied. In one or two instances the Survey document showed units of acre-inches which is common with sprinkler applied liquid. Acre inches were converted to gallons. Gallons were converted to tons assuming 267 gallons per ton or 4.16 Tons per 1000 gallons, conversion factors used by engineers for slurry and liquid animal waste. (Strictly speaking, this implies that the percent analysis reported on the survey for liquid applications is percent by weight and not by volume, but NASS was never specific about this in their directions, and it is unlikely that enumerators ever made this distinction.)

7. Using information on the method of application and the primary manure storage type for on-farm livestock operations, the manure consistency was identified as solids, slurry, or liquid. This was necessary as the manure coefficients varied depending on the consistency of the manure. Occasionally there was a conflict between the method of application code and the primary storage type as previously mentioned. The method of application was used to define the consistency in many of these cases. Where the method of application did not distinguish slurry from liquid and the storage type was not noted, an assumption was made the manure was slurry if the material was injected or knifed in during the application process.

8. In many cases, the reported application was for only part of the sample field, most often applied at different times. (Sometimes these multiple applications on part of the field also differed by animal type and method of application.) In some situations, it is inappropriate to model all of these applications as multiple applications at the NRI point. It is equally inappropriate to average the application over the entire field since we are modeling points and not fields. In some cases the actual cropped acres in the field were not noted. In those cases the field area was assumed to be the cropped area. The following assumptions and rules were used:

- If only part of the field received manure and there were no multiple applications within a crop year, it was assumed that the NRI point received the manure application.
    a. There is one exception—samples where the sum of acres receiving manure over all the years was less than the total acres in the field. In these cases, it is possible that the operator was distributing manure over different parts of the field in each year (a sound manure management practice). For these cases, the year with the largest acres applied was selected. If equal acres were applied in all years, a random number was used to select the application record.

- If there were multiple applications within a crop year and each was applied to 50 percent or more of the acres, it was assumed that the NRI point received all manure applications.
- If there were multiple applications within a crop year that summed to less than or equal to the total acres in the field, it was assumed that each application covered a different portion of the field. In these cases, it is appropriate to model only one of the applications, as the NRI point on the field would have received only one manure application. The selected application was chosen as the record with the highest acreage, or, if equal acreage, chosen randomly using a random number generator.

**9.** Some samples had reported manure applications with quantities that appeared to be unreasonably low or high, or produced application rate estimates that seemed unreasonably low or high. The survey reports for those applications deemed high were examined, and all applications were as reported. The decision was made to model all applications, so even though a note was often made in the 'comments' field an application was small, that should not affect the calculation. **These records are all included in the 2006 data set.**

### 4. Standardization of Manure Application Event Data

Due to the following data collection characteristics the reported manure applications had to be standardized as described in Section 3 directly above. The procedures of Section 3 resulted in a dataset that had to undergo further transformations for setup in the APEX simulation input datasets. Before proceeding with those further transformations, a brief summary is given here of the process applied to this point. The reasons for the required standardization include:

1) The respondents were allowed to report nutrient content as actual pounds of N and P applied or as percent analysis of total weight of material applied (see Tables 6-8);
2) The respondents were allowed to report quantities as pounds, gallons, and tons (Table 6-8).
3) For many samples, multiple application events were reported. In some cases each application occurred on a different date and covered only a portion of the field; and
4) In many cases the reported nutrient content of the manure was inconsistent with the reported livestock type and manure management system (Tables 6-1, 6-8 and 6-9)

The standardization process involved the following three major steps resulting in the dataset described in Table 6-10:

1) Assignment of the manure material, for each application event, to a specific defined composite material (see definitions in Table 6-1);
2) Standardization of application units and amounts to tons of material applied; and
3) Calculation of the quantity of N and P nutrients applied. (Note that for CEAP manure analysis, phosphorus has been converted to elemental P units, unlike fertilizer which is reported in $P_2O_5$ units).

For application events where either the total quantity of material or actual quantity of nutrients was not reported, other reported survey data on livestock type and handling methods was used to assign the material to one of the standard 43 "Manure Coefficient" data rows from Table 6-1.

However, with this method, several application events with varied lbs of N and P per ton were assigned to the same "Manure Coefficient" data row. Therefore each of these application events required a separate composition row in the APEX fertilizer definition table. These application events are identified with a "1" in the "Unique NP Indicator" variable in data associated with Table 6-10. There were 735 of these unique manure compositions and they were assigned APEX Fertilizer Table Id numbers in the range of 151 – 905.

**Procedures for 2003 and 2004 Data**

The following procedures were used to prepare the "application events" data:

a) Make a copy of the original Excel worksheet prepared with the procedures of Section 3 above. Prepare this copy of the spreadsheet for loading as an Access database table. From the original worksheet clean off extra information such as detailed column headers, standardize column names, delete blanks, etc., and rename as "Manure_Events". Column names are changed to match those in the "Manure_Events" table in the CEAP survey database (note the small differences between 2003 and 2004 survey years). Based on the original spreadsheet column headings, add an "S_" prefix to column names for original CEAP survey variables and "C_" prefix for variables calculated in the standardization process described in Section 3..

b) To the "Manure_Events" tables add a column "FertManID" that will hold the value linking each application event to a specific row in the APEX fertilizer definition table. For the application events requiring a unique entry in the APEX fertilizer definition table, (indicated by a "1" in the "UniqueNP" column), assign each event (row) a unique number for "FertManID", numbering consecutively (see range of ID assigned by survey year at end of previous sub-section). For the rows with "0" in the "UniqueNP" column, the "FertManID" is set at 101 to 143 by adding 100 to each of the composite manure IDs (the "ManCompID" values from Table 6-1).

c) Load the data from Excel into the CEAP Survey Access databases for 2003 and 2004.

d) In the 2003 "Manure_Events" table, make the following changes:

i) Convert year to 4-digits by setting "CropYear" = "CropYear" + 2000

ii) Add a variable "ManYear" to "Manure Events" table to hold the year of application and perform these updates:

[ManYear] = [CropYear] if [ManMonth] < 8 or if [ManMonth] is null

[ManYear] = ([CropYear]-1) if [ManMonth] >7

e) In both the 2003 and 2004 "Manure_Events" tables make the following changes:

a) add the following columns:

exclude (used in the edit process to mark an event as being excluded from the final simulation data set)

dataset# (denotes a classification originally applied to the samples by the NRCS headquarters team) date received (the date received by Temple team, used to track versions)

oldcropcode (hold the original crop ID code prior to crop code edits)

b) add the indices needed for the Display Edit and the Run Builder programs.

f) A number of 2003 application events were lacking either the month of application or the method of application. These were analyzed by the team and edits approved and documented.

**Procedures for 2005 and 2006 Data**

1. Copy and rename the "Manure_Events" worksheet prepared with the Section 3 procedures.

2. Add a row at the top to hold column names that will match current data base requirements, with the following column name assignments (Table 6-11):

3. Copy worksheet and load to Access (delete row with old column headings, etc.)

Change blanks to zeros in the following variables:
Old_S_ManMeth
C_tonrate
C_recordtype
C_lbsNrate
C_lbsPrate
C_lbsNton
C_lbsPton
Storsys1_13

Change "3*" to "3) for record type in 2 rows.
Change ""\" to "1" for bedding in 1 row.

4. Add the "FertManID" for the application events (rows) with "uniqueNP" equal to 1, assigning values from 704 to 891.

5. Set "Insuf_part_ran" to "1" if Dave's comments indicate row of shouldn't be simulated.

6. Add indices to the table so that data will load in Display/Edit program properly (see tables in 2004 data base for required content).

7. Assign the "FertManID" for the non-unique NP rows of data.

8. Standardize the data in the S_livestype and S_ManAnimal columns.

## 5. Conversion of Manure Attribute Data to APEX Format

The APEX model requires data on the proportion of the manure material occurring as mineral N, mineral P, organic N, and organic P forms; the proportion of the mineral N occurring in an ammonia ($NH_3$) form; and the proportion of the material occurring as organic carbon. The first step here was to add four columns to the "Manure Coefficients" table in the "CEAP cmn def data.mdb" database.

(developed from Table 6-1) and run the update query *"Man Fert rows s1 min org vs all for 43*" to populate those columns as follows:

minNvsN = [minNprop]*2000/[lbsNton]
orgNvsN = [orgNprop]*2000/[lbsNton]
minPvsP = [minPprop]*2000/[lbsPton]
orgPvsP = [orgPprop]*2000/[lbsPton]

Or, in plain English:

(Proportion of material as mineral N) = (proportion of N as mineral)* 2000/(lbs N per ton)
(Proportion of material as mineral P) = (proportion of P as mineral)* 2000/(lbs P per ton)
(Proportion of material as organic N) = (proportion of N as organic)* 2000/(lbs N per ton)
(Proportion of material as organic P) = (proportion of P as organic)* 2000/(lbsP per ton)

*This procedure uses the shares of total material in organic and mineral forms along with the total N and P content of the material to calculate the proportions of total N and total P that is mineral and organic.*

For cases where the survey reported either actual lbs of nutrients (N, P, and K) per acre per application event or reported the tons of composite material with an associated percent nutrient content each application event was assigned in the standardization process to one of the 43 data rows in the "Manure Coefficients" table. The second step was to run the query "*Man Fert rows s2 append 43*" to create and populate the table "Manure Rows for Fertilizer Table" with the 43 rows of data in "Manure Coefficients".

## 6. Adding Unique Manure Types to the APEX Fertilizer Table

For application events where no quantity of either material or nutrients was reported, other reported survey data on livestock type and handling methods to also assign the material of the event to one of the standard 43 "Manure Coefficient" data rows. However, since the lbs of N and P per ton varied across the several events assigned to the same "Manure Coefficient" data row, each application event required a separate calculated row in the APEX fertilizer definition table. In assigning a single composite material from the "Manure Coefficients" table, while at the same time allowing for variation in reported N and P content, it was assumed that for all events assigned to a specified "Manure Coefficient" row, even if the ratios of total N to total P, total N to total material and/or total P to total material ratios differed across the events, the following relationships were constant:

organic N to mineral N,
organic P to mineral P,
NH3 proportion of mineral N; and the
organic C proportion of total material .

For all the application events requiring unique fertilizer table coefficients, run the query "*Man Fert rows s3 calc append unique*" and append the calculated unique manure/fertilizer definitions to the table "Manure Rows for Fertilizer Table" (one row for each application event in "Manure_Events" table requiring unique composite manure):

[Mineral Nitrogen] = [minNvsN]*[c_lbsNton]/2000
[Organic Nitrogen] = [orgNvsN]*[c_lbsNton]/2000
[Mineral Phosphorus] = [minPvsN]*[c_lbsPton]/2000
[Organic Phosphorus] = [orgPvsP]*[c_lbsPton]/2000
[Ammonia Nitrogen] = NHx_share_minN
[Organic Carbon] = orgCprop

Or in plain English:

(New Prop of mat as N in mineral form) =
(Prop of mat as N in mineral form) * (lbs N per ton)/2000)

(New Prop of mat as P in mineral form) =
(Prop of mat as P in mineral form) * (lbs P per ton)/2000)

(New Prop of mat as N in organic form) =
(Prop of mat as N in organic form) * (lbs N per ton)/2000)

(New Prop of mat as N in organic form) =
(Prop of mat as N in organic form) * (lbs N per ton)/2000)

In summary these calculations result in slightly different shares of the different forms of N and P in the manure material due to slight differences between the N and P per ton reported in the survey and those values in the standard Manure Coefficients table. The values for proportion of manure material as organic C and for the share of mineral N in Ammonia form were used directly from the Manure Coefficients table. Note that if these procedures are run after manure application events have been replicated, e.g., for adding a year to the rotation, the result may be duplicate rows (same ID) in this table. These need to be removed before the next step since duplicates will not load into the I_APEX Fertilizer table. They can be found by running a query to count the number of occurrences of each ID.

### 7. Exclusion of Inert Manure Components from Simulation Data

As described in the introduction to this Manure Setup Chapter, the fertilizer attributes of the manure materials were simulated exclusive of inert materials. Setting this up was accomplished with three steps.

