Oklahoma Water Resources Research Institute
Annual Technical Report
FY 2004

Introduction

The Environmental Institute at Oklahoma State University has as its mission to serve as a center for stimulation and promotion of interdisciplinary research, graduate education and public education relating to understanding, protecting, utilizing and sustaining the natural environment. The federally supported Oklahoma Water Resources Research Institute, created under Section 104 of the Water Resources Research Act, is one of 54 Water Institutes. It has been housed at OSU since 1965 and in the Environmental Institute since 1992.

Research Program

In Fiscal Year 2004, the $92,524 grant to OWRRI was matched by $200,000 in non-federal money. These funds supported three research projects and water research administration and development activities as well as the information transfer program. The three research projects supported by the OWRRI program are as follows: Project 2004OK29B Springs in Time: Comparison of Present and Historical Flows determines whether spring discharge in each of five aquifers is being impacted by groundwater mining and documents the faunal biodiversity of Oklahoma springs that are at risk from groundwater mining. Project 2004OK20B Evaluation of Chemical and Biological Loading to the Blue River supports efforts to develop appropriate risk-based criteria for bacterial contaminants in surface water. Project 2004OK31B Optimal Selection of Management Practices for Phosphorus Abatement Using GIS and Economic Methodology in the Modeling of a Watershed provides spatially optimal, least-cost allocations of management practices between point and non-point sources to reduce phosphorus runoff in a watershed. It also provides recommendations on management practices each producer should adopt and investigates the feasibility of a cooperative venture to convert poultry litter into electricity and commercially saleable byproducts which would reduce the land application of poultry litter.

Springs in Time: Comparison of Present and Historical Flows

Basic Information

Title:	Springs in Time: Comparison of Present and Historical Flows
Project Number:	2004OK29B
Start Date:	3/1/2004
End Date:	8/31/2005
Funding Source:	104B
Congressional District:	OK - 4th
Research Category:	Ground-water Flow and Transport
Focus Category:	Ecology, Groundwater, Surface Water
Descriptors:	Arbuckle-Simpson aquifer, groundwater-surface water interactions, springs, dewatering, temporal change, biomonitoring, invertebrate fauna
Principal Investigators:	Aondover Tarhule, Elizabeth A. Bergey

Publication

Springs in time:

Comparison of present and historical flows

(Part 1)

Annual Report Submitted to:

OKLAHOMA WATER RESOURCES RESEARCH INSTITUTE

Report Submitted by:

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Start Date: March 1, 2004

End Date: August 31, 2005

Congressional District: 4th District

Date: June 20, 2005

Project Synopsis

This project began on March 1, 2004 and was scheduled to end on March 28, 2005. However, in November 2004, the PIs requested, and received a six-month, no-cost extension to August 31, 2005. The project built upon an earlier OWRRI funded study by Dr. Elizabeth Bergey (Co-PI on this proposal) titled: *Springs in Peril: Have changes in groundwater input affected Oklahoma Springs?* (Bergey, 2002). In that project, anecdotal evidence emerged mostly from land owners that suggested many springs in Oklahoma had either gone dry or were experiencing significantly diminished flow rates. Such outcome implied major changes in the groundwater aquifers that fed the springs. The present study was therefore developed to investigate those claims because groundwater is important to Oklahoma's economy, tourism, agriculture, and ecosystem health. The study had two main goals:

(1) To determine whether spring discharge in each of five identified aquifers was being adversely impacted by groundwater abstraction, and

(2) To further document faunal biodiversity of Oklahoma spring-fed streams and habitats.

This portion of the report, titled Part I, pertains to objective (1) above. Part two of the report will address the second objective.

Original Project Design

The study aquifers were those identified from Dr. Bergey's research as experiencing declining flow rates. These included the Ogallala Formation, Trinity Group, Vamoosa Formation, and the Garber Sandstone/Wellington Formation. Additionally, it was also decided to add the Simpson-Arbuckle aquifer, where a large-scale water sales plan has been proposed, to

the list of study aquifers. The study approach was to re-measure the discharge of 50-100 springs in the study aquifers and compare our discharge values to historical flow values.

Statement of Benefits and Outputs

The project anticipated the following benefits and outcomes, which are used in this report as benchmarks for evaluating success. This study will assess temporal patterns of discharge in the springs of five aquifers, in order to gauge the long-term sustainability of current groundwater use. For aquifers associated with proposed water sales (i.e., the Simpson-Arbuckle aquifer and the Trinity Group), this information will be helpful in indicating whether local springs may be impacted by future water sales. (2) Faunal surveys will increase our knowledge of this under-studied group and may indicate susceptible species. (3) The two P.I.'s will form an instructive and potentially fruitful hydrology-biology collaboration that will extend beyond the term of this project. (4) One graduate student and at least two undergraduate students will receive field and laboratory training in hydrology and biology. (5) Discharge records obtained from this study will be added to the USGS database; faunal records will be added to the Oklahoma Biological Survey database. (6) Results will be presented at one or more meetings, appear in at least one peer-reviewed manuscript, and be added to the project's website.

Approach

To compile the historical spring flow data, we recruited a M.Sc. graduate student in the Department of Geography, Mr. Mark Faulkner. Criteria were developed to guide the selection of springs, including length and completeness of records, as well as the number of flow measurements per year. Mark searched primarily the archives of the USGS and the OWRB. He

uncovered data for spring measurements going back to the 1930s that had not yet been digitized and digitized them. Even so, the records proved to be temporally more spotty than anticipated and it was virtually impossible to definitively establish trends over time. Given this situation, it was clear that the addition of one or a few more flow measurements (as originally proposed) would not resolve the flow trends. Although discharge records of various lengths and completeness were found for nearly 60 springs, only three springs had historical flow measurements sufficiently long and continuous to justify statistically rigorous trend analysis. These were Antelope Spring, Buffalo Spring, and Byrdsmill Spring. As an alternative, it was decided to analyze trends in well level fluctuations in the aquifers feeding the streams. The following section describes the rationale for this approach.

Theoretical Consideration

Springs, by definition, are points where groundwater flows to the surface. In Oklahoma, the two major types of springs are contact springs – where the water table intersects the surface, and artesian springs - where the water reaches the surface under pressure from a confined aquifer. If the water table in an aquifer falls due either to climatic or anthropogenic factors, then the flow of water from the discharging springs would also fall. Moreover, contact springs discharging near the top of the aquifer may dry up completely. While springs discharging near the bottom of the aquifer may not dry up, their flow rates or volumes will decline as the water pressure in the aquifer falls. Thus, the head in the aquifer - reflected in water level elevations - could be used in conjunction with data on spring elevations to determine springs at risk of drying out. In addition, because historical well water levels measurements are generally more abundant

and longer, analysis of their temporal variability is a suitable proxy for spring some flows. Figure 1 illustrates the concept.

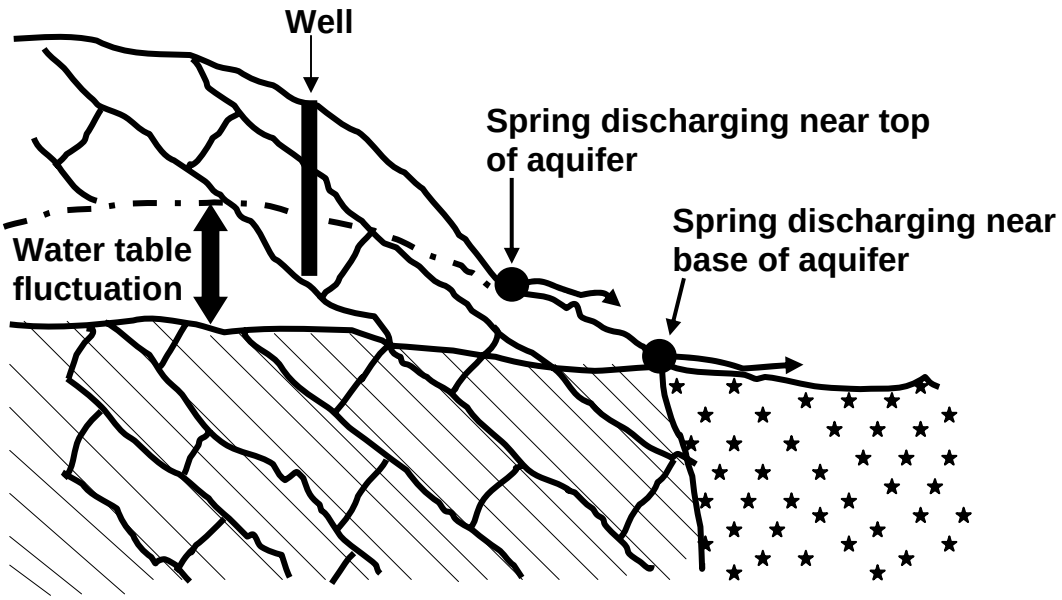

Fig. 1 Conceptual illustration of aquifer water table fluctuations and changes in spring

Data and Methods

Guided by the above consideration, we obtained data for selected wells from the USGS database. The selection criterion was that the wells should have continuous water level measurements for at least 25 years with no more than 10% consecutive missing years. We are cognizant of the fact that well level elevations are discrete point measurements that may reflect local water withdrawal patterns (or local cones of depression) and therefore may not be representative of the aquifer-wide water table. To address this problem, wells in the vicinity of springs were accorded higher priority and as many wells as possible were selected within the same aquifer. A total of 437 wells satisfied this criterion and were selected. Figure 2 shows the location of these wells. The selected study wells were analyzed for trends using both parametric

and non-parametric methods and the results visualized using GIS to reveal spatial patterns. The base period for analyzing the trends was 1970-2000, except for wells where the data began after 1970 (in which case the starting point of the data is used). The reason for using 1970 as the base period is that evidence in the literature (e.g. Karl et al., 1998; Groisman et al., 2001; Chen et al., 2004) indicates statistically significant positive increases in precipitation throughout the interior of continental North America. Thus, using this period allows us to evaluate the relative contributions of both climatic and anthropogenic effects on any observed patterns in the well level fluctuations. Details of the analytical procedures will be described in the technical report.

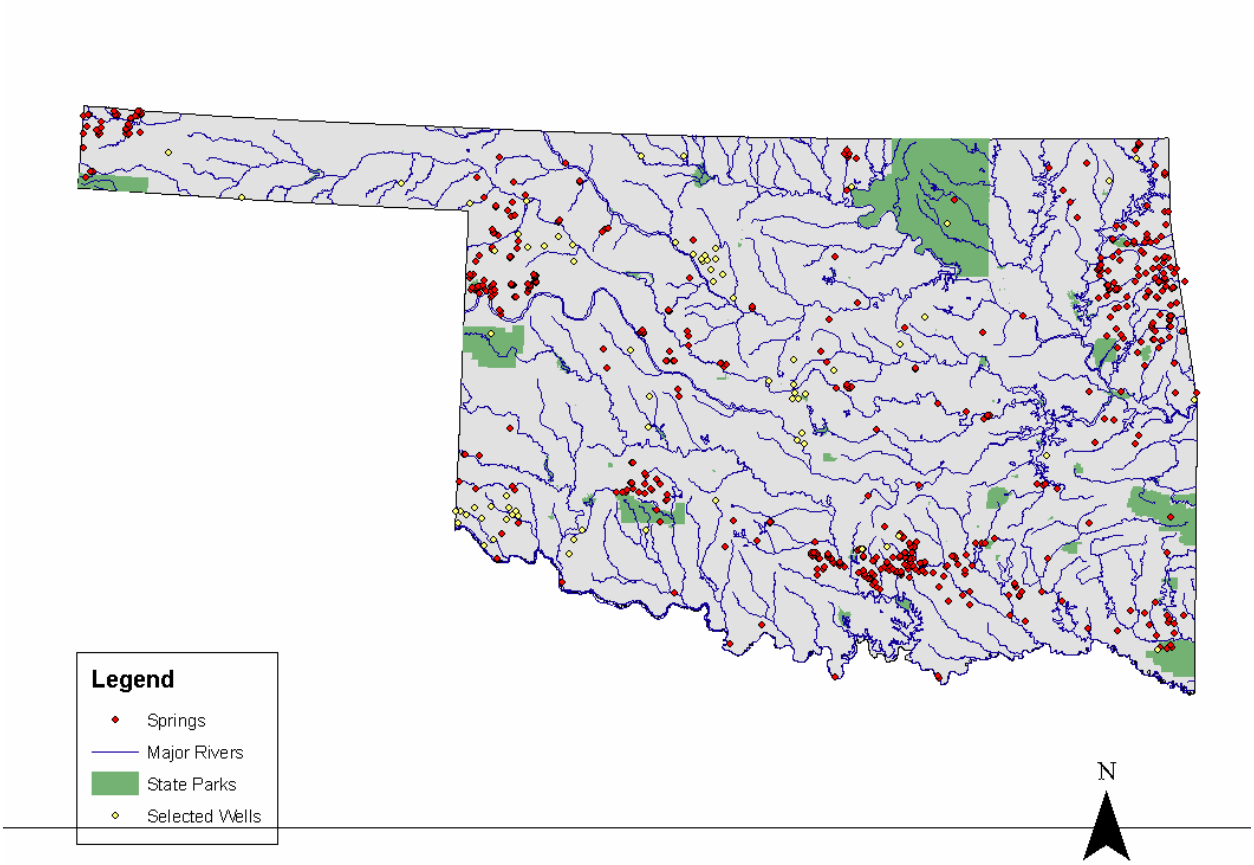

Fig. 2 Location of springs and study wells in Oklahoma

Preliminary Results

Fig. 3 summarizes the record length and data characteristics of the selected wells. Of the 437 wells analyzed, 226 (≈ 52%) showed statistically significant (P<0.05) upward trends, 112 (≈26%) of the wells showed statistically significant decreases, and 99 wells (22%) showed no change.

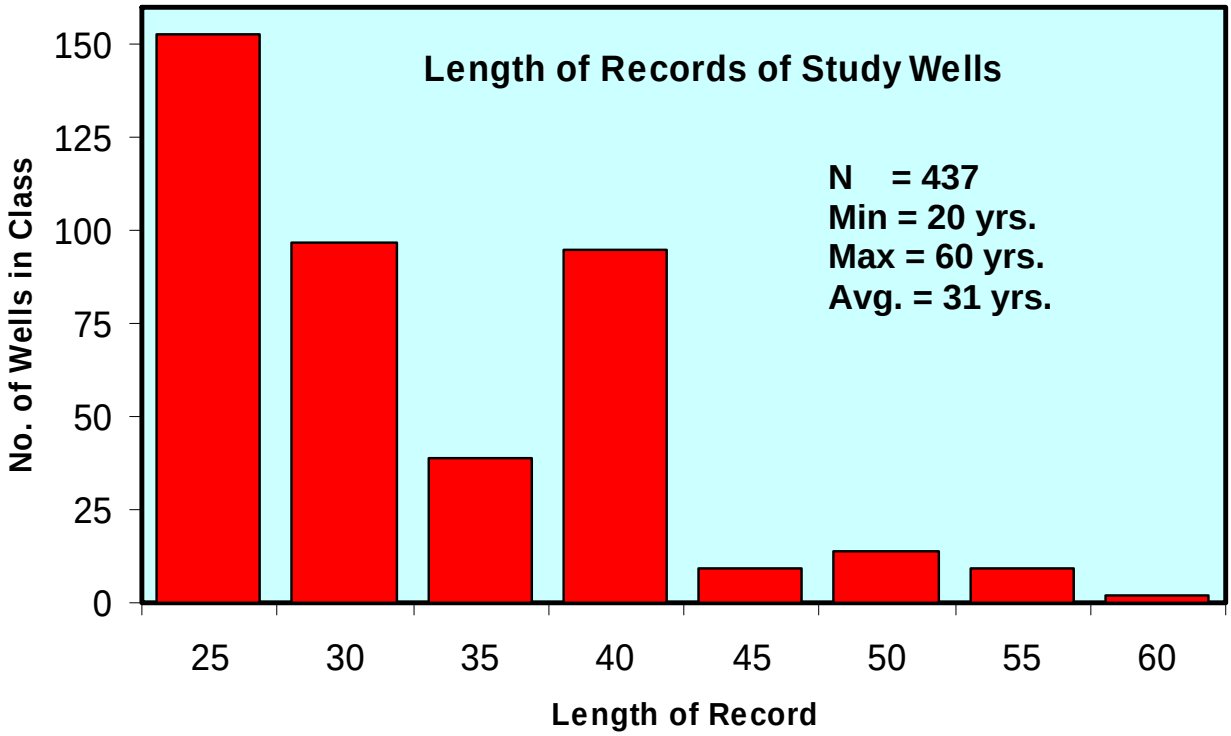

Fig. 3 The length of water elevation records at the selected study wells

Figure 4 shows the spatial distribution of these wells. It is immediately obvious that the vast majority of wells showing decreases are in the Oklahoma Panhandle (Ogallala Formation). Elsewhere, a few isolated wells also show decreases but the lack of a coherent spatial pattern to these wells suggests these are probably due to random and or localized effects.

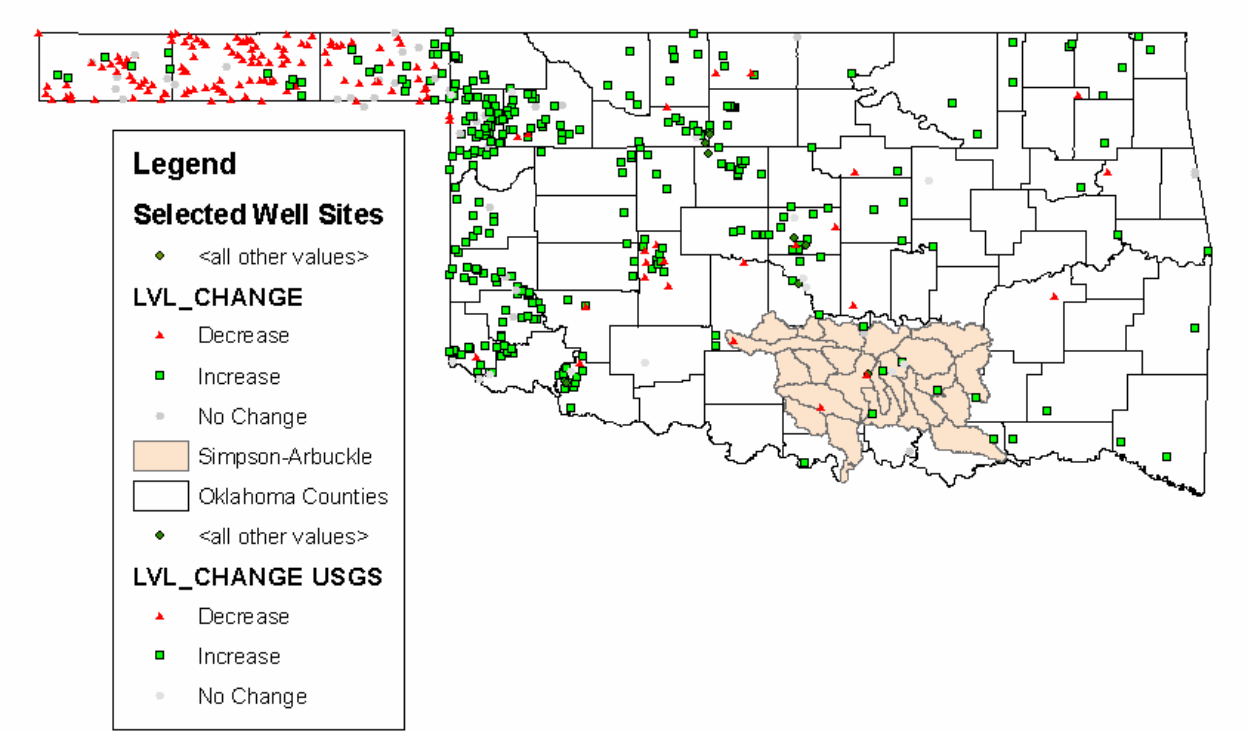

Fig. 4 Location of wells showing significant increases (P<0.05), decreases or no change

Otherwise, the general pattern outside of the panhandle is for well level rises. This result as well as precipitation trend analysis (not shown) is consistent with the findings reported in the literature (e.g. Groisman et al., 2001; Chen et al., 2004), which suggest that groundwater level rises in the continental North America are probably related to precipitation increases. Further analysis is contained in the technical report to follow. Our preliminary conclusion is that spring flows are unlikely to be declining in those parts of Oklahoma experiencing groundwater level rises. This conclusion does not preclude the fact that site specific geology and water use patterns may influence some springs even in areas of general water level rises. The Panhandle region is, of course, a different matter. Here, aquifer wide water level declines suggest that the some springs may be drying out or experiencing severe flow declines. The technical report discusses

the implications of these finding as well as the magnitudes of well level rises and declines around the state.

