MONITORING IMPACTS OF ANIMAL RESEARCH CENTER ON SURFACE AND GROUNDWATER QUALITY

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Brief Project Summary

The Animal Research Center, a facility designed to meet the research goals of the College of Agriculture, must meet the requirements of the Agricultural Water Quality Authority as established by SB 241. Intelligent hydrologic planning is incumbent upon a detailed knowledge of the hydrologic system as well as of the influences upon that system. A minimum, ongoing water quality monitoring program was instituted in October of 1996 to determine the impact of Center construction and operations on water quality.

All relevant water quality, flow, well, and spatial (excluding Research Facilities construction) data collected have been archived on BAE computer systems. These data are readily available for teaching, research, planning, and construction use and have been utilized by several individuals and departments with interests at the ARC.

Crop and animal production at the ARC is impacting surface water quality. For some constituents, the ARC is degrading water quality during certain periods of the year but, during other periods, an improvement in water quality can be detected. For some constituents, such as fecal coliform and total organic carbon, the ARC is degrading water quality throughout most of the year. Further study, including storm water analysis, is required to gain a better grasp of the processes involved, to correlate ARC landuse to water quality, and better define the seasonality of certain constituent releases into the hydrologic system.

An off-farm pollution event was detected. This event was detected in October of 1997 (triazines). Without the monitoring network, it would never have been ascertained that these pollution events originated from sources other than the ARC. Several other events have been noted (ammonia-N) that could possibly be the result of fertilization in riparian zones above the monitoring sites.

Use of the SWAT hydrologic model has made it apparent that more data is required concerning groundwater storage in the soil profile and in the karst aquifers. Measurement of subbasin flow data (obtained when weir repair is completed) will also improve assessments made by the SWAT model.

Project Objectives

1. Assess the net impact of an integrated animal production system (and construction activities) on surface water leaving the farm.

2. Assess groundwater quality at established well nests.

3. Determine the relative levels of contribution of the row crop and the pasture areas of the integrated animal production system to water quality constituents.

4. Support water quality research efforts at the Center by maintaining a minimum, ongoing monitoring program.

5. Maintain a GIS historical landuse activity database.

6. Maintain a hydrology teaching field laboratory for Biosystems and Agricultural Engineering, Agronomy, and Forestry departments.

Methods

Figure 1 gives the locations of the water sampling points at stream weirs (ST), springs (SP), and wells at the Animal Research Center.

Objective 1:

1. Collected biweekly water samples at sites ST-1 and ST-14, the two major pour points draining the Center.

2. Collected flow data at site ST-1 with an ISCO 3220 Flow Meter for periods of the year when weirs were working properly. The weir berms were breached by >100 year storm event in the Spring of 1997. Stream stage is stored every 10 minutes.

3. Purchased and installed a YSI 6000 Water Quality Datalogger at ST-1 in late summer of 1997. The YSI 6000 is equipped with electrical conductivity, pH, dissolved oxygen, turbidity, temperature, and nitrate-nitrogen sensors. It measures and stores each parameter every 15 minutes.

4. Archived water quality data in an electronic database as it became available.

Objective 2:

1. Sampled wells A-1, A-2, C-1A, C-2, and C-3 at wells nests A and C on a quarterly basis for water quality and well water level, beginning in June of 1997 after well development.

2. Archived well water quality, well level, and soil moisture data in an electronic

database as it became available.

Objective 3:

1. Collected biweekly water samples at sites ST-8, ST-10, ST-12, ST-13, ST-14, SP-2, and SP-6 and monthly water samples at SP-1, SP-3/4, SP-8, SP-11, and SP-15.

2. Archived water quality data in an electronic database as it became available.

3. Collected flow data at sites ST-4, ST-5, and ST-11 with an ISCO 3220 Flow Meter for periods of the year when weirs were working properly. The weir berms were breached by >100 year storm event in the Spring of 1997. Stream stage is stored every 10 minutes.

Objective 4:

1. Stream and groundwater water quality data utilized in four papers presented at symposia.

2. GIS data used in the construction planning of the new research facilities at the Animal Research Center.

Objective 5:

1. Maintained all known GIS coverages pertinent to the Center on the BAE HP server storage system.

Objective 6:

1. Monitoring sites have been utilized in field laboratory classes by BAE, Agronomy and Forestry.

Results and Discussion

Assessment of Animal Research Center Water Quality Impacts -- Objectives 1, 3, and 4:

The water quality monitoring program commenced in October, 1996. Biweekly grab samples were collected at sites ST-1, ST-8, ST-10, ST-12, ST-13, ST-14, SP-2, and SP-6. Monthly samples were collected at sites SP-1, SP-3/4, SP-8, SP-11, and SP-15. Flow data was collected at sites ST-1, ST-4, ST-5, ST-8, ST-10 and ST-11. All available sample analyses, flow data, and datalogger data were archived in a Microsoft Access relational database. All weirs, except ST-1, ST-12, ST-13 and ST-14, were damaged when the earthen berms around the weirs were breached after a Spring, 1997 storm. Flow data at the damaged weirs were not accurate after the failure. Temporary repairs were made with permanent repairs to be made in 1998-99. Water quality data was not affected at failed weirs.

