NONMARKET VALUATION OF AN ULTRAFILTRATION SYSTEM FOR RECYCLING CHILLER WATER IN THE POULTRY PROCESSING INDUSTRY

by

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(Under the Direction of JACK E. HOUSTON)

ABSTRACT

The poultry industry is the single largest agribusiness industry in Georgia and one of the most important in the United States, but it faces multiple water usage problems stemming from rising water and sewer charges and increasing pollution regulations. One way to reduce water usage and wastewater is through recycling the chiller water used in processing. Food scientists and applied economists at the University of Georgia are collaborating on research to evaluate the operational and economic effectiveness of ultrafiltration membrane technologies (polymeric) at a pilot poultry processing plant in Georgia. On-site tests of membrane systems are underway.

Preliminary economic analysis is positive (return rate approximates 36.7 percent and the pay-back period 5.8 years), supporting considerable variations on cost scenarios. The hedonic approach revealed that only BOD and OG reduction capacity of the filtration system were statistically significant estimators of the pilot plant's willingness to pay for the filtration system. Economically efficient technological breakthroughs are essential if the U.S. poultry industry is to continue operating competitively.

INDEX WORDS: Ultrafiltration, polymeric, recycling, chiller water, hedonic, non-market valuation, poultry industry.

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DEDICATION

Para mi esposa Alejandra y nuestros queridos hijos Maria Emilia y Federico, compañeros de viaje en esta tan ansiada aventura en U.S. y alegría de todas las horas.

Para nuestros padres, Haydée, Felipe, Alicia y Walter, quienes siempre nos brindaron su total apoyo y sabio consejo, aquí, allá, y mas allá; hoy, ayer y siempre.

A nuestros queridos hermanos y sobrinos, Felipe, Carolina, Marcelo, Bettina, Florencia y Francisco.

A tíos y primos, en especial a mi tío Venancio por su constante compañía.

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CHAPTER 1

INTRODUCTION

General Considerations

Poultry production is very important in the United States and especially so in Georgia, Arkansas and other southern states. Economically efficient technological breakthroughs are essential to maintain its competitive edge in processing and marketing. The Census of Manufacturers reports 311 companies engaged in poultry slaughtering in 2002 (U.S. Census Bureau. Census of Manufacturers, 2002). These companies own or operate 536 facilities, employ 243,000 employees, and produce about $38 billion in value of shipments annually. This industry is highly concentrated in the southeastern states. In Georgia, it represents the largest agricultural industry, with an annual contribution to the economy of $2.5 billion in 2003 (Georgia Agricultural Statistics Service., 2004). This state lies in second position behind Arkansas regarding total value of shipments and number of employees and third in number of establishments - 42 total facilities in 2002 (Census of Manufacturers).

Water use is a major issue in the poultry processing industry. Federal sanitation regulations set up in 1998 by the Food Safety and Inspection Service have caused poultry processing plant consumption of water to increase significantly (USDA, FSIS. 1996) . These regulations require the meat industry to ensure products are as pathogen-free as possible, and poultry processors have used more water in processing to help solve this problem. Water use restrictions during periods of drought can lead to increased competition between industrial and household users of water. Recycling not only reduces water use but also reduces volumes of wastewater. Finding an effective and efficient (physically and economically) way to deal with this issue could significantly benefit this industry.

Objectives and Data Sources

The objective of this research is to analyze economically the recycling process of chiller water in a pilot poultry processing plant using a polymeric ultrafiltration membrane system. The filtration system to be evaluated is provided by Sepro-Rochem Inc.

The scope of the economic analysis includes:

- the feasibility of the investment using the partial budget method and sensitivity analysis, and
- the use of a hedonic method as a non-market valuation tool to estimate the willingness to pay for this new filtration system and its intrinsic characteristics.

The Department of Food Science & Technology of The University of Georgia collects the experimental data for this work in a pilot poultry processing plant and is in charge of the physical evaluation of the filtration system. We also have used information from various other suppliers of inputs.

Justification

Increase in water consumption and environmental regulations are affecting the poultry industry's costs. An inexpensive and innovative filtration system is needed to filter poultry chilling water for reduction in suspended solids and microbes and for reduction in waste stream volumes. If this filtration system can meet the required levels to recycle chiller water, this could be of economic impact saving not only water costs, but also wastewater and energy costs.

Organization of the Thesis

The thesis is composed of six chapters. The introduction, statement of the research objectives, justification, and organizational aspects of the study are presented in the first chapter. The next chapter provides a brief characterization of the poultry industry in the United States, with special emphasis in its water consumption.

Chapter three introduces some general specifications about liquid filtration, the membrane separation technique with special emphasis in the ultrafiltration systems and finally, filtration for water reusing in poultry industry. Then, the first section of chapter four refers to the concept of economic value. The basic aspects of the non-market valuation methods found in the literature are reviewed in the sections two and three of the fourth chapter, with focus on the hedonic method. The fourth section presents some background about the hedonic function estimation.

Chapter five presents the partial budget analysis used to evaluate the investment's feasibility and a sensitivity analysis, as well as the results and discussion of the hedonic estimation of recycling water in the chilling process of broiler plant, using two econometric models. Finally, chapter 6 comprises the summary and overall conclusions of this work.

CHAPTER 2

POULTRY INDUSTRY IN THE U.S. AND WATER CONSUMPTION

Brief Characterization of the Poultry Industry in the United Sates

The poultry industry in U.S. is the world's larger producer and exporter or poultry meat. In 2003, the largest proportion of the U.S. poultry meat production was broiler meat (84 percent), followed by turkey meat (15 percent) and the remaining one percent was other chicken meat (USDA.ERS, 2004).

Broiler production is concentrated in the southeastern states from North Carolina to Arkansas. In 2003, these states accounted for over 70 percent of broilers in the United States. The five top broiler-producing states are shown in Table 2.1.

Table 2.1. Top Broiler Producers in the U.S., 2003.

State	Broilers produced annually (1,000 head)	%
Georgia	1,260,500	14.84
Arkansas	1,192,400	14.04
Alabama	1,039,400	12.24
Mississippi	790,300	9.31
North Carolina	708,200	8.34
Other	3,502,050	41.24
Total	8,492,850	100.00

Source: USDA.ERS, 2004

As stated, there were 311 companies engaged in poultry slaughtering in 2002. These companies own or operate 536 facilities, employ 243,000 employees, and produce about $38 billion in value of shipments annually.

According to Romans et al.(1994), poultry production has been increasing constantly since 1920. But before 1950, farmers viewed poultry raising as a way to produce eggs mainly (Ollinger et al., 2000) . Chickens for consumption were either those not needed for egg production or surplus animals.

The integrated structural form for producing chickens emerged during the 1950's and 1960's. Growers provided uniform – quality birds, which, combined with ever-increasing line speeds and more efficient feeding operations, enabled chicken slaughter plants to realize scale economies over the 1950 – 1960 period (Bugos, 1992).

Table 2.2 shows the per capita consumption of poultry, beef consumption, and poultry net exports in the last 40 years in the U.S. In this table we can observe that chicken consumption has grown over the last 40 years and now exceeds the consumption rate of beef. Ollinger et al., in the same report, say that from 1966 to 1970 this growth was due to a decline in chicken price from one-half that of beef to about one-sixth and by the introduction of new products, such as traypacks. After 1977, the consumption increase was mainly explained not only by a marketing emphasis on the lower saturated fat content of chicken relative to beef, but also by the introduction of more new products (deboned ready-to-cook products, chicken nuggets, etc.) and the improvement of distribution channels, including new non-traditional vendors such as fast food restaurants. Table 2.2 also reveals that there has also been a large increase in the annual rate of poultry products exported over the same period of time.

Table 2.2. Poultry per Capita Consumption, and Net Exports, 1960 – 1999.

Product	1960	1963	1967	1972	1977	1982	1987	1992	1997	1999
Per capita consumption				Retail Pounds						
Chicken[1]	27.8	30.8	32.4	41.7	40.2	47.0	57.4	67.8	72.7	78.8
Turkey	6.3	6.9	8.7	9.0	8.8	10.6	14.7	17.9	17.6	17.8
Beef	64.2	69.9	78.8	85.1	91.5	76.9	73.7	66.3	66.9	65.4
Net Exports				Million pounds						
Chicken[1]	137	157	88	100	349	524	767	1,530	5,043	4,421
Turkey	24	31	49	36	54	51	33	202	605	400

[1] Includes broilers and mature hens.

Source: Ollinger et al., 2000.

Similarly, the average liveweight per bird and the number of birds slaughtered have also increased greatly between 1960 and 1998 in the U.S. (Table 2.3).

The trend in poultry production volumes is confirmed by the fact that in the first half of 2005, a total of 17.2 billion pounds are expected, about three percent higher than a year earlier (USDA.ERS, 2004).

Table 2.3. Liveweight per Bird and Number of Birds Slaughtered, 1960 – 1998.

Product	1960	1998	Increase as % of 1960
Liveweight per bird	Average pounds		
Broilers	3.36	4.86	144.64
Turkey	15.05	24.63	163.65
Number of birds slaughtered	Million birds		
Broilers	1,534	7,838	510.95
Turkey	71	273	384.51

Source: adapted from Ollinger et al., 2000.

With regard to U.S. poultry processing, Kiepper (2003) underlines that during the past 30 years, the average slaughter plant has increased in capacity from approximately 60,000 to 200,000 birds per day. In his thesis focusing on broilers, which account for about 95 percent of the total number of poultry harvested in the U.S., he divided the processing steps into five major categories:

- First Processing or Poultry Slaughter: this step begins when live birds enter the plant and are stunned, killed and bled. Feathers and viscera are then removed under USDA inspection. The carcasses are chilled in an ice bath and washed, refrigerated, and either packaged or sent to further processing;
- Second Processing: defined as any process in which a chilled poultry carcass is separated into parts and/or meat is separated from bone. Operations in this category include cut-up, tray packing, deboning, MSC (mechanically separated chicken), MDM (mechanically deboned meat), and portion control;

- Third Processing includes all the processes that manipulate deboned poultry meat into value-added, convenience food for consumers. Poultry convenience foods are products in which services and additional ingredients have been added to the raw meat that reduces the amount of preparation time required by the consumer.
- Cook Plants: these plants process the raw whole poultry carcasses of mature or "spent" breeding and egg laying chickens into fat, broth and meat.
- Further Processing: this last category is defined as the conversion of raw poultry carcasses into convenient-to-use, value-added forms such as cut portions, buttered pieces, parfried breaded pieces, cold cuts, burger patties, and hot dogs (Baker and Bruce cited by Kiepper, 2003).

Average costs at the largest processing plants were about eight percent lower than costs at plants that were half that size, and about 20 percent lower than costs at plants one-eighth that size. The large and extensive scale economies in poultry slaughter help explain the near disappearance of small plants and the dramatic shift of production to large plants whose share of output rose from less than 30 percent in 1967 to over 80 percent in 1992 (Ollinger et al., 2005). Increases in scale economies have other public policy implications, such as enormous amounts of animal waste. In some parts of the country, more environmentally sensitive, these wastes have resulted in nitrogen and phosphates leaching into ground water or washing into streams, causing water quality problems and environmental degradation (Ollinger et al., 2000).