Major Accomplishments

To date the projects has accomplished the following targets set out in the original proposal

1. Compiled a comprehensive database of spring flows throughout Oklahoma and analyzed trends for springs with long continuous records.
2. Extracted and analyzed trends in well level fluctuations to provide insights into the likely temporal patterns of spring flows.
3. A significant part of the above data compilation and analysis was carried out by Mark Faulkner. This one of our objective to "train one graduate student in spring hydrology and biology, and to expose two or more undergraduate students to laboratory and fieldwork" (the two undergraduate students are working on the fauna inventory component of the study). Mark searched the archives.
4. These results were presented at the November 2004 regional meeting of the Southwestern Association of American Geographers (SWAAG) in Nacogdoches, Texas. We have also submitted an abstract for the forthcoming 2005 Oklahoma Water Resources conference. These efforts disseminate the findings to the wider research community.

Outstanding Tasks

While the results above are strongly indicative, they do not explain the causes of the above groundwater level trends. We have therefore selected five drainage basins with high density well points. We plan to carry out first, trend analysis between precipitation and

groundwater to compare the magnitudes of rises or declines in both variables. Then we will carry out cross correlation analysis between the two variables to establish the extent to which precipitation could be said to be the cause of groundwater level changes. Using this approach, the residual or unexplained variance between precipitation and groundwater level will be attributed to anthropogenic withdrawals. In addition, we plan to employ spatial statistical methods such as Principal Components Analysis, to define the spatial zones of patterns of different water level changes. Finally, we will again use GIS to display the results and to investigate its association with other factors, such as agricultural water use intensity, that may have impact on groundwater levels. Towards this goal, we have recruited another graduate student for two months (July-August, 2005) to do the cross correlation analysis.

It is also necessary to revisit the original the anecdotal evidence that prompted this study in the first place. Why did some landowners believe their springs are going dry when the evidence points to the contrary? Is the problem perceptual or were the landowners concerns/observations based on time frames that over weighted the effects of inter annual variability as opposed to long term patterns? The information learned will be important in facilitating communication between water researchers and stakeholders.

References:

Bergey, E. A. 2002. Springs in peril: Have changes in groundwater input affected Oklahoma springs? 2001-2001 Annual Report, OWRRI. 22 pages.

Chen, Z, S.E. Grasby, K.G. Osadetz 2004. Relation between climate variability and groundwater levels in the upper carbonate aquifer, sounthern Manitoba, Canada. Journal of Hydrology, 290: 43-62.

Groisman, Pavel Ya., Knight, Richard W., Karl, Thomas R. 2001: Heavy Precipitation and High Streamflow in the Contiguous United States: Trends in the Twentieth Century. *Bulletin of the American Meteorological Society*: Vol. 82, No. 2, pp. 219–246.

Karl, Thomas R., Knight, Richard W. 1998: Secular Trends of Precipitation Amount, Frequency, and Intensity in the United States. *Bulletin of the American Meteorological Society*: Vol. 79, No. 2, pp. 231–241.

Evaluation of Chemical and Biological Loading to the Blue River

Basic Information

Title:	Evaluation of Chemical and Biological Loading to the Blue River
Project Number:	2004OK30B
Start Date:	3/1/2004
End Date:	9/30/2005
Funding Source:	104B
Congressional District:	OK - 4th
Research Category:	Water Quality
Focus Category:	Nutrients, Water Quality, Surface Water
Descriptors:	E coli, water quality, TMDL, nutrients, Blue River
Principal Investigators:	Guy W. Sewell, Paul Mauck, David Walker

Publication

1. Prado, Baltazar. 2005 An Economic Examination of Potential Electricity and Fertilizer Production in the Eucha-Spavinaw Watershed M.S. Creative Component, Dept. of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma, 44 pp.
2. Sadhu, Joy. 2005 Evaluation of Economic Gains to Broiler Producers by Modulating Ventilation and Using Alum for Ammonia Control, M.S. Thesis, Edmond Low Library, Oklahoma State University, 84 pp.
3. Stoecker, A.L. R. Alviar, and T. Ancev, Use of GIS Simulation and Mathematical Programming to Determine Economically Efficient Pollution Abatement in a Watershed, Inv. Paper, International Seminar on Agricultural and Natural Resource Economics, Medellin, Columbia, Dec. 2004.

Annual Progress Report on Evaluation of Chemical and Biological Loading to Blue River.

June 15, 2005

Submitted by Dr. Guy W. Sewell
Professor Environmental Health Sciences
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Ada, OK

Problem and Research Objectives:

Oklahoma's abundant water resources are adequate to provide for the current needs of the State's citizens, but for future use, these resources need to be managed properly and protected from degradation. A baseline assessment of natural or background biological loading is needed to evaluate water quality standards, and to serve as a baseline for the detection of, and for evaluating any degradation of water quality.

This project will addresses one of the Priority Water Research Topics for 2004 as outlined in the call for proposals (#4),

> Quantitative relationship between runoff from wildlife habitats and in-stream bacterial concentration to distinguish between risks from human and natural contamination in setting water quality bacteriological standards.

and provide data for 2 other priority topics (#2, #5).

> Development of a phosphorus index that quantitatively relates field application of phosphorus fertilizer (e.g., chicken litter) to phosphorus loads in downstream receiving streams and lakes.
>
> Quantification of effectiveness of riparian zones to remove nutrients, sediment, and pathogens from runoff.

Blue River represents both a water and natural resource to Oklahoma (See Figure 1). Segments of the Blue River were listed in 1998 as impaired due to nutrients and noxious aquatic plants. While the river was not listed as impaired in the Oklahoma 2002 assessment report for these pollutants the need to assess and protect this resource remains.

ECU will measure and evaluate total coliforms, E. coli, phosphorus, ammonia, nitrate and other parameters along the course of Blue River, monthly, over a one-year period. Four Oklahoma Department of Wildlife Conservation designated public access points will be evaluated, upstream and down stream, plus 7 additional locations (See Figure 2). ODWC will characterize land use patterns along the river course and evaluate daily usage in the public access points. The parties will share project results and information.

The major objectives of the project will be as follows:

- Define bacterial (total coliform and E coli) load at sample locations
- Relate loading to upstream land use
- Evaluate bacterial loading in relationship to other water quality parameters
- Evaluate bacterial loading in relationship to human usage
- Define river discharge@time for sample locations
- Evaluate bacterial survival

Methodology:

A. Determination of total coliforms and *E coli* in water, and sample collection procedures: Total coliform and E coli quantification will be through the use of Hach's m-ColiBlue24® Membrane Filtration method (EPA Approved* Method 10029) for the simultaneous detection of total coliforms and *E. coli.*

B. Nitrate: Total nitrate will be determined by means of the Hach Water Analysis Handbook Method 8192, the Cadmium Reduction Digestion Method (0.01 to 0.5 mg/L range)

C. Ammonium: Total ammonium nitrogen will be determined by means of the Hach Water Analysis Handbook Salicylate, the PhosVer 3, Acid persulfate Digestion Method (0.05 to 1.5 mg/L range)

D. Phosphorus: Total phosphorus will be determined by means of the Hach Water Analysis Handbook Method 8190, the PhosVer 3, Acid persulfate Digestion Method (0.02 to 3.5 mg/L range)

F. Stream Velocity, Discharge and Cross Sectional Area Determinations:
Data and Calculations for average stream velocity and discharge will be done according to methods outlined in Fetter (2001), including the direct measurement of velocity with current meters, use of the Manning Equation, and determination of cross sectional area. Extensive characterization of sample site for elevation, gauging reference points, velocity distributions and channel geometry will be conducted at low flow periods (July 2004).

G. Land-use Determinations and Human Impact: ODWC personnel will carry out land-use characterizations, by direct visualization linked to GPS referencing, and through the use of aerial photographs. ODWC personnel will also quantify fisheries usage (human daily recreational area usage numbers) to allow for human impact studies during times or low and high usage. Trout Stocking Schedule: Blue River 2004 Jan. 5, 8, 14, 22, 28; Feb. 5, 11, 19,25; Mar. 4, 10, 18, 23.

H. Loading and Decay Determinations: Bacterial and chemical loading determinations will be conducted through the use of discharge and concentration data analysis at paired and multiple sampling locations. Bacterial decay determinations will be generated from the same data sets and evaluated for temperature impact (Joyce, 1996, Pope, 2003).

Principal Findings and Significance:

To date biological and chemical assessment of Blue River samples indicates good to marginal water quality with a general trend of decreasing quality as the river travels to the South East. Sections of the river overlaying the Arbuckle-Simpson Aquifer, which appear to have significant base flow discharge from the aquifer, tend to have more desirable characteristics, subject to some fluctuation apparently related to rainfall events and seasonal variations.

E. coli numbers have ranged from non-detect to approximately 100 cfu/ml over the sampling events to date, with average recoveries in the 0-10 cfu/ml, generally following the decrease in water quality from NW to SE.

Evidence of nitrate and phosphate loading to the watershed has been noted but identification of the possible sources and relationships to land use are still under investigation.

The relationships between chemical and biological indicators are being evaluated. Preliminary collaborative efforts with the University of Oklahoma to identify the strains of the recovered environmental isolates seem to suggest an unexpected predominance of strains related to human and animal pathogens. We will continue to evaluate these results.

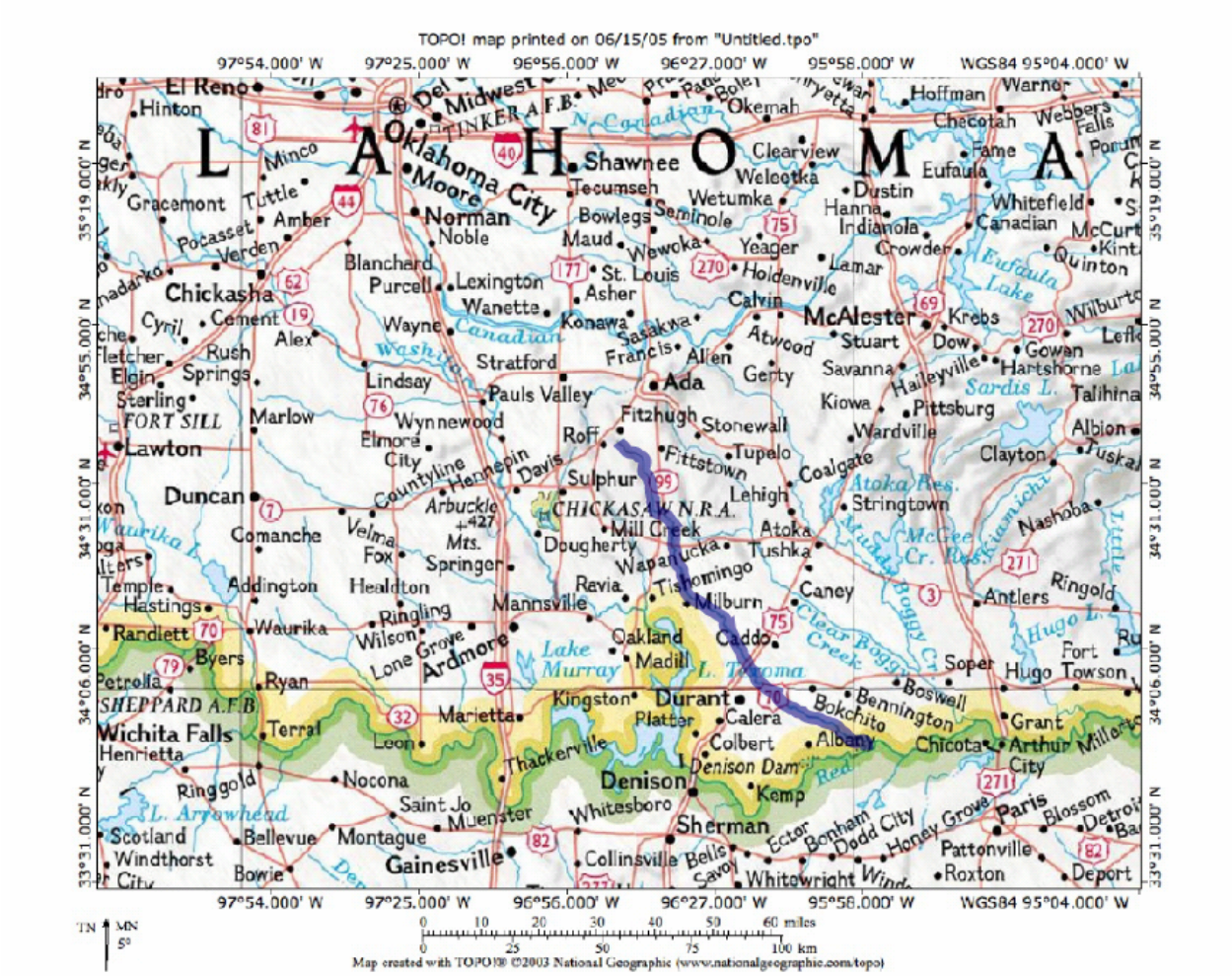

Figure 1. Map showing the location of the Blue River in Oklahoma.

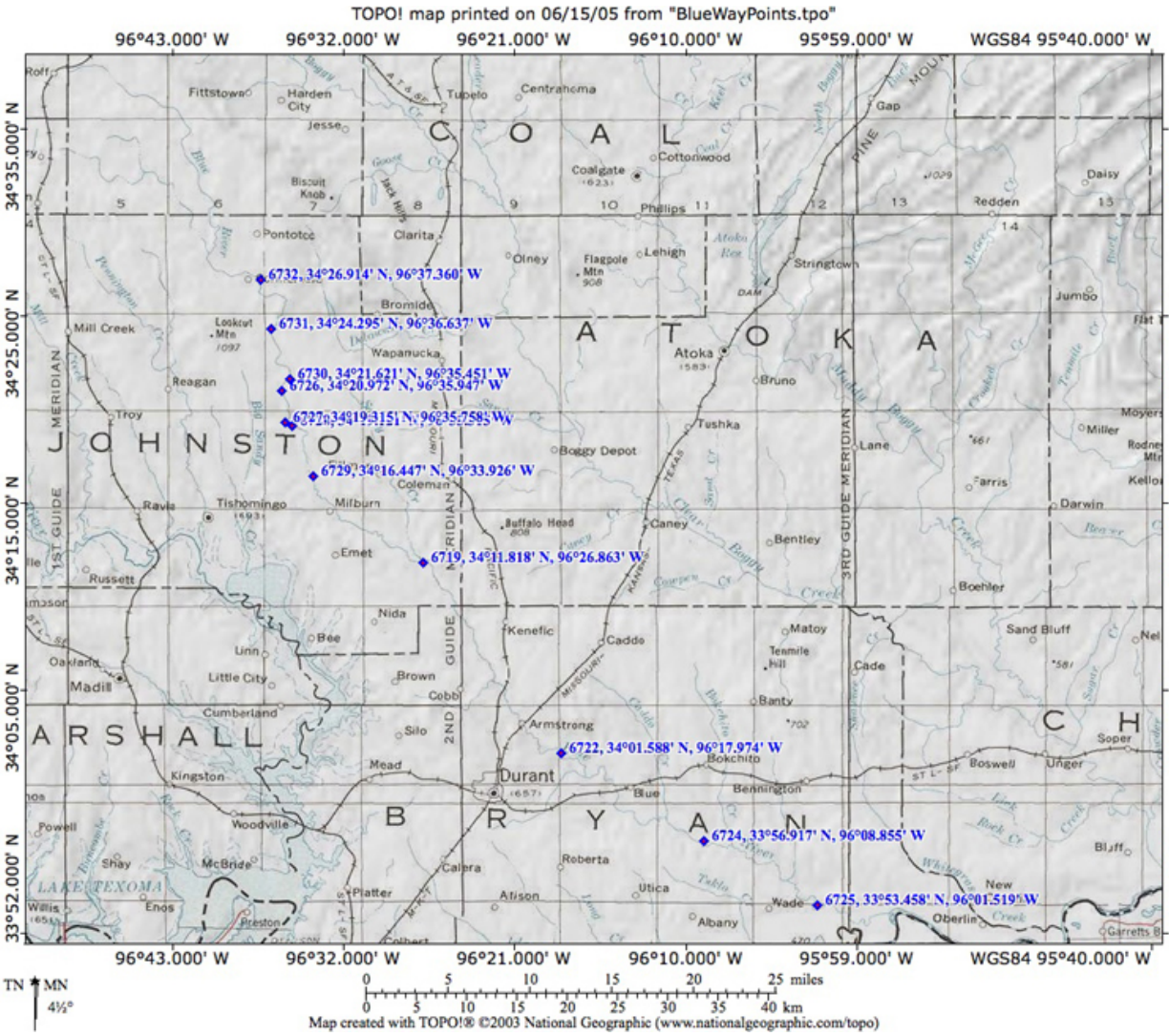

Figure 2. Map showing location of sampling points along the Blue River.

Optimal Selection of Management Practices for Phosphorus Abatement Using GIS and Economic Methodology in the Modeling of a Watershed

Basic Information

Title:	Optimal Selection of Management Practices for Phosphorus Abatement Using GIS and Economic Methodology in the Modeling of a Watershed
Project Number:	2004OK31B
Start Date:	3/1/2004
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	OK - 3rd
Research Category:	Water Quality
Focus Category:	Economics, Nutrients, Management and Planning
Descriptors:	Oklahoma, Arkansas, poultry litter, water quality, phosphorous, BMP, TNDL, litter to methane
Principal Investigators:	Brian D. Adam, Franklin Bailey Norwood, Arthur Stoecker, Daniel E. Storm

Publication

Optimal Selection of Management Practices for Phosphorus Abatement: Using GIS and Economic Methodology in the Modeling of a Watershed

A Report of Progress

by Brian D. Adam[*], Arthur Stoecker[*], Daniel Storm[**], and Bailey Norwood[*]

May 30, 2005

In eastern Oklahoma and western Arkansas, poultry litter from broiler producing operations has saturated the land, causing nitrate leaching and runoff of potassium and phosphorus, harming water supplies. In response to this problem, our research had two objectives:

Objectives:

1) To identify combinations of Best Management Practices (BMPs) that will meet the Total Maximum Daily Load (TMDL) for the Eucha-Spavinaw watershed at least cost.

2) To estimate the firm-level costs and benefits of a proposed enterprise to convert poultry litter to methane (for use in generating electricity) and commercially-saleable nitrogen, phosphorus, and potassium fertilizers. If financially feasible, this plant could help meet the TMDL for the watershed.