Figures 2, 3, and 4 show nitrate-N, triazines, and orthophosphate-P at sites ST-1, ST-8, ST-10, SP-1, SP-2, SP-3/4, and SP-6 for the time period from October 23, 1996 to March 18,

1998. The concentrations at spring SP-6 is elevated, for all three parameters, above the other sites during the course of the sampling period. Spring SP-1 appears to be the next highest in concentration for all three parameters and elevated over the other springs through most of the year (except for a few events). Spring SP-3/4 is higher for all the parameter concentrations than SP-2 except during the winter months when SP-2 equals or exceeds it. Springs SP-1, SP-6, and SP-3/4 tend to drain the cropped areas of the farm where these constituents are applied to the soil, whereas SP-2 is off-farm water draining primarily pasture land with some row crop fields on adjacent property at the spring=s basin headwater boundary. The stream location ST-8 has concentrations that tend to run lower than SP-2 due to the dilution by incoming water upstream of ST-8 on Camden Run which drains only pastures.

A statistical analysis was performed on the data for nitrate-N, triazines, orthophosphate-P, F. coliform bacteria, organic-C and ammonia-N at sites ST-1, ST-8, ST-10, SP-1, SP-2, SP-3/4, and SP-6 for the time period from October 23, 1996 to March 18, 1998 to determine if the above observations were significant. The main effects are sampling site and month-spans. The month-spans are four consecutive month periods that were found by previous statistical analyses performed on water quality data from farmland watersheds in the SB-271 Assessment Phase Report (Taraba, et al., 1995).

In the Assessment Report (Taraba, et al., 1995), the month of the year had a significant effect on the mean monthly concentrations of nitrate-N, triazines and bacterial populations in the discharge water from the eight assessment and research watersheds. To determine whether the variation in the mean monthly concentrations are meaningful, statistical testing was conducted on mean monthly concentrations. Paired mean monthly concentration comparisons were made for nitrate-N and triazines ($\alpha = 0.05$) to determine which means are significantly different. The results of these analyses follow a pattern in which a grouping of monthly means could be made. Based on these observations, the year was partitioned into three groups made up of four months each: December-January-February-March (DJFM), April-May-June-July (AMJJ) and August-September-October-November (ASON). The statistical basis for these groupings also is supported by the hydrologic implications of the soil water balance during each period and the timing of agricultural chemical application. December is, on average, the beginning of the period of the year when surplus soil moisture is available for ground water recharge. The shallow ground water sampling sites (tile drains, springs and monitoring wells) have water available for sampling. April is the beginning of agricultural field operations and chemical applications of herbicides and fertilizers. August, on average, is the month in which many of the shallowest water sampling sites do not have water available for sampling and there is no net recharge to deeper ground water.

The month-span mean concentrations were compared statistically to determine significant differences between the means in the monthly groups of DJFM1 (December 1996 to March 1997), AMJJ, ASON.and DJFM2 (December 1997 to March 1998) and sampling sites. First the normality of the data was tested. For each water quality parameter, the data was found not to be normally distributed by the Kolmogorov-Smirnov method ($\alpha = 0.05$). Based on these results, ANOVA was performed on ranked data and mean comparisons were tested by the Tukey method ($\alpha = 0.05$). The main effects of site and month-span as well as their interaction was found to be significant for all the water quality measurements. The results of these analyses are found in Tables 1 to 6 for nitrate-N, triazines, orthophosphate-P, F. coliform bacteria, organic-C and ammonia-N respectively. The means for each month-span at each sampling site are shown for water quality parameters. The means that are significantly different identified with a different letter. Mean comparisons are made between sampling sites with the same month-span (rows) and mean comparisons between month-spans within a sampling site (columns).

Tables 1 to 3 confirm the significance of the results found in Figures 2 to 4 for nitrate-N, triazines and o-phosphate-P that were previously discussed. The highest concentrations for these row crop inputs to production were found at sampling sites draining of row crop production.

Table 1. Nitrate-N means for each month-span at the sampling sites.

Nitrate-N (mg/L)*								
Month Span	**St-1**	**St-8**	**St-10**	**Sp-1**	**Sp-2**	**Sp-3/4**	**Sp-6**	**Mean**
DJFM1	$_{**b}3.57^{C**}$	$_{b}3.26^{C}$	$_{b}3.37^{C}$	$_{ab}5.87^{AB}$	$_{b}3.27^{C}$	$_{ab}4.90^{B}$	$_{ab}7.80^{A}$	$_{b}4.58$
AMJJ	$_{c}2.45^{C}$	$_{b}2.65^{C}$	$_{c}2.50^{C}$	$_{ab}5.68^{A}$	$_{b}3.48^{B}$	$_{ab}4.37^{A}$	$_{b}7.49^{A}$	$_{c}4.09$
ASON	$_{d}0.94^{C}$	$_{c}0.67^{C}$	$_{c}1.83^{C}$	$_{b}4.58^{B}$	$_{a}4.27^{B}$	$_{b}3.94^{B}$	$_{a}10.64^{A}$	$_{c}3.84$
DJFM2	$_{a}4.93^{BC}$	$_{a}4.86^{BC}$	$_{a}4.13^{C}$	$_{a}8.97^{A}$	$_{a}4.64^{BC}$	$_{a}5.67^{AB}$	$_{a}10.71^{A}$	$_{a}6.27$
12/96 - 3/98	2.97^{E}	2.86^{E}	2.96^{E}	6.27^{B}	3.91^{D}	4.72^{C}	9.16^{A}	

* ANOVA and Tukey mean comparisons were run on ranked data when normal distribution was not found.
** In columns, means with different subscript lower case letters are significnatly different (α = 0.05).
*** In rows, means with different superscript capital letters are significnatly different (α = 0.05).