1) Calculate the “NPKC fraction” for each row in the “Manure Rows for Fertilizer Table” by adding together the following variables; this was accomplished with the query “*Man Fert rows s4 calc inert props etc*”:
    a. Mineral Nitrogen
    b. Mineral Phosphorus
    c. Organic Nitrogen
    d. Organic Phosphorus
    e. Organic Carbon

2) Redefine the five nutrient variables listed in previous bullet in the “Manure Rows for Fertilizer Table” by dividing them by the “NPKC fraction”. Original values renamed by adding “all” to the name of each. This was accomplished with two queries “*Man Fert rows s5 copy orig ALL material basis*” and “*Man Fert rows s6 calc coeff non inert basis*”.

3) When writing the values for manure application (kg/ha) in the I_APEX Field Operation table row, multiply the application rate by the "NPKC fraction."

Finally, the rows from the "Manure Rows for Fertilizer Table" were appended to the APEX fertilizer definition table with the "Man Fert rows s7 append man to fert."

## 8. Calculating Missing Application Quantities for 2003 Data

For the 2003 survey data there were 230 cases (application events) where no quantity of either materials or nutrients was reported. Of these events, 37 of them were determined to involve trivial amounts of livestock or have other problems and were excluded from further consideration. Of the 193 remaining cases, 30 did not have a yield reported and a few required the month of application and/or method of application to be specified. For each of the 193 cases the team assigned one of the standard 43 composite manure definitions based on other information reported in the survey.

Several steps were then developed to fill in the manure for the cases with missing quantities. For filling in the missing nutrient amounts, first, a judgment was made as to whether or not the manure was applied according to N-standard or P-standard guidelines. In many cases, the farmer reported the standard used. For other cases it was assumed to be applied at the N-standard level. Secondly, the amount of N or P to be applied was determined according to the procedures described in this section. Since for each application event the standard manure definition coefficients (composite material) had been determined previously, the quantity of manure to be applied was calculated based on the "lbs N per ton" or "lbs P per ton" coefficient for the assigned composite manure material. In the N-standard case, the quantity of P applied was simply the amount contained in the quantity of the composite manure required to applied the calculated amount of N, and vice versa for the N application with the P-Standard.

A table was made to hold data for the cases of missing application quantity (fips, psu, crop, cropyear) and then after accounting for the following list of considerations the total N or P to be added was calculated (note that some cases involved several application events ). The data assembled each case included the following (note that for all the cases there was no other reported manure added in the same year to the same crop):

- Standard N and P uptake and removal coefficients by crop
- Legume N credits for prior and current crops
- Applied fertilizer N and P
- Calculated N and P to be add set to zero if negative
- Calculated manure quantity to supply the nutrients

<u>Nitrogen Application</u>. The amount of N required for the crop production was determined from data in the CNNP Cost Assessment, the NRCS Animal Waste Handbook and other sources, as the amount of uptake and removal per unit of yields. As in the CNMP Cost Assessment it was assumed that 30 percent of applied N would be lost or otherwise unavailable to the crop. Therefore the uptake and removal rates were multiplied by 1.43. From this calculated amount both a legume credit and applied commercial N were subtracted (see documentation for "low and missing N adjustments" for discussion of how the legume credits were calculated).

<u>Phosphorus Application.</u> For phosphorus, there was a concern that application according to the crop removal rate would be applying un-needed P in some cases due to an excess of P in the soil from previous years. Therefore, the 70% trimmed mean application based on 2003 and 2004 survey data by crop group and LRR was developed (as in the "low and missing N adjustments") and then reviewed, converted, and adjusted by Lemunyon et al. to a table of P2O5 application values by crop group and region.

Various queries were applied to build the table [Hold Calc infor for added manure]. The procedures and assumptions are summarized here:

1) The total calculated manure application was divided evenly between the applications reported on the survey (by "num added applics").

2) Total reported N and P from fertilizer sources were totaled by (fips, psu_id, cropyear, crop).

3) The presence of a legume crop in the previous or current year was checked and a legume credit accounted for.

4) Yield was multiplied by the N and P "uptake and removal" coefficients - note the few cases (non-harvested sorghum sudan and idle without a yield, with zero added manure at this point). (haven't yet checked all the yields for consistency - though Jerry Lemunyon filled in some missing values for it)

5) Calculation of the "total man N to add" and "total man P to add" account for the above factors.

6) The "total manure to add" is found by dividing "total man N to add" by the "lbsNton" (or "total man P to add" by the "lbsPton") value by the from the linked "ManCompID" and "Manure Coefficients" table depending on whether the manure was applied for an N standard or P standard (only calculated if the "... to add" value was positive).

7) The "check N added" and "check P added" are calculated by multiplying the "total manure to add" by the "lbsNton" and "lbsPton" values -- shows that if you add manure according to N standard (or P standard) then you don't necessarily match the P requirement (N requirement).

The queries used and purpose (applied approximately in the order listed):

[get crop hist crop01], set 03 crop as crop prior to 01
[get crop hist crop02], set 01 crop as crop prior to 02
[get crop hist crop03], set 02 crop as crop prior to 03
[get crop history all years all crops], pull the 3 years of history together
[assemble info for manure fill in decision], get N or P standard indicator
[assemble info for manure fill in decision s2]
[go from crop rotation to prior crop]
[build crop rots for add manure s3]
[find info to add to manure Hold table 1]
[Build Table to hold Add Manure Calc info s2]
[get total N and P by case], find the fertilizer added for these cases
[final Man to add calculation s1]
[final Man to add calc man tons s2]

[final Man to add check calc s3]
[set zero added manure to 1 ton]
[add missing to Manure Events table].

Note that these procedures resulted in 57 of the 193 cases with a zero manure application rate due to applied fertilizer and/or legume credits. None of these cases (fips, psu_id, cropyear, crop) had other positive manure nutrient application events. For now, those cases of calculated zero application rate were set to an application rate of 1 ton of manure, with N and P content from the [Manure Coefficients] table with the query ]. Finally, a query was used to add the amounts to the appropriate even rows in the [Manure Events] table.

Tracking the "Calculated" Manure Applications. So that the added applications could be tracked throughout the simulation output analysis, the application methods (and operations) were replicated for the events with added manure, as shown in the Manure Application Methods table below (CEAP Code ID 7 to 14; see Table 4-2 for Machine Id Labeling and Identification).

### 9. Accounting for Moisture Content

An assessment of all the manure application events showed only a few where the total applied water for the year would be even as large as one-half acre-inch. Consequently, it was determined to ignore the water content of the applied manure.

### 10. Guidelines for Run Builder Operation

Some additional rules were specified for the Run Builder program (instructions for the APEX Field Operation table variables are shown in Table 6-12):

- For the 2003 data, where only the application month is given and not the day, the application will be on the first day of the month if in the period of January to June. If the application date is between July1 to December 31 apply it on the 1$^{st}$ day after the last tillage operation. and/or 1$^{st}$ day before the 1$^{st}$ fall tillage operation of the specified crop year.

- Multiply the ton rate value by 2241.7 to convert from tons per acre to kg/hectare and then multiply by the sum of the N, P, K, and C proportions from the Fertilizer Table to exclude the inert material (see discussion in the beginning of the manure section).

- For all incorporated methods of application, set the depth of application at 100 mm.

Prior to Run Builder it was found that a number of application events had very small application values. These were rounded up. First, there were 39 application events with N < 0.5 lbs/acre. For these events, the tons applied, and the N and P applied were all increased sufficiently to raise the N rate to 1.0 lbs per acre. Secondly, the data were checked again for P levels and an additional 48 events had the tons applied and N and P rates increased sufficiently to bring P up to 1.0 lbs.

# Chapter 7. GRAZING

## 1. Overview

Crop grazing information was collected in the 2004, 2005, and 2006 surveys, but not in the 2003 survey. However, for 90 of the samples from the 2003 survey, grazing was simulated based on other data from the survey. Four types of grazing were reported and simulated:

1) Grazing of the crop, usually a small grain, early in the growing season, followed by a traditional grain, hay, or silage harvest;

2) Complete grazing of the crop, sometimes referred to as “graze out”, with no traditional harvest later in the season;

3) Grazing of crop residues after a traditional harvest; and

4) Various combinations of the above.

Note that for a single crop, more than one type of grazing might be reported, such as a pre-harvest graze, followed by a traditional harvest, followed by grazing of crop residues. There were also a few instances of reported post or pre-harvest grazing where apparently the biomass grazed would have been from weed growth rather than from the listed crop. Examples of implied weed grazing include post-harvest grazing of cotton fields, and spring season grazing of fields prior to planting of crop. For these cases, grazing was simulated with the herd and crop specified in the survey, but the actual extent of biomass removal would be limited by crop residues since weed growth was not simulated.

The surveys did not report on the amount of biomass removed from the field. The surveys also did not report on use of supplemental feeding, weed growth, or the proportion of the field grazed (grazed biomass may have actually come from field borders, filter strips, etc.). Consequently, as explained in more detail below, the grazing specification was only an approximation of what the farmer might have been managing. For each occurrence of a crop in a crop year in a sample the 2004, 2005, and 2006 survey data included the variables shown in Table 7-1.

For 90 of the 2003 surveys (and for a few 2004, 2005, and 2006 surveys with no harvest operations listed), grazing was inferred from other data. For the 2004, 2005, and 2006 surveys the respondents were also asked to list explicitly the purpose of each crop in each year and the possible responses included “1 Dual (grain/grazing)” and “3 Grazing only”. For small grain cases in the 2003 survey data lacking a harvest operation, a probability assessment of grazing reported in the 2004 survey was used to determine if grazing was likely for the crop and locality.

*After all of the procedures detailed below were implemented, and the after the simulations were setup and tested, it was determined that for selected crops the grazing setup was mis-characterized. In these cases, the cattle were most likely grazing on weed growth which is not simulated. Therefore, all post-harvest grazing events for Cotton, Vegetable Seeds, Pumpkins, Turnip Greens, and Peppers were excluded. This exclusion involved 11 grazing events in nine samples (added 26 March 2009).*

In the discussion below, procedures for handling the 2003 and other exceptions with missing data are presented first, followed by the procedures for setting up grazing with herd definitions for the 2004, 2005, and 2006 surveys.

## 2. Probability Assignment of 2003 Grazing with the 2004 Survey Data

An early analysis of the 2004 survey data found 276 cases of a crop in a crop year in a sample (in 125 samples) that were defined as "grazing only" according to the following criteria:

Grain Yield = 0 or null and Grazing = Yes

The cases of grazing included a few Barley, Millett, Oats, Rye, Sorghum-Sudan, and Triticale, with the majority being Winter Wheat (there were only a few cases of Durum and Spring Wheat). However, in 40 cases the "Intended Use" variable indicated that the intended purpose was either dual grain and graze or grain only. All but one of those cases had a planting date, and 13 had a harvest date listed in the crop history section of the survey data. The 2004 samples with reported grazing were used to estimate a probability of grazing by Land Resource Region portion of states, according to the following equation:

probability = (grazing/(grazing + abandoned)).

Where the probability from the above equation was greater than 0.5, samples from 2003 lacking harvest operations for small grains were set up with grazing. Since information on herd size and composition were lacking, the grazing was setup as a one-time, once-over operation, with essentially the same characteristics as a green silage harvest. A second required determination was the date of grazing. Even if the field operations were lacking, the crop history section of the survey often include one or both of planting and harvesting dates. However, it was not clear if those harvest dates applied to the "intended use" if the original intent had been grain harvest or to the grazing, so they were ignored and the grazing dates (months) were specified as shown in Table 7-2, based on expert judgment.

One of two different grazing operations was assigned. If there were no other harvest operations and only one grazing operation, then the defined operation #431 was assigned, followed by a "kill" statement. If the grazing were to be followed later in the season by another harvest operation, then the defined operation #467 was used, without being followed by a "kill" statement.

## 3. Assignment of Grazing for 2004, 2005, and 2006 Samples Lacking Herd Specifications

There were 26 samples in the 2004, 2005, and 2006 sets where the once-over grazing operation defined for use with the 2003 grazed samples were also used. These were cases where the crop purpose or other reported data indicated grazing, or cases lacking inclusion of a harvest machine, but where no information on the grazing animals was reported. Assignment of grazing for these cases was based on the following three rules:

1) If the intended use was grazing only, then the once-over grazing operation was added with the date as the 15$^{th}$ of the month shown in Table 7-2, unless the crop history section included consistent harvest data, in which case the reported date was used;

2) If the intended use was grain then a grain combine was added on the 15$^{th}$ of month shown as the harvest month, with that month varying between June and August, depending on prevailing practices in the region; and

3) If the reported intended use was dual purpose, two operations were added, the once-over grazing (Table 7-2) and the grain combine.