Procedures, Objective 1:

For the first objective, a biophysical model has been developed to determine the best management practice (BMP) for each of 695 locations within the Eucha Spavinaw watershed. This model uses Geographic Information System (GIS) data together with a Soil Water Assessment Tool (SWAT) simulation model to identify the lowest cost BMP for each localized piece of land identified by the GIS data that will ensure that overall pollution targets are met. The BMPs were selected to minimize the total cost to: poultry producers within the watershed; the city of Decatur, Arkansas (the source of 25% of the phosphorus entering the lake); and users of water from the watershed. The management practices considered were 1) reduced application of litter, 2) use of alum-treated litter, 3) shipment of litter within and from the watershed, 4) improving the management of overgrazed pasture, 5) converting row crops to pasture, and 6) increased phosphorus abatement at the city of Decatur. The cost of treating water by the city of Tulsa and loss of recreation values to users of lakes Eucha and Spavinaw was also considered. The model was based on an Arcview-Swat GIS simulation that was formulated and calibrated by Storm et al. (2000) for the Eucha-Spavinaw watershed.

Findings, Objective 1:

Total costs to poultry producers, the city of Decatur, the city of Tulsa, and to recreation users of the lakes would be minimized when total annual phosphorus loads are reduced from 50.6 short tons to approximately 27.5 tons per year.

[*] Dept. of Agricultural Economics, Oklahoma State University; [**] Dept. of Biosystems and Agricultural Engineering, Oklahoma State University.

The table below shows the costs to all parties as annual P loadings are reduced from 50.6 to 19.8 tons per year. Achieving lower annual P loadings reduces cost of phosphorus pollution, but raises cost of abatement. Total abatement plus damage costs are at a minimum when total phosphorus loading to the lake is reduced to 27.5 short tons (25 metric tons) per year.*

Maximum Phosphorus Loading (tons/year)	**Total Abatement Cost for Agricultural Enterprises** ($/year)	**Total Abatement Cost to Point Source** ($/year)	**Total Abatement Costs** ($)	**Total Damage Cost** ($/watershed)	**Sum of Total Abatement and Damage Costs** ($/watershed)
50.6	0	0	0	1,071,335	1,071,335
44.0	20,933	0	20,933	658,335	679,268
38.5	55,136	0	55,136	370,707	425,843
33.0	100,963	0	100,963	152,246	253,209
27.5[a]	**134,672**	**33,113**	**167,785**	**52,281**	**220,066**
22.0	139,446	101,207	240,653	7,693	248,346
19.8	160,688	112,484	273,172	0	273,172

[a] Level of phosphorus that minimizes costs to all parties.

The reduction in annual soluble phosphorus loading to 27.5 tons would be accomplished by the following:

a. Removing 11 of the 12.8 tons of phosphorus currently discharged by the city of Decatur, Arkansas.
b. Applying alum to 70,000 tons (out of 92,400 total tons) of litter. Thus most of the applied litter would be treated with alum which was assumed to reduce the runoff of soluble phosphorus by 75% as compared to the runoff of phosphorus from untreated litter.
c. Applying no more than 1 ton of litter on the 57,500 acres of well maintained pasture.
d. Limiting applications of litter to 2.7 tons or less on the 32,000 acres harvested for hay and hauled from the basin.
e. Converting all 16,000 acres of overgrazed pasture to well maintained pasture.
f. Converting 2,700 of the 6,500 acres of row crop to hay land.
g. The solution indicated that it was not necessary to ship litter out of the basin at the present, although the long term prospects are being investigated.

Further research is needed to examine the capability of current programs to provide incentives, regulations, or both for relevant parties to implement these changes.

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* The USGS land use land cover digital maps indicated the Eucha-Spavinaw basin contained 245,000 acres. However, only 112,000 acres are in agricultural use. There are approximately 32,000 acres of land harvested for hay, 57,500 acres of well maintained pasture, 16,000 acres overgrazed pasture, and only 6,500 acres of cultivated land. Some 957 poultry houses were located from photographic maps. These houses were assumed to produce 92,400 short tons of litter per year. Only some 53 short tons of phosphorus from all sources were assumed to enter the lake each year. Of this, 37 tons were attributed to agricultural sources while 12.5 tons were from the city of Decatur and about 3.5 tons was from forest and other background sources.

Procedures, Objective 2:
The results from Objective 1 do not consider the beneficial impact of a proposed waste-to energy-plant or the addition of a recently proposed discharge facility by the city of Centerton, Arkansas. If a waste-to-energy plant were to begin operation, it could convert some of the litter to energy and saleable fertilizer, further reducing the cost of limiting phosphorus loading. Moreover, under reasonable assumptions, the processing plant may actually be profitable, which would greatly reduce cost of limiting phosphorus loading.

Thus, the second objective of the research is to investigate the economic viability of such a plant. Since a major cost of processing litter is cost of transporting it to a processing plant, a key feature of the analysis is a GIS analysis. Rather than using straight-line "as the crow flies" map distances between poultry producers and the proposed processing plant, actual road miles were used to calculate transportation cost from each poultry farm to the plant. The difference is potentially significant because of the relatively small number of adequate roads in this section of the state.

Costs of several technologies were considered, using economic engineering estimates of both fixed (capital) costs and variable (processing) costs. Since actual production processes and output markets can be quite variable, another key feature of the analysis is a risk assessment of the proposed plant. Since the production process is new, there is uncertainty about the yield of electricity, nitrogen (N), Phosphorus (P), and Potassium (K) that can be obtained from each ton of litter. In addition, since prices of these outputs are uncertain, the analysis treated each of these variables as statistically random, with specified probability distributions. The simulation also assumed variability in capacity utilization of the plant, such as might result from operating difficulties or variability in "quality" of litter.

Findings, Objective 2:
Financial feasibility simulation of the proposed plant over a 20-year planning horizon, using conservative assumptions (although the supplied engineering coefficients have not been verified by us), would achieve an internal rate of return on investment of 16%. Years with low or negative returns are few and mild so that viability of the firm is not threatened. This simulation assumed that the firm receives the federal "green energy" tax credit. Without the "green energy" credit, the plant would achieve an internal rate of return of -2%.

Work in Progress
Research extending this project is linking these two objectives together, so that the impact of the processing-plant's litter-reducing benefits for the entire watershed can be measured. Preliminary results suggest that including the processing plant in the analysis could significantly reduce the cost of reducing phosphorus loading in the watershed. Further research is needed to verify the engineering coefficients of the processing plant.

Publications

Prado, Baltazar. 2005 An Economic Examination of Potential Electricity and Fertilizer Production in the Eucha-Spavinaw Watershed "M.S. Creative Component," Dept. of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma, 44 pp.

Sadhu, Joy. 2005 Evaluation of Economic Gains to Broiler Producers by Modulating Ventilation and Using Alum for Ammonia Control, M.S. Thesis, Edmond Low Library, Oklahoma State University, 84 pp.

Papers at Meetings.

Stoecker, A.L. R. Alviar, and T. Ancev, "Use of GIS Simulation and Mathematical Programming to Determine Economically Efficient Pollution Abatement in a Watershed", Inv. Paper, International Seminar on Agricultural and Natural Resource Economics, Medellin, Columbia, Dec. 2004.

Dual sensor for detecting xenobiotics and microorganisms

Basic Information

Title:	Dual sensor for detecting xenobiotics and microorganisms
Project Number:	2003OK17B
Start Date:	3/1/2003
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	3rd
Research Category:	Water Quality
Focus Category:	Surface Water, Toxic Substances, Water Quality
Descriptors:	spectrophotometer, cytocrome P450, autoflourescence
Principal Investigators:	Gilbert John, Mario Rivera, Gary Yen

Publication

1. Brian C. Decocq, James T. Blankemeyer, Kristen R. Workman, and Mendel Friedman. Effect of Carvacrol on Autofluorescence, Membrane Potential, and ATP Flux of Escherichia coli C600, J. Appl. Microbiol., submitted 2004.

Dual Sensor for Detecting Xenobiotics and Microorganisms

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INTRODUCTION:

Since September 11th, Homeland Security in the United States has become more important, as many aspects of security in this country are being examined and developed. One aspect is the security of drinking water. Deliberate contamination of drinking water make it imperative to have an efficient, sensitive, specific and rapid sensor that can detect both xenobiotics and microbial organisms that can cause harm to individuals. Billions of dollars are being made available from government and state agencies to develop systems that can continuously monitor drinking water. A multi-discipline group at Oklahoma State University is involved in developing a dual sensor that can be used in this capacity. Our proposal specifically addresses two critical areas that are important for further development of a dual sensor that can detect potentially harmful xenobiotics (toxicants) and pathogenic bacteria in water. The first area specifically addresses the issue of having stable proteins that can maintain their function under various environmental conditions. The cytochrome (CYP) P450 protein from the human liver is normally involved in detoxifying and toxifying a broad range of xenobiotics, thereby CYP proteins can be used to directly link xenobiotics to human toxicity. A number of isoforms are present in the liver, but some of these proteins are not stable (CYP3A4), compared to stable proteins (CYP1A2). Therefore, the first area we addressed was to develop a method of improving stability of CYP 3A4 using molecular modeling techniques thereby increasing ion-pair interactions in the protein. The second area addressed was to examine the autofluorescence signatures (spectrofluorimetry) from bacteria, which may provide a means of identifying different types of bacterial pathogens. Available methods that can be used to improve the stability of cytochrome P450 without compromising function as well as having unique spectra that can be used to specifically identify potentially harmful pathogens is critical for future development of a dual sensor.

The research report addresses two goals, 1.) to development a method involving ion-pairs to improve the stability of cytochrome P450 and 2.) to determine autofluorescence signatures differences for bacteria.

METHODS AND RESULTS

Goal 1.) (Note: All three objectives for goal 1 are discussed). To improve the stability of cytochrome P450 proteins for use in detecting xenobiotics, a computer graphics-modeling program was necessary in order to determine the important residues involved in protein stability. Three graphics programs were identified to have functions that were relevant and applicable to the project. They included PyMOL (Delano Scientific, http://www.delanoscientific.com), DeepView(Swiss Model), and WHAT IF Web Interface). Computer modeling coordinates for CYP 1A2 and 3A4 were used to generate the protein models and were obtained from Dr. Lewis (United Kingdom). The mutant protein model was tested for distances (residue positions based on 3-D images) using PyMOL prior to submitting the model for residue alteration by the WHAT IF server. Since the computer model of CYP 1A2 and 3A4 were similar, the mutational prediction for 3A4 was possible based on the analysis of the hydrogen bonds networks and ion pair networks of the CYP 1A2. Mutations were predicted based the method of Chinea.G & Vriend.G, for position-specific rotamers (14). The WHAT IF web interface calculates distances in angstroms (15).

The computational analysis allowed the selection of five candidates for site-directed mutagenesis of the CYP 3A4. The candidates were selected based on the number of additional ion pairs, hydrogen bonds, and additional residue interactions that were created based on the model and data received from the WHAT IF web interface.

Different stabilities exist within the family of cytochromes (CYP). Therefore, we hypothesize that some of the stability is due to ion pairs and/or ion networks (1-7). WHAT IF (http://swift.cmbi.kun.nl/WIWWWI/), a web server, was used to locate the number of optimal hydrogen bonds networks and salt bridge locations within the proteins according to the protein data bank files. Using the computer graphics programs, t was shown that the wildtype CYP 1A2 (more stable) had more ion pair networks than CYP 3A4 (less stable). To improve CYP 3A4 stability, residues distant from the substrate-binding region were selected for site-directed mutagenesis. Figure 1 shows the five selection residues selected for mutation, based on the superimposition generated by PyMOL. Figure 2 shows the GLU66=>ASP66 change, which increases the salts bridges (ion pairs) from 2 to 3, as well as providing a supporting hydrogen bond network (Table 1 and 2). Figure 3 shows the VAL124=>LYS124 change, which increases the salt bridges from 0 to 4 and maintains supporting hydrogen bond networks (Table 3 and 4). Figure 4 shows the GLY146=>ARG146 change, which increases the salt bridges from 0 11 and maintains supporting hydrogen bond networks (Table 5 and 6). Figure 5 shows the TYR376=>HIS376 change, which increases the salt bridges from 0 to 5 and maintains supporting hydrogen bond networks (Table 7 and 8). Figure 6 shows the ASN431=>ASP431 change, which increases the salt bridges from 0 to 3 and maintains supporting hydrogen bond networks (Table 9 and 10). Incorporation of all or selected mutations will be tested.

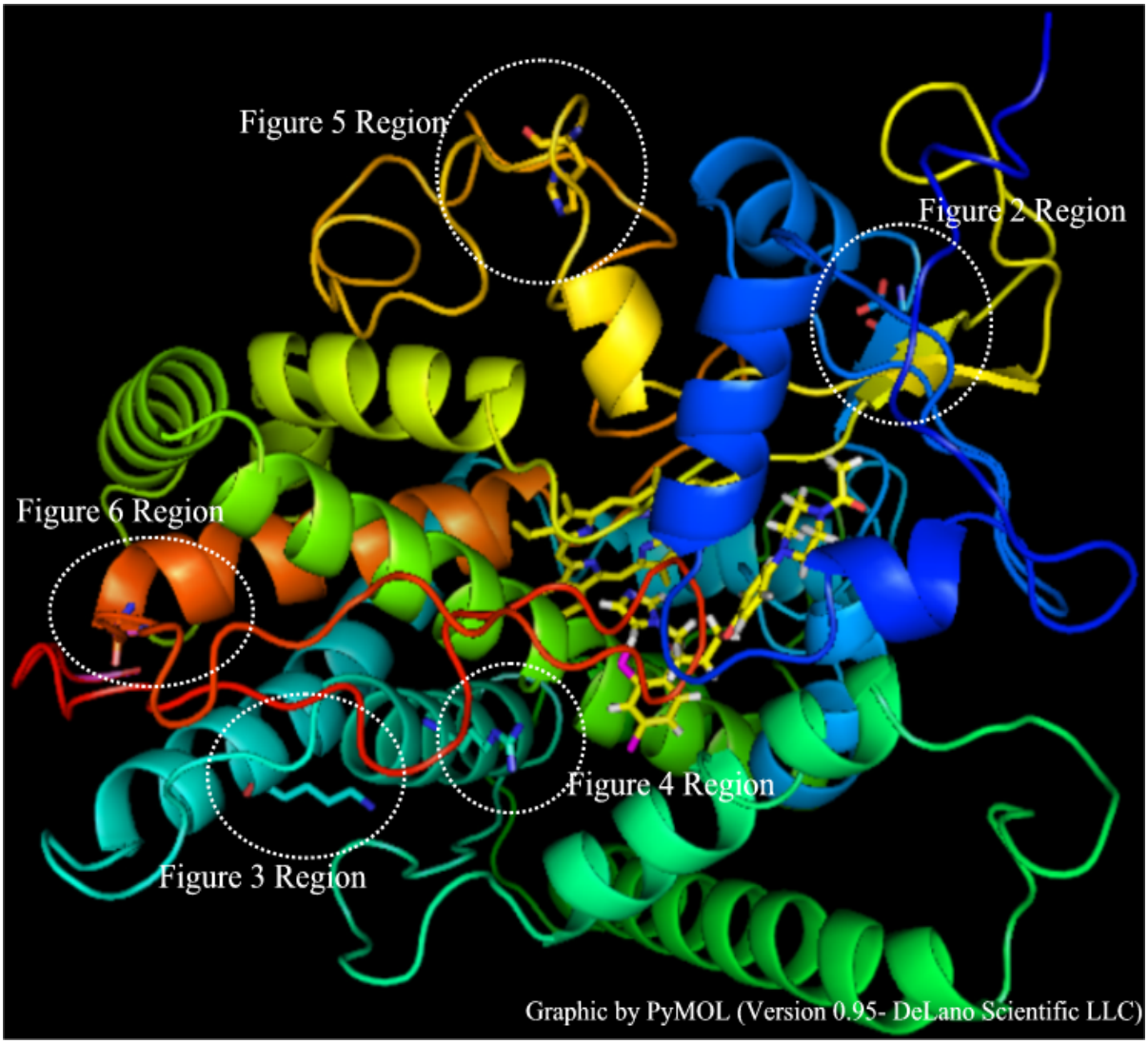


Figure 1: Superimposition of wild-type (wt) CYP3A4 and Mutant (m3a4) illustrating entire enzyme structure*.

a. Each ellipse corresponds to a mutant containing region.
b. Mutant residues are seen above as sticks.

* Graphic by PyMOL DeLano Scientific LLC & Edited with Microsoft PhotoDraw for all figures.

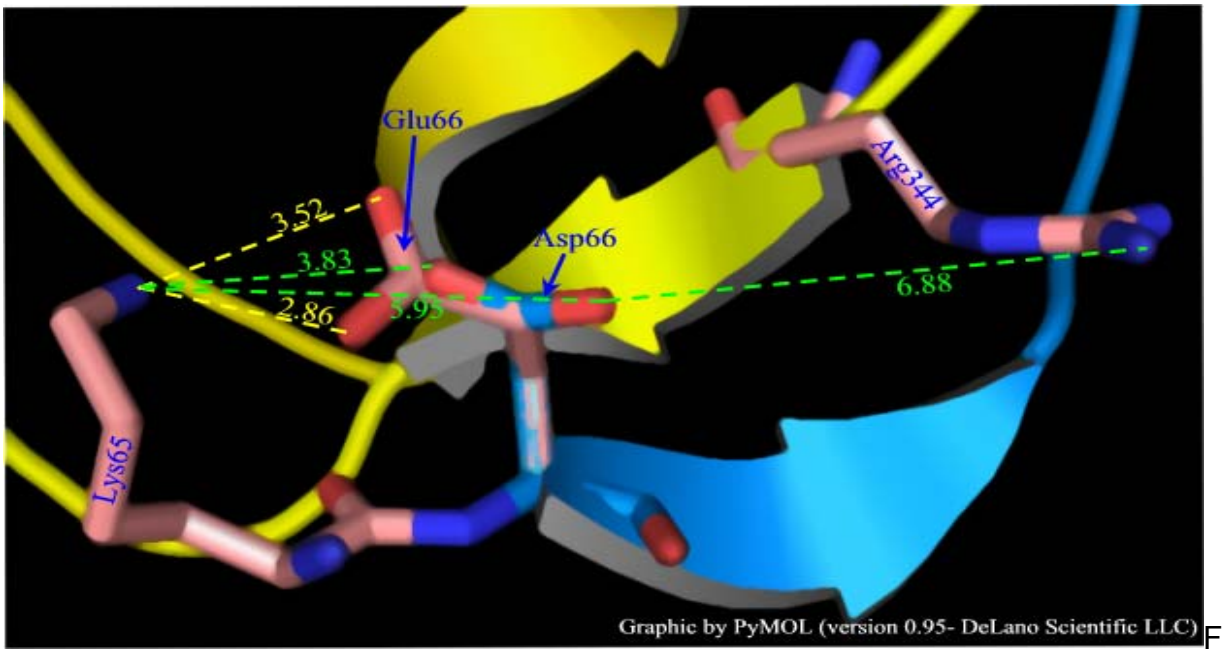


Fig. 2: Superimposition of wt- Glu66** and Mutant- Asp66 (m66)

a. m66 shown in blue sticks entangled with Glu66 pink
b. Ionic interaction- wt in yellow and m66 in green
c. Ionic interaction distance is in Å.
d. Residues Lys60, Thr61, Val62, Leu63, & Val64 were removed for clarity.