Table 2. Triazine means for each month-span at the sampling sites.

Triazines (µg/L)*								
Month Span	**St-1**	**St-8**	**St-10**	**Sp-1**	**Sp-2**	**Sp-3/4**	**Sp-6**	**Mean**
DJFM1	$_{**b}0.127^{C***}$	$_{b}0.049^{C}$	$_{b}0.101^{C}$	$_{a}0.390^{AB}$	$_{b}0.168^{BC}$	$_{a}0.390^{B}$	$_{a}1.204^{A}$	$_{b}0.347$
AMJJ	$_{a}0.470^{B}$	$_{a}0.146^{B}$	$_{a}0.341^{B}$	$_{a}0.453^{AB}$	$_{a}0.694^{AB}$	$_{a}0.455^{AB}$	$_{a}1.319^{A}$	$_{a}0.599$
ASON	$_{ab}1.028^{B}$	$_{b}0.080^{C}$	$_{a}1.326^{AB}$	$_{a}0.273^{AB}$	$_{a}0.358^{AB}$	$_{a}0.185^{BC}$	$_{a}0.681^{A}$	$_{b}0.562$
DJFM2	$_{ab}0.248^{B}$	$_{b}0.105^{B}$	$_{b}0.121^{B}$	$_{a}0.258^{AB}$	$_{ab}0.271^{B}$	$_{a}0.235^{AB}$	$_{a}0.697^{A}$	$_{b}0.269$
12/96 - 3/98	0.468^{B}	0.174^{C}	0.472^{B}	0.343^{B}	0.374^{B}	0.316^{B}	0.963^{A}	

* ANOVA and Tukey mean comparisons were run on ranked data when normal distribution was not found.
** In columns, means with different subscript lower case letters are significnatly different (α = 0.05).
*** In rows, means with different superscript capital letters are significnatly different (α = 0.05).

Table 3. Ortho-phosphate-P means for each month-span at the sampling sites.

o-Phosphate-P (mg/L)*								
Month Span	**St-1**	**St-8**	**St-10**	**Sp-1**	**Sp-2**	**Sp-3/4**	**Sp-6**	**Mean**
DJFM1	$_{**a}0.264^{B**}$	$_{a}0.249^{B}$	$_{a}0.315^{AB}$	$_{a}0.329^{AB}$	$_{a}0.247^{B}$	$_{a}0.314^{AB}$	$_{a}0.383^{A}$	$_{a}0.300$
AMJJ	$_{a}0.225^{C}$	$_{a}0.265^{BC}$	$_{a}0.325^{BC}$	$_{a}0.363^{AB}$	$_{a}0.267^{BC}$	$_{a}0.308^{BC}$	$_{a}0.431^{A}$	$_{a}0.316$
ASON	$_{b}0.149^{E}$	$_{b}0.156^{E}$	$_{b}0.201^{DE}$	$_{a}0.319^{AB}$	$_{a}0.281^{BC}$	$_{a}0.246^{BCD}$	$_{a}0.401^{A}$	$_{b}0.250$

DJFM2	$_{a}0.259^{BC}$	$_{a}0.250^{BC}$	$_{a}0.309^{AB}$	$_{a}0.293^{ABC}$	$_{a}0.227^{C}$	$_{a}0.256^{BC}$	$_{a}0.349^{A}$	$_{a}0.284$
12/96 - 3/98	0.232^{E}	0.230^{E}	0.288^{BC}	0.376^{B}	0.256^{CDE}	0.281^{BCD}	0.402^{A}	

* ANOVA and Tukey mean comparisons were run on ranked data when normal distribution was not found.
** In columns, means with different subscript lower case letters are significnatly different ($\alpha = 0.05$).
*** In rows, means with different superscript capital letters are significnatly different ($\alpha = 0.05$).

In Table 4, the lowest fecal coliform bacteria populations were associated with the springs that drained the row crop areas (Sp-1, Sp-3/4, and Sp-6). The highest populations were found during the AMJJ and ASON month-spans and were linked with pasture areas (St-8, St-10, and Sp-2).

In Table 5, the lowest ammonia-N concentrations were found at the Sp-6 sampling sitewith the minimum concentration found during the ASON month-span. The highest concentrations were from sampling sites below land areas that were primarily pastures. The peak concentrations at these latter sites occurred in the ASON month-span.