The addition of the grain combine as indicated here is consistent with treatment of missing data and failed crops throughout the analysis. The decision was made to model the farmer's intent. The APEX model would harvest yield even if the yield was so low that the farmer would likely abandon the crop. Failed and abandoned crops, as well as missing data are discussed in other sections of this report.

**4. Simulation of Grazing for Cases with Herd Specification**

Within APEX a herd of livestock is defined and then assigned to a sub-area for grazing. In the sub-area file a lower limit on biomass (kg/ha) limits the extent of grazing, regardless of herd size and type or days of grazing duration.. Grazing is turned on and off on specified dates with operations in the Field Operation file, however, even if turned on, grazing doesn't occur if the biomass limit is constraining and grazing will also stop if both the stop date and the HUSC value are reached. The IHC codes are 19 and 20 for the start and stop graze operations respectively. The grazing start and stop operations also require harvest efficiency and height of cut values. The herd specification requires:

Number of livestock (can be set for the sample, or reset with each grazing instance)
Daily biomass uptake (kg/animal)
Daily manure production (kg/animal)
Daily urine production (liter/animal – only needed if concerned with moisture in a feedlot)
Link to specific manure composition in the APEX Fertilizer table

Specification of grazing for the CEAP APEX simulations required the following items:

1. Determination of the types of grazing present for each crop in each sample (pre- or post-harvest, followed by traditional harvest or not);

2. Definition of the grazing herds. Table 7-3 shows the APEX variables used to define a herd. Tables 7-4 and 7-5 define the average animals by type and region ( see also Tables 6-5 and 6-6), including daily biomass consumption and manure production;

3. Assignment of a manure identification number for each herd linking the herd to a manure row in the APEX fertilizer specification file (Table 7-4);

4. Addition of start and stop grazing operations to the "field operations" schedule for each sample. Several different stop grazing operations were defined and used, depending on the grazing season and the proportion and type of vegetative growth grazed;

5. For grazing of crop residues the primary harvest machine had to be replaced with a redefined machine having no cutting height. This was necessary because once a harvest machine is used in APEX, all biomass above the cutting height is converted to flat dead residue and becomes unavailable to subsequent harvest (grazing) operations; and,

6. A specification of the lower limit on above ground biomass. When biomass is below this level, grazing stops until more growth occurs, and initial grazing does not start until this level of biomass is reached.

The grazing situations reported in the survey data included a variety of situations, which were categorized into the following five types:

1. Pre-harvest graze followed by a regular harvest (388 events);
2. Pre-harvest graze out (314 events);
3. Post-harvest graze, no pre harvest graze (1864 events);
4. Pre- and post-harvest graze followed by regular harvest (89 events); and
5. Pre- and post-harvest graze with graze out (11 events).

Along with traditional situations such as brief grazing of winter wheat followed by grain production or grazing of corn stalks after harvest, the data includes sequences of hay harvest and grazing in the same season, grazing of corn rather than letting it mature for harvest, grazing of vegetable crops after the produce has been harvested, and a variety of other situations. Cases of reported grazing of fallow or idle land will not be simulated at this time. For these idle and fallow land cases, as well as for some of the reported crop residue grazing cases, it is not clear whether the actual biomass would have come from weed growth, the previous crop, or supplemental feeding.

One survey data deficiency was lack of information on supplemental feeding. Consequently, there were reported cases of high stocking rates, which combined with the duration of grazing, implied biomass consumption far in excess of what was produced by the crop. With our procedures, the high stocking rate was implemented but actual grazing duration was limited by biomass availability. Since manure deposition is a function of animal type, stocking rate and days of actual grazing, our simulated manure deposition may be less than what the farmer had with the large herd, long duration, and implicit supplemental feeding. To the extent that the farmer accounted for that manure in his fertilizer decisions, our simulation would be short of nutrients for the subsequent crop. However, the fertilizer N and P adjustment rates explained in another section of the documentation take care of the issue.

Some samples reported a different number of animals for different crop years. The APEX model allows only one livestock type (herd) definition per sample; however APEX capability was expanded to allow the modeler to specify (re-set) the number of animals in the field operation table each time a “start grazing” operation was added. Out of 2,667 cases of grazing (crop in a crop year in a sample) only 100 cases had both pre- and post- harvest grazing and of those only 21 cases had different animal densities for the two seasons. Of those 21 cases the post harvest density was slightly larger than pre-harvest density for all but two cases. Consequently, the decision was made to use the post-harvest density for the initial herd specification for each case of grazing having both pre- and post-harvest grazing and differing densities for the two cases. An additional 66 cases of grazing were ignored completely since the listed crop was fallow or idle and it wasn’t clear whether or not consumption would be of residues from a previous crop, from weedy vegetative growth, or supplemental feeding.

Table 7-4 shows the livestock type definitions and Table 7-5 shows the associated manure definition coefficients for the APEX fertilizer file (see also the discussion in the pre-ceding chapter on Manure simulation). Since APEX allows only one herd per sample, it was fortunate that no samples reported two or more different livestock types for different crop years. However, the reported generic “cattle” type had to be addressed. This was done by developing a regional “Cattle” type representing a weighted mix of beef and dairy according to Census of Agriculture data (see Animal Waste documentation by David Moffitt). For all livestock types, the daily biomass consumption was assumed to be 3 percent of body weight. The manure production per day by animal type and the nutrient attributes of the manure are also described in the Animal Waste documentation by David Moffitt (see preceding chapter on Manure simulation).

Four samples (out of a total of 1569 samples with any grazing) had the additional complication of using more than one type of animal for grazing at some point during the rotation. At the time of the analysis, APEX was not set up to allow for different animal types (two or more herds) for a sample unless there were multiple subareas across which the herds could be rotated. Consequently, for these four samples, the following changes were made by a query:

8009_030701O2 goats reassigned as cattle (id 3 to 15)
18151_010401R1 beef reassigned as sheep (id 6 to 2)
19155_030502R1 sheep reassigned as cattle (id 2 to 12)
38057_040201B1 cattle reassigned as sheep (id 17 to 2)

**Determination of the Type of Grazing for Each Sample**

The first step in setting up the grazing was to determine what type of grazing was reported for each crop in each sample and make the appropriate classifications so that the field operations file and herd definition could be set up properly. This was accomplished by developing a series of queries with the results saved in a “Grazing Events” table containing one row for each grazing event (grazing occurrence for a crop in a crop year in a sample) (Table 7-6). The Graving Events table specifies the crop year, crop, type of livestock, livestock density per acre, seasons of grazing, and whether or not planting and harvesting equipment were also present in the crop year of every reported occurrence of grazing.

There were a few cases of inconsistency that had to be corrected. For example, prior to harvest of a corn crop, a rye cover crop was planted with a broadcast seeder. The reported grazing was post-harvest of the rye crop, even though the rye crop was a cover crop killed by tillage for the subsequent crop. It was obvious that the intended report was post-harvest grazing of the corn residue and pre-harvest grazing of the new rye growth. The correction was to add post-harvest grazing for the corn crop and change the grazing of the rye crop to pre-harvest type. For the 2004 survey livestock type “3” was “other” and then was changed to “5” to be consistent with the 2005 and 2006 surveys.

If the survey data for a grazed sample with reported “other” or “cattle” livestock type also reported manure application to the field with a reported animal type for the manure, it was assumed that the grazing animal type was the same as the type that produce the manure under confined conditions at some other season. This assignment was made without regard to crop or year, i.e., beef manure may be applied in 2002 to a corn crop in the field even though the reported grazing is for oats in 2003. If manure data was not available, then the “other” and “cattle” types were assigned to a regional mix “type” of dairy and beef livestock according to distributions of dairy and beef operations in the Census of Agriculture (see documentation by Dave Moffitt in the Animal Manure Chapter section).

For grazing events with a reported number of animals, the number of animals was divided by field size to estimate the density of animals per acre. Where the number of animals was not reported, averages calculated by the USDA Farm Production region were used to fill in the density. If averages were not able to be calculated at the regional level, the U.S. average was used. After using the national average, regional pre-harvest averages were used to fill in selected missing post-harvest densities and vice versa, where possible. Finally, a few cases had the density assigned as one animal per acre.

**Grazing Start and Stop Entries in the Field Operations Schedule**

For post harvest grazing the duration of grazing, along with density, could be specified by date since, assuming that the grazing would start the day after the regular harvest and continue for the number of reported days. However, in the simulation the actual duration may be shorter if 1) biomass is reduced to 2 tons per acre prior to grazing period expiration, or 2) if tillage operations for the subsequent crop commence. Accounting for all of the date issues with scheduling of grazing also required a series of steps using the data accumulated in the Grazing Events table. For example it was necessary to convert calendar months and days to Julian days so that the number of days of grazing could be properly accounted for in the programming code. The APEX Tillage file (Operations) was augmented with the following four operations and these were added to the Field Operations Schedule file for grazing cases as described below:

> #468, “Start Graze” starts grazing on the specified date;
> #469, “StopGraze035” stops grazing when HUSC reaches 0.35; crop continues to grow for the subsequent regular harvest;
> #470, “StopGraze095” stops grazing when HUS reaches 0.95 for “graze out” cases; and
> #471, “StopGrazeDay” stops grazing on the specified date.

*{An additional enhancement might be possible for the “471” operations. Heat Unit Accumulation Scheduling (HUSC) is used for field operations in the CEAP APEX simulations. This allows the operations to be delayed each year, depending on weather, until both the scheduled date and the specified proportion of heat units is reached. Many of the after harvest grazing situations have a high density of animals for a short duration. If the harvest operation were delayed even a few days,*

*the grazing period with its fixed stop date would be too short. The fix for this situation is to use the average daily accumulation of base heat units (calculated relative to 0 Centigrade from the crop kill date) to schedule the grazing stop. For example if the grazing duration is to be 10 days, then the average daily weather file is consulted to determine the proportion of annual base heat units occurring in that period. However, as noted in the introduction, information was unavailable on use of supplemental feed, weed growth, proportion of field grazed, and grazing of buffers and borders. Consequently, the additional precision from the alternative discussed in this paragraph is not warranted.}*

The following steps were used to collect the data in Table 7-6 and then write the grazing start and stop operations. After operations were written, each sample was examined individually to fix any date or other inconsistencies.

First determine the dates of harvest and planting from the reported field operation schedule for each case of a crop in a crop year in a sample being grazed. Account for the cases of forage, fallow, and idle crop or land uses for which the data base may not contain planting and harvest dates for each crop year of a crop being grazed; default values were assigned by a query and then later adjusted for consistency with hand editing. With those dates determined, the start and stop grazing operations were written. The pre-harvest grazing stop operations were written with a fixed date of only 1 day later than the start grazing operation. However, the stop operation doesn't actually occur until the specified proportion of heat units is reached (0.35 of total heat units needed for the crop to reach maturity). Also, in APEX all grazing stops automatically on December 31. Consequently, for both the grazing of winter small grains and crop residue, an extra set of start and stop operations must be written for January 1 and 2 for cases where grazing duration is expected to go into the next year. The Heat Unit Scheduling (HUSC) aspect of the stop grazing operations is written by the Run Builder program according to the following guidelines:

a. If graze type 1 (pre-harvest grazing, following by grain or forage harvest) and operation 469, then HUSC = 0.35;

b. If graze type 2 ("graze-out") and operation 470, then HUSC = 0.95;

c. If graze type 3 (specified grazing duration, usually post-harvest) then operation 471, then calculated stop date;

d. If graze type 4, (pre-harvest graze, traditional harvest, followed by stubble grazing) then 1st operation 469 has HUSC = 0.35and 2nd operation 471 has specific stop date;

e. If graze type 5, then 1st operation 470 has HUSC = 0.95 and 2nd operation 471 has specific stop date; and

f. A few even more complicated combinations of the above.