Table 1: WHAT IF- Salt Bridge Data (SBD), mutant data in boldface

Donor Residue	Donor Molecule	Acceptor Residue	Acceptor Molecule	Distance (Å)
66 ASP (66)	**OD1**	**65 LYS (65)**	**NZ**	**5.95**
66 ASP (66)	**OD2**	**65 LYS (65)**	**NZ**	**3.83**
66 ASP (66)	**OD1**	**344 ARG (344)**	**NH2**	**6.88**
66 GLU (66)	OE1	65 LYS (65)	NZ	3.52
66 GLU (66)	OE2	65 LYS (65)	NZ	2.86

** Residue numbers based on coordinate file data for sequence residue numbers add thirty-two (32) for all data.

Table 2: WHAT IF- Optimal Hydrogen Bond Network Data (OHBD), mutant data in boldface

Donor Residue	Donor Molecule	Acceptor Residue	Acceptor Molecule	Hydrogen Bond Value (0.0-1.0)[a]	Distance (Á)
65 LYS (65)	**NZ ->**	**66 ASP (66)**	**OD2**	**Val= 0.437**	**DA= 3.83**
65 LYS (65)	N ->	66 GLU (66)	OE2	Val= 0.390	DA= 2.85
65 LYS (65)	NZ ->	66 GLU (66)	OE2	Val= 0.653	DA= 2.86

a. estimated importance of hydrogen bonds relative to each other. Perfect hydrogen bond = 1.0.

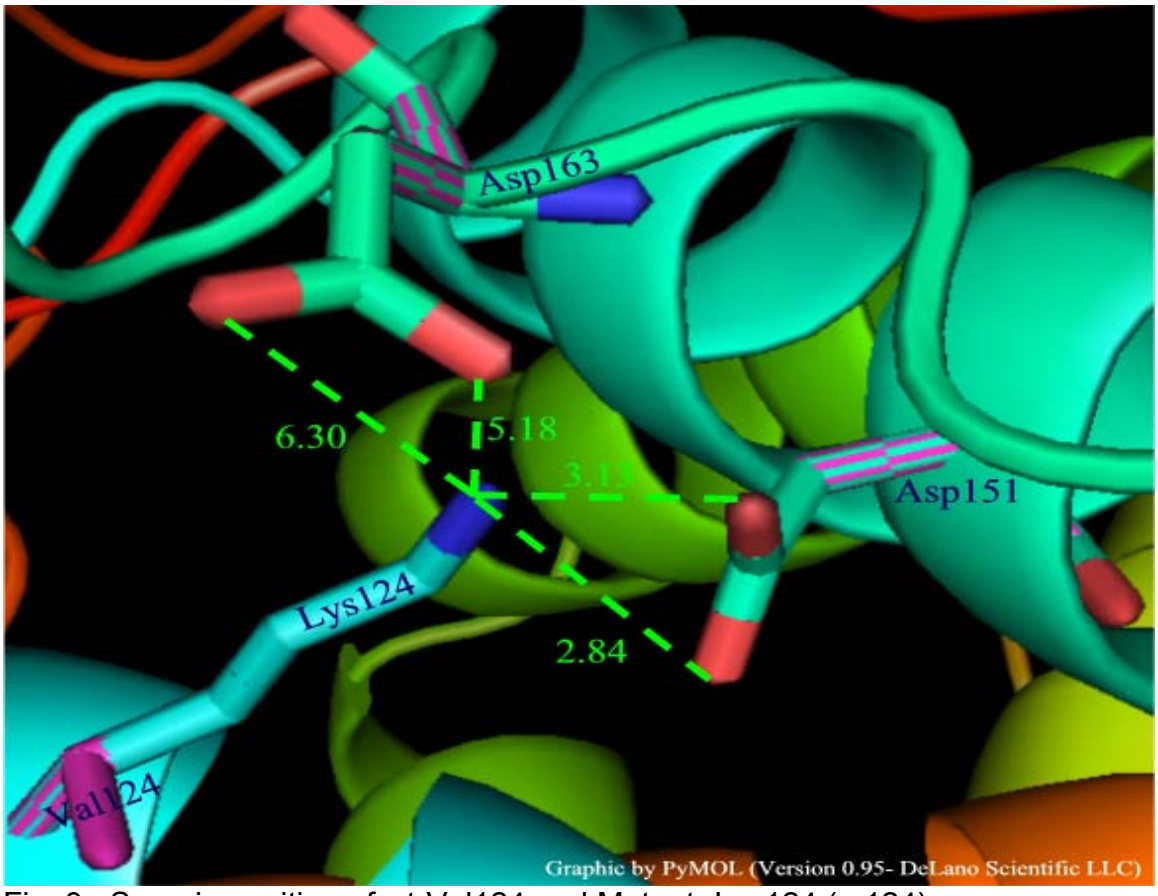


Fig. 3: Superimposition of wt-Val124 and Mutant- Lys124 (m124)

a. m124 shown through Val124 striped, other stripes show superimposed residues.
b. Ionic interaction- wt-null and m124 in green
c. Ionic Interaction distance (green) in Á.

Table 3: WHAT IF- SBD

Donor Residue	Donor Molecule	Acceptor Residue	Acceptor Molecule	Distance (Å)
151 ASP (151)	**OD1**	**124 LYS (124)**	**NZ**	**3.13**
151 ASP (151)	**OD2**	**124 LYS (124)**	**NZ**	**2.84**
163 ASP (163)	**OD1**	**124 LYS (124)**	**NZ**	**5.18**
163 ASP (163)	**OD2**	**124 LYS (124)**	**NZ**	**6.30**

Table 4: WHAT IF - OHBN

Donor Residue	Donor Molecule	Acceptor Residue	Acceptor Molecule	Hydrogen Bond Value (0.0-1.0)[a]	Distance (Å)
124 LYS (124)	**N ->**	**120 GLN (120)**	**O**	**Val= 0.706**	**DA= 2.99**
128 ASN (128)	**N ->**	**124 LYS (124)**	**O**	**Val= 0.607**	**DA= 2.82**
124 VAL (124)	N ->	120 GLN (120)	O	Val= 0.706	DA= 2.99
128 ASN (128)	N ->	124 VAL (124)	O	Val= 0.607	DA= 2.82

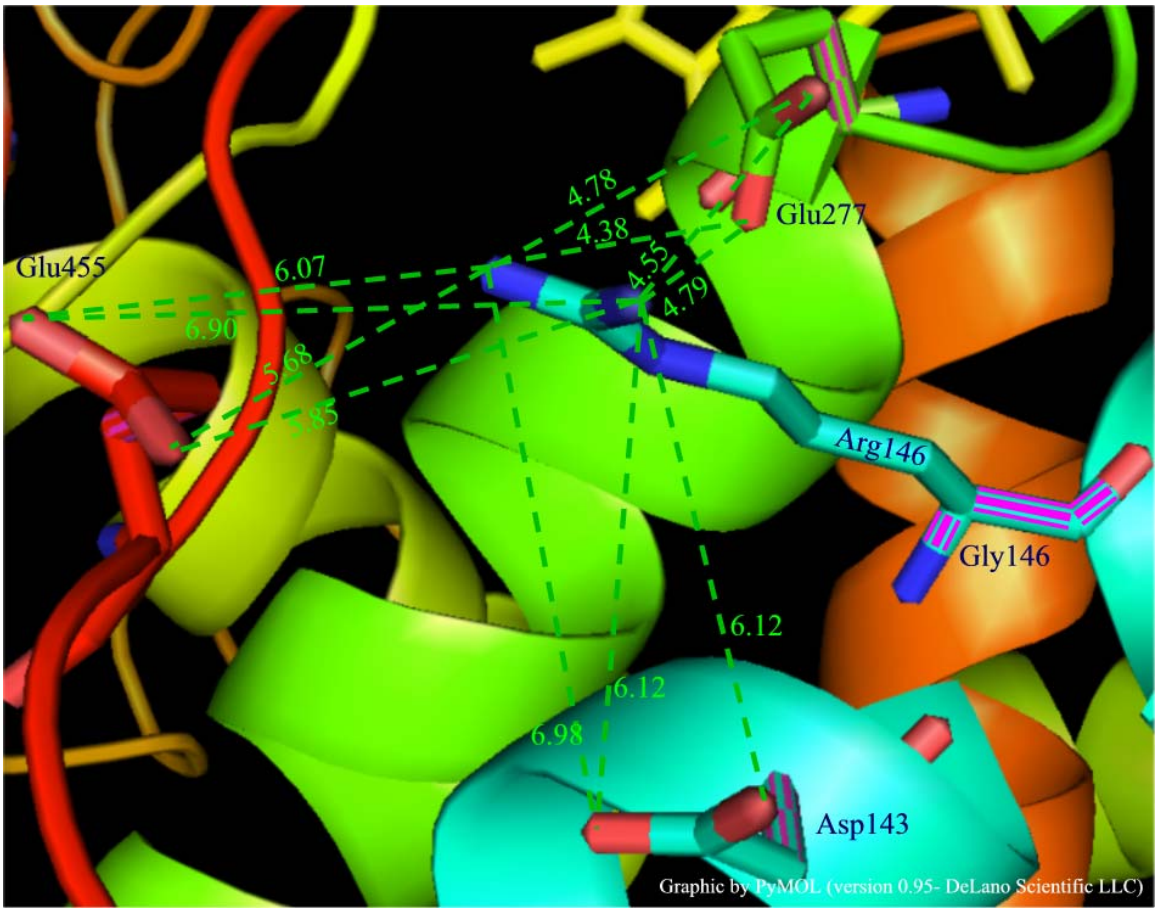


Fig. 4: Superimposition of wt-Gly146 and Mutant- Arg146 (m146)

a. m146 shown through Gly146 striped, other stripes show superimposed residues.
b. Ionic interaction- wt-null and m146 in green
c. Ionic interaction distance (green) in Å.
d. Cartoon of main chain for wt and m146 has been removed at residue 146 for clarity.

Table 5: WHAT IF- SBD

Donor Residue	Donor Molecule	Acceptor Residue	Acceptor Molecule	Distance (Å)
143 ASP (143)	**OD1**	**146 ARG (146)**	**NH1**	**6.12**
143 ASP (143)	**OD1**	**146 ARG (146)**	**NH2**	**6.98**
143 ASP (143)	**OD2**	**146 ARG (146)**	**NH1**	**6.12**
277 GLU (277)	**OE1**	**146 ARG (146)**	**NH1**	**4.55**
277 GLU (277)	**OE1**	**146 ARG (146)**	**NH2**	**4.78**
277 GLU (277)	**OE2**	**146 ARG (146)**	**NH1**	**4.79**
277 GLU (277)	**OE2**	**146 ARG (146)**	**NH2**	**4.38**
455 GLU (455)	**OE1**	**146 ARG (146)**	**NH1**	**6.90**
455 GLU (455)	**OE1**	**146 ARG (146)**	**NH2**	**6.07**
455 GLU (455)	**OE2**	**146 ARG (146)**	**NH1**	**5.85**
455 GLU (455)	**OE2**	**146 ARG (146)**	**NH2**	**5.68**

Table 6: WHAT IF- OHBN

Donor Residue	Donor Molecule	Acceptor Residue	Acceptor Molecule	Hydrogen Bond Value (0.0-1.0)[a]	Distance (Å)
146 ARG (146)	**N**	**-> 142 LYS (142)**	**O**	**Val= 0.629**	**DA= 3.19**
146 ARG (146)	**N**	**-> 143 ASP (143)**	**O**	**Val= 0.090**	**DA= 3.04**
150 MET (150)	**N**	**-> 146 ARG (146)**	**O**	**Val= 0.743**	**DA= 3.06**
146 GLY (146)	N	-> 142 LYS (142)	O	Val= 0.629	DA= 3.19
146 GLY (146)	N	-> 143 ASP (143)	O	Val= 0.090	DA= 3.04
150 MET (150)	N	-> 146 GLY (146)	O	Val= 0.743	DA= 3.06

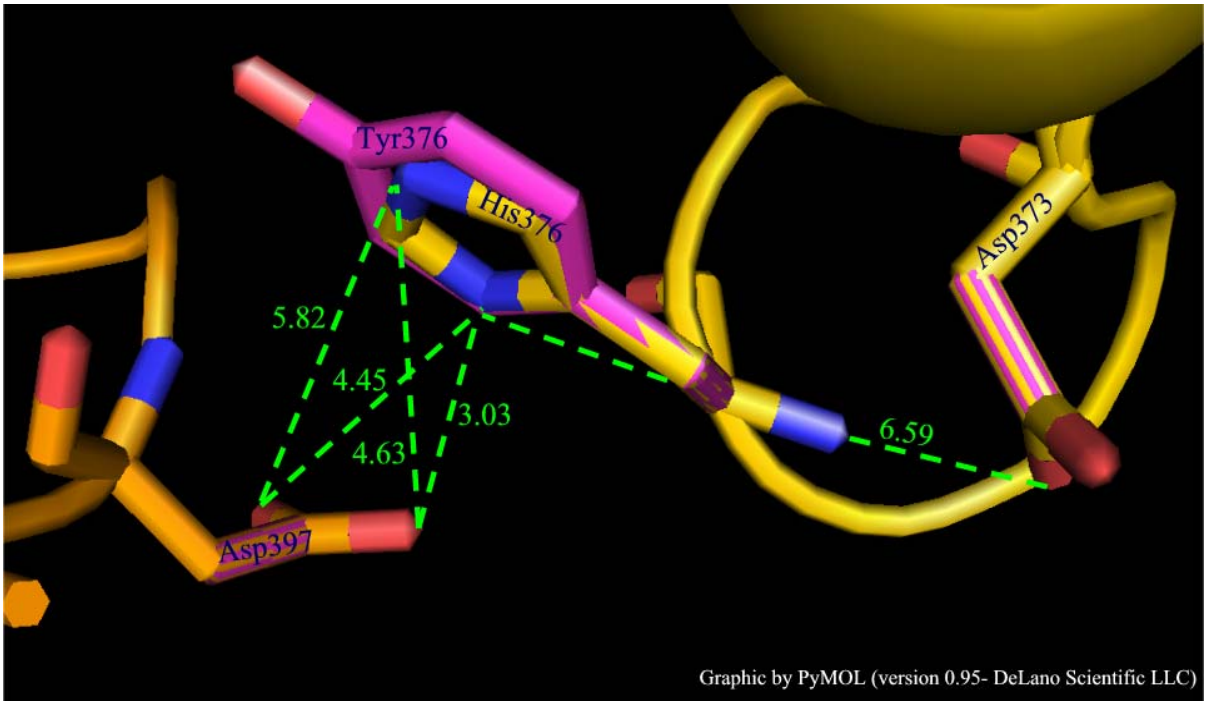


Fig. 5: Superimposition of wt- Tyr376 and Mutant- His 376 (m376)

a. m376 shown entangled inside Tyr376 purple, other stripes show superimposed residues.
b. Ionic interaction- wt-null and m376 in green
c. Ionic interaction distance (green) in Å.
d. Residues Ile 365 & 400 removed for clarity.

Table 7: WHAT IF- SBD

Donor Residue	Donor Molecule	Acceptor Residue	Acceptor Molecule	Distance (Å)
373 ASP (373)	**OD1**	**376 HIS (376)**	**ND1**	**6.59**
397 ASP (397)	**OD1**	**376 HIS (376)**	**ND1**	**4.45**
397 ASP (397)	**OD1**	**376 HIS (376)**	**NE2**	**5.82**
397 ASP (397)	**OD2**	**376 HIS (376)**	**ND1**	**3.03**
397 ASP (397)	**OD2**	**376 HIS (376)**	**NE2**	**4.63**

Table 8: WHAT IF- OHBN

Donor Residue	Donor Molecule	Acceptor Residue	Acceptor Molecule	Hydrogen Bond Value (0.0-1.0)[a]	Distance (Å)
376 HIS (376)	**N ->**	**373 ASP (373)**	**OD1**	**Val= 0.666**	**DA= 3.19**
376 HIS (376)	**ND1 ->**	**397 ASP (397)**	**OD2**	**Val= 0.233**	**DA= 3.03**
376 TYR (376)	N ->	373 ASP (373)	OD1	Val= 0.666	DA= 3.19
376 TYR (376)	OH ->	397 ASP (397)	O	Val= 0.354	DA= 3.42

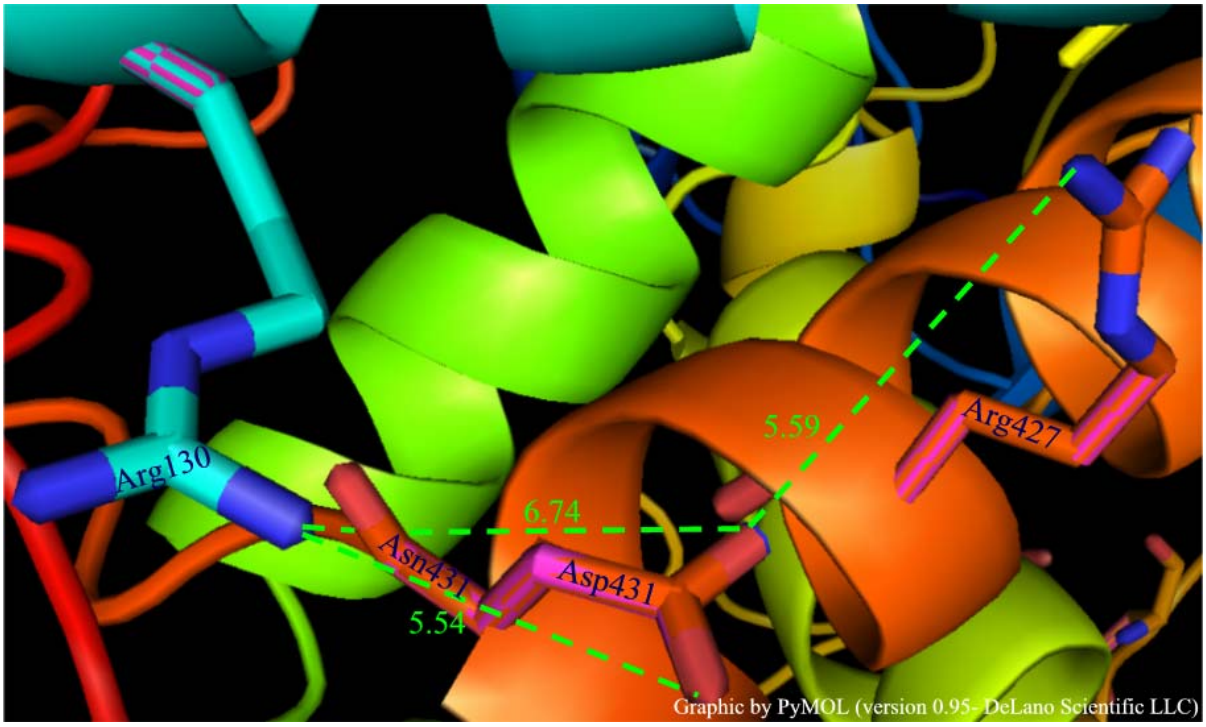


Fig. 6: Superimposition of wt- Asn431 and Mutant- Asp431 (m431)

a. m431 red shown entangled inside Asn431 purple, other stripes show superimposed residues.
b. Ionic interaction- wt-null and m431 in green
c. Ionic interaction distance (green) in Å.
d. Residues Thr468 &Val469 removed for clarity.