In Table 6, the highest organic-carbon concentrations were found at St-8 and followed by St-10 and Sp-2. These sampling points were below pasture land areas. The lowest concentration was found at Sp-6 which is linked to row crop production land. Peak seasonal concentrations took place during the month-spans of AMJJ and ASON except for Sp-6 which was found to have its lowest concentrations.

Table 4. Fecal coliform bacteria means for each month-span at the sampling sites.

F. Coliform Bacteria (cfu/L)*								
Month Span	**St-1**	**St-8**	**St-10**	**Sp-1**	**Sp-2**	**Sp-3/4**	**Sp-6**	**Mean**
DJFM1	$_{**b}502^{AB***}$	$_{a}2065^{A}$	$_{a}538^{ABC}$	$_{a}53^{BC}$	$_{a}2206^{A}$	$_{bc}25^{BC}$	$_{a}6^{C}$	$_{ab}94$
AMJJ	$_{a}9490^{A}$	$_{a}1437^{AB}$	$_{a}817^{BC}$	$_{a}483^{BC}$	$_{a}505^{BC}$	$_{ab}531^{ABC}$	$_{a}47^{C}$	$_{a}681$
ASON	$_{ab}3453^{A}$	$_{a}1026^{AB}$	$_{a}599^{ABC}$	$_{a}39^{BC}$	$_{a}422^{ABC}$	$_{a}3601^{AB}$	$_{a}13^{C}$	$_{a}399$
DJFM2	$_{b}610^{A}$	$_{a}607^{AB}$	$_{a}52^{ABC}$	$_{a}3^{C}$	$_{a}554^{AB}$	$_{c}4^{BC}$	$_{a}11^{C}$	$_{b}56$
12/96 - 3/98	1779^{A}	1166^{AB}	341^{BC}	42^{CD}	715^{AB}	121^{BC}	14^{D}	

* ANOVA and Tukey mean comparisons were run on ranked data when normal distribution was not found. Means are geometric means for bacterial populations.
** In columns, means with different subscript lower case letters are significnatly different ($\alpha = 0.05$).
*** In rows, means with different superscript capital letters are significnatly different ($\alpha = 0.05$).

Table 5. Ammonia-N means for each month-span at the sampling sites.

Ammonia-N (mg/L)*								
Month Span	**St-1**	**St-8**	**St-10**	**Sp-1**	**Sp-2**	**Sp-3/4**	**Sp-6**	**Mean**
DJFM1	$_{**b}0.018^{A***}$	$_{b}0.022^{A}$	$_{a}0.016^{A}$	--	$_{a}0.030^{A}$	--	$_{a}0.004^{A}$	$_{b}0.018$
AMJJ	$_{b}0.034^{A}$	$_{b}0.006^{A}$	$_{a}0.025^{A}$	--	$_{a}0^{A}$	--	$_{a}0.003^{A}$	$_{b}0.014$
ASON	$_{a}0.186^{A}$	$_{a}0.160^{A}$	$_{a}0.013^{B}$	--	$_{a}0.019^{B}$	--	$_{a}0^{B}$	$_{a}0.076$
DJFM2	$_{b}0.034^{A}$	$_{ab}0.086^{A}$	$_{a}0.039^{A}$	--	$_{a}0.036^{A}$	--	$_{a}0.060^{A}$	$_{ab}0.051$

12/96 - 3/98	0.068^{A}	0.069^{A}	0.023^{A}	--	0.021^{A}	--	0.017^{A}	

* ANOVA and Tukey mean comparisons were run on ranked data when normal distribution was not found.
** In columns, means with different subscript lower case letters are significnatly different (α = 0.05).
*** In rows, means with different superscript capital letters are significnatly different (α = 0.05).

Table 6. Organic-carbon means for each month-span at the sampling sites.

Organic-Carbon (mg/L)*							
Month Span	**St-1**	**St-8**	**St-10**	**Sp-1**	**Sp-2**	**Sp-3/4**	**Sp-6**	**Mean**
DJFM1	${}_{**b}1.28^{AB**}$	${}_{ab}2.03^{A}$	${}_{b}1.01^{BC}$	- -	${}_{a}0.58^{C}$	- -	${}_{a}0.36^{C}$	${}_{b}1.05$
AMJJ	${}_{a}2.34^{A}$	${}_{bc}1.15^{B}$	${}_{a}1.79^{AB}$	- -	${}_{a}1.03^{B}$	- -	${}_{a}0.28^{C}$	${}_{ab}1.316$
ASON	${}_{a}2.58^{A}$	${}_{a}2.36^{A}$	${}_{ab}1.29^{B}$	- -	${}_{a}0.76^{BC}$	- -	${}_{a}0^{C}$	${}_{a}1.398$
DJFM2	${}_{ab}1.73^{A}$	${}_{c}1.14^{AB}$	${}_{ab}1.11^{A}$	- -	${}_{a}1.09^{AB}$	- -	${}_{a}0.41^{C}$	${}_{ab}1.095$
12/96 - 3/98	1.98^{A}	1.67^{AB}	1.30^{B}	- -	0.87^{C}	- -	0.26^{D}	

* ANOVA and Tukey mean comparisons were run on ranked data when normal distribution was not found.
** In columns, means with different subscript lower case letters are significnatly different (α = 0.05).
*** In rows, means with different superscript capital letters are significnatly different (α = 0.05).

