Appendix C

"Estimates of Future Agricultural Water Withdrawal in Alabama"

This appendix contains the above titled report produced by the Auburn University Water Resources Center (AUWRC) through a grant by the Office of Water Resources (OWR).

The report provides county and HUC8 (subbasin) level forecasts for Alabama agricultural water withdrawals in five-year intervals from 2010 to 2040. AUWRC developed specific numeric county and subbasin level forecasts of agricultural water withdrawals based upon extrapolations from historic time series data and from long-range agricultural predictions about future changes in Alabama agricultural water use.

Auburn University Water Resources Center

Estimates of Future Agricultural Water Withdrawal In Alabama

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February 20, 2015

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OBJECTIVE

The Alabama Office of Water Resources contracted with the Auburn University Water Resources Center to develop county and HUC8 watershed level long-range forecasts of Alabama agricultural water withdrawals. The Auburn University Water Resources Center developed specific numeric county level and watershed level forecasts of agricultural water withdrawals based upon extrapolations from historic time series data and from long-range agricultural predictions about future changes in Alabama agricultural water use.

This objective was accomplished in collaboration with other scientist from the University of Alabama in Huntsville who used remote sensing data to identify those areas in Alabama that are currently being irrigated and to estimate the acreage irrigated. Having access to the additional information from the UAH work allowed the AU Water Resources Center to do a more rigorous analysis of the water use for irrigated agriculture.

DISCLAIMER

Forecasting by definition is the process of making statements about events whose actual outcomes have not yet been observed. Prediction is a similar, but more general term. Within the context of science, the term "prediction" is often used to refer to an informed guess or expert opinion. A science- based prediction may be inductively valid if the predictor is a knowledgeable person or expert in the field and is employing sound reasoning and accurate data. It is important to understand that the forecasts and predictions of agricultural water withdrawals for a specific county or watershed or for a specific commodity or agricultural use in this report should be interpreted as only as long-range trends relative to current withdrawals. It is impossible to know the precise withdrawal amounts for any specific future year due to all of the unknowns related to annual weather variations and climate change, as well as annual changes in production of specific commodities based on market demand. However, the water use trend forecasts and predictions in this report are the based on the best available information from many of the most knowledgeable individuals from whom information could be obtained.

When making long range forecast or predictions of any type it is advisable for the forecaster to provide appropriate disclaimers. Risks and uncertainty are central to both forecasting and prediction. Forecast and predictions of the type that we have been asked to provide have a very high degree of risk and uncertainty.

Future water usage in agriculture is subject to many variables and unknowns such as climate change, the cyclical nature of and longer term market variations for agricultural commodities, changes in technology, improvements in both plant and animal genetics, etc. Given these uncertainties that can increase exponentially over several decades.

In science it is generally considered good practice to indicate the degree of uncertainty for results and conclusions, however, it is not possible to provide a specific probability or confidence interval to the long-range forecasts and predictions being provided in this report. Again, the authors of this report want to emphasize that the forecast and predictions provided by the Auburn University Water Resources Center should be used only as general information about what is considered to the likely trends, and should not be considered as precise scientific findings.

DEFINITIONS AND TERMINOLOGY

The objective of this project is to provide useful county and watershed level forecasts and predictions about future water use by agriculture in Alabama. Although this objective seems unambiguous, it is understood that the agricultural water use forecast may have implications for water policy; therefore it is useful to establish and understand the definitions of a few key words and the meaning of some important terminology.

It is very important to understand that within the context of this report water refers only to surface and ground water. This is sometimes referred to as “blue water.” Blue water is water that is in rivers, surface impoundments or aquifers. Blue water can be used for multiple purposes, and sometimes the uses are competitive and mutually exclusive. Essentially blue water is water that can withdrawn from surface or subsurface sources, and the forecasts in this report are specifically for water withdrawals, which is not exactly the same as total water usage in agriculture as explain below. In general, blue water is the water that can be managed and regulated via water policy.

The water use forecasts do not include the vast amounts of “green water” that is used by agricultural crops. Green water is the portion of precipitation on land that does not run off or recharges the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation. Eventually, this part of precipitation evaporates or transpires through plants as part of the hydrologic cycle. Green water is a very important component of the hydrologic cycle that can only be used for plant growth (although not all green water can be taken up by plants, because their will always be evaporation from the soil and because not all periods of the year or areas are suitable for crop growth).

Green water cannot be easily regulated by policy and therefore is of less concern when forecasting water usage for policy purposes. However it is important for policy makers to be aware of green water because there is a potential for supplying a greater portion of the future water demands for agricultural crops through policies and best management practices that promote for the better storage and utilization of green water within the soil. Green water conservation can play an important role in helping to mitigate situations where water demands exceed water supplies.

The important point is that water forecasts for crop production may reflect only the very small amount of supplemental water provided through irrigation and does not reflect the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield. Again, it is important to note that water withdrawals for irrigation are subject to large annual variations depending on annual weather conditions.

The term "agricultural water use" in the context of this report refers to the blue water used directly in the production of the commodity. Agricultural water use in this context refers to the exclusive direct consumptive use of local surface or subsurface water by agriculture. The agricultural water usage forecasts and estimates in this report does not account for the larger water footprint of the agricultural products. The water footprint is an indicator of freshwater use that looks at both direct and indirect water use. The water footprint of an agricultural product such as beef, poultry, grain, etc. is defined as the total volume of freshwater used to produce the commodity. Water use is measured in terms of water volumes consumed (evaporated or incorporated into a product) and/or polluted per unit of time. A water footprint can be calculated for a particular product. The water footprint is a geographically explicit indicator, showing not only volumes of water use and pollution, but also the locations. It is important to understand that the water footprint of Alabama's agriculture is much larger than the quantity of water use reflected in this report. For example the water footprint of Alabama's poultry sector would also include the amount of water required to produce the feed grain that is imported from outside of Alabama. Based on published water footprint coefficients the estimated water footprint of Alabama's current poultry and egg production is:

5.7 billion pounds of chicken = 2.6 trillion gals water

2.6 billion eggs = 138 billion gals water

The above numbers equate to 8.5 million acre ft. of water, or more than 4X times the amount of water storage in all of Alabama Powers 13 reservoirs. Which is much greater than the in-state water withdrawal of the poultry and egg sector.

EXTRAPOLATION AND INTERPOLATION

It is important to understand that the specific county and watershed level forecasts provided in this report are a function of extrapolation. Extrapolation is the process of estimating, beyond the original observation interval, the value of a variable on the basis of its relationship with another variable. The method of extrapolation selected was based on several factors including knowledge of the process that created the existing data points, available time and financial resources allocated for the project. Extrapolation means creating a tangent line at the end of the known data and extending it beyond that limit. Again it is important to point out that extrapolation is subject to great uncertainty and a high risk of producing meaningless results.

GENERAL METHODOLOGY

Before explaining the specific methodology used for developing the forecasts and predictions in this report it may be useful to make some general comments about methodologies in general.