Table 9: WHAT IF- SBD

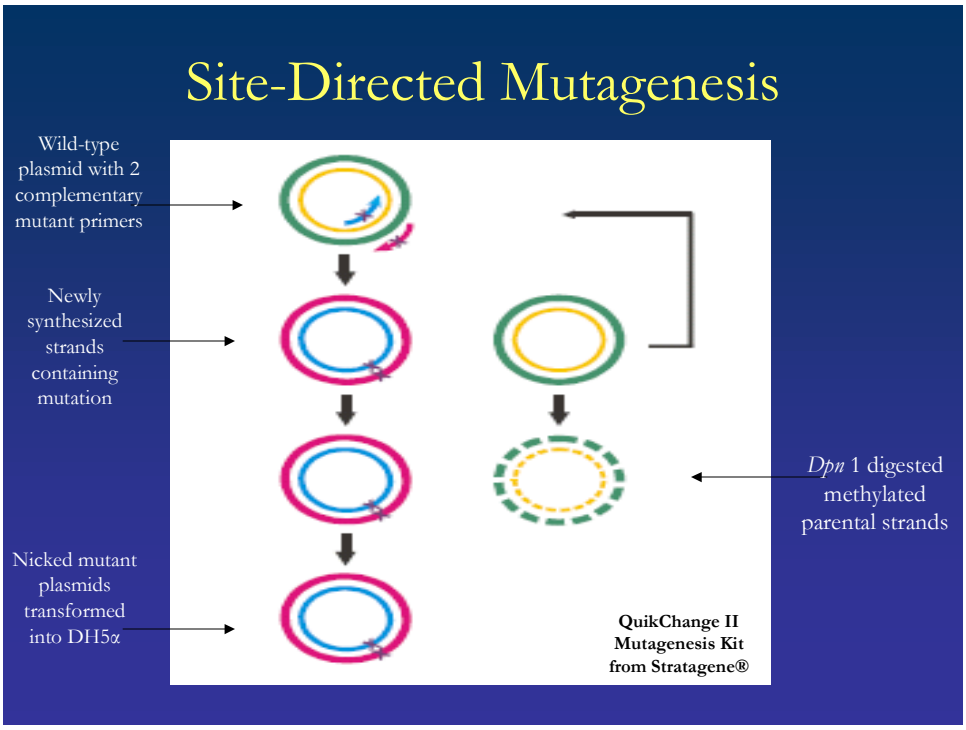
Donor Residue	Donor Molecule	Acceptor Residue	Acceptor Molecule	Distance (Å)
431 ASP (431)	**OD1**	**130 ARG (130)**	**NH1**	**6.74**
431 ASP (431)	**OD2**	**130 ARG (130)**	**NH1**	**5.54**
431 ASP (431)	**OD1**	**427 ARG (427)**	**NH2**	**5.59**

Table 10: WHAT IF- OHBN

Donor Residue	Donor Molecule		Acceptor Residue	Acceptor Molecule	Hydrogen Bond Value (0.0-1.0)[a]	Distance (Å)
430 GLN (430)	**NE2**	**->**	**431 ASP (431)**	**OD1**	**Val= 0.602**	**DA= 2.99**
431 ASP (431)	**N**	**->**	**427 ARG (427)**	**O**	**Val= 0.538**	**DA= 2.80**
465 LYS (465)	**N**	**->**	**431 ASP (431)**	**O**	**Val= 0.520**	**DA= 3.14**
431 ASN (431)	N	->	427 ARG (427)	O	Val= 0.538	DA= 2.80
431 ASN (431)	ND2	->	430 GLN (430)	OE1	Val= 0.610	DA= 3.02
431 ASN (431)	ND2	->	427 ARG (427)	O	Val= 0.416	DA= 2.85
465 LYS (465)	N	->	431 ASN (431)	O	Val= 0.520	DA= 3.14

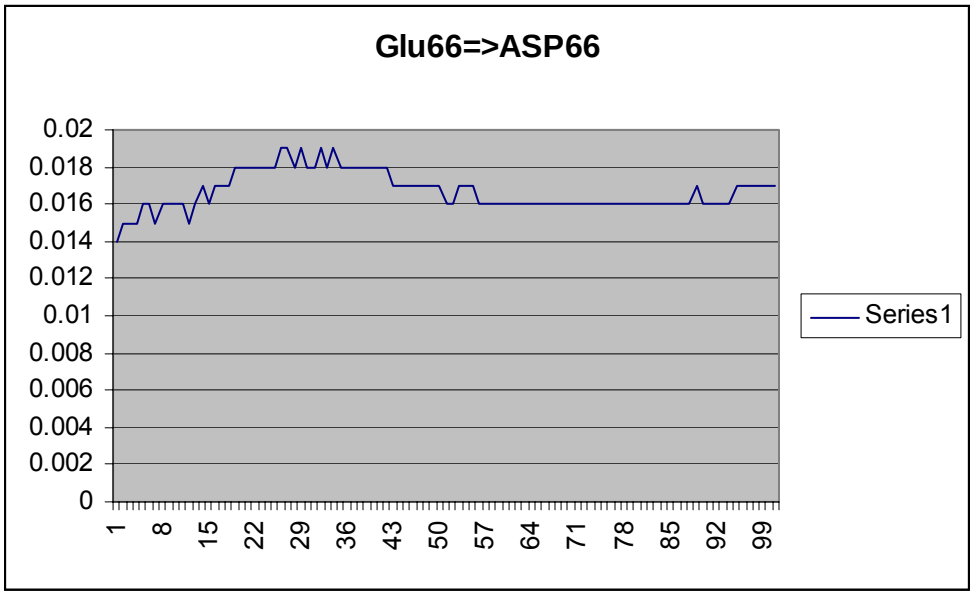
Based on the five regions selected for improve stability, site-directed mutagenesis was performed on all five regions.

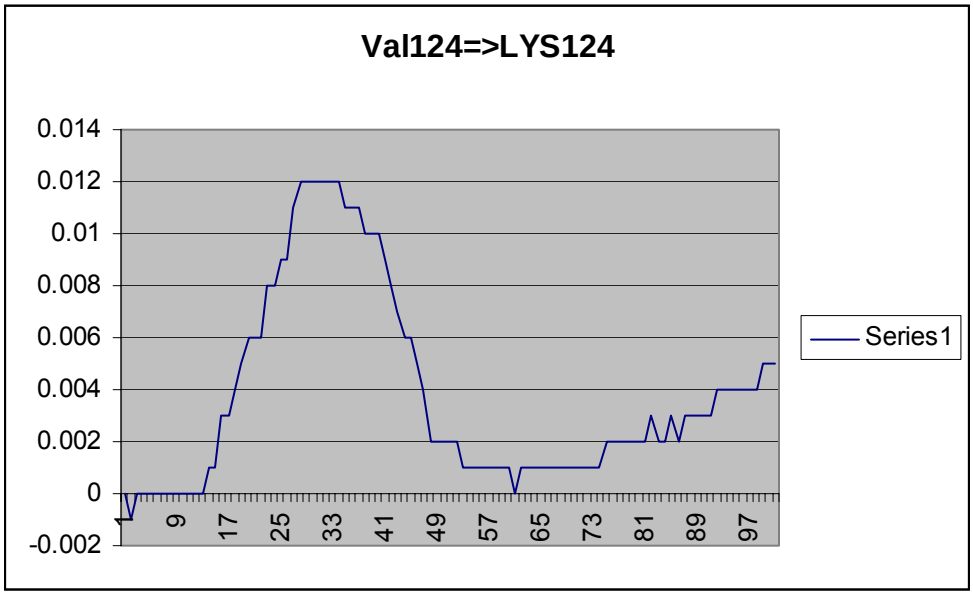
The QuikChange II Site-Directed Mutagenesis Kit (Stratagene) was used to generate all the mutants. (See below figure)

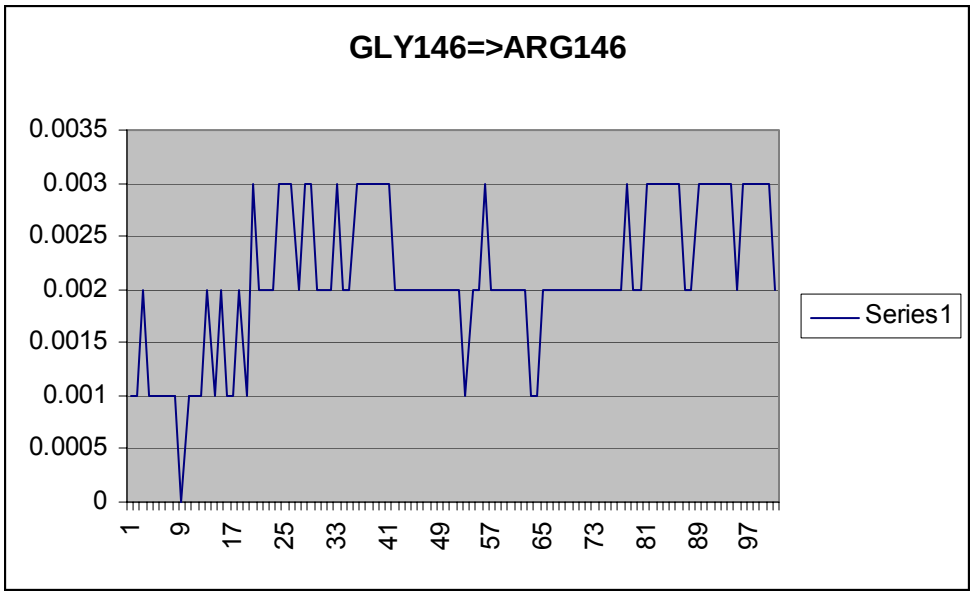


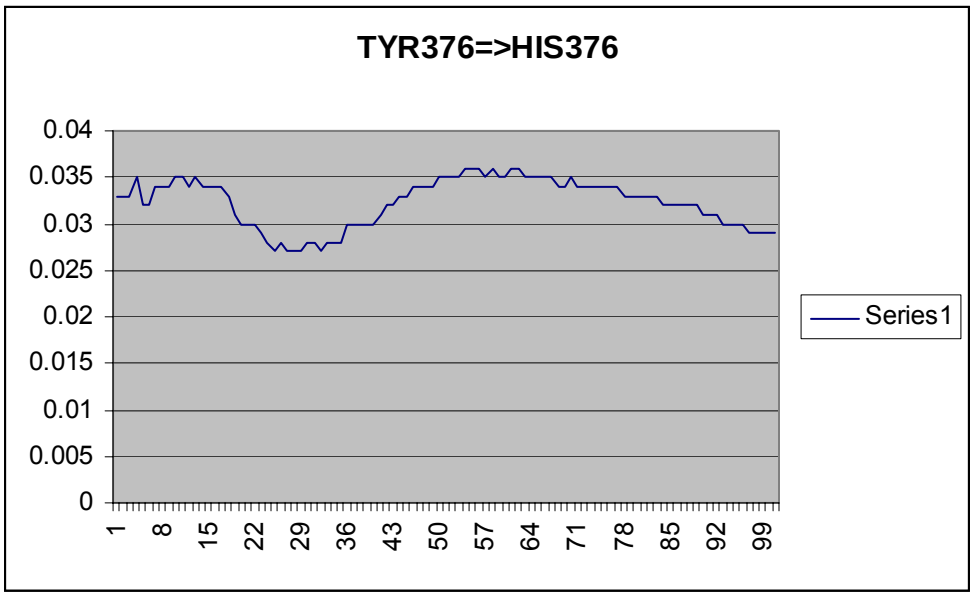
One set of the same primer is required, oriented in opposite direction. For GLU66=>ASP66, the following primer was generated: 5'GTGCTAGTGAAAGACTGTTATTCTGTCTTCACAAACCGGAGGC3'. For VAL124=LYS124, 5'GCCCAGTATGGAGATAAGTTGGTGAGAAATCTGAGGCG3'. For GLY146=ARG146, 5'AGACGTCTTTCACGCCTACAGCATG3'. For TYR376=HIS376, 5'CACCGTGACCCAAAGCATGGACAGAGCCTGAG3'. For ASN431=>ASP431, 5'GCTCTAATCAGAGTCCTTCAGGACTTCTCCTTCAAACC3'. A PCR cycling procedure enabled the changes to be made. Briefly, the plasmid containing CYP 3A4 was denatured at 95 ºC for 30 second, and an annealing temperature of 55 ºC allowed the mutagenesis primers to bind. The *PfuUltra* DNA polymerase was activated at 95ºC, and a repeat cycle of 95 and 55 was done for 18 cycles. At the end, *Dpn* I was added, which digested all parental DNA, but not the newly generated strand containing the mutation. The mutated DNA was then transformed into DH5alpha cells and screened on LB-amp plates. The plasmid was isolated and the mutations were confirmed by sequencing. The transformants (clone) were then grown for production of the newly mutated CYP 3A4 proteins. Briefly, the each clone was grown in TB broth and the promoter induced with IPTG. After 48 hours incubation at 37 ºC, the cultures were collected and pelleted at 5000 rpm with a Ti-15 rotor. The pellet was resuspended in Mops buffer and subsequently sonicated at 60% duty, continuous for 10 seconds. The sample was then centrifuges at 31,000 rpm with Ti-1790 rotor for 30 min. The supernatant contained the CYP 3A4 protein. The stability of cytochrome P450 was measured using the CO difference spectrum method. Briefly, a 1 ml sample was reduced with a pinch of sodium dithionite, and the sample was referenced (auto zero or blank) using the scanning spectrophotometer between 400 nm and 500 nm. The

sample was then bubbled with carbon monoxide for 1 min and rescanned. A peak is generated at 450 nm if proteins is present. Denatured protein is present at 420 nm. The following results were generated for all five mutations. (Note: the X axis is labeled 1-100; 50 represents 450 nm, 46.6 represents 420 nm)






GLY146=>ARG146
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
1
9
17
25
33
41
49
57
65
73
81
89
97
Series1


TYR376=>HIS376
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1
8
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85
92
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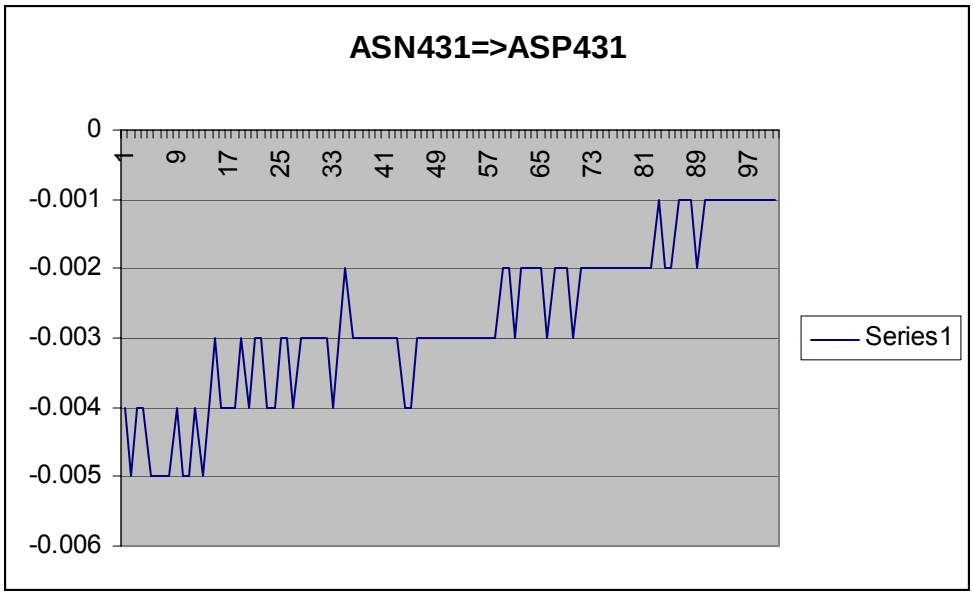
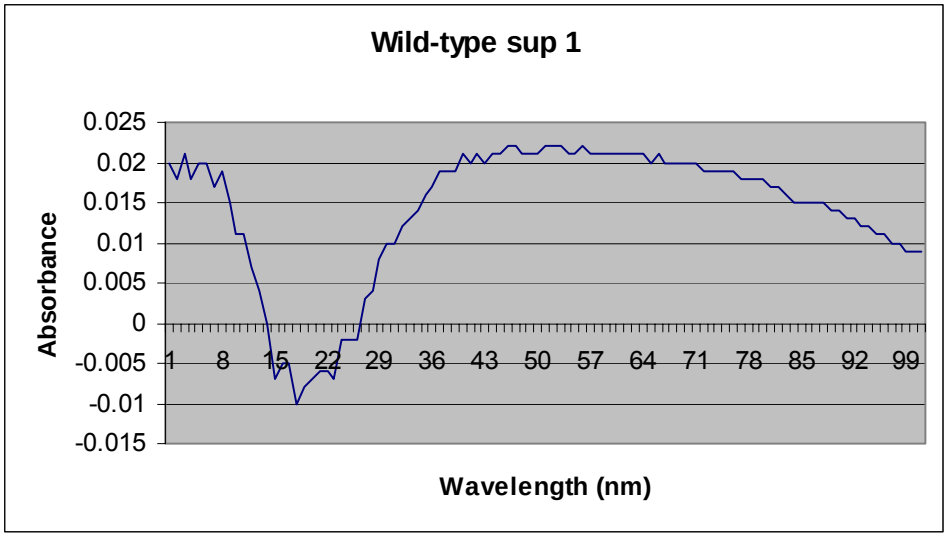
Series1





The results of the CO difference spectrum showed that all mutants did not generate an improved spectrum, compared to the wildtype. TYR376=>HIS376 produced a slight peak near 450 nm, suggesting similar stability to the wildtype. VAL124=>LYS124 produced a significant peak near 420 nm, indicating lose of substrate binding regions. The remaining mutants did not produce a clear spectrum, indicating lose of stability.

In conclusion, the computer-generated predictions of residues that were proposed to improve stability of CYP 3A4 did not result. Thereby, computer-generated predictions of CYP 3A4 was not useful in improving protein stability.

Goal 2: (Note: All three objectives for goal 2 are discussed). The stability of the autofluorescence signature for *E. coli* was analyzed based on exposure to Carvacrol, a phenolic compound present in oregano and thyme plant essential oils. *E coli* strain C600 (ATCC 47024) (a gift of Moses Vijayakumar, Oklahoma State University), and E. coli O157:H7 (two different strains) were frozen at -80°C in a Trypticase Soy Broth (TSB) containing a final concentration of 15% glycerol. For use in experiments, a 100 □l sample of thawed stock was inoculated into 100 ml TSB and incubated at 37 °C overnight in a shaker bath at 120 rpm.

A monochromatic-based spectrofluorimeter (Photon Technology, Princeton, NJ, USA) was used for fluorescence. This instrument uses a xenon arc lamp to illuminate a one-half meter monochromator. The output of the monochromator is focused on a sample chamber wherein a sample cuvette is placed. Emission from the sample cuvette was collected at an angle of 90 degrees to the excitation after passing through an emission monochromator. Collection of the data was performed using photon-counting and a Hammamatsu R920 photomultiplier tube. Photon counts were stored on magnetic media and later analyzed and plotted using S-Plus (Insightful, Seattle, WA, USA) and Prism. A digital filter was applied to the raw data to remove photon scatter less than 25 nm of the absolute value of the excitation wavelength less the emission wavelength. An additional digital filter was applied to the data to remove the emissions from doubling of the primary excitation wavelength.

For culture preparation, a 3 ml of the overnight culture was mixed and removed from the middle of the flask and centrifuged at 2000 X g for 5 min. The resulting supernatant was removed and the pellet was resuspended in 150 mM saline. After a second centrifugation at 2000 X g, the pellet was resuspended in 3.0 ml of either control (150 mM NaCl, 2% EtOH) or treatment (0.01, 0.1, 1.0 mM carvacrol, 15.0 mM NaCl, 2% EtOH) in a polystyrene fluorimeter cuvette. Both control and treatment samples were maintained at room temperature. Optical density (absorbance at 660 nm) measurements (Ocean Optics S2000, Ocean City, MD, USA) were performed on each treatment before and after measuring autofluorescence to insure equivalent numbers of bacteria in control and treatment samples. After 15 min of incubation at room temperature in either control or carvacrol treatment, the cuvette containing the bacterial sample was placed in the sample chamber of a spectrofluorimeter (Photon Technology, Princeton, NJ, USA) and fluorescence was measured using excitation wavelengths of 300-700 nm and 400-700 nm emission. Fluorescence data was acquired by a computer, stored on magnetic media, and processed as three-dimensional plots using S-Plus (Insightful, Seattle, USA). All fluorescence scans were referenced to a factory fluorescent-calibration standard (Photon Technology Inc, Princeton, NJ, USA).