Industrial Water Consumption

The poultry industry in the U.S. generally produces "ready – to – cook" poultry products. All poultry first processing stages include a series of operations necessary to transform live birds into dressed carcasses. These operations can be summarized:

Receiving → Killing → Bleeding → Defeathering → Eviscerating → Chilling → Weighing, Grading and Packaging → Shipping (USEPA, Office of Water, 2002).

In poultry processing, water is used for different purposes, such as scalding in the process of feather removal, bird washing before and after evisceration, chilling, for cleaning and sanitizing of equipments and facilities, for cooling of mechanical equipment, such as compressors and pumps, and also to remove feathers and viscera from production areas. Several studies cited by the U.S. Environmental Protection Agency (USEPA) have shown that the volume of water used and wastewater generated by poultry processing can vary substantially among processing plants. According to one study of 88 chicken plants conducted by USEPA in 1975, it was found that wastewater flows ranged from 4.2 to 23 gallons per bird, with a mean of 9.3 gallons per bird (USEPA, Office of Water, 2002). This is equivalent to 2,428 gallons per 1,000 lb LWK[1], and compared with the mean flow of 639 gallon per 1000 lb LWK in other meat processing is many times greater.

Two factors contribute to this higher water consumption and wastewater generation in the poultry industry. The first is a required continuous overflow from scalding tanks. The second is the use of carcass immersion in ice bath chillers with a required continuous overflow for removal of body heat after evisceration.

[1] LWK = live weight killed, the total weight of the total number of animal slaughtered during a specific time period.

Carcasses should be chilled rapidly to below 40 ^{o}F, to minimize microbial growth and to preserve product quality (Tsai et al., 1995). To do this, most poultry plants use two chilling tanks in series, a pre-chiller and a main chiller. Per current USDA regulations, 0.5 gallon of water per bird must be overflowed from the chiller and replaced with fresh (USDA, FSIS. 1987).

The Food Safety and Inspection Service (FSIS) defined in 1996 some requirements applicable to meat and poultry establishments designed to reduce the occurrence and numbers of pathogenic microorganisms on meat and poultry products, reduce the incidence of foodborne illness associated with the consumption of those products and provide a new framework for modernization of the current system of meat and poultry inspection (USDA, FSIS. 1996). These regulations are better known as Pathogen Reduction and Hazard Analysis and Critical Control Point (HACCP). The regulations contained four components: (1) a requirement that each establishment develop and implement written sanitation standard operating procedures (Sanitation SOP's); (2) a requirement of regular microbial testing by slaughter establishments to verify the adequacy of the establishments' process controls for the prevention and removal of fecal contamination and associated bacteria (this item refers to *E. Coli*); (3) the establishment of pathogen reduction performance standards for *Salmonella* that slaughter establishments and establishments producing raw ground products must meet; and (4) a requirement that all meat and poultry establishments develop and implement a system of preventive controls designed to improve the safety of their products, known as HACCP.

A recent survey conducted in broiler processing facilities has found that the average water use prior the implementation of the HACCP was 20.6 liters per bird (L/bird), while the current, post-HACCP water usage was reported as 26.0 L/bird (Northcutt and Jones, 2004). So, the federal sanitation regulations set up in 1996 have caused processing plant water consumption to increase significantly. This was due in part because processors discovered that high volumes of pressurized water could physically rinse contaminants off the surface of the birds.

According to Jaffe and Phillips (2004), prior to the FSIS regulation, the immersion chiller had been considered the primary means of pathogen reduction in the slaughter process. After the regulations, the pre-chill rinse cabinets were found to also be an important key to compliance. It was essential that the microbial load entering the chiller system be reduced as much as possible. Use of a pre-chiller provides a better opportunity for antimicrobials in the chiller to perform. As more fresh, chlorinated water came into contact with carcasses, the contact time for antimicrobial agents, such as chlorine, could be enhanced to improve disinfection levels. The same authors pointed out that the down side of this was that water usage increased in some poultry plants by more than 50 percent, which caused severe problems such as in some cases the overwhelming of the existing water utility infrastructure.

In summary, the new sanitary regulations induced higher water consumption by the industry, which not only increased costs but also environmental concerns due to higher volumes of wastewater. The problem the industry is now facing is how to balance food safety with water conservation and still stay in business (Jaffe and Phillips, 2004).

As the U.S. Environmental Protection Agency (EPA) tightens restrictions on the quality of water consumed and wastewater released into the environment, water costs will likely rise even more rapidly than in the past. Carawan and Merka (1996) have indicated that water and sewer costs for some poultry processing plants have risen almost tenfold during the last two decades and the upward trend is projected to continue at the same rate or higher. According to them, water conservation and waste reduction are becoming much more important because:

- Water costs and sewer charges are on the rise;

- Water quality and availability are threatened by increased consumption and pollution in many areas;

- Pollution is being aggressively attacked by public agencies and the public at large;

- Future regulations will require water conservation and elimination of pollutant discharges;

- A corporation's image can be negatively affected and its sales hurt if its plants are perceived as harming the environment; and

- Enforcement actions are becoming more severe and may involve not only lawsuits and fines, but also even prison terms.

Jordan (1998) also underlines the water cost issue, saying that in the 1980's water rates increased by more than seven percent per year, double the general rate of inflation. According to the author, this increase was due to many reasons, including a nationwide growth-induced expansion of capital facilities, replacement of old and deteriorating facilities, and required tests for more contaminants according to the Safe Drinking Water Act. Also, due to the increasing demand for water, systems across the country are designing water rates to encourage conservation.

Despite Georgia having abundant water resources and significant rainfall, the state still experiences water-related problems (Jordan, 1998). In basic terms, the rapid population growth of Georgia and the increased water use for agricultural irrigation over the last 30 years are stressing Georgia's water resources (Board of Natural Resources. State of Georgia, 2001). The major water stresses can be summarized as follows:

- Population growth in Northern and Coastal Georgia,
- Agricultural water use in the Flint River Basin in southwest Georgia,

- Interstate conflicts among the States of Georgia, Alabama, and Florida over water management in the Coosa, Tallapoosa, Flint and Chattahoochee River Basins,
- The drought of 1998-2001, which caused profound negative impacts on agricultural and municipal water systems,
- Old water and wastewater infrastructure in many communities, and
- The loss of healthy aquatic habitat and reduction in water quality through land development impacts. Land development impacts include increased wastewater discharges and nonpoint source pollution.

The priorities of water use constitute the most sensitive and important political and environmental water issue. Among important priorities, meeting human needs is first. By law, farm irrigation is second, a priority that protects the food supply. Other high priority uses are industrial and recreational uses.

The maintenance of streams and rivers in which aquatic life can be sustained is of paramount importance. Any kind of water use reduction could be important. Recycling not only reduces water use but also reduces volumes of wastewater. Therefore, finding an effective and efficient (physically and economically) way to deal with this issue could be significant for the poultry industry.

CHAPTER 3

ULTRAFILTRATION SYSTEMS: SOME GENERAL SPECIFICATIONS

Liquid Filtration

Filtration can be defined as a unit operation that is designed to separate suspended particles from a fluid media (also called "feed") by passing the solution through a porous membrane or medium. As the fluid or suspension is forced through the voids or pores of the filter medium, the solid particles (called retentate) are retained on the medium's surface or, in some cases, on the walls of the pores, while the fluid, which is referred to as the filtrate, passes through (Cheremisinoff, 1998).

Cheremisinoff classifies filtration into two major types:

- "cake", in which solid particles generate a cake on the surface of the filter medium, and
- "filter-medium" filtration (or "clarification"), where solid particulates become entrapped within the complex pore structure of the filter medium. Examples are cartridges or granular media such as sand or anthracite coal.

The first type is used more often than the second. Upon achieving some thickness, the cake should be removed to maintain the flux rate. These cleaning processes (or antifouling techniques) consist of three methods: chemical, reverse flow or mechanical. Combinations of these can also be used.

Membrane Separation Technology

A range of separations of the chemical/mass transfer type have developed around the use of membranes, including distillation, extraction, absorption, adsorption and stripping, as well as separation s of the physical type such as filtration (Scott and Hughes, 1996). Membrane separation technology is in a state of rapid growth and innovation.

Over the last few years, particularly in the last two decades, numerous different separation processes have emerged in which synthetic membranes play a prominent role. A wide range of materials of different structure and with different ways of functioning have been developed. Some examples include:

- synthetic polymers (perfluoropolymers, silicone rubbers, polyamides and polysulphones),
- modified natural products (cellulose-based),
- miscellaneous (inorganic, ceramic, metals, dynamic and liquid membranes)

Scott and Hughes (1996) indicate that, to be effective for separation, membrane materials should have the following properties: chemical resistance (to feed and cleaning fluids), mechanical stability, thermal stability, high permeability, high selectivity, and stable operation.

The feature that distinguishes membrane separations from other separation techniques is the provision of another phase, the membrane. This phase introduces an interface between two bulk phases involved in the separation and can give advantages of efficiency and selectivity. Transport of selected species through the membrane is achieved by applying a driving force across the membrane. These driving forces are hydrostatic pressure, concentration gradient, temperature or electrical potential. The use of a driving force as a means of membrane separation classification is not satisfactory, because different membrane processes can be applied for the same separation.

However, in general terms, pressure-driven membrane systems can be categorized into four main divisions, based on the size particles rejected by the membrane, or by the molecular weight cut off (MWCO) (EPA, Office of Water, 2004):

– Microfiltration (MF): can filter up to 0.1 µm particle size or 500,000 MWCO (*note*: 1µm = 0.000001 meter).

– Ultrafiltration (UF): 0.01 µ m or 20,000 MWCO.
Covers the filtration of particle's range between MF and RO.

– Nanofiltration (NF): 0.001 µm or 200 MWCO

– Reverse Osmosis (RO), also called hyperfiltration.: 0.0001 µm or < 100 MWCO.

Ultrafiltration is typically applied in the separation of macromolecular solutes and colloidal material from macromolecular solutes and solvents.

Theoretically, microbial retention can be achieved by microfiltration membranes with a pore size below 0.4 µm, but these membranes contain significant fractions of pores above this nominal cut-off rating. Ultrafiltration, with membrane pore sizes below 0.05 µm, is more effective for microbial retention (Mannapperuma and Santos, 2004). Other advantages of ultrafiltration vs. microfiltration mentioned by these authors include higher quality filtrate and longer operation time between cleanings. One disadvantage is lower flux rates from ultrafiltration vs. microfiltration.

The main strength of membrane technology is that it works without the addition of chemicals, with a relatively low energy use, and an easy, well-arranged water permeation process. Different authors suggested that the market areas for ultrafiltration are in the food and dairy industries, biotechnology, water purification and effluent treatment (Cheremisinoff, 1998; Scott and Hughes, 1996).

Filtration and Water Reuse in Poultry Industry

The Code of Federal Regulations (Subchapter E—Regulatory Requirements under the Federal Meat Inspection Act and the Poultry Products Inspection Act, Part 416.2 (g)—Sanitation), allows poultry processors to utilize properly reconditioned water, ice and solutions for direct product contact "*provided that they are maintained free of pathogenic organisms and that other physical, chemical, and microbiological contamination have been reduced to prevent adulteration of product*" (USDA, FSIS. 2004) .

Food Safety and Inspection Service of the USDA also stated a previous rule (1987) in which provided minimum percent reductions in microorganisms and minimum percent light transmission that have to be met in the treated water to replace potable water in the make-up to poultry chiller baths, in prescribed ratios. As shown in Table 3.1, water reconditioning will be permitted if there is at least 60 percent reduction of total microorganisms including similar reductions (with $\pm$ 10 percent) of coliforms, *Escherichia coli* and *Salmonella sp.,* as well as the maintenance of light transmission (at 500 nm) at a value no less than 60 percent that of fresh water. Reconditioning equipment and conditions for use must also be approved.