Quantitative forecasting models are used to forecast future data as a function of past data; they are appropriate when reliable past data are available. These methods are usually applied to short- or intermediate- range decisions. Since historic data on water usage by agriculture in Alabama is available, it is possible to do quantitative forecast. However, it is important to point out the risks and uncertainty issues associated with long-range forecasting as explained in the disclaimer section of this report.

It is also important to point out that although there is historic agricultural water usage data for Alabama for several decades dating back to 1985, the data comes from different sources (USDA, USGS, Alabama OWR, etc.) and was derived using different methodologies. In some cases the methodology used with a specific agency may have evolved over time as well. Therefore, Alabama agricultural water usage data from one source is often not consistent with data from another source, and data from a specific source for one time period may not be comparable to data from another time period. This creates very serious issues of using time series data to statistically extrapolate future demands. There was also a lot of missing data point in the existing data for many of the earlier years, and the data for one year in particular (2000) appeared to be very different from all other years which made it extremely suspect.

This concern was discussed with the Alabama Office of Water Resources, and it was concluded that the official published 2005 and 2010 agricultural water withdrawal data from OWR would be used. While this resolved the issue of consistency, it provides only two reliable historical data points from which to make statistical future extrapolations. Given the lack of reliable quantitative data, much emphasis was placed on the use of qualitative data in the form of expert predictions to validate the forecasts.

Qualitative forecasting techniques are subjective, these are generally predictions based on the opinion and judgment of experts. Qualitative forecasting techniques are appropriate if:

a. Long-term reliable past data are not available, as is this case, or
b. There are social or economic influences that will likely effect future values which are not reflected in the historic data. This is explained in more detail later in this report.

Forecasting methods can be greatly improved if it is possible to identify the underlying factors that might influence the variable that is being forecast. For example, including information about climate patterns such as more frequent droughts might improve the ability of a model to predict future water demands. Or, underlying factors about increased demand for agricultural products and the comparative and competitive advantage that Alabama might have in supplying those demands could help to improve the long range forecasting of water usage in agriculture. With that in mind, we identified faculty at Auburn University and other Universities to solicit predictions about future changes in various sectors of Alabama's agriculture examined in this report. Qualitative forecasting methods, specifically the input from knowledgeable experts can be very valuable in making long-range predictions, and have been used in this report.

PREDICTIONS AND EXPERT OPINION

The predictions are based on the expert opinions of selected Auburn University faculty and Extension specialists in the disciplines of Agricultural Economics, Agronomy, Biosystems Engineering, Aquaculture, Animal Sciences and Poultry Science. The selected faculty was asked to share their professional opinion about whether the methods proposed for this study are appropriate. They were also asked if they were aware of any better data or information on water usage/demands for various segments of Alabama agriculture; and to provide their insight and expert opinions about future trends in water usage for various segments of agriculture in Alabama.

Input and expert opinions were solicited from the following faculty:

Name	Department	Commodity
Dr. Walter Prevatt	Agricultural Economics	Beef Cattle
Dr. Eugene Simpson	Agricultural Economics	Poultry
Dr. Deacue Fields	Agricultural Economics	All Commodities
Dr. Samuel Fowler	Agricultural Economics	Irrigated Crops
Dr. Wayne Greene	Animal Science	Livestock
Dr. Lisa Kriese Anderson	Animal Science	Beef Cattle
Dr. Russell Muntifering	Animal Science	Beef Cattle
Dr. Frank Owsley	Animal Science	Livestock
Mr. Robert Spencer	Animal Science	Goats and Sheep
Dr. John Jensen	Aquaculture	Aquaculture
Dr. Jesse Chappell	Aquaculture	Aquaculture
Dr. Terry Hanson	Aquaculture	Aquaculture
Dr. John Fulton	Biosystems Engineering	Irrigated Crops
Dr. Joe Hess	Poultry Science	Poultry
Dr. Donald Conner	Poultry Science	Poultry
Dr. John Blake	Poultry Science	Poultry
Dr. Sacit Bilgili	Poultry Science	Poultry

Poultry Predictions

Dr. Joe Hess said that Alabama's poultry industry is relatively mature and there is very little talk about significant expansions or new operations coming into the state. The water use focus within the poultry sector is on conservation and using more water collected through catchment systems. Joe's feeling is that based on the underlying causal factors water use in poultry sector will probably remain fairly constant into the foreseeable future.

Dr. Eugene Simpson suggested that another method of calculating water usage in poultry production would be to calculate it on a broiler house unit basis rather than a per bird basis. Dr. Simpson provided the following water usage estimates for Alabama's poultry sector:

a) Drinking water = 3 billion gals annually
b) Cooling = 6 billion gals annually
c) Processing = 12 billion gallons
d) Total = 21 billion gals annually

Recent data indicates that a typical 40 ft. X 500 ft. broiler house using between 450,000 and 490,000 gallons per year.

Dr. Sarge Bilgili stated that either the "math" provided in a similar forecasting report by the University or Georgia, or Dr. Simpson's approach would work to estimate how much water poultry will consume, based on total sq. ft. of grow-out area and bird market weight. Estimating the additional water use through cool cell and foggers may be little more challenging. As much as 1/2 of the water use on a broiler house may be used by the cooling system in peak summer. I have heard estimates of about 20% per year additional water use per house when averaged across all seasons.

Dr. Bilgili also said that predicting the next 30 years is even harder. Dr. Bilgili said that extrapolating future growth in Alabama's poultry sector based on the last 3 decades growth would be a mistake. The phenomenal expansion rate the broiler industry experienced during this period is not likely to continue! Dr. Bilgili feels the future trends in Alabama's poultry industry will be characterized by stable broiler numbers, increasing market weights, and improvements in housing facilities.

The consensus opinion from AU poultry faculty is that future water usage in the poultry industry is not likely to increase much if any and may in fact decrease due to more efficiency in facilities.

Small Ruminants Predictions

Mr. Robert Spencer from Alabama A&M University said that he felt the Georgia daily water use coefficients for goats and sheep are valid for Alabama valid for adult animals.

Mr. Spencer was not aware of any studies on trends for future changes in the number of sheep or goats in Alabama. He stated that he has not seen any recent estimates on sheep in AL (given their low numbers, Ag Census does not count them). Based on 2012 data from NASS goat numbers are lower than they were in 2007, a decreasing trend that began in 2009. Mr. Spencer recently wrote an article using data provided by Alabama Agricultural Statistics Service courtesy of Bill Weaver. In that article he makes the case that the recent decline in goat and sheep numbers in Alabama can be attributed to the droughts beginning in 2007.

Mr. Spencer stated that based on recent observations he believes numbers may experience a modest increase over the next few years due to interest from hobby farmer types, but limited demand and limited profitability for commercial production of small ruminants is not likely to support any substantial increase in inventories for the near future. Mr. Spencer does not anticipate any significant increase in water usage by the small ruminant sector of Alabama agriculture.

Beef Cattle Predictions

Dr. Walt Prevatt said Alabama has closely followed the national trend in U.S. Beef Cow Inventory, which peaked in 1975. Since then we have seen significant increases and decreases. However, since 1975 the trendline suggests a smaller inventory over time.