In writing these operations, extra steps were required to account for grazing periods extending across two months, extending into the next year, and if they occurred in the fall and extended into the following winter and spring of the last crop year of the sample. Once these operations were added to the data table, additional queries and hand edits were used to reconcile the following:

1. For cases of post-harvest grazing, change the various small grain combines and corn picker to operation ID 432 which has no cutting height, so that residue remains “standing” for the grazing animals to remove;

2. Remove or reconcile any manual one-time once-over grazing operations added in editing procedures previously applied to the samples; and

3. Reconcile cases of obvious inconsistency, such as post-harvest grazing listed for a row crop such as cotton which obviously is meant to pertain to the winter cover crop planted immediately after harvest of the cotton. There were also a few cases of pre-harvest grazing followed by combine for corn, soybeans, sorghum, etc. For these crops the pre-harvest grazing must imply grazing of pre-plant weeds or residue from previous crop. In order to produce the grain yield these pre-harvest graze operations were dropped (only about 25 samples involved this issue).

The frequency of grazing by crop, type, and region for the nation are shown in Tables 7-7, 7-8, and 7-9. The crop groups grazed the most frequently were Corn, Wheat, and Forage crops (30.1, 29.9, and 17.4 percent of total cases, respectively) (Table 7-7). Most of the Corn grazing was post-harvest white the largest category for Wheat was pre-harvest, followed by a traditional grain harvest. The largest category for Forage crops was also post-harvest, generally indicating grazing after a traditional hay or silage harvest. Examination of Table 7-7 indicates that some instances of grazing must be weed growth, e.g., eight percent of the grazing cases were Soybeans. The Missouri river basin accounted for 45 percent of the grazing (mostly post-harvest type), followed by the Arkansas-White-Red river basin with 20 percent (mostly pre-harvest followed by traditional grain harvest) (Table 7-8). The defined “Cattle” livestock type, reflecting regional mixes of dairy and beef, was the largest class of livestock (Table 7-9).

# Chapter 8. PERENNIAL FORAGE AND GRASS SEED CROPS

## 1. Overview

The CEAP cropland survey includes approximately 1,600 samples having one or more years of perennial forage or grass seed crop or having only idle or fallow reported for any year. Those samples needed to have crops (years) added for a reasonable representation of crop rotations. This situation arose from the fact that the CEAP survey covered only a 3-year point-in-time portion of obviously longer duration management cycles. Consequently many of the reported CEAP 3-year sequences (only 1 or 2 years reported for some samples) are only portion of longer duration rotations that must be specified for the simulations to be reasonable. Those sequences include the following (and similar combinations with grass seed and cropland pasture):

Hay-Hay-Hay (one year might or might not be the establishment year)
Hay-Crop-Crop
Crop-Crop-HAY
Idle-Idle
Idle
Hay

Various simple and complex solutions were considered for either making the rotations realistic or alternatively, just insuring that the APEX simulations would execute.

1) If the first year of hay reported in the 3-year sequence included a planting operation the APEX simulation would generally work just as reported. However, the resulting simulations would be a very poor agronomic representation of hay/crop rotation production systems since the number of hay years would be under represented.

2) Idle could be simulated as idle with or without the addition of a "weed" cover crop, e.g., setup in the same way as the CRP simulations. However, if all reported years were idle or fallow in the rotation, then that sample is really outside the domain of CEAP cultivated cropland.

3) Crops could be added according to the most recent NRI history for the specific point. However, the question of where to obtain the management data for those added crops would need to be resolved, and the specific addition of data for a single point would perturb the statistical representative-ness of the entire set of samples for the area from which the sample were drawn. For example, assignment of any tillage type would change the distribution of tillage types in the area.

4) A random draw of a number of donor samples for each problem ("target") sample and expansion of the years (crops) within each donor based on data from it or the other donors, resulting in a set of "expanded" donor samples for each target sample.

    a. A first exception to 4) is the case where for any sample the reported 3-year CEAP crop history contained all of the crops listed in the 5-year NRI land use history. In that case, no donor samples would be used. Instead the crops (years of data) reported in the CEAP survey would be replicated as needed to fill out the NRI 5-year history. This replication would be done without necessarily matching years of the CEAP history to the years of the NRI history. However, to the extent possible, the crop after crop sequence attribute of the CEAP history would be used in assigning those crops to the NRI history. For example, if the CEAP history had Alfalfa-corn-corn and the NRI history had Alfalfa-Alfalfa-Corn-Corn-Alfalfa, then the corn after alfalfa from the CEAP history would be used for the corn after alfalfa year in the NRI history, and so on. Some latitude is required in matching the NRI and CEAP crop definitions, e.g., "1 Alfalfa hay and Alfalfa Hay Mixes" from the CEAP can be matched to both "142 Legume-Hayland" and "143 Legume-Grass-Hayland" from the NRI. Other examples include where the NRI lists only "Corn" and "Wheat" without specifying grain or silage for the corn or spring, winter, or durum for the wheat.

    b. A second exception to 4) is the case where the reported 3-year CEAP has one or two years of hay, but the 5-year NRI has only cultivated crops. For this case the sample is to be set it up as a rotation as reported.

Solution 4) was initially chosen because it would preserve the statistical sampling attributes of the CEAP survey. ***However, it was later dropped from consideration due to complexities in implementation. Nevertheless, it is described here below, even though the short cut solution was to model these points "as reported" with addition of planting operations and other adjustments as needed so that the simulation would function. Prior to dropping solution 4) from consideration, the samples meeting the criteria for the first and second exceptions listed above were identified and edited according to the protocol outlined for them. However, the procedure outlined below in the remainder of this section is the preferred method and may be implemented at some future date. For now the samples not meeting either exception a. or b. above are not modeled.***

The random draw for solution 4) would be conditioned by GIS techniques and agronomic criteria of “sameness” between the target and donor samples. The resulting mix of tillage methods and nutrient and pest management for each set of target/expanded samples would be representative of the mixes occurring in the area from which the target and donor samples were drawn. Implementation of solution 4) is detailed in the remainder of this document, exclusive of the exception 4) a. which needs no further explanation. The discussion refers to the following 3 types of samples:

***Target*** = an original sample that needs expanded with more years and crops;
***Donors*** = a set of samples for each target sample from which data will be obtained; and
***Expanded*** = a new “sample” developed by combining soil, landscape and other features of a “target” sample with edited and expanded data from one of its “donor” samples.

## 2. Procedures

1) For each sample needing additional crop years added to fill out the rotation (“target” sample), use the 5-year (1999 – 2003) NRI land use history directly for the "target" sample, rather than the reported 3-year CEAP crop history.

*2)* Based on clues from the CEAP reported data for the target sample and from the NRI 5-year history, soil, slope, etc., find within the Crop Management Zone, or other defined spatial area, 6 - 8 "donor" CEAP samples, each having at least one of the crops listed in the NRI 5-year history for the target point. Donor selection criteria could include, e.g. corn for a target with a corn-hay sequence come from a donor that also has a corn-hay sequence and a match between soil Map Unit of target and donor. *Note the implicit assumption that the random draw of expanded donor samples will statistically match the distribution of tillage types, nutrient management regimes, etc. of the area from which the target and donor samples were drawn.*

   a) It is likely that NO donor sample will have all the crops reported in the NRI 5-year history, but for instance, if the donor point has 1 year of corn and the NRI 5-year has 3 years of corn, then that 1 year of data will be replicated for all 3 needed years within the expanded donor sample dataset.

   b) In some cases, a donor year of hay harvest may need to be augmented with appropriate tillage and planting operations to create a hay establishment year in the expanded donor sample.

   c) Where one or more of the selected donor points are missing one or more of the needed crops for the NRI 5-year history, either obtain that crop from another donor point, or drop the donor and find another donor or reduce the number of required expanded donor data sets.

   d) If all of the available donor points are missing one or more of the needed crops, then find that crop (or an entire donor point) from a larger area or relaxation of other selection criteria.

   e) There may be cases where the tillage operations, scheduling, fertilizer, etc., of years/crops within the expanded samples will end up being inconsistent with a preceding or following year in the developed expanded donor data and these will be edited for consistency based on agronomic rules.

3) Assuming all of the difficulties in 2) are overcome, the result will be 6 - 8 new donor datasets (or other acceptable number) to use in place of the original "target" data set. Individual APEX

simulations will be set up for each of the 6 - 8 expanded donor datasets. Each will have the soil, landscape, structural practice, and weather datasets of the original "target".

4) Acreage expansion weights for the expanded donor simulations (identified by fips, psu_id, and pseudo) will be developed by splitting the weight of the original target point. The split will be proportional to the acreage weights of the donor samples, i.e., if the target sample represents 4000 acres, donor sample x represents 2000 acres, and all donors represent 5000 acres, the new acreage weight for the simulation for expanded donor x will be ((2000/5000)*4000) or 1600.

### 3. Tasks

1) Development of a program that uses GIS techniques and agronomic rules to identify the donor sample candidates for each target sample. The output of this program will be in the form of a table or spreadsheet showing specifically the source of data for each year (crop) for each new expanded donor sample. This file will have multiple rows per target sample (one per expanded donor row) and five columns, one for each year (crop) of the 5-year NRI crop sequence.

2) Development and implementation of a Visual Basic program to locate and extract donor data, re-label it appropriately as to new sample and year of occurrence identification, and insert it into the proper sequence in the expanded donor simulation datasets.

3) Extensive review and hand editing of each expanded donor dataset to resolve any consistency issues that were not possible to be accounted for in the Visual Basic program.

### 4. Exceptions and Decision Criteria

After implementing the program to build the 5-year sequences of data as described above, many of the samples would be found to lack pre-plant soil preparation and planting operations. These guidelines were also followed in adding necessary operations to the samples identified in exceptions a. and b. above.

1) If the last harvest operation of the cultivated crop just prior to the first hay crop was earlier than September 1, then a chisel plow, tandem disk, and drill were inserted on subsequent days after that harvest operation. For late harvests of that cultivated crop, either 2) or 3) below were done.

2) If the harvest operations in the first year of the hay crop did not occur until after July 1 the planting was done with a drill in that year on April 25, preceded 5 days by a tandem disk and 10 days by a chisel plow.

3) If the harvest operations in the first year of the hay crop were earlier than July 1, they were changed to planting operations as described in 1) or excluded.

Note that these are the same planting procedures were used for the samples set up as continuous perennial grass seed where the survey data lacked grass establishment.

## Chapter 9. SUGARCANE SIMULATION

### 1. Overview

The final data set included 74 samples with sugar cane. Of these, all except two from Florida and three from Texas were from Louisiana. The data reported for sugar cane required fairly extensive editing, particularly for the 2003 and 2004 survey years. In this documentation, more information is included on the procedures applied for the 2003-2004 survey years than for 2005 and 2006. However, that does not imply different treatment of the survey years. The 2003-2004 survey years reflect less training and/or survey data coding materials for the survey collection staff and that resulted in less adequate data. For 2005 and 2006 the years reported were essentially complete and accurate and the extent of the required editing was to replicate one or more of the harvested years, or to add a year at the beginning of the rotation with appropriate establishment operations.

There were four major reasons why the data reported for samples containing sugarcane in the rotation were insufficient for setting up model simulations:

1. The three year survey period covered only a portion of the perennial life cycle of the sugar cane crop, which was generally expected to be five years in length, although occasionally shorter or longer;
2. The period from planting to first harvest for sugarcane is usually about 15 months and planting generally occurs in the late summer or early fall. In the survey reports, the establishment year was often reported (labeled) as “fallow” or “idle” rather than as “sugarcane”, although a few samples included a short season field crop early in that year;
3. The list of machines and other reporting options provided in the survey was insufficiently labeled for accurate reporting of the sugar cane management processes (particularly in the 2003 and 2004 survey periods), e.g., “small grain combine” since options didn’t include “sugarcane harvester”;
4. A single field may have included acres with sugarcane growing at different life-cycle stages or for different purposes, e.g., cane for seed versus cane for production or cane-first harvest versus cane-rattoon harvest, with various management activities reported for each part of the field.