Northcutt and Jones (2004) conducted a survey about water use and common industry practices in commercial broiler processing facilities. Of the 140 surveys sent out, 68 were completed and returned, representing a 48.6 percent response rate. The authors found that 38.5 percent of the facilities that responded to the survey recycle water and that there was a significant relationship between size of facilities and amount of water recycled. Large and medium facilities recycle more water than small facilities (44 percent, 36 percent and 20 percent respectively).

Table 3.1. Reconditioning Guidelines for Chiller Water.

Minimum reduction in microorganisms (%)	Minimum light transmission (%)	Volume of reconditioned water to replace one volume of freshwater (gal.)
60	60	1.75
70	70	1.50
80	80	1.35
90	80	1.25
98	80	1.10

Source: Code of Federal Regulations, Title 9, Section 381.66. (USDA, FSIS. 1987).

Several different methods have been tested to evaluate the effectiveness on reconditioning broiler process water (waste-water treatments). Lillard (1980) treated chiller water in a commercial broiler processing plant with chlorine and chlorine dioxide and found that all treatments significantly reduced bacterial counts on carcasses over those chilled in untreated water. However, there was no significant difference in carcass counts among different treatments groups.

Chlorine dioxide is effective in controlling the natural flora occurring in poultry chiller water, but it can be used only in certain concentrations because it could otherwise be risky for human health. Tsai et al. (1995) have found that disinfecting the poultry chiller water with this product at a reasonable level, for example 20 mg/L, not only was microbiologically efficient, but also had a low risk from the standpoint of chlorite and chlorate contaminations.

Sheldon and Brown (1986) evaluated the efficacy of ozone as a disinfectant for poultry carcasses and chiller water in a pilot poultry plant. The USDA requirements for microbial reductions for chiller water reuse (Table 3.1) were consistently achieved in this study. About one half the required increase in percent light transmission was achieved using ozone. Therefore, the authors concluded that ozone-treated chiller water partially fulfills the requirements of the USDA for recycling and that this deserves further investigation.

Chang and Sheldon (1989) and Chang et al. (1989) tested several wastewater treatments for their ability to recondition broiler process waters. The treatments included direct ozonation, and a combination of ozonation with either slow sand filtration, dissolved air flotation, or diatomaceous earth filtration. Of all the treatments tested, a combination of screening, diatomaceous earth filtration, and ozonation yielded the highest quality water, which qualified to be recycled back to the chiller at a rate of 1.1 gal of reconditioned water to replace every 1 gal of fresh water. But the quality of broiler prechiller overflow water was significantly improved with all treatments examined, surpassing the USDA's recycling requirements in nearly all trials. Sand filtration, however, resulted in inadequate treatment for removing the microflora.

In a second phase of the previous research project, Sheldon and Carawan (1989) found that passage of poultry chiller water trough a screen and diatomaceous earth (DE) pressure leaf filter significantly improved the quality of the water and satisfied the USDA microbiological and water clarity standards for recycling chiller water. They also found that the discharge waste loads from the chillers were reduced more than 60 percent which would reduce the plant's total waste load discharge to municipal treatment works.

Diatomaceous earth[2] filtration was also evaluated in another project for reconditioning prechiller overflow water using a bench-top, diatomaceous earth pressure leaf filter (Chang et al.,

[2] Diatomaceous earth: the skeletal remains of tiny aquatic plants called diatoms, which when deposited on a filter septum forms a rigid but porous filter cake which sieves out particulate matter from liquids as they pass through the filter.

1989). This device was effective to achieve the goal, but because the amount of diatomaceous earth body feed is a direct function of the solids to be removed, it would be necessary to adjust the former periodically to maintain an optimal ratio, as percentages of solids fluctuate. This fact could be a disadvantage.

Chang et al. (1989) used a filtration test unit of their construction to evaluate the influence of type of filter aid on reconditioning chiller overflow water for recycling. They found that sometimes the total microbial reduction fell below 60 percent, suggesting possible use only when microbicides are added to the reconditioned water prior to recycling. They also found that the rate of filtrate flow dropped rapidly, regardless of the use of filter aids, due to the deposition in the filter of two kinds of solids present in the overflow chiller water. Only one type of filter aid achieved the clarity and percentage of microbial reductions without prior filtrate's treatment.

Filtration of chiller water using ceramic microfilters (membranes with 0.20 – 0.45 μm pore diameter) also has been effective regarding to microorganisms levels and turbidity reduction. Hart et al. (1988) and Hart et al. (1990) reported microorganisms' reductions to almost zero and turbidity's reduction of about 90 percent. But the authors indicate that, because of the large capital costs involved, this kind of microfiltration is unlikely to be used unless improvements in capital costs or operating savings can be made. Other factors, such as nonchemical control of microbial growth, water savings, and reduced discharge levels, may be other important reasons for considering microfiltration.

In 2002 the California Energy Commission sponsored a study to evaluate three protocols approved by USDA for processing chicken on a pilot scale for marketing and also to study water and energy management practices of the plant and to propose conservation strategies. The protocols are:

1. Plant evaluation of pre-wash of chickens with ozonated water
2. Plant evaluation of ultrafiltration of poultry chiller water for reuse
3. Eliminate use of chlorine as anti-microbial agent for poultry products and chiller bath water.

The Commission found that not only was ozonated water as effective as chlorinated water for pre-washing chickens, but also the volume of ozonated water used was 30 percent less than the volume of chlorinated water used. Secondly, ultrafiltration met all USDA requirements for maximum use of reconditioned chiller water, including light transmission and reduction in microorganisms.

Lastly, no differences in performance between ozone and chlorine as anti-microbial agents were detected. Both treatments have shown similar sensory evaluations.

Mannapperuma and Santos (2004) conducted a study with ultrafiltration membranes (hollow fiber and spiral polymeric modules) for reconditioning poultry chiller water overflow. Their first objective was to obtain flux characteristics under all possible operating conditions to select design criteria, and the second objective was to obtain quality characteristics to verify that the membrane treatment produces reconditioned water that meets guidelines for reuse. They found that ultrafiltration produces water acceptable for reuse in the chiller to partially replace freshwater makeup (in a ratio of 1.1 gal of reconditioned water for every 1 gal of freshwater to be replaced). This method achieved rejections of chemical oxygen demand (COD) over 73 percent and turbidity reductions over 99.2 percent. The reduction of microbes during all the monitored trials was above 98 percent. The economic assessment of the system operation indicated a 2.4 – year simple payback period.

In spite of the fact that industrial water can be recycled meeting the USDA requirements (Code of Federal Regulations, CFR 416.2, Section (g)(3)) some authors consider this statement to be ambiguous and alert about the risk that could be permitted to reuse pathogen laden reuse water on chicken carcasses. Jaffe and Phillips (2004) indicated that if the CFR is liberally interpreted, as written, water from inside outside birdwashes and final rinse cabinets, after minimal treatment to "reduce physical, chemical and microbiological contamination" is now being reused upstream in the slaughter process to replace potable water.

In the same way, Russell (2003) wanted to determine if the new regulations of the USDA – FSIS are sufficient to prevent cross-contamination of pathogenic bacteria from carcasses in the chiller to carcasses upstream if the water that is reused is not fully decontaminated. Previous regulations required that water used in a particular process, such as washing or chilling, be disinfected (free from pathogenic bacteria) prior to reusing the water for equipment rinsing or product contact further upstream in the process. New regulations instead, allow for the water to be used upstream without any stipulations regarding the presence of pathogenic bacteria in the water prior to reusing. The results from this study indicate that there is a clear danger to using process waters that have not been thoroughly disinfected because pathogenic bacteria may be transmitted from contaminated carcasses in the chiller to uncontaminated carcasses upstream in the process. The author concludes that reusing water upstream should be done with caution and reuse water should be decontaminated prior to use upstream.

Besides these threats, we can see the membrane filtration technology as a very promising method to reuse water in poultry industry. It will depend on its physical performance to filter each pollutant present in the chiller water and also on its economic performance. In the next chapter, we will present the theoretical background to be used for the economic valuation of this filtration unit, taking especial consideration of its intrinsic characteristics. We will focus on the hedonic method for valuation of non- market products.

CHAPTER 4

THEORY AND METHODOLOGY

Economic Valuation

The word value has different meanings according to the perspective of who uses it. For example, consider the definitions from the Webster's New World Dictionary, Third College Edition "Meanwhile, ecologists use the word to mean "that which is desirable or worthy of esteem for its own sake; thing or quality having intrinsic worth". Economists use this same word to mean "a fair or proper equivalent in money, commodities, etc", where "equivalent in money" represents the sum of money that would have an equivalent effect on the welfare or utilities of individuals (Freeman, 2003).

The economic concept of value is based on two fundamental premises of neoclassical welfare economics:

- that the purpose of economic activity is to increase the well-being of the individuals in the society, and
- that individuals are the best judge of how well off they are in any given situation.

So, the preferences of individuals over alternative states are the basis for valuation.

Substitutability has a central role in the definition and measurement of economic value, because it establishes trade-off ratios between pairs of goods that matter to people. The trade-offs that people make as they choose less of one good and substitute more of another good reveal the relative values that people place on these goods. The money price of a market good is a special case of a trade-off ratio, because the money spent to purchase one unit of one element of the bundle is a proxy for the quantities of one or more of the other elements in the bundle that had to be reduced to make the purchase.

Value measures based on substitutability can be expressed either in terms of willingness to pay (WTP) or willingness to accept compensation (WTA). The former (WTP) is the maximum sum of money the individual would be willing to pay rather than do without an increase in some good such as an environmental amenity. This sum is the amount of money that would make the individual indifferent between the options of paying for and having the improvement and forgoing the improvement while keeping the money to spend on other things. WTP is constrained by the individual's income. The latter (WTA) is the minimum sum of money the individual would require to voluntarily forgo an improvement that otherwise would be experienced (Champ et al., 2003; Freeman, 2003) . WTP is typically associated with a desirable change and WTA compensation is associated with a negative change.   There exists a variety of methods to estimate consumer willingness to pay for products, such as choice experiments (Alpizar et al., 2001), experimental auctions (Lusk et al., 2004), surveys, hedonic prices.

Non - Market Valuation Methods

A fundamental distinction in economics is between market and non-market goods and services. Goods and services in a free market economy are sold for prices that reflect a balance between the costs of production and what people are willing to pay.

Some environmental goods and services, such as fish and seaweed, are traded in markets; thus, their value can be directly observed. Conversely, a non-market good or service is something that is not bought or sold directly. Therefore, a non-market good does not have an observable monetary value. Examples of this include beach visits, wildlife viewing, etc.

Table 4.1 Non-Market Valuation Methods

	Method
Stated Preference Methods	* *Contingent Valuation*: commonly used to value a single good
	* *Attribute-based methods*: to value numerous goods, estimation of a preference ordering of similar goods that differ in the level of their common attributes.
	* *Paired comparison*: to value numerous goods, estimation of a preference ordering.
Revealed Preference Methods	* *Travel Cost*: based on decisions to visit recreation sites that differ in travel cost and quality.
	* *Hedonics*: based on market transactions of differentiated goods to determine the value of some key underlying characteristics of the good.
	* *Defensive Behavior*: based on expenditures that households make to avoid exposure to an environmental disamenity.
	* *Cost of Illness*: represents the simple summation of the direct and indirect costs of treating an illness.