Fig. 2 represents autofluorescence data from *E. coli* that was treated without carvacrol (control) or various concentrations of carvacrol. One axis of Fig. 2 represents the excitation wavelength, which varied from 300 nm to 700 run, and the second axis represents the emission wavelength, which varied from 400 nm to 700 nm. The vertical axis of Fig. 2 represents the fluorescence from the bacterial sample and is in volts, representing the number of photons emitted. Fig. 2 is divided into four panels representing the control autofluorescence and the autofluorescence of *E. coli* exposed to increasing concentrations of carvacrol. Fig. 2A, the control autofluorescence panel, shows complex peaks of autofluorescence uniquely characteristic of the C600 strain of *E. coli* and a characteristic trough near 550 nm emission for all excitation wavelengths. Figures 2B, 2C, and 2D autofluorescence data from E. coli treated with 0.01 mM carvacrol, shows little change in the overall signature based on the excitation and emission data.

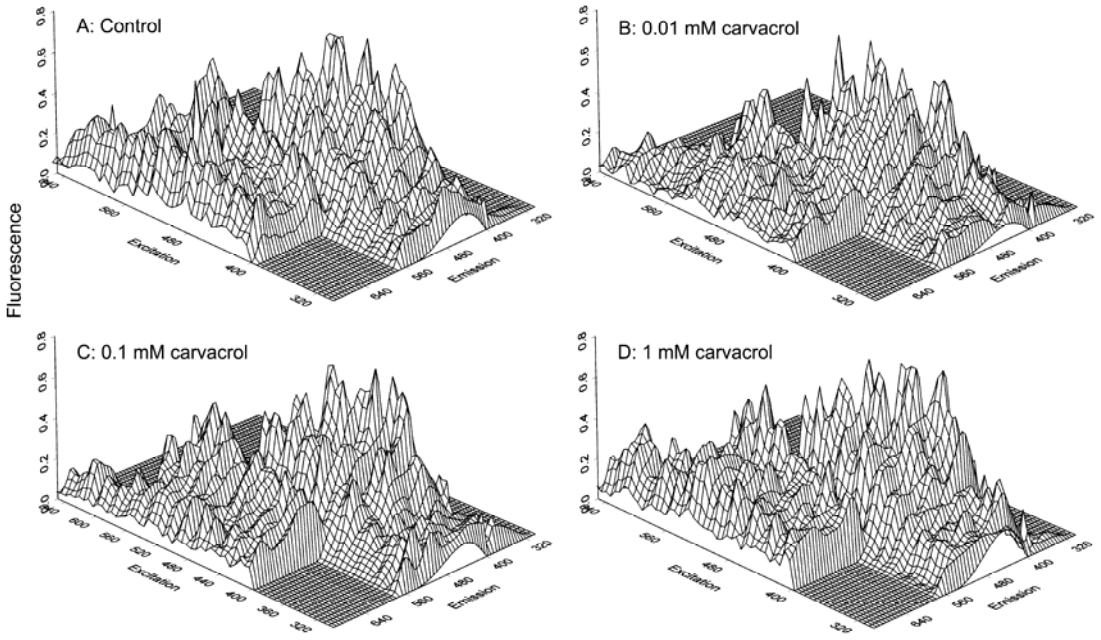


Fig. 2. Three-dimensional representation of autofluorescence of *E. coli* exposed to the control (Fig. 2A) and 0.01 (Fig. 2B), 0.1 (Fig. 2C), and 1.0 mM (Fig. 2D) carvacrol. Excitation (axis leading away from observer and marked Excitation) ranged from 300 to 700 nm while emission (axis appearing flat) ranged from 400 to 700 nm.

We also presented the results as subtractions between control and treatments (difference spectra) in the panels of Fig. 3. Fig. 3A shows a control autofluorescence. Fig. 3B is the algebraic difference between the control autofluorescence spectrum and the 0.01 mM carvacrol spectrum (see Fig. 2B).

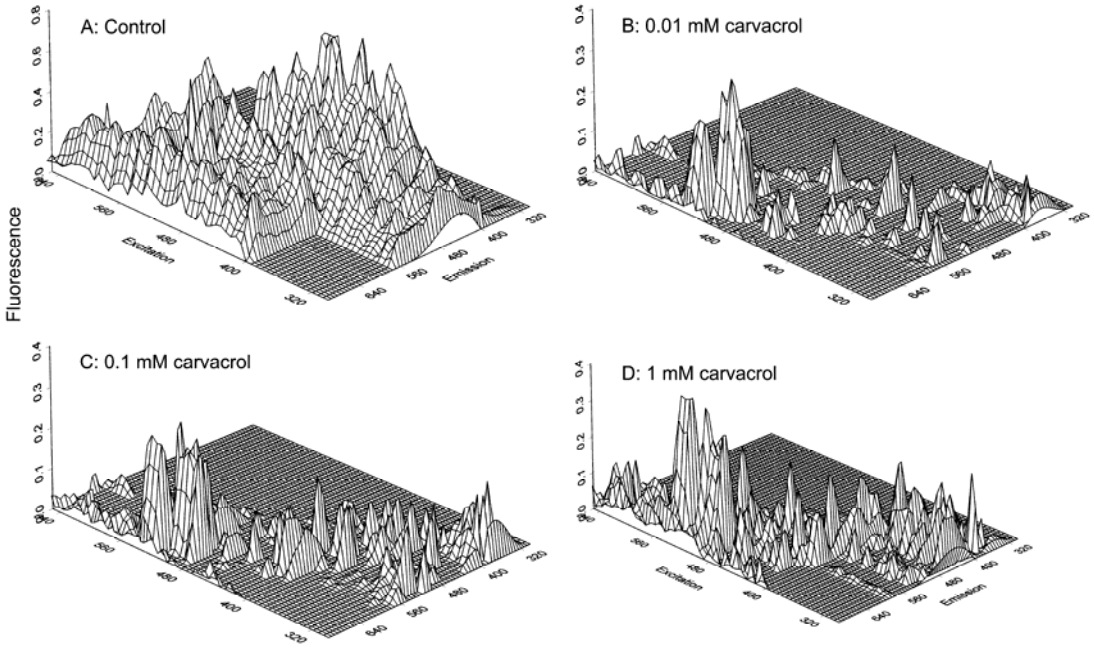


Fig. 3. Three-dimensional representation of the autofluorescence of *E. coli* with control subtracted from each of the treatments (difference spectra): (Fig. 3A), control; (Fig. 3B), 0.01 mM carvacrol less control; (Fig. 3C), 0.1 mM carvacrol less control; and (Fig. 3D), 1.0 mM carvacrol less control.

Although some changes did occur based on exposure to carvacol, overall there are peaks that remain stable, which is represented by flat or no peak formations in figures B, C, and D. Therefore, a stable autofluorescence signature for *E. coli* exist.

Further analysis of spectra data involved using the neural network system (13). Neural networks, an emerging machine learning approach, can perform highly complex mappings on noisy and nonlinear data, thereby inferring subtle relationships between sets of input and output parameters. They can in addition generalize from a limited quantity of training data to overall trends in functional relationships. Although several network architectures and training algorithms are available, the back-propagation type remains the most popular in bioinformatics applications (3). Feed-forward neural networks trained by back-propagation algorithm consist of several layers of simple processing elements called neurons, interconnections, and weights that are assigned to the interconnections. These rudimentary processors are interconnected in such a way that information relevant to the input-output mapping is stored implicitly in the weights. Each neuron contains the weighted sum of its inputs filtered by a sigmoid transfer function, endowing neural networks with the ability to generalize with an added degree of freedom not available in any statistical regression techniques. The input layer of neurons receives the external information such as the difference spectrum. The output layer transmits information to the outside world and this corresponds to the specific

xenobiotics binded. Back-Propagation networks also incorporate one or more hidden layers of neurons which do not interact with the outside world, but assist in performing classification and nonlinear feature extraction tasks on information provided by the input and output layers. Neural network can be easily implemented in software, hardware or firmware, as appropriate. The ability of real-time processing, noise rejection and continuous learning when more data become available make it a perfect tool for data analysis proposed herein. A nonpathogenic and two different strains of a pathogenic *E. coli* culture were analyzed using scanned data information. The different scans were analyzed and compared based on the number of data points having the same outputs (with a 5% threshold), which demonstrated a metric for comparison similar to regression analysis or sum square error analysis. Approximately 30% commonality exist between nonpathogenic and pathogenic *E. coli* (Table I). Approximately 60% commonality exist between the two strains of pathogenic *E. coli* (Table I). Based on the results, a distinction between nonpathogenic and pathogenic bacteria can be made. In addition, there is sufficient difference between the different stains of pathogens.

Table I

Percentage of commonality between scan 1, scan 2 & scan 3 of DISK 765

Scan 1 and scan 2	Scan 1 and scan 3	Scan 2 and scan 3	Scan 1,scan 2 & scan 3
30.22 %	30.15 %	60.62 %	30.15 %

*For the points of commonality refer figure **022102disk765.fig***

Overall Conclusions:

1.) Goal 1 (3 objectives) were completed. Molecular modeling coordinates were used to determine ion-pair distributions in the CYP 3A4, site-directed mutagenesis was used to incorporate the five selected regions, and the CO difference method was used to test protein stability. It was concluded that computer graphics modeling programs used to determine the most ideal residues for mutation in order to increase stability of the CYP 3A4 protein was not ideal. Note: The current computer modeling study was based on cystalized coordinates from bacteria. Recently, the human CYP 3A4 was cystalized and coordinates are available. Therefore, the used of these coordinates may be used to better predict potential residues for improved proteins stability.

2.) Goal 2 (3 objectives) were completed. Autofluorescence signatures were generated for both Gram positive, Gram negative, pathogenic and nonpathogenic microorganisms; the neighbor approach help define a unique pattern for each microbe, and the patterns generated provide some evidence that a taxonomic grouping system could be generated. It was concluded that the autofluorescence method was able to successfully generate a 3-D plot for different species of bacteria. Thereby, supporting the potential of autofluourescence signatures serving as method of identifying and distinguishing between different types of bacteria

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Facilitating the Tenkiller Utilities Authority Public Water Decision Project

Basic Information

Title:	Facilitating the Tenkiller Utilities Authority Public Water Decision Project
Project Number:	2003OK28B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	1st and 2nd
Research Category:	Water Quality
Focus Category:	Water Quality, Water Quantity, Water Supply
Descriptors:	stakeholder decision-making, public education and outreach, water
Principal Investigators:	Mac McCrory, Weldon Schieffer

Publication

Facilitating the Tenkiller Utilities Authority Public Water Decision Project
Oklahoma Water Resources Research Institute (2003OK19B)
August 25, 2004

Background

The Institute of Issue Management and Alternative Dispute Resolution (IIMADR) was created within the OSU Seretean Wellness Center by a statute (70 O.S. §3430) enacted by the Oklahoma Legislature in the spring of 2002. According to this legislation, IIMADR provides:

> Issue management and alternative dispute resolution services and activities for agriculture, rural living, agribusiness, environmental, natural resources, and rural business or industry issues. The Institute is authorized to deliver issue management and alternative dispute resolution services and related activities to individuals, organizations, local, state, and federal government agencies, Native American tribes, and others that have an interest in or need for such services and activities.

The scope of services that IIMADR may provide to these entities include: collaborative discussion, deliberation, issue management, conflict prevention, dispute resolution, communication, training, and decision making. IIMADR was also charged with operating the Oklahoma Agricultural Mediation Program (OAMP) and the program is housed within the Institute.

The U.S. Army Corps of Engineers assessment report of 2001 found that the three-county Lake Tenkiller region of northeastern Oklahoma lacked adequate water storage and distribution capacity to serve the current population of the region. The region's population is projected to increase rapidly due to the desirability of the area as a retirement and recreation location.

At the same time that the region has exceeded service capacity, Lake Tenkiller's water quality has been affected by concentrated animal production, increased

wastewater discharges, and the demands of industrialization within the watershed. The region was traditionally the poorest area in the state of Oklahoma and any economic development no matter how adverse was welcomed by the local citizens. By the 1980s the degradation of water resources had become apparent. In 1992, the Oklahoma Legislature enacted a resolution establishing a commission to investigate methods for solving the dilemma of natural resources and economic development in eastern Oklahoma.

Two municipal water systems and over thirty rural water districts serving nearly 100,000 people in this region participated in establishing the Tenkiller Utilities Authority (TUA) as a trust in 1995. The concept of the TUA was to centralize water supply and treatment for the region's water systems. The purpose of the TUA project is:

1. Serving to prevent political units from competing for water storage, water rights, and the struggles for independent funding and compliance;
2. Creating collaboration and partnering for the benefit of the entire the region;
3. Preventing costly litigation and harsh competition among resource-strapped government offices; and
4. Generating more productive, direct methods of addressing both social and economic issues.

For nearly a decade the TUA floundered as parties attempted to work together and vied for state and federal government grants to fund the project. Two years ago, TUA contacted IIMADR for the purpose of facilitating a dialog among the various participants. The mission of IIMADR, mandated in its enabling legislation enacted by the Oklahoma Legislature, was well-suited for providing needed direction to the TUA project.

Project Objectives

The project proposal outlined a statement of critical regional or state water problem; a statement of results or benefits and the nature, scope and objectives of the project; established a timetable for the project; outlined methods, procedures, and facilities of the project; and commented on related research and training potental.

Among the objectives outlined in the project proposal, IIMADR was responsible for:

1. assembling various data related to the project, based on geographical considerations, political boundaries, population densities, natural resource availability, census figures and other published projections, and developing computer data bases for use by the stakeholders;
2. assembling and neutrally disseminating contact data on and for stakeholders choosing to join in the IIMADR efforts;
3. planning, organizing, marketing, publicizing, and convening preliminary stakeholder meetings regarding TUA's water project, its long-term planning and cost recovery, and all facets of construction;
4. surveying and documenting consumer preferences and other stakeholder dynamics involved in the project; and,
5. neutrally engaging stakeholders in the direction and scope they choose to take the project.

Data on the evaluation of how IIMADR met these project objectives is found in Appendix D of this report.

Methods, Procedures, and Facilities Used in the Facilitation Process

Two types of meetings were held in conjunction with IIMADR's involvement with the TUA project: a) neutral convenor/informational communicator meetings and b) formal facilitation process meetings.

The neurtral convenor/informational communicator meetings were those meetings in which the IIMADR program manager relayed information and related focus of activities regarding the project which had escaped the TUA Board of Directors, RWD Boards of Directors, municipal policy makers, and state environmental and water agency representatives. A total of eight *neurtral convenor meetings were held by the IIMADR program manager. In addition, numerous informational communicator meetings were convened. These meetings were called by the IIMADR program manager by scheduling appointments with various TUA members' representatives or by the IIMADR program manager serving as a neutral convenor/informational communicator during TUA Board meetings, RWD Boards' monthly public meetings, and other conferences dealing with the issue of the TUA. These conferences included the Governor's Water Quality Conference, Department of Environmental Quality meetings, and other agricultural-related meetings. The neutral convenor/informational communicator meetings took place at a variety of locations including the Tahlequah Public Works Authority office in Tahlequah, the Webbers Falls City Hall, and state agency offices in Oklahoma City. IIMADR attended a total of 25 TUA Board meetings and six other conferences fallijng under the category of neutral convenor/informational communicator meetings.

The formal facilitation process meetings were those meetings where the IIMADR program manager served as the focal point of discussion about TUA and its project. There were two specifically convened facilitated meetings were called by IIMADR for

the facilitation purpose. Both meetings were prefaced by an early neutral assessment meeting with individuals prior to the group meeting.

The two facilitation sessions were held in Tahlequah, one at the Resource Conservation and Development (RC&D) office and the other at the Tahlequah Public Library. In both instances free public meeting rooms were utilized. Coffee and other refreshments wer provided by the RC&D office.

Research Question(s)

The primary research question addressed in this study:

1. Was the facilitation process of the TUA project effective in averting or overcoming a dispute or disputes regarding water supply to Eastern Oklahoma?

The secondary research question addressed in this study:

2. Were the evaluation methods, protocols, and instruments effective measurement devices?

Research Methodology

The purpose of this research was to evaluate the application of the facilitation/issue management processes to avert a regional water dispute involving the Lake Tenkiller Utilities Authority, a public water supply, treatment and distribution system in northeastern Oklahoma. A secondary purpose was to investigate methods used to evaluate the process and determine if those methods or variations of methods could be applied in other similar situations.

The importance of this study is to evaluate efficacy of the facilitation process and to determine the efficacy of the evaluation methods. Little or no research has been conducted evaluating facilitation processes and/or the instruments/methods themselves.

Research methodology was developed by members of the IIMADR staff, IIMADR board, and private contract consultants.

The research methodology utilized for the evaluation was the case study method; a qualitative research method that used for the study of an organization, program, or project and understanding the effectiveness, interaction or dynamics of the organization, program or project.

Case study interview questions were asked of TUA board members and other stakeholders in the TUA project. Those questions are found in Appendix A.

A secondary research method was developed to be administered to members of the Independent Water District Boards who make up the majority of the TUA board. These survey questions are found in Appendix B.

In addition to measuring the efficacy of the facilitation process, the study provided a case study of the successes, weaknesses, opportunities, and threats of a facilitation of a dispute over natural resources in a rapidly-developing rural area to funding agencies, facilitators, and scholars of facilitation and conflict resolution efforts. Research findings may also be used by the participants of the study and their agencies in future facilitation processes.

It should be noted that the facilitation process began before this retrospective study. IIMADR conducted early neutral assessments of stakeholders' attitudes and abilities. The actual measurement time is not necessarily reflective of the total amount of time

required for all components of the facilitation process. Facilitating board meetings and planning sessions were an integral part of the process. But the process also included several interviews, phone conversations, letters, emails, and faxes in the early neutral assessment phase. The entire facilitation process will continue after the conclusion of this study. Facilitation may not be completed until after the project is finished.

Early neutral assessment and initial facilitated dialogues began in the summer and fall of 2003. The research was conducted during the late Fall of 2003 and early spring of 2004.

Two groups of stakeholders in the Tenkiller Utilities Authority asked to participate in the study. One group consisted of members of the board of directors of the Tenkiller Utilities Authority who were directly involved in the facilitation process. A second group consisted of policy-makers who serve on the governing bodies of the municipalities and rural water districts within the region. These agencies selected representatives that served on the Authority's board of directors.

Interviews of Group I were conducted in November and December 2003 and in January 2004. The sampling method employed in this study was critical case sampling. Critical case sampling is a qualitative design method that permits logical generalization and maximum application of the sample case to other cases. A definition of critical case sampling is found in the Definitions section of this report. Group I consists of all 30 members of the board of directors of the Tenkiller Utilities Authority.

A total of 19 members of the Group I population of 30 members were interviewed. Group I participants were interviewed in a face-to-face interview with open-ended questions. The purpose of the interview was to collect data describing and documenting

the activities of the facilitation process and its success and failures regarding the TUA and its project. The interview was the standardized open-ended interview approach. The interview insturment consisted of questions that were written in advance of the interview. The interview questionaire contained eleven questions. The structure of the interview allowed for additional follow-up questions so the interviewer, who in effect became the interview instruement, could dig deeper in eliciting information on the interviewees perceptions of the facilitation process and the TUA.

The interview instrument used in the evaluation is Appendix A All of the interviews were conducted in the individual offices or homes of the study participants. The Tenkiller Utilities Authority board members yielded the most information on the facilitation process and had the greatest role in the development of knowledge in the field of issue management and the facilitation process.

The interviews were taped. After the interviewer returned to the IIMADR office the tapes were transcribed along with field notes from the interviewer about the interview. The interview transcipts were analyzed by assigning codes to contiguous units of the transcipt text. The coding marked off fixed units of the text for later retrieval and indexing. Analytical statements were developed out of the coded transcipts.