His thoughts are that we will see small increases and decreases in inventory numbers as market prices and weather help determine profit levels. Inventory increases as profit levels increase and decreases as operations become unprofitable. Dr. Prevatt stated that he thinks the trend will be downward sloping over the next couple of decades due to high input costs, reduced pasture acreage, and low levels of profit (not sufficient to compete with alternative uses of rural land). The consumer today is voting more for other consumptive items (entertainment, cell phones, etc.) than for beef. Hence the sharp decline in the demand indexes for beef since the mid 70s.

Dr. Prevatt thinks we lack the resources and level of profitability to see robust expansion. Based on his assessment of the beef cattle situation it appears unlikely that water use by the beef cattle sector will increase significantly in the foreseeable future.

The predictions on future Alabama agricultural water usage trends are very insightful, and provide good information about future water use in agriculture in general terms, but they do not provide the county or watershed level quantitative data that we are seeking.

METHODS USED TO DERIVE SPECIFIC COUNTY AND WATERSHED QUANTITATIVE FORECASTS

As previously explained after discussions with the Office of Water Resources it was agreed that the only two historical data observations in which we have great confidence are the ones published by OWR for

2005 and 2010. Therefore these two observations formed the basis for the numerical quantitative forecast for future years. Two points define a line. There is no error or curvature associated with a line defined by two points. Water use values from OWR define two points and a line, which may be used to predict future water use values. Producing a forecast trend line from two points is highly risky and must be based on the following assumptions or known facts:

1. Methods of obtaining water withdrawal data were consistent for both years;
2. Water withdrawal values for both years are accurate and reflect reality;
3. Differences between the two years represent accurate longer-term trends;
4. The water use increase/decrease will be continuous and constant for the forecasted period;
5. Future agricultural production and land use development patterns will follow current agricultural and current land use development patterns for the forecast period; and
6. Slope of the line defined does not produce absurdly unreasonable or impossible long-term projections based on available water supplies and/or other constraints.

Since the data for 2005 and 2010 are OWR data we assume number 1 and 2 to be true in all cases. Assumptions 3 through 4 are risky assumptions which are impossible to prove, but must be understood as the basis for the forecasts. Assumptions 5 and 6 were validated as much as possible by seeking expert opinion and predictions from Cooperative System field staff field and by comparing the long range forecasts to prior research finding regarding potential for expansion of agricultural production for specific geographic regions.

Assumptions 5 and 6 were also addressed by comparing county-based information with HUC 8 based information. All OWR data were collected and reported on a County basis. OWR desired to have water use data reported by Hydrologic Unit Code level 8 (HUC 8). The boundaries of the two systems rarely coincide. To ensure that county water use values were properly distributed to HUC 8 units we extracted respective land use categories from the CDL, NLCD, golf course locations, and UA-H irrigation sites and associated the HUC 8 drainage name. We then computed the area distribution of that land use within each HUC 8 relative to each county. The use specific distribution by HUC within County was used to allocate water use values from county readings to the HUC 8 areas within each county

If all assumptions are true or can be accepted it is possible to project water use values to the year 2040 with some degree of certainty. However, if one or more of the assumptions are not true, then the projected value must be altered subjectively. Subjective estimates must be based upon information from ancillary data or personal knowledge of the region.

Methods to project water usage to the year 2040 varied for each water use category. Golf course and aquaculture were easily located, spatially correlated with OWR withdrawal sites, and had extensive, reliable, fine grained ancillary data upon which to base subjective estimates. Irrigation, which includes row crop, orchard, sod, and nurseries, were not as well correlated with OWR withdrawal sites.

VALIDATION OF FORECASTS

Ancillary data provided considerable context for making subjective projections, but local knowledge was considered to be invaluable. We contacted six Alabama Cooperative Extension System Regional Agronomists and conferred with them concerning the potential for irrigation development within each county. The regional agronomists reviewed the ancillary data we provided but also considered the local economy, the age and mindset of the agricultural community, farm size and ownership, and market opportunities. In some cases the regional agronomists identified some significant issues with the projected trend lines, in other cases the information was confirmed and the trend line validated. Livestock water use estimates were confirmed as-is. We had no ancillary information from which we could base making alterations of the trend lines. Personal communications with various faculties at Auburn University as explained earlier in this report were also used to validate long-term forecasts.

To ensure that the critical pieces of information that we used to underpin our subjective estimates were as accurate as possible, we used 1-meter resolution NAIP imagery to interpret the land use that was designated by the OWR data. We also used NAIP data from appropriate years to validate Crop Data Layer classifications (aquaculture, sod, and horticulture nurseries), GAP data (aquaculture), and golf courses. The validated areas were spatially joined with county and HUC 8 polygons to determine land use distribution by HUC 8. Validated locations were used to make subjective judgments about the potential of a particular land use to change by the year 2040.

Irrigation Forecasts

Without doubt the area of greatest concern and uncertainty regarding agricultural water withdrawal forecasting and possible future water policy is irrigation. There is much interest in increasing irrigation of agricultural crops in Alabama, and there are recent and current incentive programs to encourage the increase in irrigation of agricultural crops. Water use data for irrigation includes irrigation withdrawals for row crops, sod production, commercial horticultural uses (nurseries, grow hoops), orchards, and commercial fruit and vegetable production. The water source may be either surface or groundwater but is always fresh, never saline water. The water can be distributed with a sprinkler system, fixed set, lateral move, center pivot, volume gun, drip, or buried tape. Irrigation does not include domestic and urban landscape use, golf course or recreational site use. Not all irrigation sites are readily visible with aerial photography, namely drip and buried tape systems and orchards. Irrigation use specific distribution by HUC within each county was estimated by computing the sum of long-term croplands, irrigation sites, and sod production areas.

We prepared tables and maps showing current levels of irrigation relative to potential expansion areas for each county. Estimates for irrigation growth/retraction by county were developed based solely upon the available digital information from co-researchers at UAH. Error brackets were assigned to the estimates such that estimates for 2015 had a much lower error than estimates for 2040. We used a simple incremental system starting at 10% error in 2015 incrementing to 60% error by 2040. This created a conical high/low bracket around the estimate.

Table 2. Example Irrigation water use projection table, Barbour "straw-man" values.