Figures 5 and 6 show the concentrations of triazines, nitrate-N, fecal coliform bacteria, orthophosphate-P, ammonia-N, and total organic carbon in water entering the farm via Pin Oak Spring above ST-10 and the Blue Hole Spring at ST-8 and leaving the farm at ST-1. Figures 7 and 8 show the differences in water concentrations of the above water contaminants between ST-10 and ST-1 (Pin Oak Branch) and ST-8 and ST-1 (Camden Run). Values below zero (negative values) reveal when the respective concentration is higher leaving the farm than when it entered and the ARC is degrading water quality. If a value is equal to or above zero (positive values), the ARC has either no impact or a beneficial impact on the water quality. The conclusion that the ARC is having a negative or positive impact on water quality can only be stated during periods where both lines are below zero (negative) or equal to or above zero (positive). This is due to the mixing of the water from both inputs at ST-1. Camden Run and Pin Oak Branch tend to switch places during certain periods of the year, i.e. one side of the farm tends to dominate in a particular concentration during a given period and the other side tends to dominate in another period. The impact of the ARC landuse on water quality can not be assessed under this condition. To resolve this situation, water sampling should begin immediately at ST-4 and ST-5 to get a better picture of what is happening in both subwatersheds. Since weirs ST-4 and ST-5 were unable to provide flow data after the Spring 1997 storm that breached the weir berms, the relative mass contributions (concentration x flow rate) could not be assessed. This is the more accurate approach to assess the ARC landuse impacts and will be used when repairs are completed. Table 7 summarizes the percentages of the sampling dates that have positive (+), negative (B), or unknown (could not be determined as noted above).

Nitrate-N. It appears that a yearly pattern for nitrate-N is found in Figure 5. In general, minimum concentrations occur during August through October. Concentrations rise in December when groundwater recharge begins and peaks in February. After this winter peak, concentrations decline continuously through to August, with a sharp decline occurring in July when groundwater recharge ceases. These three phases are characterized by a set of patterns in the concentrations of the three sites. During the minimum concentration period (August to October), the concentrations of nitrate-N at ST-1 and ST-8 are similar while ST-10 has a higher concentration. During the winter period (December to February), the concentrations of nitrate-N at ST-1 and ST-8 are again similar while ST-10 has a lower concentration. During the third period of declining concentrations (March to July), all three sampling sites are comparable.

In Figure 7, the ARC appears to have both beneficial (positive) and degradative (negative) impacts on water quality and the trends seem to be seasonal. Six percent of the paired samples were positive and occurred during the AMJJ and ASON periods. A negative impact was found for 41% of the sampling periods. These highest periods occurred during the winter DJFM1 and DJFM2 month spans.

Triazines. Triazines peak concentrations in Figure 5 occur when expected after spring application and decrease in concentration to non-detects by October. Concentrations increase slightly above non-detects in December after groundwater recharge begins and then continuously decreases to non-detects by March. A significant but real concentration spike (~5 ppb) occurred in October of 1997 at ST-10, just below the Pin Oak Spring, which discharges water that originates primarily off-farm. The source is unknown. If the EPA sampled at ST-1 but not at Pin Oak Spring, the ARC could be blamed for such an incident.

In Table 7, the ARC was found to degrade water quality by increasing the triazines concentration. Negative impacts on the water quality occurred in 44% of the sampling periods, occurring in the winter DJFM1 and DJFM2 month spans and ASON month-span. The inability to ascertain the ARC=s impact during the spring AMJJ month-span illustrates the need for flow data at ST-4 and ST-5 so that mass flow rate can be calculated in order to determine if high off-farm loads are occurring at a particular input monitoring site. In this case, the Blue Hole Spring, SP-2, was the source of high triazines concentration water.

Fecal Coliform Bacteria. The fecal coliform bacteria concentrations in the water leaving the ARC at ST-1 are higher than ST-8 and ST-10 for nearly the entire monitoring period of 1997-98. The concentrations reach the highest level from March to November, which corresponds to the time when pastures have the highest population of grazing cattle.

Table 7. Landuse impacts (+, -, or unknown) on measured water quality between water entering (St-8 and St-10) and water exiting (St-1) the Animal Research Center.

	Nitrate-N			**o-Phosphate-P**			**Triazines**			**Ammonia-N**			**Organic Carbon**			**Fecal Coliform Bacteria**		
Month Span	+	-	**Unk.**	+	-	**Unk.**	+	-	**Unk.**	+	-	**Unk.**	+	-	**Unk.**	+	-	**Unk.**
DJFM1	0.0%	70.0%	30.0%	30.0%	0.0%	70.0%	10.0%	50.0%	40.0%	88.0%	0.0%	12.0%	44.0%	33.0%	22.0%	22.0%	0.0%	77.0%
AMJJ	12.5%	25.0%	62.5%	50.0%	12.5%	37.5%	12.5%	0.0%	87.5%	50.0%	12.5%	37.5%	0.0%	75.0%	25.0%	0.0%	100.0%	0.0%
ASON	12.5%	12.5%	75.0%	25.0%	0.0%	75.0%	37.5%	62.5%	0.0%	12.5%	62.5%	25.0%	0.0%	62.5%	37.5%	12.5%	75.0%	12.5%
DJFM2	0.0%	50.0%	50.0%	25.0%	0.0%	75.0%	0.0%	62.5%	37.5%	37.5%	37.5%	25.0%	0.0%	50.0%	50.0%	25.0%	37.5%	37.5%
TOTAL	5.9%	41.2%	52.9%	32.4%	3.3%	66.7%	14.7%	44.1%	41.2%	48.5%	27.3%	24.2%	12.1%	54.5%	33.3%	15.2%	51.5%	33.3%