Source: Adapted from Champ et al., 2003.

There are several different methods to value the non-market goods or services, as we can see on Table 4.1, and they can be placed into one of two large categories, according to the data used: stated preference methods and revealed preference methods. The first set of methods uses data that come from carefully designed surveys, and so are based on what people "state" are their preferences.

Revealed preference methods are based on "observed" rather than stated preferences. They draw statistical inferences on values from actual choices people make within markets (Champ et al., 2003).

The Hedonic Method

<u>The Importance of Product Characteristics and Quality, Base of the Hedonic Approach</u>.

One of the first references about the importance of quality factors was the paper of Waugh (1928), in which the author found a relation between prices and quality factors for three commodities studied: asparagus, tomatoes and cucumbers. Based on this work, Griliches (1961) used the hedonic valuation method to see the effect of quality change on measured prices and price indexes of automobiles.

Lancaster (1966) suggested a new approach to consumer theory. His approach has broken away from the traditional one that goods are the direct objects to utility and, instead, suppose that it is the properties or characteristics of the goods from which utility is derived. Utility or preference orderings are assumed to rank collections of goods indirectly through the characteristics that they possess.

The key points of his approach can be summarized as follows:

1. The good, per se, does not give utility to the consumer; it possesses characteristics and these characteristics give rise to utility.

2. In general, a good will possess more than one characteristic, and many characteristics will be shared by more than one good.

3. Goods in combination may possess characteristics different from those pertaining to the goods separately.

Griliches (1971) used the hedonic technique with price indexes. He pointed out that viewing the problem this way can reduce the magnitude of the pure new commodity or “technical change” problem, since most new models of commodities may be viewed as a new combination of “old” characteristics. He described the methodology and indicates the questions that arise:

1. What are the relevant characteristics?

2. What is the form of the relationship between prices and characteristics?

3. How does one estimate the “pure” price change form such data?

(From “Price Indexes and Quality Changes”, Griliches, 1971, page 5)

Griliches warns against the use of variables which are not direct characteristics of the commodity. The characteristics theory would predict that models which have more “quality” per dollar will sell better, but this is a characteristic of the market, not of the commodity.

Rosen (1974) defined hedonic prices as the implicit prices of attributes, and they are revealed to economic agents from observed prices of differentiated products and the specific amounts of characteristics associated with them. He described how suppliers and consumers interact within a framework of bids and offers for characteristics.

These authors, Waugh, Griliches, Lancaster and Rosen can be considered some of the pioneers of the hedonic approach. The important feature of the hedonic model is that an implicit market exists for attributes of goods, such as proximity to open space or job risk, that are not explicitly traded in markets (Champ et al., 2003). But this method requires an identifiable link between the nonmarket goods and some subset of the market goods. The author indicates that there also must be sufficient variation in the prices of the market goods and the quantities of the nonmarket goods accompanying the observed transactions to be able to statistically identify these relationships. These concepts are the basis for the revealed preferences techniques.

Applications of the Hedonic Method.

The hedonic technique has been frequently used. Griliches (1971) mentioned its use by various researchers in many different topics, such as automobile prices, electric apparatus, house prices, diesel engines, washing machines and carpets, steam power generators, computers and people. The method was also used to construct or to adjust price indices. The hedonic price indices show the change in the price of a good net of changes in its quality (Griliches, 1971; Goodman, 1978; Murray, 1978; Fernandez-Cornejo and Jans, 1995; Bover and Izquierdo, 2001; Perez-Garcia and Guerrero de Lizardi, 2002).

Hedonic methods have also been employed in art. Using a sample of auction prices for major Canadian painters for the period 1968-2001, Hodgson and Vorkink (2004) run hedonic regressions to analyze the influence of various factors, including painter identity, on auction prices, as well as to construct a market price index.

Hedonic price analysis was also run to identify the values that marketers and consumers place on the information carried by the label of Australian wines in the British wine retail market (Steiner, 2004). Although many grape varieties are given a highly distinct valuation by market participants, the results also suggest that consumers consider regions jointly with grape varieties as proxies for brands. This contrasts with the general observation that grape varietal labeling is the distinctive feature of New World wines.

Other application of the hedonic method is the economic analysis of the environmental aspects of investments projects financed by institutions like the Interamerican Development Bank. However, in the past few years, as the number of projects of an environmental nature in the Bank's portfolio has increased, new methods, such as contingent valuation, have been used to complement or replace the hedonic method because of the inherent tendency toward benefit overstatement in the hedonic approach as applied in the IDB. Instead, the hedonic price function alone has been used to produce an upper bound to the benefits of an attribute change, which makes projects with internal social rates of return below our 12 percent cutoff certain losers, but does not make projects slightly above 12 percent certain winners. (Vaughan and Ardila, 1993; Ardila et al., 1998).

To illustrate the wide use of the methodology, we have to take into account that it also was used:

- to estimate the market price premium for preconditioned calves using a hedonic model which assumes that the price of a given lot is dependent on attributes of the calves and sale lot characteristics (Avent et al., 2004),
- to compare price differences between the nation's largest satellite video cattle auction and three large regional auctions (Bailey et al., 1991),
- to estimate the willingness to pay for school quality, neighborhood safety and environmental quality in six Ohio metropolitan areas (Bhattarai et al., 2004),
- to estimate bulls' market values associated with some of their attributes such as bull color, polled, conformation, muscling, disposition, age, birth weight, weaning weight, milk "expected progeny differences" (EPDs), birth and weaning weight EPDs, sale location,

order bull was sold, whether the bull had a picture in the sale catalog, and whether a percentage of semen rights were retained by the seller (Dhuyvetter et al., 1996),

- to explain variations in residential sales price with standard house attributes as well as the effect of distance and density of livestock feeding operations (Herriges et al., 2003),
- to estimate the real estate premium from improved access to a regional greenway system in three distinct counties in the Central Piedmont Region (Munroe et al, 2004),
- to estimate the implicit prices for the physical characteristics of crude oil (Wang, 2003),
- to estimate consumers' willingness to pay for breads marketed as "low – carbohydrate" (Ngange et al., 2005),
- to enhance new product success integrated with other technique, such as factorial surveys (Tomkovick and Dobie, 1995).

Limitations of Revealed Preference Methods.

Different authors indicate the inability to estimate either nonuse values or values for levels of quality that have not been experienced as some limitations of the revealed preference methods (Champ et al., 2003; Freeman, 2003). Nonuse values are the values individuals give to some goods or services independent of any kind of observable use. For example, people may be willing to pay to ensure some endangered species even though they never expect to see them.

Estimation of the Hedonic Function

The hedonic approach considers that the observed price of a product is a function of its characteristics. If the product class contains enough products with different combinations of characteristics, it should be possible to estimate this function.

Rosen (1974) pointed out that hedonic price theory is similar to spatial equilibrium. In spatial equilibrium, buyers and sellers choose their locations in physical space, and in differentiated markets, they choose locations in product attribute space. Therefore, we can consider markets for a class of commodities that are described by n attributes or characteristics, $z = (z_1, z_2, z_3, \ldots, z_n)$. The components of z are objectively measured, so all consumers' perceptions or readings of the amount of characteristics embodied in each good are identical. In the hedonic equilibrium, the differentiated commodity z is assumed to be sold in a perfectly competitive market, and the interactions of the many producers and consumers together determine an equilibrium price, which we state as $P(z)$, being $P(z) = P(z_1, z_2, z_3, \ldots, z_n)$. Thus, each product has a quoted market price and is also associated with a fixed value of the vector z. This function is the buyer's and seller's equivalent of a hedonic price regression, obtained from shopping around and comparing processes of brands with different characteristics. It gives the minimum price of any package of characteristics (Rosen, 1974).

According to Rosen and from the consumer- decision side, we can suppose consumers purchase only one unit of a brand or commodity with a particular value of z. The utility function $U =(x, z_1, z_2, z_3, \ldots, z_n)$, is assumed to be strictly concave and includes x as all other goods consumed. Set the price of x equal to unity (x is the "numeraire" good) and measure income, y, in terms of units of x, so that $y = x + P(z)$ is the non-linear budget constraint. Hence, the consumer will maximize the utility function U subject to the budget constraint by choosing x and z $(z=z_1, z_2, z_3, \ldots,z_n)$ to satisfy the budget and the first -order conditions

$$\partial p/\partial z_1 = p_i = Uz_i/Ux, \ \forall \ i = 1,2,\ldots n.$$

It follows that the shadow price of an attribute z_i is equal to Uz_i/Ux, or the marginal utility of z_i relative to the marginal utility of money (the numeraire good).

If we define a value or bid function $\theta(z_1, z_2, z_3, \ldots, z_n; u, y)$ according to

$$U(y- \theta, z_1, z_2, z_3, \ldots, z_n) = u$$

then, the expenditure a consumer is willing to pay for alternative values of $z=z_1, z_2, z_3, \ldots, z_n$ at a given utility index and income is represented by $\theta(z; u, y)$. It defines a family of indifference surfaces relating the z_i with money. The amount the consumer is willing to pay for z at a fixed utility index and income is $\theta(z; u, y)$, while $P(z)$ is the minimum price he must pay in the market. Therefore, utility is maximized when $\theta(z^*; u^*, y) = P(z^*)$ and $\theta z_i (z^*; u^*, y) = P_i(z^*)$, $\forall\ i = 1,2,\ldots\ldots n$, where z^* and u^* are optimum quantities. These optimum locations on the z-plane occur where the two surfaces $P(z)$ and $\theta(z; u^*, y)$ are tangent to each other (figure 4.1).

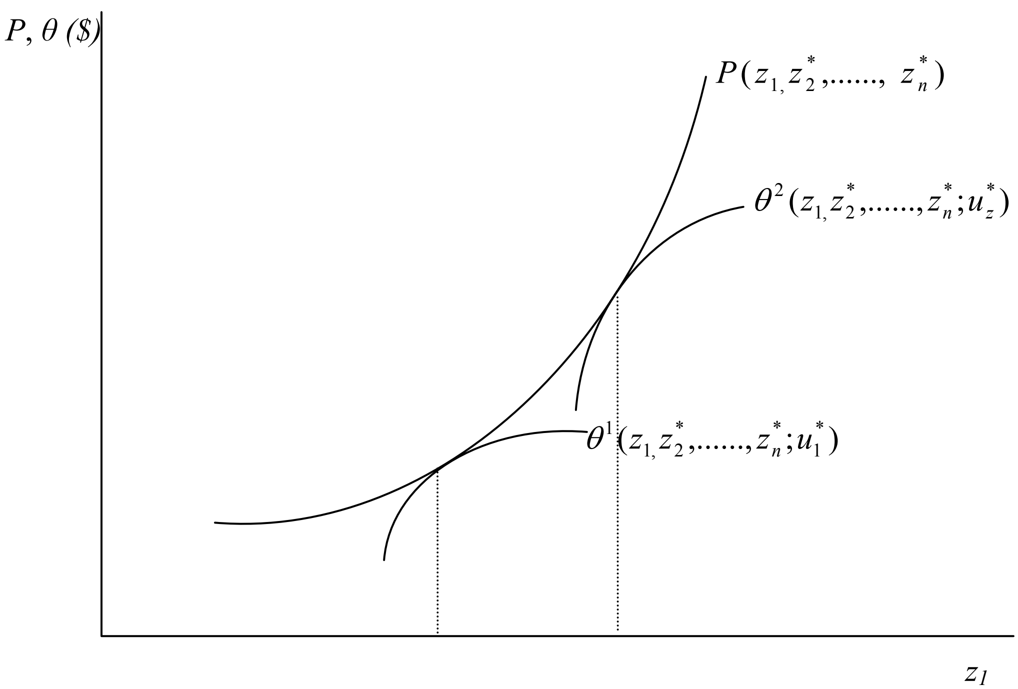


Figure 4.1 The Hedonic Price Function and WTP for z_1

Source: Rosen, 1974

In the above figure we can see two different buyers, one with value function θ^1 and the other with θ^2. The second one purchases a brand or commodity offering more z_1. Recalling the hedonic price function is an envelope function relating sales price of a differentiated good to its characteristics, hence, the independent variables in a hedonic price regression are only those product characteristics that affect price.