Other project objectives were also addressed in this study. These may be found in Appendix C.

Results

The evidence from the Group 1 interviews indicates that the facilitation project was effective. Coded responses support the idea that the TUA project was at a “stand still” until IIMADR began providing faciliation process support. Members of the TUA

board and other stakeholders in the project were not communicating in an effective and positive manner. IIMADR early neutral assessment and facilitated dialogue assisted the project members in re-establishing communication, conduct productive meetings, and return the project to a positive direction.

Research Question: Was the facilitation process of the TUA project effective in averting or overcoming a dispute or disputes regarding water supply to Eastern Oklahoma? The preponderance of data indicate that the facilitation process was effective in overcoming an existing dispute regarding water supply.

The evidence gleaned from the interviews supports the notion that these methods, protocols, instruments were effective measurement devices. Interview subjects willingly gave testimonial information regarding the facilitation process and research study. Not all participants completely understood the entire facilitation process.

The interview data suggest that participants believed that IIMADR was to take a more directive role; seeking funding, contracting consultants, and leading the lobbying efforts in the political arena. During many of the early neutral assessments and facilitated dialogues, IIMADR facilitators stated and re-stated that IIMADR's role was that of a neutral convener, fact finder, and issue manager.

All participants in the Group 1 interviews agreed that the facilitation process was positive and more is needed, especially when disputes or issues arise among the board.

In the initial planning of research methods, it was determined that a secondary stakeholder evaluation should be conducted. A Likert scale written survey was

developed (See Appendix B) to administer to each of the board members of the Independent Water Districts represented on the TUA board.

The initial plan was to administer this survey at a series of meetings called by the districts. This would allow IIMADR to explain the survey, its purpose, and importance.

These meetings were to be in conjunction with the development of proposal for grant funding to the USDA/RD. At the time of the conclusion of this research study those meetings had not been coordinated by the Independent Water Districts. Therefore, written surveys were not administered to the secondary participant group.

Research Question: Were the evaluation methods, protocols, and instruments effective measurement devices? Interviews were effective in determining the efficacy of the process. It is not known at the time of this writing if the written survey instruments were effective at determining the efficacy with regard to the secondary participant group.

Discussion of Results

The purpose of this evaluation report was to examine as a case study the efficacy of the facilitation process in the TUA public water decision project, and to determine if the evaluation methods, protocols, and instruments were effective measurement tools. The TUA project at the time that IIMADR became involved was stalled because of the difficulty of bringing together 32 public water systems, and in addition, a Native American Indian tribal government, and numerous federal and state agencies, to agree on a course of action for the project.

The evaluation of the TUA facilitation process was a qualitative study involving TUA board members and other TUA stakeholders who had firsthand knowledge of IIMADR

activities. The study involved in-depth interviews with open-ended questions written in advance of the interviews and with follow-up questions to clarify responses.

Techniques such as the facilitation process, issue management, and ADR are novel tools which can be utilized among stakeholders to stave off litigation and legislative battles. The IIMADR staff perfected these techniques through the Oklahoma Agricultural Mediation Project experience. The enabling legislation expanded the scope of IIMADR and mandated that these techniques be utilized in other agriculture, rural living, agribusiness, environmental, natural resources, and rural business or industry issues.

The purpose of the use of the IIMADR facilitation process in the TUA project was to keep stakeholders linked to the ongoing data or status of activities, and to energize the level of ideas and willingness to do something related to funding, permitting, or design of the project, tasks necessary to get the project moving.

Regardless of the type of meeting conducted by IIMADR, the program manager always stated IIMADR's neutrality and the capacity IIMADR had to link the participation of all stakeholders. In neutral convenor/informational communicator meetings, the IIMADR staff used a leadership role to ask for specific participation; to ask probing questions of those representatives who had information but had not had an opportunity to describe their findings or opinions; to test the viability and feasibility of data through the use of questions that were outside the scope of any particular individual, but relevant to the context of the general project.

In the two facilitated sessions, in addition to asking participants for participation through questions and refining statements, IIMADR staff would write notes on flip charts and use

diagrams to bring focus and clarity to the statements and questions that participants would forward to the session through the role of neutral facilitator.

The facilitation process worked well in the TUA project. This is evidenced by the comments of the TUA Board members to evaluator's questions and through the continuation of work by the TUA Board in seeking funding for the project through the USDA-RD and in working on a preliminary concept design for a scaled-down project in the project area's North End.

The facilitation process, issue management, and ADR are new techniques in public policy decision-making. As a pioneering effort it is helpful to have examples of how these techniques work in real world situations. Both strengths and weaknesses of these techniques were revealed in the TUA project. The TUA project is one such example of the use of these techniques in a public utilities dispute. The lessons learned from the use of these techniques in the TUA project can be applied to other public works projects.

A Likert-scale survey was to be administered to Independent Water District board members. The administration of the survey depended upon a series of meetings to be called and conducted by the districts. These meetings had not taken place at the time of this writing.

As a casual observation from the project investigator, one should not rely on other individuals or entities to determine or affect the administration of research methods, such as written surveys.

A further research opportunity exists to expand the data by administering the Likert-scale survey. This qualitative survey, if administered to an expanded sample consisting of waters system policymakers who are potential wholesale consumers of TUA and a sample

of retail customers of the water systems themselves, could provide supporting data to both research questions.

Conclusions and Recommendations

The primary research question addressed in this study: Was the facilitation process of the TUA project effective in averting or overcoming a dispute or disputes regarding water supply to Eastern Oklahoma?

The evidence from the Group 1 interviews indicate that the facilitation process was effective at averting disputes regarding the water supply issue.

Recommendations include conducting more interviews with primary stakeholders. Recommendations for the facilitation process should include more information about the role of the facilitation to preclude a lack of knowledge about the process on the part of the stakeholders.

The secondary research question addressed in this study: Were the evaluation methods, protocols, and instruments effective measurement devices?

It appeared from the interview data that this method was an effective measurement tool. A lack information regarding the administration of the Likert-scale did not reveal a conclusion to this question.

APPENDIX A

Group I Interview Questions

TUA Interview Questions

1 Concerning the Lake Tenkiller regional water dispute, how would you describe the situation as it existed before the OSU Institute became involved?

#2 Along those same lines, how would you now describe the current situation since the OSU Institute became involved 15 months ago?

#3 Could you describe how you feel the OSU Institute contributed to that change?

#4 In your own words, would you describe what the OSU Institute facilitation process is?

#5 In your opinion what do you see as being the strengths of the OSU Institutes facilitation process?

#6 Conversely, what do you see as being the major weaknesses in the OSU Institutes facilitation process?

#7 Are there any areas you feel the institute has not explored, which would be positive in nature, or that would further enhance the facilitation process among all the participants?

#8 In your opinion, what are the biggest threats to the institutes dispute resolution process?

#9 If you were attempting to resolve a dispute of a similar nature, and were acting as a neutral participant, what processes would you invoke to facilitate its resolution?

#10 If IIMADR were to leave and other than legal intradiction by the court, what do you feel the chances are that some form of neutral party dispute resolution would continue?

#11 Are there any skills or lessons you have personally learned through watching the Institutes processes?

APPENDIX B

Group II (Likert-Scale) Survey

Tenkiller Utilities Authority Group II Survey

How important to you is the supply of drinkable water?

1	2	3	4	5	6	7	8	9	10
not important								very important	

How concerned are you about the current drinking water supply situation in your area?

1	2	3	4	5	6	7	8	9	10
not concerned								very concerned	

How concerned are you about the future of your drinking water supply in your area?

1	2	3	4	5	6	7	8	9	10
not concerned								very concerned	

The present cost of my drinking water is reasonable.

1	2	3	4	5	6	7	8	9	10
very reasonable								too expensive	

I am very concerned about the future cost of my drinking water.

1	2	3	4	5
strongly agree				strongly disagree

In the next ten years, it is anticipated that the cost of drinking water will increase. A fair cost increase would be:

0%	1-10%	11-25%	26-50%	50%+

The my drinking water comes from:

- Well
- Cistern
- Stream
- Lake in Arkansas
- Lake in Oklahoma

The source of my drinking water is very important.

1	2	3	4	5
strongly agree				strongly disagree

Why is drinking water of such concern to you

- Lack of supply
- Cost
- Distance to pipe
- Quality

In my opinion, there seems to be a lot of conflict among people/communities concerning drinking water.

1 2 3 4 5
strongly agree strongly disagree

In my opinion, there is more disagreement concerning water supply than in the past year.
1 2 3 4 5
strongly agree strongly disagree

In my opinion, there will be more conflict and disagreement concerning water supply in the future.
1 2 3 4 5
strongly agree strongly disagree

In my opinion, the reason for the conflict over water is because
Nobody knows who owns the water
Arkansas poultry wastes
Cities want all the water
Indian tribal claims on the water rights
Texas is stealing our water
Big corporations

I am optimistic about future of drinking water supply in my area.
1 2 3 4 5
strongly agree strongly disagree

We are working on a solution to the water problem in our area.
1 2 3 4 5
strongly agree strongly disagree

I am confident that all parties in this area will discuss the water issue and come to an agreement.
1 2 3 4 5
strongly agree strongly disagree

I am more optimistic about a future solution to the problem of the supply of good drinking water than I was a few months ago.
1 2 3 4 5
strongly agree strongly disagree

Using a neutral facilitator has been beneficial to finding a solution to our area's water supply.
1 2 3 4 5
strongly agree strongly disagree

If a neutral facilitator left the discussions today, I think the parties would still reach an agreement.
1 2 3 4 5
strongly agree strongly disagree

The reason the neutral facilitator is important to the water supply project is:

It keeps the parties talking.
Helps focus on issues.
Eliminates petty bickering.
Doesn't allow one party to take over the whole project.

The use of a neutral facilitator was new to me.

1 2 3 4 5
strongly agree strongly disagree

My understanding is that neutral facilitation includes:

I do not know.
Leads the discussion.
Introduces everyone.
Conducts background evaluation.
Furnishes information.

APPENDIX C

Interview Coding Memo

CODING MEMO: TENKILLER EVALUATION REPORT

Facilitating the Tenkiller Utilities Authority Public Water Decision Project
Oklahoma Water Resources Research Institute (2003OK19B)
July 1, 2004

The Institute of Issue Management and Alternative Dispute Resolution (IIMADR) was created within the OSU Seretean Wellness Center by Oklahoma Statutes (70 O.S. §3430) enacted by the Oklahoma Legislature in the spring of 2002 . According to this statute, IIMADR provides:

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Two municipal water systems and over thirty rural water districts in the Lake Tenkiller region participated in establishing the Tenkiller Utilities Authority (TUA) as a trust in the 1990s. The purpose of the TUA was to centralize water supply and treatment for the region's water systems. For nearly a decade the TUA floundered as parties attempted to work together and vied for state and federal government grants to fun the project. Nearly two years ago, TUA contacted IIMADR for the purpose of facilitating a dialog among the various participants (see Appendix I).

Research Methodology

The purpose of this research is to evaluate the application of the issue management processes to avert a regional water dispute involving the Lake Tenkiller Utilities Authority, a public water supply, treatment and distribution system in northeastern Oklahoma. The study is within the mandate of the orginal grant application (2003OK19B) to "survey and document consumer preferences and other stakeholder dynamics within TUA's project."

The research question to be addressed is: How did the utilization of the issue management process work in averting a water supply dispute in the Lake Tenkiller region.

The research will provide funding agencies, facilitators, and scholars of facilitation and conflict resolution efforts a case study of the successes, weaknesses, opportunities, and threats of a facilitation of a dispute over natural resources in a rapidly-developing rural area. Research findings may also be used by the participants of the study and their agencies in future facilitation processes.

There are two groups of stakeholders in the Tenkiller Utilities Authority who were going be asked to participate in the study. One group consisted of members of the board of directors of the Authority who were directly involved in the facilitation process. A second group consisted of policy-makers who serve on the governing bodies of the municipalities and rural water districts within the region. These agencies select representatives that serve on the Authority board.

Interviews of Group I were conducted in November and December 2003 and in January 2004. The sampling method employed in this study was critical case sampling. Critical case sampling is a qualitative design method that permits logical generalization and maximum application of the sample case to other cases. Group I consists of all 30 members of the board of directors of the Tenkiller Utilities Authority. The Tenkiller Utilities Authority board members yielded the most information on issue management and have the greatest impact on the development of knowledge in the field of issue management.

Group I participants were interviewed in a face-to-face interview with open ended questions. The interview was the standardized open-ended interview approach. The interview insturment consisted of questions that are written in advance of the interview. The exact interview instrument used in the evaluation is available for inspection by those who will use the findings of the study. All of the interviews were conducted in the individual offices or homes of the study participants.

The interviews were taped. After the interviewer returned to the IIMADR office the tapes were transcribed along with field notes from the interviewer about the interview. The interview transcipts were analyzed by assigning codes to contiguous units of the transcipt text. The coding marked off fixed units of the text for later retrieval and indexing. Analytical statements were developed out of the coded transcipts.

Findings

The following are six analytical statements developed from the data gathered from Group I participants' interviews:

1. IIMADR, especially Weldon, got people talking, closer together, and higher visibility to the project.

2. IIMADR brings people together to exchange information, brainstorm, find common ground, and move a once stalled project forward.

3. IIMADR is credible as it is neutral, partly because it is associated with OSU. It's neutrality put those involved at ease and did not have an attitude. Some participants hope that IIMADR will bring in grant money to their project.

4. IIMADR seemed to come late to the process and some participants found that it was not clear why they were there at first. Some of the issues where not fully covered and others missed because of time constraints, plus, Weldon was hard to get a hold of and IIMADR is not close to the community. Finally, not only didn't IIMADR have funds, but the communication process to the people outside the facilitation was rather slow.

5. Threats to the process were that the process was confusing, for example, the schedule and planning wasn't clear, the project was not finished and what was done was not what they said they would do, and there were no hard figures, such as the cost of water, and most people don't see where IIMADR fits in to the discussion.

6. Participants, overall, seemed to have learned about how a facilitation process, that once seemed doomed, can move things along even when emotions flare.

Analysis

Respondents perceptions of how IIMADR helped.

IIMADR, especially Weldon, got people talking, closer together, and higher visibility to the project.

TUA board members believe the intervention by IIMADR helped focus the board members and was an impetus for coalescing the members who represented the participating water systems to work for funding the TUA concept.

> when I got there, there was an established concept and a project that...um...was in trouble because it was unfundable. And to try and break the log jam you guys came in and I think **you did some due diligence in terms of trying to find out where things are and we're all the different parties saw it where in needed to go** and I think at this point now from what I understand there's a the concept has been downsized to something that is probably something that has a better chance of getting support and you've requested funding at the federal level which everyone always recognized that was kind of silver bullet. So I think from the movement **I've seen I think things have a better chance of happening now then they did a year ago.**

Another participant commented:

> I think that the **facilitation at least got the project moving.**

IIMADR helped TUA board members to see look beyond the parochial interests of the individual water systems and appreciate the TUA regional approach:

> OSU got parties talking and got the project moving. Ya know and got us looking, the meetings I was in, got us looking at the **project from a regional standpoint as opposed to just what Cherokee Nation might think instead of just that more of an idea of what could we do to benefit the entire area from utilization of Tenkiller water.**

There were various levels of involvement for members of the TUA board and this member's comment reflected those who had difficulty finding time to particpate:

> not very involved, so not sure.

Many members of the TUA board had a different impression of IIMADR's purpose and instead viewed the Institute as a grant-seeking agency:

> Weldon he works as a mediator up there with people that have maybe put their hands on grants that maybe we wouldn't have the opportunity by not being up there.

Other TUA board members identified the focus and utility of the issue management and conflict resolution activities of IIMADR:

> **you really brought us together more** when you came in and we could see maybe there were some answers out there for us in financing that we could that we would be able to move forward then.

Many TUA board members viewed the IIMARD involvement as reinvigorating the TUA regional water concept:

> I'm very appreciative after working on a project for some time you get so tired so worn out it is great to have somebody else come in that has the skills to get people fired back up and refocused. And I'm very appreciative. **Weldon came in fired things back up**

> I think the current situation the involvement of OSU has been more positive and people looking forward to possibility and getting things established than before. But I think there is still probably a little **more leariness of all this of who is going to actually going to have the control.** Now since OSU came in or course one thing that helped what Weldon did and what Weldon came in on was **a increased interest of elected officials at the federal level to become more involved** and to see what they could do to get funds to this project.

Another role that the TUA board identified that IIMADR fulfilled was for research on water issues and in getting the TUA story out to federal and state policymakers.

> Information gathering personal input

> I hope it has been able to get more people involved at the meeting that Weldon has been at, this is prior to your thing, but as to what he has done in here and the information he has got to keep us informed and **Weldon being an errand boy to the various agencies which none of us had the time for effort or initial contact to make these contacts with Oklahoma water systems with congressional reps** with state politicians with DEQ etc.

TUA members appreciated the IIMADR facilitator Weldon Schieffer's approach, empathy, and personal appeal:

> And I think that that part of it IIMADR or **Weldon Schieffer has done a real good job of keeping them informed and he is a real intelligent person who does a really good job as a facilitator.**
>
> I think that IIMADR with Weldon Schieffer in these series of meetings and getting other people involved and **getting people to talking and going across on the board** that this there was money here and then coming in that there was a research project available with money to extend farther into the government did give validity that hey this maybe is gonna go.

Respondents perceptions of what IIMADR does?

IIMADR brings people together to exchange information, brainstorm, find common ground, and move a once stalled project forward.

Most of the TUA members appreciated the third party neutrality of IIMADR contributing to the resolution of the impasse:

> is basically you come in as a **third party and try to brainstorm solutions and manage them** I guess brainstorm go through a process and break a logjam and bring something to a point where it can be resolved
>
> similar to what OSU did ya know to **try and meet with the parties and find some common ground and find where some strengths and weaknesses are found**. And it's not my cup of tea so I don't really know but that's what I would say

Some TUA members felt that the board lacked a certain sophistication but that IIMADR helped to provide a degree of that in their efforts to contact federal and state policy makers:

> Well it appeared to me that, we had a bunch of people at that meeting who were workers in the rural water districts they were usually the people in charge of the water districts and as a result they were just ordinary people and we really did lack what I consider the ability to somehow mount an effort by someone to make this go. We just met and we couldn't ever seem to get it together. Jim Wilson came into that meeting who is the state rep here and that was one of the things he suggested that we somehow get off the pot and get moving and this had been going on for years and we just didn't seem to get it together and it was kinda discouraging to me that we really needed some help from someone who could give us some help.

IIMADR also helped the board in doing some of their homework and maintaining contact on behalf of the board with the policymakers:

> What I see is your getting to the entities that is involved in this where maybe our board didn't get a chance to get out there, they tried somewhat ya know just like this **interview your gonna go meet with everybody and get some input from them and what they want which is pretty tough for these guy to do**

> Ok, in my words and I'm not positive that I understood properly but I think it is a means of **assembling people and getting information from people that would assist in better understanding in what the project is about how it's going to be implemented and how it could be carried out**. Letting the people know then the pros and cons of the state agency, the federal agency and others that could impact this program, today and in the future.

Several board members commented that IIMADR provided guidance to the board:

> **you're probably a guiding light there that well your someone that we can come to and request you assistance and your there to give it for us and the support** and this is what is so very important in something like this.

> Well it could be a lot of different things depending on the situation. Weldon has on two occasions facilitated meetings between two different agencies different governmental groups employees as well as politicians being there. A maybe I got off board there just that facilitation part is what I appreciate.

Board members also commented on the fact that their experience with IIMADR motivated them to expend more efforts to bring people to the table so the TUA regional effort could become a reality:

> Trying to, in my opinion, trying to **be a catalyst to progress and get TUA and bring information out to all the members and keep them supporting themselves more and more**

> I think that IIMADR with Weldon Schieffer in these series of meetings and getting other **people involved and getting people to talking** and going across on the board that this there was money here and then coming in that there was a research project available with money to extend farther into the government did give validity that hey this maybe is gonna go.