+ Contaminant concentrations are reduced as the water passes through the ARC farm.
- Contaminant concentrations rise as the water passes through the ARC farm.
Unk. **Unknown** - unable to assign a + or - designation as water passes through the ARC farm

The highest concentrations of bacteria that enter the farm are associated with the Camden Run branch, ST-8, above which the watershed is predominantly pasture, while the Pin Oak Branch watershed is predominately row crop and horse pastures.

The impact of the ARC on the bacterial water quality is summarized in Table 7. After March 1997, cattle were put onto pasture and it was found that 51% of the sampling periods indicated that bacterial contamination occurred as the water passed through the ARC.

Orthophosphate-P (o-PO_4-P). The concentrations of o-PO_4-P in Figure 6 indicate that concentrations of water entering and leaving the ARC peaked during the May to July period (0.4 to 0.5 ppm) and continually decreased until a minimum concentration was reached during October. The concentrations began to rise in November when groundwater recharge began and rises to a level that is steady (0.2 to 0.3 ppm) until May. The water entering the Pin Oak branch at ST-10 is always higher than the Camden Run entry point, ST-8. A significant off-farm pollutant release was detected in July-August of 1998 at ST-10 for phosphorus, ammonia-N, and total organic carbon. The Kentucky Division of Water was tracing the source and tentatively pointed to an origin in Versailles.

The impact of the ARC on the o-PO_4-P concentrations for the water passing through is shown in Table 7. The ARC does not indicate a degradation of water quality based on o-PO_4-P. There were no periods when both values were negative. The plot shows that o-PO_4-P concentrations decrease in 32% of the water sample periods as water passes through the farm.

Ammonia-N. In Figure 6, the ammonia-N concentrations for water entering the ARC was generally comparable to water exiting the farm from January through June and were at their lowest values (< 0.1 ppm). From June to December the concentration of ammonia-N leaving the ARC was at its highest and exceeded the concentrations entering the ARC. On four different occasions, spikes in the concentrations entering the farm occurred. Three of the occasions occurred at the ST-8 sampling point on Camden Run. No explanation was found.

The impact of the ARC on water quality can be assessed from Table 7. Water quality, based on ammonia-N, improved in 48.5% of the sampling periods. But water quality degenerated on passage through the ARC, particularly during the ASON month-span. This accounted for 27.3% of the sampling periods during 1996-98.

Total Organic Carbon. The concentrations for total organic carbon in the water entering and leaving the ARC (Figure 6) tends to peak during the June to August period while the minimum concentrations are found in January to April. Concentrations of total organic carbon are generally highest in the water leaving the ARC (ST-1) relative to the water entering at ST-8 and ST-10. There was a spike in concentration that occurred during July-August of 1998 at the Pin Oak Branch site, ST-10 and was an off-farm pollutant release as noted above.

The impact of the ARC on the total organic carbon in the water passing through is found in Table 7. The only period when total organic carbon concentrations improved while passing through the ARC was January to February of 1997. This represented only 12.1% of the sampling periods. During the remainder of the sampling period, the water passing through the ARC was found to be degraded during 54.5% of the sampling periods. This latter period did not show any seasonal effects.

Diurnal Stream Dynamics. After the purchase and installation of the YSI 6000 at ST-1, plotting of the YSI data revealed strong diurnal variations in water temperature, E. C., pH, D. O., and nitrate-N. Temperature, pH, and E. C. data from the YSI at ST-1 is plotted for a period of 27 days, beginning at midnight on 8/12/97, in Figure 9. Two steps were taken to determine if the diurnal variations were real or an artifact produced by air temperature variations effecting the electronics of the YSI.

First, the YSI was placed in springs SP-2 (Blue Hole) and SP-7 (Pin Oak). Data was collected for 27 days beginning at midnight on 9/12/97 (day one for SP-1 in Figure 9) at SP-2 and beginning at midnight on 10/10/97 (day one for SP-7 in figure 9) at Sp-7. As can be seen, water temperature and E. C. at the two springs varies very little, especially in comparison to ST-1. There is some variation in pH at SP-7 but it is not diurnal. It appears that the diurnal variations were real and not an artifact of air temperature fluctuations. But to make absolutely certain, another brief study was conducted. An ISCO 3700 sampler was placed at ST-1 and samples were collected every hour for 48 hours from 8/20/97 to 8/22/97. The results of the sample analyses are shown in Figure 10, along with the values obtained from the YSI during the same period. As can be seen, a strong diurnal pattern can be seen in both the YSI data and the ISCO collected samples. Discrepancy in YSI and ISCO sample pH can be attributed to the lag time of 48 hours in collecting and measuring the pH in the ISCO samples. The spike in Nitrate-N late on 8/22/97 is due to the application of ammonia nitrate to the pasture along Pin Oak Branch. The YSI picked up the concentration of Nitrate-N from the fertilizer granules that entered the stream and dissolved.