	Irrigation		0.10	0.20	0.30	0.40	0.50	0.60
County	2005	2010	2015	2020	2025	2030	2035	2040
		High	2.34	2.50	2.66	2.80	2.94	3.07
Barbour	**3.40**	**2.17**	**2.13**	**2.08**	**2.04**	**2.00**	**1.96**	**1.92**
		Low	1.91	1.67	1.43	1.20	0.98	0.77
% growth		-36.2%	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%

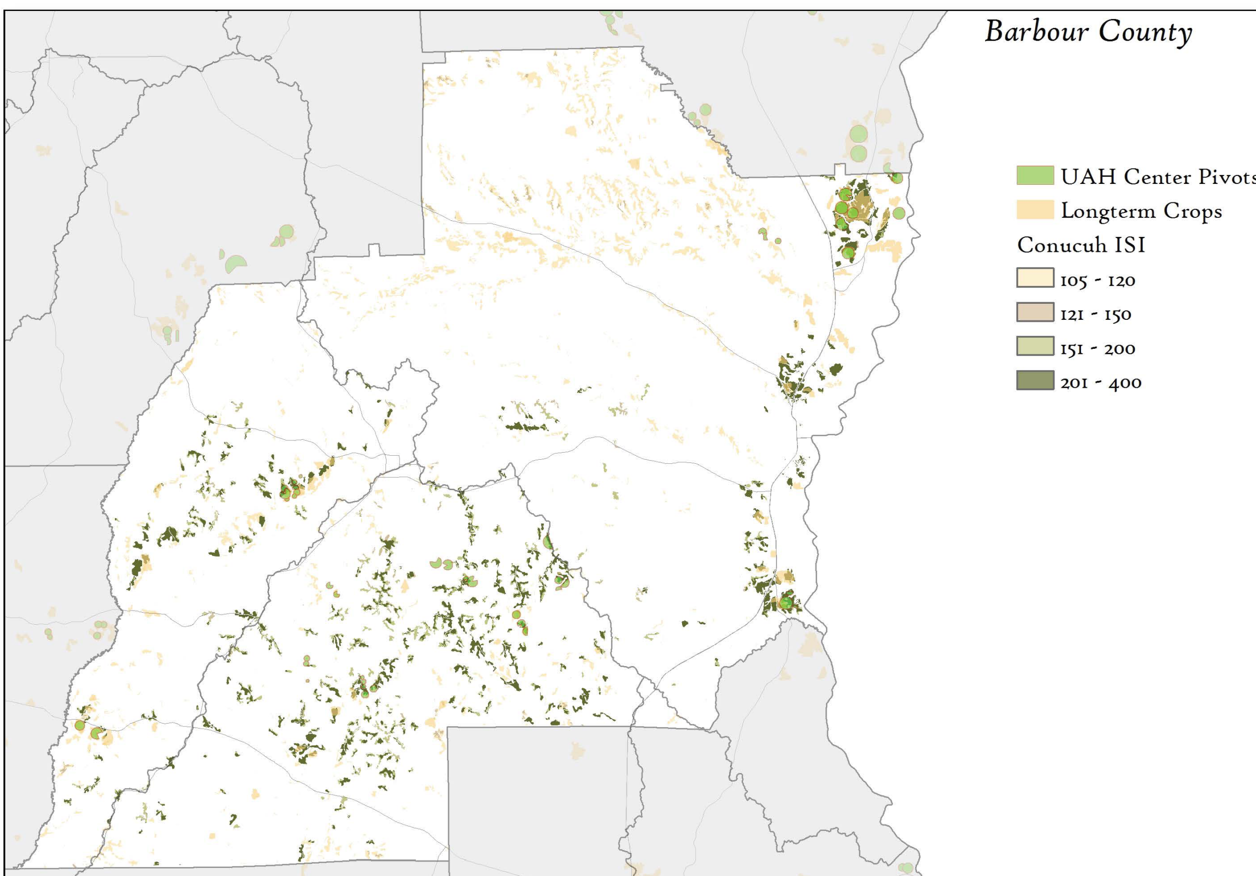
Table 2 above is an example of the initial "straw man" estimation values for Barbour County. The values for 2005 and 2010 are from OWR and are fixed. The bottom line (% growth) reports the relative change of growth from the previous reporting period.

Also included was a small table of ancillary information to estimate the potential for growth in irrigated acres. Cropland area is the long-term croplands for Barbour County. ISI>200 is the acres of Barbour County that has a high Irrigation Suitability Index (ISI), representing the areas that have the highest probability of sustainable irrigation implementation. Irrigated area is the acres of center pivot irrigation systems in this county while Sod area is the acres of validated sod acres from the CDL in this county. These areas do not necessarily overlap, although they commonly do. Irrigation is most likely to be developed on existing cropland as opposed to clearing timber. We have assumed that 70% of the cropland area would be a functional ceiling of development for irrigation. Irrigation acres can exceed this theoretical threshold if existing irrigated sites are not cropland. Irrigated pasture, sod, or vegetables would not be included in the croplands total.

Croplands were not properly identified in the CDL in 3 or more years thus removing them from the long-term cropland category. Irrigation development is taking place in non-cropped areas.

High ISI acres do not necessarily coincide with croplands. Some irrigators may recognize the opportunity to develop irrigation on some non-cropped areas.

The ISI was computed using NRCS SSURGO (county soils digital data). While these data are the most modern soil surveys available, some counties were produced nearly three decades ago. Soil analysis techniques and personnel have changed over that time period. Thus there are some inconsistencies when comparing ISI across county lines. Thus, high ISI must be used as its name implies – an index of suitability. High ISI area can be a threshold for development if the high ISI acres are much less than cropland acres. In the example of Barbour County, High ISI areas are much greater than long-term cropland areas and is therefore not a limiting threshold.



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The map of the Barbour County above shows irrigation sites, long-term croplands, and high ISI areas.

Examining this map may give some insight into the coincidence of these three irrigation factors, which may also be indicative of irrigation growth potential within a county. Examining the map of Barbour County please note that:

a. There are distinct differences among the three HUC 8 watersheds.

b. Croplands, irrigation, and ISI values are not equally distributed.

a. Three clusters of irrigation were detected, all in the Chattahoochee valley.

b. All seem to be nearly fully developed. Areas of High ISI are scattered, areas of long-term croplands are also scattered but not coincident with each other.

c. Several irrigated sod sites were noted as the isolated pivot systems away from the Chattahoochee valley.

Little potential was seen for expansion of existing clusters. Any irrigation development would probably occur independently of the clusters, somewhere in the area in the northern part of the county in the long-term croplands or in the southwestern portion in the high ISI area. Estimates for Barbour are reflected by the underscored estimates in the table below.

Growth Potential:	(acres)
Barbour Acres	578,540.7
Cropland area	4,671.7
ISI >200	13,986.4
Irrigated area	3,675.8
Sod area	185.6
% croplands irrigated	82.7%
% ISI irrigated	26.3%

Irrigation development is not constrained by only these factors, however. There are numerous social issues that are taken into account, including:

a. Land ownership and owner attitude;

b. Commodity prices, energy costs, interest rates;

c. Access to water; Climate and local weather patterns;

d. Tax structure and subsidy programs.