The survey information on planting dates and harvest years and available literature indicate 4 – 5 years for the sugarcane production cycle, sometimes longer depending on weed infestation and climatic conditions (see literature list at end of report). In year 1, the land is fallowed, or planted to a field crop during the spring, and then planted to sugarcane sometime in the August – September period. Planting consists of shallow burying of short pieces of sugarcane stalk in bedded rows spaced 4 – 7 feet apart. In year 2 the “plant cane” harvest occurs sometime between October and December. The cane is then allowed to re-grow (rattoon) for subsequent years, with a harvest performed during October – December of years 3, 4, and possibly 5 or 6. The rotation may involve another field crop before the sugar cane cycle is repeated. Following harvest, a disk bedder type implement is generally used to cover the sugarcane row and protect it through the winter. In the spring the top of the rows are scraped off and a heavy field cultivator and/or disk bedder type implement is used several times in to cultivate for weeds and continually bed the soil up around the sugar cane rows.

The NRI sometimes reports "fallow" for a crop year even though sugar cane was planted in the fall of that year. The NRI indicates up to 8 years of continuous sugarcane. However, it is likely that within that time frame there would be one year where after a fall cane harvest, the crop is plowed under, and the land fallowed until late summer of the following year, when it is replanted. Of the 37 sugarcane samples for 2003-04 surveys, only one sample included one year of cotton in the rotation and five samples included a year labeled as fallow. Of the 37 sugar cane samples from the 2005 – 2006 surveys, three samples included soybeans and one sample each included cotton and corn silage and four samples included a year labeled as fallow.

## 2. Procedures

APEX simulation data sets for each sample reporting sugarcane were developed by evaluating and augmenting the reported survey information as described in this document. Where additional harvest years were required for a sample, one of the reported harvest years from the same sample was replicated for the additional years. Where no suitable reported harvest year existed for a sample, a generic harvest year was added (defined after this paragraph). Where no planting year was reported for a sample, a generic harvest year was added. Unless survey data specifically indicated otherwise, a five year rotation was assumed, consisting of a fallow-plant year, a "cane harvest" year, and three "rattoon harvest" years. To the extent possible the reported field operation and crop history information was used as reported, with only a few machine substitutions. The field operations for the generic planting and harvest years are shown here:

**Generic Planting**
April 15, #15 Tandem Disk-Regular
May 15, #15 Tandem Disk-Regular
June 15, #11 Offset Disk-Light Disk
July 15, #44 Disk bedder - Row
August 15, #352 Sugarcane Equipment - Hand Planters
August 30, # 41 Bedder shaper

**Generic Harvest:**
March 15, #43 Disk bedder - Hipper
April 15, #43 Disk bedder - Hipper
November 15, #351 Sugarcane equipment -single row chopper/harvester

The literature (see list at end of report) indicated that in almost all cases sugar cane is burned at harvest time, either prior to the harvest operation, or prior to transport to the sugar factory. The purpose of the burning is to remove leaves and other "trash" material so that they do not absorb sugar solution during the cane processing stage. Prior to burning, the above ground portion of the sugar cane plant consists of approximately 25% leaves and "trash" material, of which 50% (12.5% of total above ground biomass) is consumed by the fire. However, there was only one burning operation reported in all of sugarcane sample reports. Consequently, the APEX sugarcane harvest operation parameters were adjusted to reflect removal of 12.5% less than the normally harvested biomass as yield. That procedure results in 12.5% of the biomass remaining on the soil surface as residue instead of being removed by burning.

### 3. Summary of Rotation Development

Table 9-1 shows the data used for each rotation year for each of the 2003-04 sugarcane samples. Samples from the 2003 survey generally had reported harvest (H) or plant (P) years for 2001, 2002, and 2003 (2002, 2003, and 2004 for the 2004 survey). Additional years labeled as 1998 or 1999 were added as needed. The specific calendar year label is not important as long as the sequence of different stages of sugarcane production over time is correct. When the data is used as an APEX simulation model input dataset, the years are relabeled as 1, 2, 3, …, and so forth. Considering all 5 plus crop years used in the rotations for the 2003-2004 samples, 70 percent used data reported in the survey, with only 30 percent using the generic assignments. Generic planting years had to be added for 30 of the 37 samples. Only 16.5 percent of the harvest years (8 samples) were populated with generic harvest operations instead of copying data from another harvest year in the same sample. These were cases where the reported machines and/or dates were clearly wrong or inconsistent for all years reported in the sample.

Table 9-2 shows the crop rotations for samples with sugarcane in the 2005 – 2006 samples. Of the 37 samples, 29 required addition of the generic planting operation year and all required addition of at least 1 harvest year (replicated from one of the reported years).

### 4. Sugar Cane Fertilizer Data

For the 2003 – 2004 survey years, the reporting of fertilizer applications seemed quite incomplete, while for the 2005 – 2006 years, the reporting was both complete and consistent. The 2003 – 2004 samples were edited and transformed to simulation datasets approximately 2 years prior to the same being done for the 2005 – 2006 samples. Consequently, for the 2003 – 2004 samples a fairly complex analysis of the reported data was completed, and adjustments made to the reported fertilizer for some samples. Total N, P, and K fertilizer per acre per year were calculated from the reported data each sample and crop year in the 2003 – 2004 set. For 29of the 37 reported samples those rates were very consistent with published literature. Consultations with experts indicated that the rates for all samples were possibly correct for the period survey, although clearly not sufficient to sustain yields in the long run. For one sample, the reported N rate is approximately three times that of the other samples while for the other seven outliers, the N rate was generally about one-halve that of the 29 "consistent" samples. For all crop years for which the reported data was used directly, the reported fertilizer rates were used. However for consistency in the simulation, fertilizer rates had to also be assigned for the generic years added to the rotation cycle. That was done by calculating the average annual application of N, P, and K for the reported years in each sample and then applying that average for the added years, including for the fallow/planting year. In a few cases, with very low or no reported rates, the rates were copied from another sample in the same state.

### 5. Sugar Cane Pesticides

The variation in reporting of pesticide use across survey years was similar to that of the other data elements already discussed. For the 2005 – 2006 surveys the reporting seemed consistent and complete. For all survey years, pesticides were not added for the added generic planting years. When the data from one harvest year was replicated and used for another harvest year, the pesticides were also copied. Note that for the 2003 – 2004 surveys (and to a lesser extent in the 2005 – 2006 surveys), even where the survey reported three similar years of cultural practices, the pesticides reported varied from year to year.

# Chapter 10. IRRIGATION

## Overview

The setup of irrigation simulation in the CEAP analysis was a complex task, involving combining data from the CEAP cropland survey and the NRI with other NRCS technical information. Simulation of irrigation in the CEAP analysis was set up to account for the following factors:

1) Seepage and evaporation losses in the conveyance system transporting the water on-farm and within field, to the point of distribution within the farm field;

2) Evaporation losses associated with pressurized application systems;

3) The CEAP cropland survey report of technology (systems) used for conveyance and distribution within field, and application method;

4) Use of system specific distribution efficiencies, runoff percentages, and percolation coefficients;

5) NRI report of the method of water conveyance to the field by canal or ditch; or by pipeline;

6) The use of Irrigation Water Management (449) or Irrigation Land Leveling (464) practices;

7) The field had been graded to a specific slope, including no slope;

8) Variation in annual timing and quantity of irrigation applications due to weather fluctuation which assumes full irrigation supply;

9) CEAP cropland survey report of disposition of runoff;

10) Use of differing distribution and application systems for different crops or crop years within a rotation (and even irrigation of some years and/or crops but not others);

11) NRI report of field slope and soil hydrologic group;

12) Increase of the leaching fraction to at least 15% for samples where the farmer indicated that irrigation water management was used to address a salinity issue; and

13) Ability to change water conveyance, distribution, and application efficiencies, the runoff proportion, and the percolation proportion in order to simulate alternative scenarios of practice adoption.

In addition to the factors and issues listed thus far, the issue of runoff of natural precipitation from irrigated lands was also investigated. The structure of the APEX model would have allowed (required) specification of the Runoff Curve for each case of irrigation in order to insure that natural precipitation runoff was limited where irrigation runoff was also controlled. However, examination of the data and consultation with regional technical experts led to the conclusion that this was not an issue that needed to be explicitly addressed in the model setup.

The CEAP cropland survey included data elements reported at different spatial and temporal scales:

For each crop in each crop year of a sample the following was reported:

1) Whether or not irrigated;
2) Total quantity of water applied, or total time of irrigation and water flow in gallons per minute;
3) Number of irrigation events;
4) Whether or not a pre-plant irrigation occurred; and
5) Method of scheduling of irrigation events.

For each crop year of a sample the following information was reported:

1) Type of irrigation systems used (see Table 10-1);
2) Irrigation source [*sic*] for gravity fed systems (see Table 10-2);
3) Furrow width and length;
4) Indicator of unequal within field application;
5) Use of poly-acrylamide (PAM), slope grading, laser leveling, Irrigation Water management, and Irrigation Land Leveling practices; and
6) Disposition of runoff from the field (see Table 10-3).

For each sample the following was reported:

1) Whether or not slope was adjusted as part of a conservation plant;
2) Year of installation and refurbishing of system if pressurized; and
3) Whether or not irrigation was managed to address salinity problems.

The NRI survey (2003) reported the following variables for each survey point (type of system was used to fill in some systems not reported in the CEAP survey):

1) Source of irrigation water (Table 10-4);
2) System of conveyance of water to the field (1= canal or ditch and 2 = pipeline); and
3) Type of irrigation system (Table 10-5).

Not all of these survey items were used in the analysis. The quantity of water, number of irrigation events, method of scheduling, and whether or not a pre-plant irrigation occurred were not used since these things are highly dependent on weather which varies from year to year. In place of these data elements, the auto-irrigation options of APEX were used as described below. Also not used was "Furrow width and length" and use of PAM.

Setup of irrigation in the APEX model required specification of three variables for each irrigated case of a crop in a crop year in a sample:

1) EFM – proportion of water not lost to seepage and evaporation during on-farm conveyance and during pressurized application;
2) FIRG – proportion of field capacity deficit to be added for gravity fed distribution systems when an auto-irrigation event is triggered; and
3) Runoff – proportion of applied water that runs off end of field.

Before explaining those three variables, an explanation of the APEX auto-irrigation process is given. The cropping system reported for each sample is repeated through the 62 years of the simulation. .Auto irrigation was used, rather than the reported schedule of application events, to account for expected variation in weather within each year and across years because we do not have irrigation information other than the years surveyed. Table 10-6 shows how the APEX variables were set for auto-irrigation.

In earlier versions of APEX, the EFM and runoff proportions were assigned at the subarea level and were constant across all crops and years. The FIRG variable is newly defined for the CEAP assessment. APEX was enhanced for the CEAP assessment so that EFM, runoff proportion, and FIRG can be reset at any time within a crop rotation through inclusion of an additional field operation row. This is important to account for reported differing systems and practices used on a sample, e.g., soybeans versus rice in a rotation.

**Irrigation System Efficiency (EFM)**

Within the APEX model datasets the irrigation seepage and evaporation efficiency (EFM) variable is part of the definition of a "machine" or operation. For each individual APEX simulation the modeler can specify which irrigation operation to use. This can be done for all years and crops in a subarea with a subarea file, or it can be reset at any point in the rotation by including an irrigation row in the field operations file. Since the CEAP assessment includes cases where the system changes during the rotation, we specified which irrigation system to be used for each case of a crop being irrigated by inserting an irrigation row into the field operation file on the same day as the planting operation.

For the CEAP assessment the EFM variable accounts for seepage and evaporation losses during on-farm conveyance of water from point of acquisition to point of in-field distribution or discharge plus the evaporation losses associated with pressurized application systems. The 19 basic CEAP reported irrigation distribution and application systems were expanded to 58 to account for on-farm conveyance losses associated with ditches (canals) or pipes, and for use of Irrigation Water Management (IWM) or not. The determination of ditch versus pipe was from the 2003 NRI "Irrigation System" variable while the IWM determination was from the CEAP report of the use or non-use of Practice Standard 449 or not. The field operation Id and EFM values for the expanded set of systems are shown in Table 10-7.

The criteria for setting this variable included the following:

1) If CEAP reported system was pressurized (1 – 9), assume PIPE
2) If CEAP reported system was gravity (10 – 19), check the NRI irrigation system:
    a. If Canal or Ditch, then DITCH
    b. IF Pipeline then PIPE.