Impact of Topographic Data Resolution. In the Spring of 1994, the ARC and surrounding area (approximately 3000 acres) was mapped at a 2-ft contour resolution. Seventeen map sheets, at a scale of 1≅=200=, were produced. Upon inspection of the maps and comparison with existing topographic maps, it became apparent that the 10-ft contour maps inadequately mapped the karst terrane. A study was undertaken to assess the impact of topographic data resolution on hydrologic model input and performance in a karst setting. AGNPS was the hydrologic model selected for the study. A brief summary of the results is included here. Details of the study are documented in Fogle, 1998.

A detailed comparison of the 2-ft contour maps with the older 10-ft contour maps revealed that the number of sink holes found at the ARC was inadequately mapped on the 10-ft contour maps. Twenty three sinks could be located on the 10-ft contour maps. The 2-ft contour maps produced 71 sinks. The drainage area that flows to the mapped sinks increased approximately two-fold. In other words, the amount of the watershed that contributes surface runoff to sink holes doubled when measured using a 2-ft contour interval as opposed to a 10-ft interval. This flow becomes part of the karst subsurface drainage system as opposed to becoming runoff flowing directly into streams.

The increase in the subsurface drainage was the most significant factor affecting model results, and resulted in significant differences between predicted runoff volumes, peak runoff rates, sediment yields, and nutrient yields for 2-ft contour interval data compared with 10-ft contour interval data. This difference can be significant when analyzing the effectiveness of some BMP=s (e.g. grass filter strips).

When comparing model output with measured water quantities, using a 2-ft contour interval did little to improve the predicted results. Discrepancies between measured and predicted results can be attributed to several things. The most significant reasons for the discrepancies are the fact that AGNPS does not account for the collection of subsurface water by a karst system and the subsequent rapid discharge of that water at a spring, as occurrs at the ARC. Also, it is possible, though unproven, that water discharged from the spring used in the study was collected from outside of the delineated surface catchment boundary. This phenomenon has been demonstrated by dye tracing in other catchments within the vicinity (Thrailkill et al, 1982; Thrailkill, 1985; Keagy et al, 1993).

Objective 2:

Figures 11, 12, 13, and 14 are plots of nitrate-N, triazines, o-PO_4-P, and fecal coliform concentrations, respectively, for each of the wells sampled. The shallower wells, C-2 and C-3, tend to have higher concentrations of nitrate-N, triazines, and o-PO_4-P, as expected since they are located in a corn field. Well C-1A is a brine well and is not considered indicative of the hydrologic system. All wells have no fecal coliform concentrations. The high coliform count in June of 1997 is considered to be contamination from well redevelopment. In general, the well data tend to follow the same patterns seen in the springs that are related to each well nest. Not enough data has been collected to determine any real trends in water quality.

Objective 5:

Maintained GIS database and supplied maps and data to several Ag College personnel with interests at the ARC.

Objective 6:

Continuance of this project will meet Objective 6. However, repairs to existing weirs and construction of a few new weirs are vital to making the Center an ideal hydrology teaching field laboratory in support of courses that use the farm in BAE, Agronomy, and Forestry.

Conclusions

All relevant water quality, flow, well, and spatial (excluding Research Facilities construction) data collected have been archived on BAE computer systems. These data are readily available for teaching, research, planning, and construction use and have been utilized by several individuals and departments with interests at the ARC. Data volume has grown such that a work station computer has been ordered to enhance data management efforts.

Crop and animal production at the ARC is definitely impacting surface water quality. For some constituents, the ARC is degrading water quality during certain periods of the year but, during other periods, a possible improvement in water quality can be detected. For some constituents, such as fecal coliform, the ARC is degrading water quality throughout most of the year. Springs whose waters emanate from cropped areas have higher concentrations of nitrate-N, triazines, and orthophosphate-P than springs emanating from pasture lands. This is to be expected due to the fertilization inputs required to produce row crops. The release of these and other constituents appear to follow seasonal trends, and is not just related to the application periods of herbicides and fertilizers. Further study, including storm water analysis, is required to gain a better grasp of the processes involved, to correlate ARC landuse to water quality, and better define the seasonality of certain constituent releases into the hydrologic system. It has been learned that data from ST-4 and ST-5 are required to ascertain quantitatively the impact the ARC is having on incoming waters.

Off-farm pollution events have been detected. Two such events were detected in October of 1997 (triazines) and in July-August of 1998 (o-PO_4-P, ammonia-N, TOC). Without the monitoring network, it would never have been ascertained that these pollution events originated from sources other than the ARC. Several other events have been noted (ammonia-N) that could possibly be the result of fertilization in riparian zones above the monitoring sites.