To assess social factors we contacted the six Regional Extension Agronomists in Alabama. They have the local knowledge necessary be able to take these social factors into account regarding the potential of irrigation development. The regional Agronomists who participated in this study were:

1. Kimberly Wilkins: Baldwin, Butler, Clarke, Conecuh, Escambia, Mobile, Monroe, and Washington counties;
2. David Derrick: Blount, Calhoun, Cherokee, Cleburne, Cullman, DeKalb, Etowah, Jackson, Marshall, and St. Clair counties;
3. Christy Hicks: Autauga, Chambers, Clay, Coosa, Elmore, Lee, Macon, Montgomery, Randolph, Russell, Talladega, and Tallapoosa counties;
4. Tyler Sandlin: Colbert, Fayette, Franklin, Jefferson, Lamar, Lauderdale, Lawrence, Limestone, Madison, Marion, Morgan, Shelby, and Winston counties;
5. Rudy Yates: Bibb, Chilton, Choctaw, Dallas, Greene, Hale, Lowndes, Marengo, Perry, Pickens, Sumter, Tuscaloosa, and Wilcox counties;
6. William Birdsong: Barbour, Coffee, Covington, Crenshaw, Dale, Geneva, Henry, Houston, Pike, and Russell counties.

They provided feedback on the initial irrigation estimates for each county and provided guidance for more appropriate values. Any issues with OWR data, irrigated site data, cropland data, or ISI data were noted and recorded on a table for each county.

Table 4. Example Irrigation water use projection table, Barbour county regional agronomist values.

	Irrigation		0.10	0.20	0.30	0.40	0.50	0.60
County	2005	2010	2015	2020	2025	2030	2035	2040
		High	3.06	3.90	4.78	5.75	6.81	7.97
Barbour	**3.40**	**2.17**	2.82	3.39	3.72	4.10	4.51	4.96
		Low	2.49	2.54	2.55	2.47	2.30	2.02
% growth		-36.2%	30.0%	20.0%	10.0%	10.0%	10.0%	10.0%

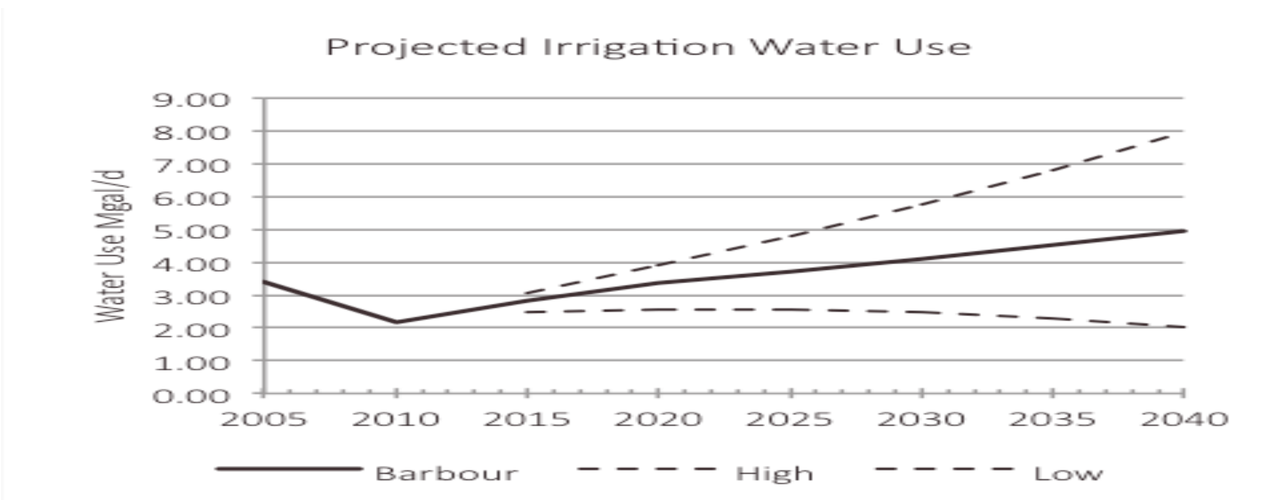
Table 4 above shows the values that were hammered out with William Birdsong. Along with altering the straw-man water use values, Mr. Birdsong noted:

a. Farm sizes are getting larger, field sizes are getting larger, farming patches are getting large enough to support an irrigation system;
b. Commodity prices are improving giving farmers more impetus to install irrigation;
c. New generation of young farmers are taking over and are more technologically aggressive;

d. Access to water is a major issue in SE Alabama.
e. Cost of well drilling is a major impediment.

In Barbour County the decrease of water use from 2005 to 2010 cannot be explained. He knew of new irrigation systems coming on line in that time period.

His assessment of Barbour county was that irrigation water use for 2015 should be increased approaching or exceeding 2005 levels by no later than 2020 followed by steady increases as new lands are developed. He foresaw new irrigation systems being placed in the SW portion of the county in the high ISI area. Figure 1 below shows a graph of the projected water use for Barbour County with high/low estimate brackets.



The interview procedure was completed for all counties for each Regional Extension Agronomist and their projections and comments were recorded on the worktable for each county. In some cases it was more representative to increase water use values incrementally by a discrete water use value than to estimate a percentage growth of irrigation. We estimated that a new center pivot system with enough towers to irrigate 160 acres (1/4 section pivot) could apply as much as 0.5 Mgal/day of water. This is probably a bit a high but it should capture the worst-case scenario. Actual use with best management practices will probably be closer to 0.35 Mgal/day but will vary depending upon weather conditions, crop being raised, soil drainage, and availability of water. For the purposes of this study, we used a value of 0.5 Mgal/d to represent the addition of one new center pivot.

We used the incremental method when the regional agronomist knew the count of additional irrigation systems definitively for a time period. A couple of counties had very low water use values (less than 0.1

Mgal/d) but had one or more center pivots identified by UA-H. In those cases we incremented the 2015 irrigation water use by (number of identified systems * 0.5 Mgal/d) to obtain the projected water use. If the regional agronomist foresaw the potential for more growth a percentage was applied to the 2015 value.

County water use projections were incorporated into a statewide worksheet with a table for each county. A subsection of this worksheet summarized HUC 8 water use values subdivided by irrigation use specific percentages by county by HUC.

Summary tables showing the projected values, high and low values for both County and HUC 8 areas were computed. These tables are included in the separate data file provided to OWR.

Irrigation water use values by county were joined to a county shapefile. Attributes for the shapefile include the county name, high/estimated/low irrigation water use values for 2015, 2020, 2025, 2030, 2035, and 2040. The same procedure was used to create Irrigation water use values joined to a HUC 8 shapefile.

Aquaculture Forecasts

Water use data for aquaculture includes withdrawals for fish and shellfish production, cleaning, and transport. The water source may be either surface or groundwater usually fresh, but may be saline water groundwater. Most aquaculture facilities are excavated impoundments that may be rectilinear and interconnected with other ponds. The ponds may range in size from less than one acre to over 50 acres. Water can be a range of colors but the water quality is usually quite eutrophic to keep maximum production. Fish and shellfish are harvested by draining the pond to concentrate the fish into a collection basin. Drainage water is either recycled in other ponds, re-used in irrigation, or returned to the nearest stream. There are a few enclosed raceway systems in Alabama. These are commonly used for hatcheries and rearing stations but also offers a good future for fish production.