There were a few survey reports lacking specification of one of the basic 19 irrigation systems. These missing systems were filled in by the following ordered criteria:

1) If reported, assign the system most recently used for a previous crop in the same sample;
2) Consult the NRI and if pressurized, assign as a"#4 center pivot or linear move with impact sprinkler" and if gravity, assign as "#18 open discharge"; and
3) If still not assigned, consult NRCS technical experts.

**Irrigation Fraction Field Capacity (FIRG)**

The fraction of the field capacity deficit (FIRG) added with each auto-irrigation event is a new variable designed to account for uneven with-in field distribution and percolation losses associated with surface flood irrigation types. Even if the field had a perfectly uniform graded slope and soil condition throughout, it is generally not possible to avoid percolation losses at the top of the field while waiting for the water flow to reach the lower end of the field. For example, if when an auto-irrigation event was triggered, the average field capacity deficit was calculated to be 200 mm, the FIRG variable might specify that 300 mm be added, with 100 mm being allocated within the model to the accounting of percolation below the root zone.

The FIRG variable was set with criteria based on the following factors:

Basic reported CEAP irrigation system;
Reported use of either "slope grading" or practice 464 (irrigation land leveling);
Reported source of water for gravity distribution systems;
Use of IWM or not;
CEAP report of runoff disposition;
Soil Hydrologic Group; and
Slope of field.

Before presenting the detailed methods used to assign this variable, it is necessary to present some additional classification documentation. Table 10-8 shows how the basic irrigation system codes (19 originally) were expanded to account for combinations of land leveling and CEAP reported source (sic) of gravity fed irrigation water. In addition to those factors, the following criteria were applied in choosing the FIRG variable from those shown in Table 10-9:

1) If reported runoff disposition was 2, 3, or 4 (conveyed from field or otherwise eliminated), use the FIRG setting.
2) If reported runoff disposition was 0,1,5, or null, then check the following conditions:
    a. If soil hydrologic group A, use FIRGnorun_A
    b. If soil hydrologic group D or slope >3%,use FIRGnorun_Dor G3
    c. If soil hydrologic group D and slope >3%,use FIRGnorun_Dand G3
    d. If none of those conditions, then use FIRG_norun

Multiple runoff values were estimated for each system to account for differences in soil properties and slope, and a revised FIRG is needed to account for end-of-field ponding and infiltration of runoff.

The basic calculation is:

Water to the field = FIRG*FC/((1 – RO)*EFM)

Where:

FIRG is coefficient to account for deep percolation
FC is roughly equivalent to Field Capacity of the soil profile
RO is runoff at the end of the furrow/border expressed as decimal percent of water applied
EFM is a coefficient to account for infiltration and evaporation losses in the on-farm and field delivery systems and as the water is applied to the field

To calculate a revised FIRG to account for infiltrated runoff (runoff ponded at the end of the field), the above equation is solved for 'Water to the field', the runoff is set to zero, and the above equation is solved for the revised FIRG where:

FIRG*FC/( (1 – RO)*EFM) = Revised FIRG*FC/EFM
Terms cancel and the Revised FIRG = FIRG/(1 – RO).

The count of assignments made with the queries is shown in Table 10-10.

**Runoff Proportion**

The runoff fraction was set based on the same factors as the FIRG variable, except that the CEAP report of type of runoff disposition was not considered. However, only the runoff disposition 4, 'Drained from the farm,' will have APEX calculated values of irrigation runoff. The runoff values are shown in Table 10-11. The count of assignments made is shown in Tables 10-12. For runoff disposition = 1,2,3,5, and Null the APEX runoff coefficient is set to 0.

**Salinity Management**

Consultation with regional irrigation specialists resulted in the assumption that if the farmer was managing irrigation water to control salinity, the leaching fraction would be at least 15 percent. Of all irrigated samples, 340 reported salinity management (734 cases of a crop in a crop year in a sample). The FIRG was increased to reflect the additional percolation need for the salinity leaching fraction by the following procedures.

First, define four additional FIRG variables:

a. FIRG_salt for cases reporting irrigation water runoff, no IWM
b. FIRG_norun_salt_adj for cases reporting no irrigation water runoff, no IWM
    1. (1.15 - FIRG and 1.15 if FIRG < 1.15, 0.0 otherwise)
c. FIRG_salt_IWM for cases with runoff and IWM
    1. FIRG_norun_salt_adj_IWM for IWM but no reported runoff
d. (1.15 - FIRG_IWM if FIRG < 1.15, 0.0 otherwise)

Second, fill in the values for those four new FIRG variables and adjust the FIRG values for all conditions with the following four steps:

> For (a), with runoff reported and no IWM, if FIRG less than 1.15, set FIRG_salt to 1.15, otherwise, set FIRG_salt equal to FIRG.
>
> For (b), with no runoff reported and no IWM, where FIRG less than 1.15, calculate FIRG_norun_salt adj as 1.15 minus FIRG and then in a later step add that value to each type of FIRG_norun.
>
> For (c), with runoff reported and IWM, if FIRG_IWM less than 1.15, set FIRG_salt_IWM to 1.15, otherwise, set FIRG_salt_IWM equal to FIRG_IWM.
>
> For (d), with no runoff reported and IWM, where FIRG_IWM less than 1.15, calculate FIRG_norun_salt_adj_IWM as 1.15 minus FIRG_IWM and then in a later step add that value to each type of FIRG_norun_IWM.

The above steps found that out of the expanded set of 44 systems in "Irr_data_DM", 15 systems had FIRG < 1.15 and 22 systems had FIRG_IWM < 1.15. The count of cases with revised FIRG is:

FIRG_salt = 213
FIRG_salt_IWM = 56
FIRG_norun_salt_adj = 213
FIRG_norun_salt_ajd_IWM = 54

The final result was that 536 cases from the total of 734 cases reporting that irrigation water was managed to control salinity were changed. The ones that were not changed were already large enough to meet the leaching requirement. Table 10-13 shows the average FIRG by type of situation after all these adjustments were made.

# Chapter 11. RUN BUILDER AND I_APEX

## 1. Overview

The Run Builder software is a complex set of programs that combines data from the CEAP cropland survey, the NRI, and other sources and then writes the I_APEX databases that hold the completed APEX simulation input data. The Run Builder software also includes code allowing for alteration of the I_APEX databases for the purpose of scenario assessment, e.g., "enhanced nutrient management" or "no practice" scenarios. Among the many specific things that Run Builder does are the following:

1) Conversion of the calendar survey dates of all the management activities included for a simulation into a consistent ordered schedule with years labeled as 1, 2, 3…, and so on;

2) Estimation of the "Plant Heat Unit Requirement" value input with every planting operation;

3) Insertion of operations to start and stop irrigation and auto-irrigation settings;

4) Insertion of crop termination ("kill") statements for each crop;

5) Setup of the subarea characterizations for APEX, including slope, slope length, drainage channels, profile drainage, routing scheme, Runoff Curve numbers, etc.,

6) APEX specification of herds for grazing; and

7) Writing of data to represent structural practices including the following;
   a) Adjustment of runoff curve numbers;
   b) Adjustment of slope and slope lengths;
   c) Setting of the USLE P-factor;
   d) Addition of subareas as needed;
   e) Replication of the cropping subarea as needed;
   f) Buffer strips, grass water ways, etc.

## 2. Date Conversions

In APEX input, all field operations, including tillage, planting, harvest, and application of pesticides are specified by year, month, and date, with the year specified in integer format, starting with 1 and going forward for however many years the rotation covers. APEX also does not allow a gap in the

years, i.e., an idle year will need to have at least one “place holder” type operation, even if that operation does not disturb the soil or have an effect on biomass. Irrigation and fertilizer events are also scheduled in the same manner, unless they are exclusively specified with the auto-irrigate and auto-fertilizer options. Likewise, grazing requires start and stop operations unless it is set up at the main run level with a herd that is rotated across sub-areas in an automated fashion.
The survey data included actual dates for each tillage, fertilizer, manure, and pesticide event, including both the crop year (year in which the crop is harvested) and the calendar year of the event. . The Run Builder program converted these actual dates into the sequential dates needed for APEX simulation, accounting for previous fall tillage or planting and other complexities.

### 3. Plant Heat Unit Requirement

APEX requires that the annual potential heat units to maturity (PHU) be specified with the planting operation for each crop. Internally APEX uses an index of the HU value to determine timing throughout the year for plant physiological growth stage changes, such as changing from early vegetative stage to flowering stage or to maturation, with different nutrient uptake and energy conversion at each stage. This feature also allows the modeler to specify that field operations will be “heat unit scheduled”, meaning that they cannot occur until both the specified calendar date and specified proportion of the PHU are reached.

Within APEX the calculation of heat units (HU) occurs on a daily according to this definition:

$$HU_k = ((T_{max} + T_{min})/2) - T_{base} \text{ for days with } HU_k > 0$$

where $T_{max}$ is the maximum temperature for the day in Celsius;
$T_{min}$ is the minimum temperature for the day in Celsius; and
$T_{base}$ is the crop base temperature (temperature required for growth).

Traditionally, APEX modelers calculated this with a PHU utility program where the inputs were days to maturity, plant minimum temperature, plant maximum temperature, and the daily average temperature minimum and maximums for the location. Assessment of the CEAP survey data indicated a wide variety of planting and harvesting dates, particularly in regions outside of the Corn Belt. This variation reflects the varietal and management choices possible in those regions. Such choices are dependent on weather and market conditions. USDA survey data on typical planting and harvesting dates also support the variety of choices. Consequently, the decision was made to calculate the heat units occurring during the reported interval between planting and harvesting for each crop in each sample and input that as the Heat Unit Requirement. This calculation is done with an option in the Run Builder program. Compared to the traditional Heat Unit requirement estimation procedures, this approach resulted in slight increases of yields for most crops and regions.

The variety of crop management in the CEAP survey meant that some additional guidelines for calculation of the Heat Unit requirement were needed to address situations lacking a traditional harvest operation. These situations included primarily cover crops and grazing.

With cover crops, the Run Builder program notes the planting date and then goes forward in time to the first tillage operation for the next crop. At that point, it backs up one day and inserts a “kill” statement for the cover crop (“kill” statements are usually inserted the day after a traditional harvest). For cover crops, the interval used to calculate the Heat Unit requirement is calculated as the period from planting to the insertion of the “kill” statement.

For “graze out” of a crop, like winter wheat or “hogging” of corn grain, both “start graze” and a “stop graze” operations are inserted a few days after the planting operation. Even though the “start graze” operation has that early date, actual grazing will not occur unless biomass exceeds 2 tons per acre. The “stop graze” operation has a “heat unit schedule” value of 0.95, meaning that once 95 percent of the required heat units have accumulated, grazing will stop. Calculation of the required heat units was setup for two different cases:

> If the crop was a winter crop, having been planted the previous fall, then the interval for calculation was from the “start graze” date in early January to 135 days later (4.5 months).
>
> Otherwise (for a typical spring planted crop) the interval was from the plant date to 105 days later (3.5 months).

A few other guidelines were followed to achieve overall consistency in results:

> If the harvest date were prior to June 1, calculate the Heat Unit requirement as if the harvest date were June 1.
>
> If harvesting (graze or baler) of crop residues after a primary harvest, base the Heat Unit requirement on the date of the primary harvest rather than the later residue harvests.
>
> If multiple primary harvests (grain or forage) in one season, the Heat Unit requirement calculation is based on the last harvest date (this occurs not only for hay, but also for silage harvesting of small grains).

Finally, for a few cases more complex than those above, the traditional APEX modeler approach was used to estimate default PHU values, based on weather station and crop temperature growth coefficients.

## 4. Irrigation

Run Builder writes the parameters governing auto-irrigation into the “Management” table and also inserts into the field operation schedule operations for starting and stopping irrigation and setting the irrigation efficiency, runoff proportion, and percolation proportion for each specific irrigation event. For each cases of a crop being irrigated, Run Builder writes a “start” irrigation operation on day of planting and a “stop” irrigation operation on day of kill. The “stop” irrigation operation is actually a start irrigation operation with the auto-irrigation trigger set so that no irrigation will occur.