Use of the SWAT hydrologic model has made it apparent that more data is required concerning groundwater storage in the soil profile and in the karst aquifers. Measurement of subbasin flow data (obtained when weir repair is completed) will also improve assessments made by the SWAT model.

References

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Keagy, D. M., J. S. Dinger, A. W. Fogle, and L. V. A. Sendlein, 1993. Interim report on the occurrence of pesticides, nitrate, and bacteria on ground-water quality in a karst terrain-The Inner Blue Grass Region, Woodford County, Kentucky. Kentucky Geological Survey, ser. 11, Open-File Report OF-93-04, 31 p.

Taraba, J.L. J.S. Dinger, L.V.A. Sendlein, G.K. Felton, P.G. Conrad, J.C. Currens and D.M. Keagy. 1995. Agricultural Chemical Use Impacts on Kentucky Groundwater Resources B Assessment Report 1990-1993. Water Quality Research and Assessment Program. College of Agriculture, Kentucky Geological Survey, Kentucky Water Resources Research Institute, University of Kentucky.

Thrailkill, J., 1985. Flow in a limestone aquifer as determined from water tracing and water levels in wells. Journal of Hydrology, v. 78, p. 123-136.

Thrailkill, J., L. E. Spangler, W. M. Hopper, M. R. McCowen, J. W. Troester, and D. R. Gouzie. 1982. Ground-water in the Inner Bluegrass karst region, Kentucky. Kentucky

Water Resources Research Institute, Research Report 136, 136 p.

Appendix

3. **Publications**
4. Refereed outlets
5. Technical Reports or Papers

Fogle, A. W., 1998. Impact of Topographic data resolution on hydrologic and non-point source pollution modeling in a karst terrane. Report of Investigations No. 13, Kentucky Geological Survey, University of Kentucky, 22 p.

6. Extension numbered series or fact sheets
7. Symposium proceedings published

Taraba, J.L., J.S. Dinger, L.V.A. Sendlein, and G.K. Felton. 1996. Land Use Impacts on Water Quality from Small Karst Agricultural Watersheds in Kentucky. Proceedings 41st Annual Midwest Groundwater Conference. September 29-October 1. Lexington KY.

Taraba, J.L., J.S. Dinger, L.V.A. Sendlein, and G.K. Felton. 1997. Land Use Impacts on Water Quality from Small Karst Agricultural Watersheds. Proceedings of Karst Water Environment. P 99-109. VPISU Water Resources Reserch Center. Roanoke VA.

Taraba, J.L. and J.S. Dinger, 1998. Land use impacts on water quality from small karst agricultural watersheds. Proceedings Kentucky Water Resources Annual Symposium, pp 1-2. Kentucky Water Resources Research Institute, University of Kentucky. February 11, Lexington.

Taraba, J.L., and J.S. Dinger. 1998. Groundwater quality in Kentucky assessment and research watersheds Proceedings Kentucky Water Resources Annual Symposium, pp 5-6. Kentucky Water Resources Research Institute, University of Kentucky. February 11, Lexington.

Taraba, J.L. and J.S. Dinger. 1998. Land Use Impacts on Water Quality in Small Karst Agricultural Watersheds. Waterworks 4, (2) 1. Kentucky Water Resources Research Institute, University of Kentucky.

8. Abstracts
9. Mimeos written
10. Pamphlets with facts or program promotion uses

11. **Manuals, Workbooks, Training Packages, etc.**

Provided the following products to the following people.

Scott Shearer, BAE	GIS coverages of ARC topography and soils.
Larry Turner, BAE	Paper maps of ARC topography and soils.
College of Agriculture, Management and Operations	Paper maps of ARC soils, slope, slope aspect and topography.
Steve Workman, BAE	Paper maps of ARC topography, flow meter data, and sampling data.
Richard Warner, BAE	Paper maps of ARC soils.
Jim Currens, KGS	Paper map of ARC topography, roads, and dye traces.
George Day, BAE	Digital Orthophotos of ARC.
Anne Geydon, BAE	Paper maps of ARC, project data, and graphs of that data.

12. Videos

13. Displays

Monitoring impacts of Animal Research Center on surface and groundwater quality. 1998 KGS Annual Meeting, Kentucky Geological Survey, University of Kentucky, May 15, 1998

14. Meeting Presentations

Research conferences or annual meetings

Taraba, J.L., J.S. Dinger, L.V.A. Sendlein, and G.K. Felton. 1997. Groundwater Quality in Kentucky Assessment and Research Watersheds. ASAE Paper No. 972159. Presented at ASAE Meeting Minneapolis MN, Aug 10-14.

Spruill, C.A., S.R. Workman, and J.L. Taraba. 1998. Hydrologic Assessment and Calibration of the SWAT Model for Small Watersheds in Central Kentucky. ASAE Paper No. 98- . Presented at ASAE Meeting, Orlando FL, July 12-15.

Extension or other public meetings explaining data, using videos or displays

Kentucky Water Interagency Coordinating Committee. Water Quality Research at the University of Kentucky Animal Research Center. Versailles KY. September 9.

15. Training sessions conducted