They are generally more efficient with water and have higher water quality than ponding systems. Pond aquaculture is commonly located Blackland Prairie soils which exhibit extremely low percolation rates. We found 59 OWR permitted sites designated for aquaculture. The Alabama GAP data appeared to do a good job of identifying aquaculture ponds. Numerous small, shallow, turbid, or highly eutrophic ponds may have been misclassified as aquaculture. NASS CDL data commonly misclassified aquaculture ponds as either bare soils (if the imagery was collected while the ponds were drained), wetlands, or open water. The CDL also misclassified sandy, turbid, or highly eutrophic open water in rivers and reservoirs as aquaculture.

To verify aquaculture acreages from both GAP and CDL we overlaid the classifications on NAIP imagery as near to the classification date as possible. What we found was that the total aquaculture sites have changed little since 2000. We cleaned up the erroneous “flier” points in reservoirs and rivers. We used the GAP aquaculture class for Blackbelt counties as a baseline against which changes in 2005 or 2010 could be measured. There were a few instances where ponds were destroyed or obviously changed to something other than aquaculture. We also found a few instances where new aquaculture facilities were constructed in counties outside the Blackbelt.

Area values from the validated GAP and NASS CDL data were used to compute the aquaculture specific distribution with HUC 8 areas by county.

All of this is to say that aquaculture infrastructure is amazingly stable and will likely continue to be stable into the foreseeable future. The only major changes in aquaculture acres will be seen when producers adopt a raceway structure. That will be a slow process but will produce a slow but steady reduction in water use for aquaculture while maintaining the same level of productivity.

We believe that the market for aquaculture using conventional pond culture is saturated and don’t expect to see increases in the number of aquaculture ponds, or in water withdrawal for aquaculture.

We constructed a county table for predicting aquaculture water use that was very similar to the tables used for irrigation with these notable exceptions –

- Lacking a table of “Ancillary data for Growth Potential” since no such ancillary data exists;
- Error associated with predicting future uses are much lower than with irrigation. Aquaculture is much less dynamic unless there is catastrophic failure in the market, which is unpredictable.

OWR water use data had several counties reporting small values for aquaculture water use for which we could not validate any aquaculture sites distinctive enough to appear on NAIP imagery. These could be cage culture sites in ponds or small minnow ponds raising baitfish. We projected flat-line growth for these activities since they are too small to detect. Also, this water use may not be transferred to a HUC 8 area if there was no verified aquaculture within that county.

County water use projections were incorporated into a statewide worksheet with a table for each county.

A subsection of this worksheet summarized HUC 8 water use values subdivided by aquaculture use specific percentages by county by HUC. Summary tables showing the projected values, high and low values for both County and HUC 8 areas were computed. These tables are included in the separate data file provided to OWR.

Aquaculture water use values by county were joined to a county shapefile. Attributes for the shapefile include the county name, high/estimated/low irrigation water use values for 2015, 2020,

2025, 2030, 2035, and 2040. The same procedure was used to create Irrigation water use values joined to a HUC 8 shapefile.

Livestock And Poultry Forecasts

Water use data for livestock includes withdrawals for cattle, hogs, poultry, horses, sheep, and goats animal production, cleaning, and comfort. The water source may be either surface or groundwater. Livestock water uses are not necessarily associated with an identifiable land use with the exception of large feedlots. Feedlots will most likely be classified as barren, however. Livestock tanks can be excavated ponds that may be mistakenly classified as open water, bare ground, or aquaculture.

Poultry and swine water use is concentrated in houses and sheds specifically designed for concentrated production. Traditional satellite land use classification methods (GAP and CDL) are based upon a 30-meter cell size. Poultry and swine houses will commonly escape detection with that large of a pixel. The Alabama Poultry Association does have location information on all poultry production facilities but that information is closely held for food security reasons. Therefore, the only location based information about livestock water use is the OWR water permits data. There are 34 permitted water withdrawals that issued to names that are readily identifiable as a livestock producer.

We do not have sufficient data to provide a robust distribution of livestock specific water use by HUC 8 by county. For the 2005 Water Use Report, OWR documented that "Water withdrawals for livestock by sub-basin were determined by applying GIS techniques. The sub-basin boundaries were superimposed on the county boundaries to create a sub-basin/county areal unit. Each sub-basin/county unit represents a percent of the sub-basin area within a county. Surface-water and ground-water withdrawals were distributed among the sub-basin/county units based on the assigned areal percentage." We used the same method for determining livestock sub-basin distribution.

As with aquaculture, we believe that the market for livestock is somewhat stable. Discussions with Livestock experts noted that there is a long-term downward trend for beef and dairy cattle within Alabama. Hogs are thought to be holding steady. Poultry production is stable and is expected to continue a near current levels for the foreseeable future. As a side note, it appears that the water requirements for the poultry sector may be underestimated in 2005 and 2010.

Water use conservation and reuse methods within the poultry industry have been improving and gaining acceptance. Even while the total poultry population may be increasing, the water use by the poultry industry will increase at a slower rate. Incremental increases in water use will occur if and when new poultry houses are constructed, which are dependent upon market demands.

We constructed a county table for predicting livestock water use that was very similar to the tables used for irrigation with the following notable exceptions:

- Lacking a table of “Ancillary data for Growth Potential” since no such ancillary data exists;
- Error associated with predicting future uses are much lower than with irrigation. Livestock is less dynamic than irrigation but more dynamic than aquaculture.

OWR water use data for livestock was projected for each county. County water use projections were incorporated into a statewide worksheet with a table for each county. A subsection of this worksheet summarized HUC 8 water use values subdivided by percentages by HUC.

Summary tables showing the projected values, high and low values for both County and HUC 8 areas were computed. These tables are included in the separate data file provided to OWR.

Livestock water use values by county were joined to a county shapefile. Attributes for the shapefile include the county name, high/estimated/low irrigation water use values for 2015, 2020, 2025, 2030, 2035, and 2040. The same procedure was used to create Irrigation water use values joined to a HUC 8 shapefile.

Golf Course Irrigation Forecasts

Water use data for golf course includes withdrawals for golf courses (greens, fairways, tee boxes, water hazards) and grounds surrounding the course and clubhouse that are irrigated. The water source may be either surface or groundwater but is always fresh. The water can be distributed with a sprinkler system, usually a buried fixed set. Golf course irrigation does not include domestic and urban landscape use, or recreational site use. Golf courses are readily visible in aerial photography, but may be a mix of open water, barren sand, trees, lawns, and open grasslands.

OWR provided a list of golf courses for 2005 and 2010 that included the name, address, and tier ranking and water use by month. Courses were assigned a water use tier based upon the amount of the course that was watered where –

- Tier 1 -- extensive watering including greens, fairways, tees and surrounding grounds;
- Tier 2 -- frequent watering of greens and tee boxes. There may be some fairway watering as well;
- Tier 3 -- essential watering of greens only.

We validated the golf course information to ensure the proper distribution of golf course water use in HUC 8 basins. Using the golf course name and/or address we collected the geographic Longitude/Latitude coordinate of each golf course (centering on the club house, if present) using Google Earth™. When a course was located we validated the existence of the course in 2000, 2005, and 2010. Next we did a visual assessment of tier level. There had to be clear evidence of differences to alter the tier level assigned by OWR. Multi-course golf complexes were consolidated to one name to minimize replication under a different name in subsequent years. If a course could not be found it was deleted from the list. If a new course was identified we made our best effort to properly count the holes and assign a tier level appropriately.