## 5. Crop Termination (“kill”) Statements

In APEX a crop continues to grow, regardless of various tillage and harvest operations, until a termination (“kill”) operation is encountered. These were written in the field operation schedule by Run Builder based on the following criteria:

- day after harvest if single terminal harvest operation only;
- day after straw removal or grazing termination if those occurred post- harvest;
- for cover crops, day before 1$^{st}$ tillage operation of next crop; and
- for nurse crops and inter-seeding, day after harvest, or if no harvest, then logically according to what would happen to the crop with the primary crop was harvested or tilled.

## 6. Subarea Specification

The data elements specified for the subarea definition by Run Builder included the following (see the other APEX documentation and Simulation of Conservation Practice chapters for full detail):

Curve Number Type
Filter Strip Flag
Standing Dead Crop Residue (at start of simulation)
Drainage Area
Channel Length
Channel Depth
Channel Slope
Mannings N for Channel
Slope
Slope Length
Mannings N for Upland

The data setup for simulation of multiple subareas was required for simulation of some conservation practices and those procedures are described in a separate document. For some types of practices, the initial 16 hectare crop subarea was divided into two equal subareas and the data described in this document for crop management repeated exactly in the two subareas. In that case the second subarea would have other parameters changed as described in the conservation practice setup to reflect concentrated flow of runoff. The management data for small buffer type subareas is also described in the conservation practice document.

## 7. Livestock Herds

The Run Builder program read the various data tables described in the Grazing Chapter and writes the required I_APEX data as described in that chapter.

## 8. Representation of Structural Practices

A detailed explanation of the setup for simulation of structural practices is contained in a separate document. Here, we just note that most practices could be represented by one or more of the following three procedures:

1) Split additional subareas off the main subarea and set them up with appropriate vegetative cover and route the water flow off the main subarea through them, as in the case of buffer strips.

2) Reduce the USLE P-factor and slope lengths to simulate the presence of terracing, contouring, and similar practices.

3) Divide the main subarea into two subareas with the "lower" one having concentrated drainage flow with associated erosion (or not if grassed waterways were specified to be present.)

Each subarea required specification of its own soil, field operations, and grazing herd. Field operations for the conservation subareas representing vegetative cover were developed from on a simple generic basis (see the Conservation Practices document).

# Chapter 12. CRP SIMULATION PROCEDURES

## 1. Introduction

The CEAP CRP analysis addressed all 13,178 sample points from the 2003 NRI classified as CRP. However, 50 of the sample points were classified as “shallow water cover” and so were not included in the analysis.

For the APEX model CRP simulations the input data involves the same elements as the cropland simulations, although in substantially simplified format. The CRP simulations have no fertilizer, manure, or pesticide inputs. The Field Operation schedules consist of planting operations for all vegetative species, an annual weed control mowing or clipping for non-tree species, and a harvest operation for tree species. To the extent that structural practices previously installed on the land when it was cultivated cropland are durable and changed the recorded slope and/or slope length, those practices are assumed to continue during the CRP enrollment.

The environmental benefits of CRP will be estimated as the difference in between the CRP cover APEX simulations and the output from cultivated crop simulations. To facilitate this calculation, “cropping” simulations will also be set up for each CRP sample point. These simulations will be set up by linking each NRI CRP point to the management dataset from one or more of the CEAP cultivated cropland points according to location, soil type, slope characteristics, and cropping history.

The major steps in setting up the CRP APEX simulations include the following:

1) Definition of six general vegetative cover types for simulation of CRP sample points;
2) Assignment of each CRP point to one of the six cover types;
3) Development of a species mix for each of the six cover types by Land Resource Region (LRR);
4) Determination of the presence of “durable” (structural) conservation practices such as terraces and drains for each CRP point that are expected to continue to function during the CRP enrollment period;
5) Development of Field Operation datasets for each CRP specie, including region specific tree maturity ages and annual “Heat Unit to Maturity” requirements;
6) Development of other required APEX simulation “site” and landscape information, such as soil, slope, slope length, etc., for each CRP sample; and
7) Selection of the corresponding CEAP cropland simulation data sets for each CRP sample point.

## 2. Definition of CRP Vegetative Cover Types

Two sources of data were available for determination of the practices and vegetative cover used at NRI CRP points. The FSA official dataset of contracted CRP practices included the practices listed in Table 12-1, although that data was not available for every NRI CRP point. The NRI includes the smaller, more general list of CRP vegetative cover shown in Table 12-2. Based on these two sources of cover information the following six general vegetative cover types were chosen for this study:

1) Introduced grasses;
2) Native grasses;
3) Trees;

4) Softwood trees;
5) Hardwood trees; and
6) Wildlife habitat.

The assignment of each survey point to a cover class was made by first evaluating the list of contracted CRP practices for each survey point in the FSA database. Where an assignment was not able to be completed with the FSA database, the NRI database was consulted. The FSA database was given higher priority because it reflected actual practices with more diversity than the listed covers developed in the NRI database. The available FSA practice database consisted of three separate subsets of NRI sample points, with data extracted for each subset at a different point in time. For points extracted for the 2003 CEAP cropland survey, no acreage information is included and the presence or absence of each practice is simply denoted with a 1/0 variable. For points extracted for the 2004 CEAP cropland survey, the acreage of each practice is reported rather than the 1/0 variable, but not “total” acreage of the tract or field is given. For the final set of points, both the individual acreage of each practice and the “total” acreage of the field are reported. This distinction is important because at each NRI CRP point, the field containing the point may have had multiple contracts at different points in time, with possibly different contracted practices and concerning different parts of the field.

The procedures and results of assigning the NRI CRP sample points to one of the six CEAP CRP vegetative covers is described in Table 12-3. All but 50 points, which had shallow water cover, were assigned by this process. The 14 rows in Table 12-3 represent the 14 sequential steps in assigning the cover type. Introduced grass was the most prevalent cover at 72.9 percent of the points, followed by Native grass with 12.3 percent, Trees at 6.7 percent, and Wildlife habitat at 6.6 percent. Data was only available for a few sites that specified either Softwood or Hardwood trees, rather than not specifying. However, the species mixes developed by LRR for each cover type include the most commonly used tree species for the “Trees” category.

The count of points by CRP cover type and River Basin is shown in Table 12-4. The species mix for each of the six vegetative types for each LRR is shown in Table 12-5. Note that for some regions, the specie is listed as a general type of grass rather than specific specie, e.g., “short grass prairie” or “cool season grasses” rather than “brome grass”. This was to account for the fact that most CRP plantings are not mono-specie in nature. Tree and wildlife habitat points also included planting of a grass mix. The mixes of species include 19 different crops. The APEX crop parameter file was expanded to include all of these species. The complete final parameter file was reviewed and approved by ARS and NRCS specialists.

Note that on any actual CRP contract, not all of the species listed in Table 12-5 would have necessarily been planted. However, for this analysis there was not data available on the specie mix for individual CRP contracts. For the APEX simulations the complete mixes of species shown Table 12-5 were planted. Over the duration of the simulation the individual species in the mixes compete with each other for light interception, nutrients, and water.

The samples were classified as being a “new” planting or “previous” planting. However, this aspect of the data was not accounted for in setting up the simulations since the intent was to compare a fully mature CRP vegetative cover to continued cropping, rather than look at the effect of the maturing CRP cover over time.

## 3. APEX Field Operations Development

APEX requires that at a minimum separate operations be specified for planting and killing each specie. In addition for non-tree CRP cover species APEX requires that the annual potential heat units to maturity (PHU) be specified with the planting operation and that for tree species the age to maturity (or to harvest) be specified on both the planting and the harvesting operations. In addition to planting of all species and harvesting of trees, the simulation of annual CRP weed control is accomplished by including a late summer mowing or clipping operation. Plant populations are set automatically within the APEX simulation based on parameters in the crop parameter table.

Internally APEX uses an index of the HU value to determine timing throughout the year for plant physiological growth stage changes, such as changing from early vegetative stage to flowering stage or to maturation, with different nutrient uptake and energy conversion at each stage. Model users may also schedule field operations to occur according to an index value (proportion) of the annual HU rather than for a specific date. Within APEX the calculation of heat units (HU) occurs on a daily according to this definition:

$HU_k = ((T_{max} + T_{min})/2) - T_{base}$ for days with $HU_k > 0$

where $T_{max}$ is the maximum temperature for the day in Celsius;
$T_{min}$ is the minimum temperature for the day in Celsius; and
$T_{base}$ is the crop base temperature (temperature required for growth).

For standard field crops the APEX model developers provide a PHU utility program for a designated weather station data set, produces estimates of the number of heat units (and days) to maturity and the optimal planting date. The PHU program also produces a planting "time" based on proportion of annual heat units accrued at the location, which can be used in APEX to allow the actual planting date to vary each year based on that year's weather conditions. Since most of the CRP species were not part of the standard field crops included in the PHU utility program, similar procedures to those of that program were used as follows for the set of 1041 weather station datasets and the CRP non-tree species:

1) For each calendar day of the year calculate the average across years in the weather data set of HU occurring on that day, by crop, based on the minimal temperature for growth;

2) Sum average daily HU for the months of April through September, with a reduction for those occurring on any day when the actual heat units exceeded the optimal temperature according to the following decision tree:

   a) If daily heat unit value between crop minimum and optimal, add to the annual sum;

   b) If daily heat unit value greater than optimal, reduce by difference between actual and optimal;

3) For each crop determine the maximum annual heat unit value found across all weather stations and divide it by 2700 to determine an index value (explicitly assumes 2700 will be the maximum PHU); and

4) For each crop and weather station having total annual heat units greater than 2700, divide by the index value calculated in 3) to restrict maximum HU to about 2700).

The values developed by those procedures were found to compare favorably to published values. Kiniry et. al (1995?) developed the following parameters for Northern Great Plains conditions:

| Crop | PHU |
|---|---|
| Crested Wheatgrass | 1000 – 1350 |
| Western Wheatgrass | 1100 |
| Meadow Bromegrass | 1050 |
| Wild rye (Russian and Altai) | 1400 |

Kiniry et. al (2002) used a PHU value of 1800 for the following grasses and sites in Texas on a variety of soils: Gamagrass, Switchgrass, Big Bluestem, Little Bluestem, Buffalo grass, Sideoats Grama, Blue Gramma, Black Gramma; and Central Texas, High Plains, Northeast Texas, West Texas, and Gulf Coast.

The age to maturity tree species by LRR was determined by NRCS specialists (Table 12-6).

Table 12-7 shows the simple generic sets of APEX Field Operations defined for the CRP simulations and Table 12-8 shows specifically which of the sets of Table 12-7 is used for each species. Development of the APEX Field Operations file is with a "Run Builder" program with the detailed instructions shown in Appendix A.

### 4. Soil, Slope, and Weather Data

Soil, slope, and slope length data were obtained from the NRI data set. Weather data was the same as used in the cultivated crop simulations.

## 5. Crop Simulation Donors for CRP Benefit Estimation

The benefit of the CRP (or of similar long-term conserving cover) is defined as the difference between the APEX simulation output for the CRP points and the output that would be obtained if those points had been cropped. The big question is what exactly would the management look like if the points were cropped? An assumption was made that the management on the points if they were cropped would be the same as that of similar CEAP cropland points, with the similarity consisting of same locality, soils, and slope characteristics. However, since no cropland point is an exact match of any CRP point there is the question of which cropland point to use for each CRP point. The decision was made to use a set of randomly drawn nearly identical cropland points for each CRP point and to do an acreage weighted average of the APEX output for the matched set of cropland points. This procedure results in the "crop" scenario output for the CRP point consisting of the mix of likely management that would be applied to that CRP point.

As of March 2009, the approach used was to take the completed cropland output and do the weighted average and compare that to the output from the CRP simulation. However, it was found that even with the "closeness" criteria used for picking the set of donor cropland points, substantial variation in weather and soil characteristics existed with each donor set for each CRP point. Consequently, the decision was made to build a new set of donor APEX simulations for each CRP point, each member of each donor set consisting of the CEAP cropland management data set combined with the exact soil, weather, and slope data of the CRP point. The data elements and their assignments for this approach are shown in Table 12-10.