Econometrically, the estimated regression coefficients represent the "shadow prices" of product attributes, that is, the value of an additional unit of attribute "i", holding all other attributes constant (Bover and Izquierdo, 2001). Griliches (1971) indicates that there is no *a priori* reason to expect price and quality to be related in any particular fixed way. This is an empirical question and so the choice of the functional form should be done based on the previous inspection of the data.

The empirical applications of the hedonic technique typically regress prices or the logs of prices of the different varieties of a type of good on such specification variables. Deaton and Muellbauer (1980) indicate that there are two main variants of the empirical forms that have been used: single year, cross-section regression and pooled (over at least two years) time series/cross-section regressions. The first variant claims to estimate the shadow prices of the characteristics of the goods in question for a given year, as in our work.

Characteristics of the consumers and sellers of the product do not have to be included (Champ et al., 2003). Regarding the intercept of the equation, Muellbauer (1974) cited by Edmonds (1984), suggested that a non-zero intercept implies that one unit of the model has an intrinsic value apart from its characteristics content.

According to Champ et al. (2003), in general, non-linear relationships between size attributes and some quality attributes are expected. For this reason there is a preponderance of use of the semi-log functional form in the applications. But a hedonic price function that allows for sales price to be affected non-linearly by the characteristics of the good may be specified in many possible ways, some of which are displayed on Table 4.2.

Table 4.2 Common Functional Forms for the Hedonic Price Function.

Name	Equation
Linear	$P = \alpha_0 + \sum \beta_i z_i$
Semi – Log	$\ln P = \alpha_0 + \sum \beta_i z_i$
Double – Log	$\ln P = \alpha_0 + \sum \beta_i \ln z_i$
Quadratic	$P = \alpha + \sum_{i=1}^{N} \beta_i z_i + \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \delta_{ij} z_i z_j$
Quadratic Box-Cox	$P^{(\theta)} = \alpha + \sum_{i=1}^{N} \beta_i z_i^{(\lambda)} + \frac{1}{2} \sum_{i,j=1}^{N} \delta_{ij} z_i^{(\lambda)} z_j^{(\lambda)}$

Source: Champ et al. (2003)

In Table 4.3, we can see the way to compute the corresponding implicit prices.

Table 4.3 Implicit Prices of Each Functional Form.

Name	Implicit Prices
Linear	$\partial P / \partial z_i = \beta_i$
Semi – Log	$\partial P / \partial z_i = \beta_i .P$
Double – Log	$\partial P / \partial z_i = \beta_i .P / z_i$
Quadratic	$\partial P / \partial z_i = \beta_i + \frac{1}{2} \sum_{j \neq i} \delta_{ij} z_j + \delta_{ij} z_j$
Quadratic Box-Cox	$\partial P / \partial z_i = \left(\beta_i z_i^{\lambda-1} + \sum_{j=1}^{N} \delta_{ij} z_i^{\lambda-1} z_j^{(\lambda)} \right) P^{1-\theta}$

Source: Champ et al. (2003)

The use of a best fit criterion to choose functional forms does not necessarily lead to more accurate estimates of characteristics prices (Cassel and Mendelsohn, 1985). These authors put a word of caution about that, pointing out firstly that the large number of coefficients estimated with the Box-Cox functional form reduces the accuracy of any single coefficient, which could lead to poorer estimates of specific prices. Secondly, negative values are difficult to include in the analysis. Finally, the nonlinear transformations introduce a bias in the estimation of the mean untransformed dependent variable and results in complex estimates of slopes and elasticities which are often too cumbersome to use properly.

In chapter 5 we propose for our study the use of linear and double log models, to estimate the WTP for the filtration membrane system and the shadow prices for some intrinsic characteristics. This shadow prices are given by the coefficients of the linear model. Likewise, the double-log model's coefficients represent the elasticities of the dependent variable with respect to each independent variable considered in the model.

CHAPTER 5

RESULTS AND DISCUSSION

As we have indicated in chapter 1, the objective of this research is to analyze economically the recycling process of chiller water in a pilot poultry processing plant using a polymeric ultrafiltration membrane system. The analysis includes:

- the feasibility of the investment using the partial budget method and sensitivity analysis, and
- the use of a hedonic method as a non-market valuation tool to estimate the willingness to pay for this new filtration system.

Data

The Food Science & Technology team initially conducted experiments with a smaller version of the membrane technology system in their laboratories, for a short period of time. A larger ultrafiltration system was then installed and monitored in a poultry processing plant, to which we will refer as the "pilot plant". We will use only the information obtained with the large filtration unit in the pilot plant. The water quality variables we have considered are listed in Table 5.1

The quality variables in Table 5.1 are all continuous variables, and measured observations of their values were obtained in the Food Science lab by sampling the chiller water overflow at the pilot plant before and after filtration. For each variable, we have the value on the retentate, the value on the filtrate, and a computed difference, retentate content – filtrate content. Table 5.2 shows the descriptive statistics of these variables.

Table 5.1 Variables Considered in the Study.

Variable	Units	Description
TSS	mg/L	Total Suspended Solids
BOD	mg/L	Biochemical Oxygen Demand
COD	mg/L	Chemical Oxygen Demand
OG	mg/L	Oil and Grease
LT	%	Light Transmission: a measure of turbidity of the water
TPC	cfu/mL[3]	Total Plate Count: indicate the level of microorganisms present in a product
Coliform	cfu/mL	Other type of microbial contamination. Indicates fecal pollution.

Light transmission (LT) increases after filtration, which is desirable (Table 5.3). According to the EPA reconditioning guidelines discussed in chapter three (Table 3.1), a 98 percent reduction in microorganisms and a minimum light transmission of 80 percent is required for reusing water in the chillers at the highest allowed ratio of 1.10:1. From Tables 5.2 and 5.3, we can observe that the filtration process in our pilot plant has achieved these requirements. Indeed, the decrease in TPC from 7,822.9 to 117.2 cfu/mL represents a 98.96 percent reduction, and LT after filtration has values above 90 percent.

The Coliform reduction represents an 87.3 percent decrease. That also meets the requirements of +/- 10 percentage points' decrease referred to TPC reduction for recycling chiller water (USDA. FSIS, 1987). For processing the statistical/econometric analysis, we have used the software Limdep, version 7.0.

[3] cfu/mL = Colony – forming units per mililiter

Table 5.2 Means and Standard Deviations of the Variables.

Variable		Retentate (Before filtration)	Filtrate (After filtration)	Reduction (Retentate-Filtrate)	Reduction %
TSS	*Mean*	3.838571	1.355	2.475476	64.49
(mg/L)	*Std*	0.059853	0.072052	0.054826	
	n	14	42	42	
BOD	*Mean*	2252.00	46.70	2205.30	97.93
(mg/L)	*Stdv*	39.606397	2.867442	38.516952	
	n	3	3	3	
COD	*Mean*	3240.0	110.0	3130.0	96.60
(mg/L)	*Stdv*	45.460606	4.082483	41.432676	
	n	3	3	3	
OG	*Mean*	455.3	92.0	363.3	79.80
(mg/L)	*Stdv*	4.988877	1.632993	6.182412	
	n	3	3	3	
TPC	*Mean*	7822.857543	117.190476	7741.380952	98.96
(cfu/mL)	*Stdv*	980.764447	13.239332	910.022218	
	n	14	42	42	
Coliform	*Mean*	6	0.785714	5.238095	87.30
(cfu/mL)	*Stdv*	1.037749	0.716894	1.1001	
	n	14	42	42	

Table 5.3 Light Transmission Variation.

Variable		Retentate (Before filtration)	Filtrate (After filtration)	Increase (Retentate-Filtrate)	Increase %
LT	*Mean*	45.10	91.15	46.05	102.11
(%)	*Stdv*	2.83	0.07	2.90	
	n	2	2	2	

Table 5.4 Means and Standard Deviations of the Generated Variables.

Variable		Retentate (Before filtration)	Filtrate (After filtration)	Reduction (Retentate-Filtrate)	Reduction %
TSS	*Mean*	3.841696	1.350819	2.490877	64.84
(mg/L)	*Std*	0.059563	0.072214	0.095039	
	n	1000	1000	1000	
BOD	*Mean*	2251.45473	46.675472	2204.77926	97.93
(mg/L)	*Stdv*	39.174739	2.936392	39.427615	
	n	1000	1000	1000	
COD	*Mean*	3241.49445	109.698912	3131.79554	96.62
(mg/L)	*Stdv*	45.221577	4.192456	45.537818	
	n	1000	1000	1000	
OG	*Mean*	455.255990	92.060275	363.195715	79.78
(mg/L)	*Stdv*	4.957678	1.606069	5.241826	
	n	1000	1000	1000	

To increase the number of observations in the first four variables, which are measured only at longer intervals, we generated random normal values using the means and standard deviations shown in Table 5.2. We used the procedure of drawing random samples with the procedure of number generator from normal distribution of Limdep (Greene, 1996). Each generated variable has 1000 observations. We will focus on the content of each pollutant retained by filtration, what we have called the reduction on each pollutant due to the membrane system. Table 5.4 shows the descriptive statistics of these generated observations.

In the United States, both federal and state agencies exercise jurisdiction over the quality and quantity of wastewater discharge into public waterways. The primary authority for the regulation of wastewater is the Federal Water Pollution Control Act, commonly referred to as the Clean Water Act (CWA) (Public Law 92-500). The CWA requires states to set water quality standards, thus establishing the right to control pollution from wastewater treatment plants, as long as such regulations are at least as stringent as federal rules. Primary jurisdiction under the CWA is with the EPA, but in most states the CWA is administered and enforced by the state water pollution control agencies (USDA. EPA, 2004).

According to the fee schedule for water and wastewater services of the unified government of Athens – Clarke County, Georgia, there are wastewater surcharges for BOD, TSS and OG emissions. There is also a maximum allowed level for each of these pollutants in the industrial effluents, which are 1,000 mg/L for BOD, 750 mg/L for TSS and 200 mg/L in the case of OG (Appendix 1). From Tables 5.2 and 5.4, we observe that not only BOD, but also OG, largely exceed these allowed limits before filtration. The variable TSS does not present this problem. Instead, its values are so small that no wastewater surcharge has to be applied.