Growth/retraction of golf course complexes by tier is shown in table 5 above. There was a major growth spurt for golf course complexes between 2000 and 2005. The economy was booming. The time frame from 2005 to 2010 was much more stable for Tier 1 courses but saw losses of five courses in Tier 2 and 3. The economy was starting to slump.

All this information was collected and stored in a geographic information system shapefile, which was spatially joined with a county spatial location and the HUC 8 spatial location.

Table 5. Number of golf course complexes detected by year and tier.

Tier	2000	2005	2010
1	21	28	28
2	151	167	164
3	46	51	49
Total	218	246	241

Incremental increases in water use will occur if and when new golf courses are constructed, which are dependent upon market demands and the economy. The Professional Golf Association (PGA) has made water conservation on golf courses a major issue. The US Open at Pinehurst #2 was a high profile example of the industry making every effort to illustrate that fairways and roughs can be more “natural” and un-watered and still be considered among the best in the world. It will be interesting to see if the sandy waste roughs are adopted in Alabama. If they are, water use for golf courses could be reduced significantly.

We constructed a county table for predicting golf course water use that was very similar to the tables used for irrigation with these notable exceptions –

- Lacking a table of “Ancillary data for Growth Potential” since no such ancillary data exists;
- Error associated with predicting future uses are much lower than with irrigation. Golf is less dynamic than irrigation.
- Water use changes should be marginally less (percentage decreases) as conservation practices are implemented on Tier 1 courses.

- Water use will increase incrementally in large steps if new courses are developed.

OWR water use data for golf was projected for each county. County water use projections were incorporated into a statewide worksheet with a table for each county. A subsection of this worksheet summarized HUC 8 water use values subdivided by percentages by HUC.

Summary tables showing the projected values, high and low values for both County and HUC 8 areas were computed. These tables are included in Appendix A.

Golf water use values by county were joined to a county shapefile. Attributes for the shapefile include the county name, high/estimated/low irrigation water use values for 2015, 2020, 2025, 2030, 2035, and 2040. The same procedure was used to create Irrigation water use values joined to a HUC 8 shapefile.

CONCLUSIONS

The analysis of OWR's Alabama's agricultural water withdrawal data from 2005 and 2010, along with the expert opinions and predictions of numerous agricultural faculty and Alabama Cooperative Extension System field staff and analysis lead to the following forecasts:

1. By 2040 overall combined Alabama agricultural water withdrawal for all areas examined in this report is forecasted to increase by approximately 15% (prediction range is -5% to +34%) over the 2010 level. The increase will be primarily a function of increased row crop irrigation.

2. The largest amount of increased water withdrawals will be for crop irrigation. The overall statewide water withdrawals for crop irrigation are forecasted to increase by approximately 110% (prediction range is -16% to +236%) of the 2010 levels. Given the recent state tax incentives and federal (NRCS) cost-share incentives, it is very likely that actual irrigated row crop acreage could increase by well over 200%, but efficiencies in the use of water for irrigation will improve as well which will reduce the water withdrawals on a per acre basis.

3. Water withdrawals for livestock and poultry are forecasted to decrease by slightly less than 7% (prediction range is from -36% to +26%) from the 2010 level. Some of this will be a function of reduced numbers of beef cattle, and a of improved water efficiency in poultry production.

4. Overall statewide water withdrawals for pond-culture aquaculture are forecasted to decrease by approximately 6% (prediction range is -22% to +11%) from the 2010 level. It is likely that aquaculture will change from the current pond culture to more emphasis on raceway culture, which will require less water.

5. Overall statewide water withdrawals for golf course irrigation are forecasted to increase by approximately 13% (the prediction range is -15% to +41%) over 2010 levels. The numbers of irrigated golf courses may increase by more than 13%, but this will be partially offset by improved efficiencies in water usage for irrigation.

It is important to note that the above forecasts are in agreement with the expert opinions and long-term water use trend predictions of the respective agricultural faculty and Extension field staff that were interviewed as part of this project.

While we can not provide any statistical confidence level for the above forecasts, we feel fairly confident that the overall trends in agricultural water use forecasted in this report are as good as can possibly be predicted given the available data and unknowns about the future.

Forecasting the changes for specific counties and watersheds is more difficult, but we have attempted to provide the best forecasts we can for those as well. Those specific county-level and HUC8 watershed level forecasts are presented in both tabular spreadsheet format and in maps, with graphs and diagrams showing projected future trends as well as the upper and lower limits of forecasted water withdrawals for irrigated crop production, aquaculture, livestock and poultry, and golf course irrigation.

APPENDICES, MAPS, GRAPHS AND DIAGRAMS

We created four county-level and four watershed level shapefiles containing the projected water use for different categories (irrigation, aquaculture, livestock and golf course irrigation) by time series. Each of these files were overlaid upon basemaps for Alabama and then shaded with a blue color intensity to illustrate both county-level and watershed level agricultural water use by category.

Due to the large number of pages, the appendix, including all maps, graphs and diagrams have been provided as separate data files within a single data directory to the Office of Water Resources for publication as deemed most appropriate.

EXPLANATION OF DATA USED TO DERIVE FORECASTS

Water Use Data

The Alabama Office of Water Resources (OWR) provided water use data for each county in Alabama for 2005 and 2010. OWR compiled the data for these two years in conjunction with the USGS using modern methodology and assumptions. Water use data from previous years were compiled using different methods and assumptions and were therefore not used. Water use categories were Irrigation, Aquaculture, Livestock, and Golf Courses where water was withdrawn from surface water or groundwater. Irrigation uses include row crops, horticulture, sod production, nursery production, and orchards. Aquaculture water use includes commercial food production use, fish hatcheries and rearing, transportation, and cleaning. Livestock water uses were compiled for all terrestrial animal forms for commercial or recreational purposes including cattle, hogs, poultry, horses, sheep, turkey, and quail. Golf course water use included water hazards, irrigation on greens, fairways, tee boxes, driving ranges, and any area under the ownership of the golf club.

Table 1. Sample of OWR water use data for 2005 and 2010 for Irrigation, Aquaculture, Livestock, and Golf course

	Irrigation		Aquaculture		Livestock		Golf	
County	2005	2010	2005	2010	2005	2010	2005	2010
Autauga	2.40	2.94	0.30	0.00	0.22	0.15	0.38	0.06
Baldwin	41.92	38.96	0.05	0.16	0.44	0.35	1.90	1.59
Barbour	3.40	2.17	5.91	2.43	0.35	0.38	0.19	0.19
Bibb	0.03	0.69	0.36	1.45	0.07	0.07	0.06	0.06
Blount	0.57	0.48	0.00	0.00	0.96	0.98	0.19	0.24

Table 1 shows a five county sample of water use data expressed in MGal/d. The two data points were used to compute the slope of a line that could project water use into future use. Appendix Table 1 shows water use for all counties.