<u>Perceptions of IIMADR's Strengths</u>

IIMADR is credible as it is neutral, partly because it is associated with OSU. It's neutrality put those involved at ease and did not have an attitude. Some participants hope that IIMADR will bring in grant money to their project.

TUA board respondents believed that IIMADR's third party status gave them credibility with all of the participants:

> your going to have some **credibility,** and then your going to be a **disinterested party,** which will most likely make you acceptable in any kind of a conflict type of situation your going to acceptable to both parties

> A, the neutral atmosphere that they brought created a and I'm gonna say the **expertise** in Weldon too ya know his domineer and working with people that makes a big difference **made them feel comfortable**. There's a lot that goes along with a personality how they

> are approached stand point from where they are being approached so I think that neutral atmosphere helped a lot.
>
> **Getting information out to people**, and to the water associations. Meeting with them and as a **neutral agency** being neither for nor against being as a facilitation agency that can explain the project, hopefully, and to then come back to the TUA board with the both pro and con or what the feelings are of the people about the project as a whole.

Some TUA board members recognized the communication skills IIMARD as a great strength in the facilitation process:

> I think the **communication process** that you utilized was appropriate and adequate and I think that's the key to a lot of this is communication and so I think you guys did a good job at that

TUA board members perceived a positive attitude on the part of IIMADR personnel. While IIMADR was associated with Oklahoma State University, they did not act as though they had all of the answers or they were there to tell rural people how to operate their organization:

> the facilitator **didn't come in oh he wasn't patronizing** which is something that tribes run into routinely I'm from the government and I'm here to help kind of attitude, he just came in and to provide a service to assist in this project and generally Native American people are open to that, **they are opened to assistance as long as a person isn't coming in with the attitude that you don't know how to fix this so** I'm going to show you how and that wasn't the attitude at all so I didn't pick up on any problems that anyone had with that issue

TUA board members also recognized the ability of IIMADR to keep the group focused:

> I suppose the strengths are the **ability to get groups of people discussing pertinent issues** as I said earlier or...um, to draw together a group to actually accomplish a goal to **keep a meeting on track.**
>
> **Neutrality**. I believe that the strongest aspect being able to relieve any animosity anyone might have or a lot of people are reserved about their opinion but when the scene is set a certain stage they are willing to open up what their reservations are and if you can get those out then naturally you can resolve some of the problems.

TUA board members appreciated IIMADR's association with Oklahoma State University will assist in more funding of the TUA concept:

> **if the money comes through** then I thing OSU could really give us some help.
>
> They got a **good track record and OSU**; I went to school at OSU so I gotta say it's good
>
> I think that the familiarity with working through OSU cause they got **direct contact with senators and congressmen** and then with them having that direct contact and then you

> getting back here with the local I think you should put it together and show the needs properly better than just local people
>
> Well I think that you can do a lot of information that we haven't had before and probably **assist us with some grants**
>
> Well I think with your participation is will strengthen us and I think it's going to encourage us to go forward more, otherwise **without you participating I really don't think we would be able to go forward**

Perceived weaknesses of IIMADR

IIMADR seemed to come late to the process and some participants found that it was not clear why they were there at first. Some of the issues where not fully covered and others missed because of time constraints, plus, Weldon was hard to get a hold of and IIMADR

The leading weakness that IIMADR faces according to TUA informants is the TUA members did not understand the role of IIMADR:

> I didn't have background on what exactly they were there to do. I didn't know who had called in the facilitator or if anyone had I knew nothing of that and so I had a little **problem understanding why they were there and what it was the were hoping to accomplish** and ya know that's not so much a problem with facilitation as much as it was whoever called the meeting and set it up but ya know I think the big weakness
>
> I think there was a couple of other people in the tribe that might **have been confused about why exactly we were there**
>
> that perhaps the fact that **the grant for that came through when we were way down the line** probably hurt them in their ability to really understand the program and help us at that point because they got some money and came into help us we had years of effort that had been going to prior to that time. And I don't even know if they had the documentation that we had necessary for the to do a lot of the work,

Consistent with the misunderstanding over the role of IIMADR is the belief that IIMADR was brought in to provide grant funds or technical assistance to secure grants:

> Well the major weakness is that you **don't have the funds for us**.

Another weakness identified is TUA members perceived that IIMADR did not have time to deal effectively with TUA problems:

> is the fact that you **just haven't had enough time** to get right down to the point to see the needs and understand the needs and getting the things together that would help to get the grant to me

> Probably just like most people, you've got more work out there then you've got time for I know Weldon is just covered up **it's hard to cover all the basis**. There's a lot of issues out there that really need attention and it's hard to jump from one issue to another and that's difficult to switch I don't know how many people are in Weldon's position?
>
> It seems like there are pretty well overloaded. I **don't we've tried to access Weldon a few times and he was out of pocket and that gets a little frustrating** but you realize that people are out working the field and you can't always get a hold of him. But I would say a he always responds back at a reasonable time if he was out of the country or out of the state he gets back to us it's just the time breakdown.
>
> With any type of situation like this there are **150 miles away and not right here in the community per say I think that that might possible be**, but I don't know whether to cause ya know their here mostly for me and they come on their own it's not local I mean it could be a positive or negative
>
> There would be a weakness in the speed in which the information could get to the people the actual being able to communicate to the people the balancing act of a water system and it's meaning and what the future holds for it. This could be a weakness because I don't think any agency that being a not involved from the word go could go out here and communicate totally to the people what **they've done and what the project is all about and being able to get back their feelings in a should I say systematic manner which could be transmitted into working project itself.**

TUA perceptions of threats to the IIMADR facilitation process

Threats to the process were that the process was confusing, for example, the schedule and planning wasn't clear, the project was not finished and what was done was not what they said they would do, and there were no hard figures, such as the cost of water, and most people don't see where IIMADR fits in to the discussion.

TUA members' perceptions of the threats to the IIMADR facilitation process was an opinion that IIMADR lacked a coherent plan for the TUA situation:

> probably the biggest threat to that **not having some kind of a schedule and a plan** here's what we're here's how were going to proceed and here's the milestone.
>
> The only thing I can think of **not finished what they started and not doing what the said they were gonna do**, I mean I don't know.

Likewise, was the lack of understanding about IIMADR's role in relation to the TUA project:

> No, no, I think that from the time I observed the guy at the meeting he was very helpful and what he's done since then, I don't know anything about it.

> **Lack of understanding of the people that's going to be talking to. That they don't understand where you fit where the OSU project fits into the total mix and I think that's is probably the biggest.**

Some TUA members confused the issue of threats to the process with the issue of threats to TUA going forward with a regional water plan for individual water systems in the Tenkiller region:

> **They want to know what's the water gonna cost and** that's the first question we run into and how do you tell them that when you don't have the project off the ground yet ya know. Everybody asks us what does it cost that's gonna be tough to answer cause who can you really can't until the thing gets going and we can see ya know. There has been some studies but that's still kind of up **in the air because 'm seen some of those figures and I have a hard time believing them.**
>
> I would say **funding** like everybody else.

What TUA board members learned about the IIMADR process.

Participants, overall, seemed to have learned about how a facilitation process, that once seemed doomed, can move things along even when emotions flare.

Some TUA board members learned how a neutral, third party facilitator could revive enthusiasm in a project:

> I don't know that I learned a lot other than just an **overall concept that a third party coming in can sometimes move something along that looks like it's doomed to failure** and where it stood a year ago I think we gave it a five percent chance of it going anywhere.
>
> said **the longer we work with those groups the less we become neutral** to an outside group internally the folks that are setting on that board and dealing with us understand that we are neutral and we're there to facilitate whatever we do a lot of their administrative work just to keep their group going we would have to step back in and hopefully regain that **neutrality with people** and I don't see anyone else stepping up to be a neutral to facilitate there's no one out there that I know of that does that.
>
> I haven't served 25 years a community developer I'm not sure I saw any really new processes but what's being done with the process is basically the correct manner in going about it. Trying to serve as a **facilitator a neutral agency to get closure or to get to help an organization get a real good project going**.
>
> Mmm over the years I have worked 28 years with the state worked on federal programs and everything so I'm pretty familiar with the process.

TUA members were impressed that a third party facilitator could enter a highly-charged situation and could get parties working together without leaving in frustration:

> One of the things was as I said the mediator would **keep us on track** ya know that that's not what we are here to talk about today, this is the important issue maybe so but that's not what we're hear to talk about today **and he never got flustered, I** don't keep my cool that well that's why I say I'm usually have to be mediated

Other TUA respondents had the opportunity to learn tools of diplomacy and how professionals function within such circumstances:

> **I like your diplomacy that you use**. When you meet with the boards and everything you have been very good, very educational, but **very professional and everything** and professional and I like that. I like people being professional and that's one thing that I really commend them on. And that's important to me, it always has been. So but if you're a professional person, I think they have been very professional.

Final Considerations

The evaluation of the TUA facilitation process was a qualitative study of involving TUA board members and other TUA stakeholders who had firsthand knowledge of IIMADR activities. The study involved in-depth interviews with open-ended questions written in advance of the interview and with follow-up questions to clarify responses.

A further research opportunity exists to expand the data by administering a Likert-scale survey. This qualitative survey would be administered to an expanded sample consisting of waters system policymakers who are potential wholesale consumers of TUA and a sample of retail customers of the water systems themselves. This proposed study (see Appendix B) would generate in-depth data on the preferences and dynamics of proposed users of the TUA project.

APPENDIX D

Evalution Data for Project Objectives

Meeting Project Objectives

IIMADR according to the following narrative met the objectives of the IIMADR Tenkiller project proposals:

Objective One: Project Data Base

- Assembling various data related to the project, based on geographical considerations, political boundaries, population densities, natural resource availability, census figures and other published projections, and developing computer data bases for use by the stakeholders.

IIMADR met this objective by providing information to stakeholders at facilitation meetings, bringing together engineers and other natural resources and/or consultants to provide consultation to the TUA Board of Directors, and coordinating the flow of information to federal and state policymakers. IIMADR was credible as a neutral party. The Institute was credible because it was associated with OSU. Its neutrality put those involved at ease. It discouraged participants from having "an attitude." Some particpants hoped involvement with IIMADR would bring in grant money to their project.

A board member observed how IIMADR's data base was appreciated by the stakeholders: "[The IIMADR program manager] being an errand boy to the various agencies which none of us had the time or effort or initial contact to make these contacts with Oklahoma water systems and congressional representatives."

Objective Two: Stakeholder Contact Data

- Assembling and neutrally disseminating contact data on and for stateholders choosing to join in the IIMADR efforts.

IIMADR met the second project proposal objective by developing and maintaining a computerized data base on the stakeholders of the TUA project for use by all stakeholders.

Board members interviewed in the project evaluation used pharses and terms such as “credibility”, “disinterested party”, “expertise”, and “made them feel comfortable”, in describing how they felt about turning over information about themselves to IIMADR. IIMADR’s “disinterested third-party” status enabled IIMADR staff to “getting information out of people” and facilitated the “communications process”.

Objective Three: Stakeholders’ Meetings

- Planning, organizing, marketing, publicizing, and convening preliminary stateholder meetings regarding TUA’s water project, its long-term planning and cost recovery, and all facets of construction.

IIMADR met the third project objective by conducting two facilitation meetings in Tahlequah, Oklahoma in 2003. IIMADR, especially with the help of IIMADR’s program manager, got people talking, brought them closer together, and gained higher visability for the project. The meetings were attended by all of the stakeholders interested in TUA and the IIMADR facilitation process. Attendees at the facilitation process believed that the preliminary stakeholder meetings helped focus the board members and was an impetus for coalescing the members who represented the participating water systems for work on implementing the TUA concept.

A participant at one of the meetings, a representative of an interested federal agency, stated “you [IIMADR] did some of the due diligence in terms of trying to find out where things are, where all the different parties saw it, and where you needed to go...I think things have a better chance of happening now then they did a year ago.”

Another participant commented:

> The facilitation at least got the project moving...[it] got us looking at the project from a regional standpoint as opposed to what Cherokee Nation might think instead of just more of an idea of what could we do to benefit the entire area from utilization of Tenkiller water.

Objective Four: Consumer Preferences and Stakeholder Dynamics

- Surveying and documenting consumer preferences and other stakeholder dynamics involved in the project.

IIMADR was not able to complete the survey and documentation of consumer and stakeholder preferences specified in Objective Four. IIMADR proposed to conduct a survey of stakeholders in Groups II and III but only completed a survey of board members under this evaluation. There was no time nor opportunity to complete this survey. IIMADR recommends that this objective be completed by surveying the Group II and III populations.

Objective Five: Engaging the Stakeholders

- Neutrally engaging stakeholders in the direction and scope they choose to take the project.

IIMADR met the objective of engaging the stakeholders and directing them toward a goal or resolution for the project. Respondents in interviews believed that IIMADR brought people together to exchange information, brainstorm, find commom ground, and move a once stalled project forward. TUA members appreiated the neutrality that IIMADR contributed to resoluting impasses. He observed “basically you [IIMADR] come in as a third party and try to brainstorm solutions and manage them, I guess go through

a process and break a logjam and bring something in to a point where it can be resolved."

The IIMADR involvement pushed the stakeholders to choose a direction for the program that many of the stakeholders believed they had the training to accomplish. The engagement helped to develop direction for stakeholders as one board member describes:

> We had a bunch of people at that meeting who were workers in the rural water district...As a result they were just ordinary people and we were just ordinary people and we really did lack what i consider the ability to somehow mount an effort by someone to make this go. We just met and couldn't ever get it together. Jim Wilson came into that meeting, who is the state representative here, and that was one of the things he suggested that we somehow get off the pot and get moving and this had been going on for years and we just didn't seem to get it together and it was kinda discouraging to me that we really needed some help from someone who could give us help.

IIMADR enabled the stakeholders to develop a vision for the TUA project, in the words of one board member, "by assembling people and getting information from people that would assist in better understanding what the project is about, how its going to be implemented, and how it could be carried out."

Another stakeholder attributed a large role to IIMADR in providing guidance, stating, IIMADR was "probably a guiding light here . . . someone that we [could] come to and request assistance and [it was] there to give it to us."

The neutral engagement in assisting TUA participants in choosing a direction for the project was observed by one stakeholder as follows:

> Well it could be a lot of different things depending on the situation. [The IIMADR program manager] has on two occasions facilitated different agencies, different groups, employees as well as politicians being there. . . . [T]hat facilitation part is what I appreciate.

The IIMADR facilitation process helped board members to see a workable program for the TUA project. Still another board member commented:

> In my opinion, [IIMADR was] trying to be a catalyst to progress, bringing information out to all the members . . . getting other people involved and getting people talking . . . . [Knowing] that there was money here and . . . that there was a research project available with money to extend farther into the government, did give validity, that hey, this maybe is gonna go!

Timetable

The IIMADR activities specified in the timetable of overlapping activities were accomplished within the specific time periods.

Related Research

The IIMADR project in conjunction with the Tenkiller Utilities Authority and the evaluation of this project were designed to add to research on the utilization of alternative dispute resolution processes relative to public sector utility projects in Oklahoma. Journal articles, conference presentations, and other publications will be developed from the data generated by this case study.

Training Potential

The IIMADR project, “Facilitating the Tenkiller Utilities Authority Public Water Decision Project,” provided opportunities for graduate and undergraduate students to be involved in the design, management, and business topics associated with environmental, economic, and other public utilities issues impacting eastern Oklahoma. Three graduate students and one undergraduate student were employed by IIMADR on various phases of the TUA project. These students were enrolled in agricultural economics, environmental science, and occupational education programs. The

exposure to the IIMADR issue management and facilitation process and to the TUA and the project's issues of water quality, water supply, and water treatment supplement the students' classroom experiences and provide potential research opportunities.

The project provided contacts for additional research in issue management and alternative dispute resolution and in related interdisciplinary studies.

Information Transfer Program

Activities for the efficient transfer and retrieval of information are an important part of the Environmental Institute/OWRRI program mandate. The Institute maintains a web site on the Internet at URL http://environ.okstate.edu/ that provides information on the OWRRI and supported research. The site provides links to information on publications of the Institute, grant opportunities and deadlines and any upcoming events. A listing of technical reports and other publications generated by OWRRI and other Environmental Institute sponsored research is updated regularly and is accessible on the Institute web site. Abstracts of each publication are available.

The Environmental Institute/OWRRI also produces a quarterly newsletter called "The Aquahoman" to disseminate information on upcoming events and grants, provide updates on research etc.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	9	0	0	0	9
Masters	8	0	0	0	8
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	19	0	0	0	19

Notable Awards and Achievements

The 2004 program year was one of great changes in the OWRRI. Two new staff members joined the OWRRI Team. A new Unit Assistant and Outreach Specialist joined the OWRRI team. These additions have had a large impact on the productivity of OWRRI. The Outreach Specialist is especially important as OWRRI seeks to provide information to policy makers, researchers, students, and the public. The addition of this position allowed the development of a newsletter, The Aquahoman, which is distributed to the OWRRI constituency quarterly.

This year saw the second annual Oklahoma Water Research Conference. This conference brought together over 120 professionals, policy makers, researchers, and students to discuss water research developments and needs in Oklahoma. The OWRRI cooperates with the OSUs Biosystems and Ag Engineering Department in sponsoring the three-day event. The planning committee for the conference includes representatives of three state agencies, three federal agencies, and The University of Oklahoma.

One of our research projects, begun in FY04 and continuing through FY05, has been of particular interest to law makers. Senator Inhofes staff of the Senate Environment and Public Works Committee requested information generated by a team of OSU researchers lead by Dr. Brian Adam. The project Optimal Selection of Management Practices, Policies, and Technological Alternatives for Phosphorus Abatement: Using GIS and Economic Methodology to Model a Watershed is a timely and important project that seeks to address the issue of accelerated eutrophication in the Eucha-Spavinaw watershed by providing spatially optimal, least-cost allocations of management practices between point and non-point sources. In addition, it will provide recommendations on management practices and investigates the feasibility of a facility to convert poultry litter into electricity.

A new area of emphasis for OWRRI is the support of social science projects that address the priorities for research funding identified through consultations with water policy makers and researchers. This is just the first step in an effort to establish a truly interdisciplinary vein of water research in Oklahoma. To this end, OWRRI supported the work of the Institute for Issue Management and Alternative Dispute Resolution (IIMADR) in resolving conflicts over the Lake Tenkiller water supply.

IIMADR has begun a multi−year effort to facilitate a dialogue among the participants in the Tenkiller Utilities Authority (TUA). Researchers are developing and testing a protocol for linking stakeholder input to such issues as water quality and quantity, environmental justice, compliance with federal water laws, and homeland security. To accomplish this, IIMADR has provided stakeholders with information about these issues, facilitated dialogues among TUA participants, and serves as a neutral clearinghouse for public access and involvement in the TUA project.

The response to both the information transfer and facilitation from the TUA has been completely positive. One participant summed up the sentiments of many by stating, [IIMADR] got parties talking and got the project movinggot us looking at the project from a regional standpoint. TUA is again making progress toward regional water planning, and participants are optimistically seeking funds for water infrastructure development which will allow further economic development.

OWRRI has continued this effort toward truly interdisciplinary research by sponsoring a project lead by Dr. Beth Caniglia, Science, Development & Public Opinion: The Adjudication of Groundwater Policy for the Arbuckle-Simpson Aquifer for FY05. The Institute recognizes that most, if not all, natural resource problems are at their core behavioral problems. Thus, it is anticipated that addressing both the social and natural science aspects of issues will contribute to a swifter and more acceptable resolution.

Publications from Prior Projects