However, in all the variables the ultrafiltration system reduced the amount of pollutant discharge substantially, for which it is important to compute the possible cost (and water) savings. In the case of TSS, the reduction reaches 64.8 percent, which is consistent with previous research. Sheldon and Carawan (1989) cited a value of 65 percent for this TSS reduction. After filtration in our pilot plant, no pollutant reaches the minimum levels at which the plant would be required to pay wastewater surcharge rates.

We also have used information from different suppliers of inputs. The water and wastewater charges and surcharges are from the Department of Public Utilities, Unified Government of Athens Clarke County, GA.

Partial Budget Analysis

With the available information, the partial budget method permits us an acceptable first approach to an economic evaluation of the recycling of chiller water. The proposed change in the pilot plant's processing is the incorporation of the polymeric ultrafiltration system. This system is composed of 150 m^2 membrane sets, plus pumps and tanks. Each pump and tank can handle up to 4 membrane sets.

Considering a flow rate of 16.33 L/hour per m^2 (average, considering membranes are fouled during the recycling operation, causing the original flux to drop), the total number of units required to filter the daily chiller overflow is 16 membrane units. Other budgetary information and assumptions are presented in Table 5.5. The filtration units must be cleaned frequently: about two minutes every eight hours with 10 L per unit of a solution containing 0.5 percent of cleaner, and about two minutes every hour without cleaner, using only backflush with permeate.

Table 5.5. Budget Information for Pilot Plant Chiller Water Recycling.

Factor	Price or cost or unit
SEPRO ROCHEM	$42,000 (pump + tank)
Ultrafiltration Polymeric Membrane Unit (excluding taxes, with installation costs)	$20,000 (150 m^2 membranes)
Useful life of ultrafiltration unit	3 years, membranes 10 years, unit & pump
Filter cleaner[a] (Ultrasil 25)	$ 1.886/L
Cleaner use per unit	0.05 L/8 hours
Labor wage[b]	$ 9.27 /hour
Energy to chill the water[c]	12 watt-hr/bird
Energy cost of kilowatt-hour[d]	$0.0429/kwh
Annual Interest rate[e]	8 %
Efficiency of recycling chiller water with the filtration unit[f]	85%
Total daily chiller overflow[g]	624,525 L
Water[h]	$1.73/100 cubic feet + $ 23.19/month base charge
Sewage surcharge by level of pollutants[h]	$160/1,000 lb of OG and $138/1,000 lb of BOD
Sewage surcharge by volume[h]	$1.54/100 cubic feet + $ 5.60/month base charge
Labor, maintenance and cleaning (daily)[h]	$ 74.16
Annual work-days of pilot plant	260 days

[a] Ecolab, Food and Beverage Division.
[b] Poultry & Egg Association an U.S. Department of Labor, 80% above the federal minimum wage
[c] California Energy Commission, (2002). [d] Advantage Georgia, (1998).
[e] Bank of America. This rate can vary from 6.25 to 11.5 percent for amounts of $250,000.
[f] Sheldon and Carawan, (1989) and also by the achieved recycling ratio of 1.10:1 in our pilot plant.
[g] 165,000 gal, estimated from EPA requirement of 0.5 gallon per bird, multiplied by the 330,000 broilers/day that the pilot plant actually processes
[h] Department of Public Utilities, Unified Government of Athens Clarke County, GA
[i] Assuming 1 hour-worker/ 8 hours/ "hard unit" for maintenance and cleaning; firm has two 8-hour shifts.

Table 5.6 presents the partial budgeting results in the pilot plant, accounting for the cost to discharge pollutants into surface waters. It was computed using the average values of the pollutants. By recycling the chiller water, this plant could avert $313,931 in water, sewage and energy costs annually. Approximately 27 percent of this amount would come from water savings, 59 percent from sewage cost savings, and 14 percent from energy savings (energy required to chill the water). These annual dollar savings exceed the additional costs of recycling, which amount to $229,609 annually.

The main component of the additional costs is amortization of the filtration system (54 percent), followed by other items, such as annual interest (25 percent), labor (8 percent, especially for cleaning and maintenance), insurance (8 percent), miscellaneous and cleaning costs. Thus, the net annual change in income or gross margin after the proposed change is $84,322. The insurance premium was estimated online from eLease International Inc. for a $488,000 equipment value, with ordinary hazard,

Considering this initial investment of $488,000 by purchasing the filtration units ((4 x $42,000) + (16 x $20,000)), the pay-back period should be 5.8 years. The return rate per additional costs (net change/total annual debits) equals 36.7 percent, which, compared to the 40.4 percent profit before taxes/tangible net worth and 12.0 percent profit before taxes/total assets of the upper quartile in this industry (Robert Morris Associates., 2004), this result could be considered good.

It is also important to remember here that the BOD and OG levels of the chiller water before filtration are above the allowed limits for industrial effluents. Thus, filtration also produces the benefit of minimizing the environmental contamination and achieving the EPA compliance requirements.

Table 5.6. Partial Budget for Incorporation of Ultrafiltration Units to Recycle Chiller Water in Pilot Plant, with Sewage Surcharge.

BUSINESS CREDITS		
A. ADDITIONAL ANNUAL RECEIPTS		
None	Total additional receipts	$ 0.00
B. REDUCED ANNUAL COSTS		
B.1 Energy savings by returning recycled chiller water (12 watts/bird)		$ 44,169.84
B.2 Water savings (85% efficiency recycling chiller overflow)		$ 84,600.75
B.3 Sewage costs savings (in Athens Clarke, GA, 85% efficiency)		$ 185,160.57
	Total reduced annual costs	$ 313,931.16
	Total annual credits	$ 313,931.16
BUSINESS DEBITS		
C. ANNUAL RECEIPTS REDUCTION		
None	Total reduced receipts	$ 0.00
D. ADDITIONAL DIRECT ANNUAL COSTS		
D.1 Depreciation (4 & 16 units, straight-line method, 10 & 3 years useful life, salvage value = 0)		$ 123,466.67
D.2 Annual Interest (commercial loan to purchase the equipment)		$57,946.37
D.3 Insurance premium ($488,000 equipment value, ordinary hazard)		$18,056.00
D.4 Labor ($9.27 /hour; 1 hour-worker/ 8 hours/ "hard unit")		$19,281.60
D.5 Filter - cleaning costs (0.1 L of cleaner/unit/day * 260 days* 16 units)		$ 784.58
D.6 Miscellaneous (5% of the additional direct annual costs)		$ 10,073.96
	Total additional annual costs	$229,609.18
	Total annual debits	$229,609.18
NET CHANGE IN INCOME		$84,321.99

Sensitivity Analysis

To see the potential effect of changes in the input and output prices, we run a sensitivity analysis. We have increased the costs of the debit items by 5 percent, 10 percent, 15 percent and 20 percent. This shows us the worst scenarios. But we also have increased the credit items in the same previous percentages, obtaining the best scenarios. Credit items come from averted costs due to the filtration system (our proposed change in the partial budget). Table 5.7 summarizes the results of this analysis.

Table 5.7 Sensitivity Analysis.

	Change in Debit or Credit Items			
	5%	10%	15%	20%
A) Increasing Debit Items – Holding Credits Constant:				
Net Change in Income ($)	72,329	60,285	48,186	36,035
Percentage Change with respect to Initial Budget (%)*	85.8	71.5	57.1	42.7
B) Increasing Credit Items – Holding Debits Constant:				
Net Change in Income ($)	99,972	115,725	131,376	147,129
Percentage Change with respect to Initial Budget (%)*	118.6	137.2	155.8	174.5

* Initial situation: Net Change = $84,322

Even with the worst cost situation, the net change in income due to the filtration system incorporation was positive. Indeed, assuming 20 percent increase of the filtration system's purchase price, labor wage, cleaner cost insurance premium and annual interest rate, the result is still favorable to the incorporation of this change. The annual interest rate is for a commercial loan to purchase the filtration equipment, 5 year period. The detailed assumptions for this analysis are included in Appendix 2. We don't have the information of the ad-valorem tax to include in the budget, but we can assume it could be covered according to the results of this sensitivity analysis and also considering we have included a miscellaneous item that increase the debits.

Econometric Models

Following Rosen (1974), we measured each z_i (the characteristics or attributes of the ultrafiltration system) so that they all may be treated as "goods". That is, consumers place positive, rather than negative, marginal valuations on these water quality enhancing attributes. For every combination of "characteristics", we have run a partial budget analysis and have obtained a corresponding set of net changes in income that could be achieved with the incorporation of this technology.

Our specific goal is to estimate not only the overall willingness to pay (WTP) but also the WTP premiums for each considered characteristic of the membrane system. As a proxy of the industry's annual WTP for the filtration system (here filtration system refers to the whole 16 membranes' kit plus the 4 hard units), we used this set of net changes in income or gross margin as a plus above the considered annual depreciation with the current prices.

That is, $WTP_{ij} = Depreciation_i + Gross\ Margin_{ij}$

where WTP_{ij} = willingness to pay for the filtration system in year "i" with characteristics' bundle "j"

$Depreciation_i$ = depreciation amount corresponding to year "i"

$Gross\ Margin_{ij}$ = gross margin in year "i" with characteristics' bundle "j"

The proposed models are :

<u>Linear</u>:

$WTP_i = \beta_0 + \beta_1 TSSr_i + \beta_2 BODr_i + \beta_3 CODr_i + \beta_4 OGr_i + \varepsilon_i$ and also

<u>Double – log</u>:

$lnWTP_i = \beta_0 + \beta_1 lnTSSr_i + \beta_2 lnBODr_i + \beta_3 lnCODr_i + \beta_4 lnOGr_i + \varepsilon_i$

where the subscript "i" indicates the considered year and the subscript "r" indicates the reduction's amount in each variable after passing through the filtration membrane; that is, the difference between the retentate and the filtrate contents attributable to the filtration system. This allows us to consider as a good the reduction in what initially is considered a bad (elevated concentrations of each pollutant).

As discussed in chapter 4, the regression coefficients of the linear model represent the "shadow prices" of product attributes (Bover and Izquierdo, 2001). In this study, the product attributes of interest are the reduction levels of each pollutant (BOD, COD, TSS, and OG).

Likewise, the regression coefficients of the double –log model represent the percentage change in WTP given a percentage change in one characteristic, holding the other variables constant. Or, in other words, each slope coefficient equals the elasticity of the dependent variable with respect to that independent variable:

$$\in_{y,x} = \frac{\partial \ln y}{\partial \ln x}$$

Table 5.8 shows the descriptive statistics of the WTP and logs of the variables.

Table 5.8. Means and Standard Deviations of the Generated WTP and Log Variables.

Variable		Reduction (Retentate-Filtrate)
WTP	*Mean*	286,688.343
($)	*Std*	1,678.66784
	n	1000
lnWTP	*Mean*	12.5661339
($)	*Std*	0.0058551481
	n	1000
lnTSS	*Mean*	0.911903739
(mg/L)	*Std*	0.038313071
	n	1000
lnBOD	*Mean*	7.69822292
(mg/L)	*Stdv*	0.0178850966
	n	1000
lnCOD	*Mean*	8.04925610
(mg/L)	*Stdv*	0.0145474022
	n	1000
lnOG	*Mean*	5.89483777
(mg/L)	*Stdv*	0.014436875
	n	1000

Considering that all the independent variables were generated using the normal distribution, normality holds as an "*a priori"* assumption. Besides normality, another important assumption of the classical linear regression model is that the variances of the disturbances or error terms are constant (homoscedastic). If homoscedasticity is rejected, the ordinary least squares (OLS) estimators of our model's parameters (the β's) are no longer efficient. We used the Breusch – Pagan (BP) test to check whether this assumption holds, and as a complement, we plotted the residuals for the two tested models. Appendix 3 presents all the relevant Limdep outputs.