Permitted Water Withdrawal sites

OWR has the responsibility to issue a permit to and monitor all water pumps that have the capacity to extract 100,000 gallons/day (gpd) regardless of the type of use. OWR provided a list of permitted surface water intakes and groundwater pumps. Fields in the table included the following:

1. Type – Surface water or groundwater;
2. CertNum and SeqNum – certificate number of the owner, sequence number of the withdrawal site;
    a. Owner
    b. County
    c. Latitude and Longitude – expressed in decimal degrees;
    d. Active – active or inactive site;
    e. Aquifer (for groundwater withdrawals) or Source (for surface water withdrawals)

We added the following fields :

3. UnqID – a unique identifier for each entry that consisted of Type+CertNum+SeqNum.
4. WUtype – we assigned a water use type to each active permit by examining the owner name and geographic location.
5. WUtype names are Aquaculture, Crop, Golf, Hort, Sod, Orchard, Livestock, and Recreation.

We converted the active sites in the table into a spatial dataset based upon the geographic coordinates. We found numerous spatial errors such as sites located in Georgia, Mississippi, and the Gulf of Mexico, sites that were noted to be in one county but were located an a different county, sometimes quite distant, and sites that were noted as a specific water use type that were not located near anything that looked like that type of use. Those errors were noted in the spatial data with a validation code. Withdrawal locations were used to validate land use types described by other data, and conversely, land use data were used to confirm water withdrawal location and water use type.

Ancillary Data

Numerous other data sources were used to obtain a more precise location and extent of water use values from OWR. The water use data from OWR was at a county grain size. By using other data sets that have a finer grain size we can more accurately subdivide the county based water use data into HUC 8 groupings. Ancillary data we used to enhance and corroborate the OWR water use values included --

- Golf Courses of Alabama. A list of golf courses in the state of Alabama for 2005 and 2010 compiled by OWR. The list included the address, number holes, address, county, HUC 8 code, and the OWR estimated water use. We compared the two annual listings to ensure consistent naming, tier ranking, and address. Next we used Google Earth to locate the courses and assign a geographic Longitude/Latitude coordinate in degree-minute-second format to ensure proper assignment to HUC 8 basin. We used historical National Aerial Imaging Program (NAIP) 1 meter resolution ortho imagery from 1998, 2006, and 2009, to validate the existence and tier rating of the golf course over the study period.

- Irrigation sites. Researchers at University of Alabama at Huntsville (UAH) had undergraduate students examine aerial photography from 2009, 2011, and 2013 to identify and delineate irrigation circles or other irrigation sites. Their product was a GIS map of pivot and volume gun systems that were clearly identifiable. They delineated approximately 119,000 acres of "crop circles" with this method. No attempt was made to see if these sites were active in previous years, thus these data area a reference of current irrigation development in a county. The data provide a spatially correct means of assigning irrigation development within a county and within a HUC 8 unit.

- National Agriculture Statistics Service (NASS) Crop Data Layers (CDL). The USDA, NASS Cropland Data Layer (CDL) is a raster, geo-referenced, crop-specific land cover data layer. CDL has a ground resolution of 30 meters. The CDL is produced using satellite imagery from the Landsat sensors collected during the current growing season. Agricultural training and validation data are derived from the Farm Service Agency (FSA) Common Land Unit (CLU) Program. The NLCD 2006 is used as non-agricultural training and validation data. The strength and emphasis of the CDL is agricultural land cover. Please note that no farmer

- reported data are derivable from the Cropland Data Layer. The purpose of the Cropland Data Layer Program is to use satellite imagery to (1) provide acreage estimates to the Agricultural Statistics Board for the state's major commodities and (2) produce digital, crop-specific, categorized geo-referenced output products. Classification accuracy is generally 85% to 95% correct for the major crop-specific land cover categories. (USDA, National Agricultural Statistics Service, 2013 Alabama Cropland Data Layer Metadata, USDA NASS Marketing and Information Services Office, Washington, DC.) We had CDL for 2008-2013.

- Alabama GAP data. The Alabama Cooperative Fish and Wildlife Research Unit at Auburn University began conducting a Gap Analysis Project (GAP) for the State of Alabama in August 2001. This Alabama Gap Analysis Project (AL-GAP), is part of a larger nationally sponsored GAP program administered by the U.S. Geological Survey (USGS), in which the main objective is to produce large-scale biodiversity and conservation assessments for native wildlife species and natural land cover types. The product of this research was a 30 m spatial resolution land use classification that was used to refine and enhance croplands, irrigated areas, and especially aquaculture ponds.

- Long-term Croplands were derived from Crop Data Layers from all years. We extracted all agricultural crop class names from the list of land use types. Long-term croplands are defined as areas that were used for some type of cropping activity in four of the six year and had a minimum size of 20 acres. We identified ~ 736,000 acres of long term croplands in the state. Land owners and developers are most likely to install irrigation on lands that are in long-term croplands.

- Irrigation Suitability Index (ISI) was computed as part of the Alabama University Irrigation Initiative in 2006. The ISI is a numeric ranking of 24 attributes from the NRCS State Soil Survey Geographic (SSURGO) that had influence on irrigation suitability. Each value of each attribute was assigned a rank ranging from -1 (entirely unsuitable) to 5 (most suitable) with reference to how that attribute value would impact irrigation. A similar ranking was applied to slope (%), streams and wetlands, and land use. Index values had a spatial resolution of approximately 30 meters. In essence, lands with an ISI value of less than 200 will not support irrigation sustainably while lands with an ISI value of greater than 200 are most likely to support irrigation for the long term. ISI did not consider access to water. We identified 652,368.5 acres in Alabama with High ISI values.

- National Aerial Imagery Program (NAIP). Aerial imagery from 1998, 2006, 2009, and 2011 were used to validate the locational accuracy of the OWR water withdrawal sites and to confirm that the water use associated with the permit was plausible. We used these data to confirm the age, location, and tier rating of golf courses.

- Center Pivot Irrigation system "crop circles". Researchers at University of Alabama-Huntsville used NAIP imagery from 2006 – 2011 to identify and delineate irrigated crop circles for each county in Alabama. Visual cues to identify irrigation sites identified circular shape of fields, circular "green areas", circular tracks, and/or linear towers. Other irrigation methods like drip, buried tape, solid set, or flood were not identified. A total of 120,000 acres of center pivot irrigation sites were identified.

- Hydrologic Unit Code boundaries. Hydrologic Unit Code (HUC) areas are watersheds, stream drainages, drainage basins, or basins in which all water that flows over the surface of the land will be consolidated to a single receiving hydrologic feature such as a stream, river, reservoir, lake, or ocean. We used HUC 8 (stream drainage) definitions from NRCS. The NRCS based their watershed boundaries upon USGS digital elevation models. There are fifty-three HUC 8 stream drainages in Alabama shown below. Major rivers and river complexes are shown in a similar tone, e.g., Chattahoochee River in dark green, Tennessee River in mauve.