## 6. Selection of Cropland Donor Points for the Upper Mississippi River Basin

The Upper Mississippi River Basin (UMRB) included 1,847 CRP points (16 had shallow water cover and were not modeled). For each of these a set of cropland donors was drawn from the 3,703 cropped points in the UMRB. The first 1836 CRP points were matched according to Crop Management Zone (CMS), Soil Class, Hydrologic Group, and Slope Class criteria. The last 11 points were matched and assembled by hand. The matches were performed in a sequential fashion, with the steps labeled A – Q below, followed by the steps of hand matching the last 11 points.

The steps are shown below with three lines of text in a block for each step. For each step, the first line is the descriptive comment line for a procedure in SAS, followed by the name of the procedure. The third line describes the results of the step. The definitions for the criteria in the blocks of code are shown in Table 12-9.

```
*A--hydro Class5code Class3Code HydGroup SlopeClass;
CRPmatch_huc8
--556 matches with 5-21 donors per CRP point

*B--hydro Class3Code HydGroup SlopeClass;
CRPmatch_huc8Class3
--147 matches with 5-22 donors

*C--huc6 cmz class5code Class3Code HydGroup SlopeClass;
CRPmatch_huc6st
--589 matches with 5-63 donors (only 7 points had more than 35 donors)

*D--huc6 st cmz Class3Code HydGroup SlopeClass;
CRPmatch_huc6stclass3
--175 matches with 5-52 donors (only 5 had more than 27 donors)

*E-- huc6 Class3Code HydGroup SlopeClass, but adjacent CMZs;
*cmz 17 and cmz 16;
CRPmatch_huc6stclass3cmz16_17
--46 matches with 6-22 donors

*F-- huc6 Class3Code HydGroup SlopeClass, but adjacent CMZs;
*cmz 04 and cmz 16;
CRPmatch_huc6stclass3cmz16_04
--142 matches with 6-52 donors (only 5 points had more than 30 donors)

*G-- huc6 Class3Code HydGroup SlopeClass, but adjacent CMZs;
*cmz 04 and cmz 01;
CRPmatch_huc6stclass3cmz01_04
--36 matches with 5-63 donors (only 1 had more than 26 donors)

*H-- huc6 Class3Code HydGroup SlopeClass, but adjacent CMZs;
*cmz 02 and cmz 01;
```

CRPmatch_huc6stclass3cmz01_02
--no matches with 5 or more donors

*I--huc4 cmz class5code Class3Code HydGroup SlopeClass;
CRPmatch_huc4
--14 matches with 5-6 donors

*J--huc4 cmz Class3Code HydGroup SlopeClass;
CRPmatch_huc4class3
--25 matches with 5-10 donors

*k--huc4 Class3Code HydGroup SlopeClass;
CRPmatch_huc4class3nocmz
--20 matches with 4-15 donors (dropped criteria to 4 points)

*L--cmz st class5code Class3Code HydGroup SlopeClass;
CRPmatch_cmzst
--22 matches with 4-44 donors (only 3 had more than 10 donors)

*M--cmz class5code Class3Code HydGroup SlopeClass;
CRPmatch_cmz
--39 matches with 4-27 donors

*N--cmz Class3Code HydGroup SlopeClass;
CRPmatch_cmzclass3
--3 matches with 4-12 donors

*O-- Class3Code HydGroup SlopeClass;
*adjacent cmzs...01 and 04 (no CRP left in 02);
CRPmatch_cmz01_04
--15 matches with 3-37 donors (dropped criteria to 3 points)

*P-- Class3Code HydGroup SlopeClass;
*adjacent cmzs...16 and 04 (no CRP left in 02);
CRPmatch_cmz16_04
--6 matches with 5-21 donors

*Q-- Class3Code HydGroup SlopeClass;
*adjacent cmzs...16 and 17;
CRPmatch_cmz16_17
--1 match with 20 donors

11 points CRP remaining without donors—donors were found by relaxing texture or slope or hydgroup classes:
--6 points by reducing texture (class5code) by one class
--1 point by reducing slope class by 1 class
--4 with texture=900 obtained donors by matching to a single crop point with texture=900 and slope class and hydgroup within 1 class.

However, a planned refinement is to then reduce the number of donors for each CRP point by either ranking according to spatial distance from the CRP point or by a random selection. The goal is to reduce to about 5 – 6 donors per CRP point, rather than the current average donor count of just over 11.

## 7. Possible Refinements

**Simulation of FSA partial field practices.**

a) A few points have only currently non-modeled partial field practices.
b) There is currently no way to know if the practices overlap on same area or on separate areas within the "field" associated with the NRI point.
c) Some practices are designed for the purpose of protect adjacent (?) cropland areas or of capturing effluent from adjacent areas. For these practices the protected area is more important than the area occupied by the practice.

The 2003 FSA data included only yes/no indicators of contracted practices while the 2004 FSA data included acres of each contracted practice, but not the total acres of CRP at the point. Note that even if the total CRP acreage at each sample point had been included in the data, it would still not be clear in many cases whether or not the CRP practices "overlapped" on a portion of the land or were applied to separate parcels of land. In many cases the field enrolled in the CRP for the point may have had portions and/or contracts enrolled at different times. It is not the field size that is important - it is the proportion of the CRP acreage for that sample point in each of the practices. If there are multiple contracts and/or covers for the sample point, what is the total acreage of CRP at the point - gives some indication of overlapping or mutually exclusive covers.

The single dominant cover approach for the simulations may not be the best. It appears that there are 3 options for setting up the simulations (note that for 2003 the presence or absence of each practice is denoted by a 1 or 0, while in 2004, actual contracted acres are given although we don't know if they overlap or not):

1) Continue with the single dominant cover type assigned for each point;

2) Assume cover types don't overlap on identical acreage and set up sub-areas for each cover type (don't really know spatial relationships, e.g., tree area relative to grass area relative to wildlife food plot); or

3) Assume cover types completely overlap on same acreage and set up a single area with a mix of cover types including all covers appearing with acreage greater than x proportion

For example, the sample point (1065_030403B2) has 29.1 acres of previously established grass and 111.9 acres of previously established trees. Points like this could be simulated three different ways:

1) Model entire point by as if it had only the cover with largest acres - trees

2) Assume it all has grass, even if trees are listed for part of it, and model as grass/tree mix

3) Make two simulations, one with grass, one with trees, and split the point weight

There are other samples having covers that are most likely mutually exclusive, such as CP04R - wildlife habitat and CP10 established grass. For example, the sample (5079_020302G2) has 0.8 acres filter strip and 51.6 acres riparian buffer.

## Chapter 13. Pesticide Applications

Pesticide input variables from CEAP surveys required for APEX runs include: FIPS, PSUID, crop year, crop type, pesticide aicode (active ingredient ID code), application rate, application method and application dates as presented in Table 13-1. Additional meta-data provided by the surveys are also shown in this table. Pesticide properties required for APEX to perform fate simulations were taken from the USDA NRCS/UMASS Extension Pesticide Properties Database (2008). Pesticide toxicity thresholds used to evaluate aquatic risk were taken from the USDA NRCS/UMASS Extension human drinking water, aquatic plant and fish (Plotkin, Bagdon and Hesketh, 2008a, 2008B and 2008c, respectively). Most of the aquatic plant and fish toxicity thresholds were acquired from the EPA Environmental Effects Database (EPA, 2008).

Each record of data in the survey supplies information from one pesticide application event. For the Upper Mississippi River Basin (UMRB) (the first basin for which the CEAP analysis was completed) APEX output included simulation of 368,158 loss records over the 47-year model runs on the 3705 points that were simulated (2 points were not used in the output analyses due to an inability to determine a valid “weight” to be applied to those points). However, in cases where a pesticide was applied multiple times during a year, only one record of annual losses appeared in the output file.

### 1. Crop Year Designations

As alluded to in Chapter 5 on fertilization, there were a small number of points where the calendar years designated in the surveys were not in synchronization with the crop year and pesticide application. For some crop years the pesticide was applied in the prior fall. These year designations were corrected so that pesticide applications and crop planting occurred in sync as appropriate.

### 2. Application Rates

There were several issues with pesticide application rates as follows:

1) Pesticide application rates from NASS were reported in pounds/acre. These values were converted to grams/hectare as required by the APEX model.

2) Some application rates appeared to be too low. However, these rates may actually be correctly recorded in the surveys in that they were usually associated with numerous other pesticides in tank mixes. It was decided that these rates should not be arbitrarily altered.

3) There were a dozen or so very high rates of application. Although these rates were greater than is recommended on pesticide labels, it is possible in these few cases that applicators did actually apply at these levels.

4) Missing rates were found in 2 UMRB records that were used in APEX runs. These rates were estimated by determining the mean of the rates for the specific pesticide on other points

with the same crop, application method and whether the pesticide was applied from a tank mix.

5) Spot treatments with missing pesticide application rates (9 records in the UMRB) were determined by calculating the mean of rates for the same pesticide applied on the same crop, whether there was a tank mix and were spot treated. If there were insufficient comparable points that had spot treatment, the rate was generated by taking 5% of the mean of rates from other points with the same pesticide, crop and whether there was a tank mix. It has been estimated that typically about 5% of an agricultural field is treated with spot treatment (Harold Coble, personal communication, 2008).

### 3. Application Dates

The 2003 survey application dates only included year and month of pesticide applications. Additionally, 74 records had no application date at all in the 2003-2006 survey records. Since planting dates in the 2003 survey data also included only month and year, there was no way of knowing when a pesticide was applied pre or post emergently. Furthermore, some pesticides have multiple purposes of pest control such as for several species of insects, insects and nematodes, weeds and insects, etc. Therefore a generic schema had to be devised to generate application dates as shown below.

2003 Survey missing "days" in the dates were generated by the following schema:

- If month is same as crop planting month, then date was generated as 7 days prior to planting date.

- If month is not the same month as planting month then 15$^{th}$ day of the month was assumed.

- If there were multiple applications of a specific pesticide during a month then application days in the month was determined by evenly distributing the applications over the course of the month.

- For all four survey years, if the date was missing then an herbicide application date was assumed to be 7 days prior to planting.

- For any type of pesticide, if no planting occurred that year such as with perennial grasses), then the pesticide was assumed to be applied on June 15$^{th}$. If there were two applications of the same pesticide with no applications dates or planting dating dates then June 15$^{th}$ and August 15$^{th}$ were used. In cases, where there were three applications of the same pesticide all with missing dates and no planting date, then June 15th, July 15th and August 15$^{th}$ were assumed.

- A fungicide application that had a missing date, but that had planting and harvest dates was applied 50% into the growing season. If there were two applications of the same fungicide without dates, then the first application was 33% through the growing season and 66% for the second application.

- An insecticide application that had no date, but that had crop planting and harvest dates was applied 33% into the growing season. If there were two applications of the same insecticide without dates, then the first application was 33% through the growing season and 66% for the second application.

**4. Application Methods**

The 2003 Survey reported 9 methods of pesticide applications including:

1. Broadcast, ground without incorporation
2. Broadcast, ground with incorporation
3. Broadcast, by air (aerial application)
4. In seed furrow
5. In irrigation water (chemigation)
6. Chisel/injected or knifed in
7. Banded/side dressed in or over row
8. Foliar or directed spray
9. Spot treatments (Section D only)

The three subsequent surveys (2004-2006) allowed more explicit method selection which expanded the possibilities to:

1. Seed Furrow
2. Chemigation (in irrigation water)
3. Chisel/injected or knifed in
4. Direct spray, foliar
5. Seed Treatment by producer prior to planting
6. Broadcast, ground, not incorporated
7. Broadcast, ground, w/ hood, not incorporated
8. Broadcast, ground, foliar
9. Broadcast, ground, incorporated
10. Broadcast, ground, w/ hood, incorporated
11. Broadcast, aerial
12. Broadcast, aerial, foliar
13. Banded/side-dressed
14. Banded/side-dressed, w/ hood
15. Banded/side-dressed, foliar
16. T-Banded (combo of banded and injected), soil
17. Spot treatment
18. Spot treatment, with hood

Application methods were modeled in APEX in a manner similar those expressed in Chapter 5 on fertilization. The vast majority of methods used in the UMRB were broadcasted spray (ground). There were 48 UMRB records where no application method was reported. The broadcast spray (ground) method was assumed for these applications. None of the pesticides with missing application methods were the fumigants such as metam-sodium and 1,3-dichloropropene that would likely be soil injected due to high volatility.

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