In both models, the BP chi-square value was smaller than the one and five percent chi-square critical values (3.4181 and 4.9851 for the linear and double – log models, respectively). That means we fail to reject the null hypothesis that the variances of the error terms are constant (homoscedasticity holds). Therefore, we use the method of ordinary least squares (OLS) to run the models.

Tables 5.9 and 5.10 present the OLS parameter estimates for the linear and double – log models of WTP for each of the pollutant-reducing characteristics of the ultrafiltration system in the pilot plant.

As we can see in both models, neither CODR nor TSSR (neither lnCODR nor lnTSSR) were statistically significant at one percent or either at five percent levels. That means these variables are not meaningful predictors of our dependent variable (WTP and lnWTP).

In the case of COD, this pollutant does not have to pay wastewater surcharges, so it does not affect directly neither the costs of our pilot plant nor the WTP for the filtration system. The insignificance of the TSS is likely due to the fact of some pre-screening process that makes huge reductions of suspended solids before ultrafiltration takes place. Therefore, the result of this reduction is a very low level of TSS either before ultrafiltration, far below the minimum required level to be surcharged (Tables 5.2 and 5.4 and Appendix 1).

Table 5.9. Parameter Estimates for Linear Model of WTP for each of the pollutant-reducing characteristics of the ultrafiltration system in the pilot plant.

	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]
Constant	176,657.1042	0.43327635	********	0.0000
BODR	41.90280800	0.95419195E-04	********	0.0000
CODR	-0.1718137183E-04	0.82092700E-04	-0.209	0.8342
OGR	48.58221683	0.70283750E-03	********	0.0000
TSSR	-0.7576127948E-03	.40353712E-01	-0.019	0.9850

Table 5.10. Parameter Estimates for Double - Log Model of WTP for each of the pollutant-reducing characteristics of the ultrafiltration system in the pilot plant.

	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]
Constant	9.723689176	0.16723951E-02	5814.230	0.0000
lnBODR	0.3221551169	0.17775122E-03	1812.393	0.0000
lnCODR	-0.7848124624E-04	0.93408803E-04	-0.840	0.4008
lnOGR	0.6158487282E-01	0.11915521E-03	516.846	0.0000
lnTSSR	0.2376405758E-04	0.39343492E-04	0.604	0.5458

The contrary is demonstrated for the BODR and OGR variables. That is, the ulfiltration system's attributes which reduce the amount of BOD and OG present in our pilot plant industrial effluents were statistically significant. Thus, both are important in determining the annual WTP for this filtration system.

The constant term or intercept was also statistically significant in both models. It represents the value assumed by the dependent variable when all the independent variables equal zero. Despite the fact that zero is out of our variables range, it likely signals that there are other factors affecting the WTP for the ultrafiltration system. In the present research, there are no other explicit variables to be included in the model. Because there is no clear direct relationship between interactions and product characteristics, tests of inclusion of these terms produced insignificant parameter estimates.

In the linear model, the BOD and OG's coefficients represent the "shadow prices" or WTP premiums for these characteristics. That is, for every one mg/L increase in the BOD's reduction capacity of the filtration system, holding all other variables constant, this pilot plant would increase its annual WTP for it by $ 41.90. Likewise, for every one mg/L increase in the OG's reduction capacity, the annual WTP would increase $48.60 (Table 5.9). These are also called the marginal effects of each attribute.

The regression coefficients of the double –log model represent the percentage change in WTP given a percentage change in one characteristic, holding the other variables constant. In our estimation for this pilot plant operation, for every one percent increase in BOD's reduction capacity of the filtration system, holding all other variables constant, this pilot plant would increase its annual WTP for it by 0.32 percent. Likewise, for every one percent increase in OG's reduction capacity, the annual WTP would increase 0.62 percent.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Summary

The poultry industry is the single largest agribusiness industry in Georgia and one of the most important in the United States. It is also facing multiple water usage problems stemming from rising water and sewer charges and an increase in pollution regulations. One way to reduce water usage and volume of wastewater is through recycling the chiller water used in processing. Food scientists and applied economists at the University of Georgia are collaborating on research to evaluate the operational and economic effectiveness of ultrafiltration membrane technologies (polymeric) at a pilot poultry processing plant in Georgia. The objective of this study is to analyze economically the recycling process of chiller water in a pilot poultry processing plant using a polymeric ultrafiltration membrane system.

On-site tests of membrane systems are underway. However, more observations for the considered variables were generated, due to the small number of sample observations. To do this we have used the random normal generation procedure of the software Limdep. Limdep (version 7.0) was also used to run the econometric models.

Preliminary economic feasibility was highly positive. This is consistent with results from other manufacturing settings, where similar systems have been employed. The partial budget analysis has shown encouraging results, with a positive annual change in income of $84,322 and a return rate equal to 36.7 percent, which is good compared with the RMA indicators for this industry. The sensitivity analysis conducted has indicated that even in the worst cost situation (increasing debit items by 20% and holding credits constant), the net change in income due to the filtration system incorporation was positive.

For each combination of the pollutants BOD, COD, OG and TSS, we constructed a partial budget and added the annual depreciation amount of money plus the net change in income reached. This new variable was used as a proxy of our pilot plant's annual willingness- to- pay (WTP) for the product "ultrafiltration system". This system includes 4 hard units (pumps and tanks) and 16 membrane units (of 150 square meters each), required to filter the daily amount of chiller water overflow.

Using a hedonic approach, we run two models to assess how the specific reduction capacity for each pollutant affects the WTP. Only BOD reduction and OG reduction were statistically significant. In the linear model, the BOD and OG's coefficients represent the "shadow prices" or WTP premiums for these characteristics. For every one mg/L increase in the BOD's reduction capacity of the filtration system, holding all other variables constant, this pilot plant would increase its annual WTP for that unit by \$41.90. Likewise, for every one mg/L increase in the OG's reduction capacity, the annual WTP would increase \$48.60.

The regression coefficients of the double –log model represent the percentage change in WTP given a percentage change in one characteristic, holding the other variables constant. In our situation, for every one percent increase in BOD's reduction capacity of the filtration system, holding all other variables constant, this pilot plant would increase its annual WTP for that unit by 0.32 percent. Likewise, for every one percent increase in OG's reduction capacity, the annual WTP should increase 0.62 percent.

It was also important to notice that the BOD and OG levels of the chiller water before filtration were above the allowed limits for industrial effluents. Therefore, filtration produced multiple benefits, such as reduction on levels of pollutant of the effluents (allowing the plant to operate among the allowed range of pollutant discharges), minimization of the environmental contamination, achieving the EPA requirements, positive economic feasibility, even in the worst cost increasing scenarios modeled. Economically efficient technological breakthroughs are essential if the U.S. poultry industry is to continue operating competitively.

Conclusions

With the data gathered so far, our initial findings of incorporating an ultrafiltration chiller water recycling unit in the pilot poultry processing plant indicate positive impacts. At the specific plant level, the profitability could be more than $80k per year, supporting considerable variations on cost scenarios. This profitability comes mainly from averted costs the firm would face because of reducing pollutant discharges to the environment. The pollutants which reduction by filtration affects the economic result are mainly BOD and OG. The reduction achieved on the microorganisms levels (TPC and Coliforms) and the increase in light transmission (LT, as a measure of turbidity's reduction) by ultrafiltration in the pilot plant, have met the EPA requirements for recycling chiller water at the highest allowed ratio of 1:10 volumes of recycled water to substitute 1 volume of freshwater (1.10 : 1).

Importantly, this technology addresses the water quantity and quality issues that have been raised in this industry by reducing primary water use by approximately 36.5 mega gallons and electrical energy use to chill water by nearly 1.03 gigawatt-hours annually in our pilot plant. Given that such poultry processing plants can have very large local impacts, these averted water and sewage treatment savings are quite significant to municipalities and stressed watersheds. Taking into account that some counties have different water and wastewater rates (Appendix 1), the economic analysis must consider every site-specific situation. Considering that the poultry production in Georgia in 2003 was 1.26 billion birds (Georgia Agricultural Statistics Service., 2004) and our pilot plant process 85,800,000 birds annually (330,000 birds/day x 260 annual operating days), then our pilot plant represents 6.8% of Georgia's total annual production. This implies that the impact of incorporating this filtration system on the poultry industry of the State of Georgia for recycling chiller water, under the assumptions considered in the present study can produce savings of 524 mega gallons of water per year and 14.7 gigawatt –hour per year.

From the ultrafiltration system suppliers' viewpoint, it seems that special attention deserves the filtration performance of the two significant pollutants in this industry: BOD and OG. This could be relevant in order to price the product.

The importance of this study is that it represents a first approach to the feasibility of this new water recycling method in the poultry processing industry, and also gives some orientation about which intrinsic characteristics of the filtration system deserves special attention because they affects the WTP. The weakness of the study is the small number of records in some variables, which can be hiding a higher variability in real conditions.

Further stages of this research may consider to improve this aspect and also to extend the scope including not only the chiller water but also all the water used in the processing plant. The present analytical frame can be used easily in next stages.

REFERENCES

Advantage Georgia (1998) European Edition. Vol. I, Issue III. 3rd Quarter. Internet site: http://www.southerncompany.com/gapower/grc/pdf/AdGaEur3.pdf.

Alpizar, F., F. Carlsson, and P. Martinsson (2001) Using Choice Experiments for Non-Market Valuation., Working Papers in Economics No. 52. Gothenburg University. Department of Economics. Internet site: http://www.handels.gu.se:81/epc/archive/00001849/01/gunwpe0052.pdf.

Ardila, S., R. Quiroga, and W. J. Vaughan (1998) A Review of the Use of Contingent Valuation Methods in Project Analysis at the Inter-American Development Bank, Environment Division Technical Study ENV-126. Washington, D.C.: Inter-American Development Bank. December. Internet site: http://www.iadb.org/sds/doc/ENV126e.pdf.

Avent, R. K., C. E. Ward, and D. L. Lalman. "Market Valuation of Preconditioning Feeder Calves." *Journal of Agricultural and Applied Economics* (2004).

Bailey, D. V., M. C. Peterson, and B. W. Brorsen. "A Comparison of Video Cattle Auction and Regional Market Prices." *American Journal of Agricultural Economics.* Vol. 73, no. No. 2(1991): 465-475.

Bank of America (2005), Internet site: http://www.bankofamerica.com/.

Bhattarai, G. R., R. Pandit, and D. Hite (2004) Willingness to Pay for Public Goods: A Hedonic Demand Model for Neighborhood Safety, School and Environmental quality. Tulsa, Oklahoma, Southern Agricultural Economics Association, pp. 21.

Board of Natural Resources. State of Georgia (2001) Water Issues White Paper. Atlanta, Georgia.

Bover, O., and M. Izquierdo (2001) Quality-adjusted prices: Hedonic methods and implications for national accounts, The Banco de España Research Department. Internet site: http://www.bde.es/informes/be/sazul/azul70e.pdf.

Bugos, G. E. "Intellectual Property Protection in the American Chicken-Breeding Industry." *The Business History Review* 66, no. 1(1992): 127-168.

California Energy Commission (2002) Applications of Ozonation and Membrane Treatment in Poultry Processing. Final report. Sacramento, California, Internet site: http://www.energy.ca.gov/reports/2003-03-21_400-02-023F.PDF.

Carawan, R. E., and B. Merka (1996) Poultry CEO'S: You May Have a $60 Million Opportunity! North Carolina Cooperative Extension Service., ed. Publication Number: CD-24. Internet site: http://www.bae.ncsu.edu/programs/extension/publicat/wqwm/cd24.html.

Cassel, E., and R. Mendelsohn. "The choice of functional forms for hedonic price equations: Comment." *Journal of Urban Economics* 18, no. 2(1985): 135-142.

Champ, P. A., K. J. Boyle, and T. C. Brown, eds. *A primer on nonmarket valuation*. Dordrecht; Boston and London: Kluwer Academic, 2003.

Chang, S. Y., R. T. Toledo, and H. S. Lillard. "Clarification and decontamination of poultry chiller water for recycling." *Poultry Science* 68, no. 8(1989): 1100-1108.

Chang, Y. H., and B. W. Sheldon. "Application of ozone with physical wastewater treatments to recondition poultry process waters." *Poultry Science* 68, no. 8(1989): 1078-1087.

Chang, Y. H., B. W. Sheldon, and Carawan R.E. "Research Note: Reconditioning of Prechiller Overflow Water Using a Diatomaceous Earth Pressure Leaf Filter." *Poultry Science.* 68(1989): 447 - 449.

Cheremisinoff, N. P. *Liquid Filtration.* 2nd ed: Elsevier., 1998.

Deaton, A., and J. Muellbauer. *Economics and consumer behavior*. Cambridge ; New York: Cambridge University Press, 1980.

Dhuyvetter, K. C., et al. "Determinants of Purebred Beef Bull Price Differentials." *Journal of Agricultural and Resource Economics* 21, no. 2(1996): 396-410.

Edmonds, R. G. "A Theoretical Basis for Hedonic Regression: A Research Primer." *Real Estate Economics* 12, no. 1(1984): 72-85.

eLease International Inc. (2005) Equipment leasing, Internet site: http://www.eleaseinternational.com/.

Fernandez-Cornejo, J., and S. Jans. "Quality-adjusted price and quantity indices for pesticides." *American Journal of Agricultural Economics* 77, no. 3(1995): 645.

Freeman, A. M. *The Measurement of Environmental and Resource Values : Theory and Methods*. 2nd ed. Washington, DC: Resources for the Future, 2003.

Georgia Agricultural Statistics Service. (2004). Internet site: http://www.nass.usda.gov/ga/pubs/agfacts/pltrysec.pdf.

Goodman, A. C. (1978) Hedonic Prices, Price Indices and Housing Markets., vol. 5, Academic Press Inc., pp. 471.

Greene, W. H. *LIMDEP: Version 7.0.* New York: Econometric Software Inc., 1996.

Griliches, Z. *Hedonic Price Indexes for Automobiles: An Econometric Analysis of Quality Change.* Edited by National Bureau of Economic Research. Price Statistics Review Committee., United States. Congress. Joint Economic Committee., and United States. Bureau of the Budget. Office of Statistical Standards. New York., 1961.

Griliches, Z. *Price Indexes and Quality Change. Studies in New Methods of Measurement*. Edited by Griliches for the Price Statistics Committee. Board of Governors of the Federal Reserve System (U.S.). Cambridge, Mass.: Harvard University Press, 1971.

Hart, M. R., et al. "Microfiltration of chicken process waters for reuse: plant studies and projected operating costs." *Journal of Food Process Engineering* 12, no. 3(1990): 191-210.

Hart, M. R., et al. "Preliminary studies of microfiltration for food processing water reuse." *Journal of Food Protection* 51, no. 4(1988): 269-276.

Herriges, J. A., S. Secchi, and B. A. Babcock (2003) Living with Hogs in Iowa: The Impact of Livestock Facilities on Rural Residential Property Values., Iowa State University, Center for Agricultural and Rural Development. Downloaded from http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=11100&ftype=.pdf.

Hodgson, D. J., and K. P. Vorkink. "Asset Pricing Theory and the Valuation of Canadian Paintings." *Canadian Journal of Economics* 37, no. 3(2004): 629-55.

Jaffe, S. M., and J. D. Phillips (2004) Water Reuse and Pathogen Reduction Part of the Solution or Part of the Problem ?, Zentox Corporation, 538 Wythe Creek Road, Poquoson, VA 23662. Internet site: http://www.zentox.com/Cascade/pathogen2.pdf.

Jordan, J. L. (1998) Georgia Water Series -- Issue 1: An Introduction to Water: Economic Concepts, Water Supply and Water Use., University of Georgia. Department of Agricultural and Applied Economics. Athens, Georgia. Internet site: http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=941&ftype=.pdf.

Jordan, J. L. (1998) Georgia Water Series -- Issue 4: Issues in Water Pricing., University of Georgia. Department of Agricultural and Applied Economics. Athens, Georgia. Internet site: http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=948&ftype=.pdf.

Kiepper, B. H. "Characterization of poultry processing operations, wastewater generation, and wastewater treatment using mail survey and nutrient discharge monitoring methods." M.S. Thesis, Department of Food Science & Technology, The University of Georgia., 2003.

Lancaster, K. J. "A New Approach to Consumer Theory." *Journal of Political Economy.* 74, no. 2(1966): 132-157.

Lillard, H. S. "Effect on Broiler Carcasses and Water of Treating Chiller Water with Chlorine or Chlorine Dioxide." *Poultry Science* 59, no. 8(1980): 1761-1766.

Lusk, J. L., T. Feldkamp, and T. C. Schroeder. "Experimental Auction Procedure: Impact on Valuation of Quality Differentiated Goods." *American Journal of Agricultural Economics* 86, no. 2(2004): 389-405.

Mannapperuma, J. D., and M. R. Santos. "Reconditioning Poultry Chiller Overflow by Ultrafiltration." *Journal of Food Process Engineering* 27, no. 6(2004): 497-516.

Munroe, D. K., D. C. Parker, and H. S. J. Campbell (2004) The Varied Impact of Greenways on Residential Property Values in a Metropolitan, Micropolitan, and Rural Area: The Case of the Catawba Regional Trail. Denver, Colorado, American Agricultural Economics Association. Internet site: http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=14264&ftype=.pdf, pp. 27.

Murray, M. P. "Hedonic Prices and Composite Commodities." *Journal of Urban Economics* 5, no. 2(1978): 188.

Nganje, W. E., et al. (2005) Consumer Willingness to Pay for Breads Marketed as "Low-Carbohydrate". Providence, Rhode Island, American Agricultural Economics Association. Internet site: http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=16572&ftype=.pdf, pp. 22.

Northcutt, J. K., and D. R. Jones. "A Survey of Water Use and Common Industry Practices in Commercial Broiler Processing Facilities." *Journal of Applied Poultry Research* 13(2004): 48-54.

Ollinger, M., J. Mac Donald, and M. Madison (2000) Structural Change in U.S. Chicken and Turkey Slaughter. Washington, DC 20036-5831, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 787. Internet site: http://www.ers.usda.gov/publications/aer787/aer787.pdf.

Ollinger, M., J. M. MacDonald, and M. Madison. "Technological Change and Economies of Scale in U.S. Poultry Processing." *American Journal of Agricultural Economics* 87, no. 1(2005): 116-129.

Perez-Garcia, J., and C. Guerrero de Lizardi (2002) Comparación del precio de los ordenadores en Estados Unidos y España 1990-2000: un enfoque hedónico. Madrid, Instituto de Predicción Económica L.R.Klein – Centro Stone, Facultad de CC. EE. y EE. Universidad Autónoma de Madrid. Internet site: http://www.uam.es/otroscentros/klein/stone/fiirs/cuadernos/pdf/FIIRS005.PDF.

Robert Morris Associates. (2004) Annual statement studies. Philadelphia, Robert Morris Associates., pp. 12 v.

Romans, J. R., et al. *The Meat We Eat.* Thirteenth Edition ed. Danville, Illinois: Interstate Publishers, 1994.

Rosen, S. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *The Journal of Political Economy.* 82, no. 1(1974): 34-55.

Russell, S. M. (2003) Processing tip . . .Water Reuse Considerations., ed. The University of Georgia. College of Agricultural and Environmental Sciences. Athens, Georgia 30602-4356, Cooperative Extension Service.

Scott, K., and R. Hughes (1996) Industrial membrane separation technology., London : Blackie Academic & Professional.

Sepro Rochem Inc. 4115 Avenida de la Plata, Oceanside, CA 92056, Internet site: http://www.sepromembranes.com/.

Sheldon, B. W., and A. L. Brown. "Efficacy of ozone as a disinfectant for poultry carcasses and chill water." *Journal of Food Science* 51, no. 2(1986): 305-309.

Sheldon, B. W., and R. E. Carawan. "Demonstration for selected food processes of a pollution reduction system utilizing ozonation, Phase II." Department of Food Science North Carolina State University.

Steiner, B. E. "Australian Wines in the British Wine Market: A Hedonic Price Analysis." *Agribusiness* 20, no. 3(2004): 287-307.

Tomkovick, C., and K. E. Dobie. "Applying Hedonic Pricing Models and Factorial Surveys at Parker Pen to Enhance New Product Success." *Journal of Product Innovation Management* 12, no. 4(1995): 334-345.

Tsai, L. S., R. Higby, and J. Schade. "Disinfection of Poultry Chiller Water with Chlorine Dioxide: Consumption and Byproduct Formation." *Journal of Agricultural and Food Chemistry.* 43(1995): 2768 - 2773.

U.S. Census Bureau. Census of Manufacturers (2002). Washington, D.C., U.S. Department of Commerce.

U.S. Department of Agriculture. Economic Research Service. (2004) Briefing rooms, Poultry and eggs. Washington, D.C., Economic Research Service.

U.S. Department of Agriculture. Food Safety and Inspection Service (2004) Code of Federal Regulations. Title 9, Part 381. Poultry Products. Washington, D.C., Office of the Federal Register.

U.S. Department of Agriculture. Food Safety and Inspection Service (1987) Code of Federal Regulations. Title 9, Section 381.66. Washington, D.C., Office of the Federal Register.

U.S. Department of Agriculture. Food Safety and Inspection Service (1996) Part II. Food Safety and Inspection Service. 9 CFR Part 304, et al. Pathogen Reduction, Hazard Analysis and Critical Control Point System Final Rule. 38806 Federal Register. Vol. 61, No. 144. Thursday, July 25, 1996. Rules and Regulations. Washington, D.C.

U.S. Environmental Protection Agency. Office of Water (2002) Development Document for the Proposed Effluent Limitations Guidelines and Standards for the Meat and Poultry Products Industry Point Source Category., vol. 2004. Washington, D.C.

U.S. Environmental Protection Agency. Office of Water (2004) Guidelines for Water Reuse. Washington, D.C.

Vaughan, W. J., and S. Ardila (1993) Economic Analysis of the Environmental Aspects of Investment Projects., Inter-American Development Bank, Productive Sectors and Environment Subdepartment, Environment Protection Division, Working Paper ENP100. December.

Wang, Z. "Hedonic Prices for Crude Oil." *Applied Economics Letters* 10, no. 13(2003): 857-61.

Waugh, F. V. "Quality Factors Influencing Vegetable Prices." *Journal of Farm Economics.* 10, no. 2(1928): 185-196.

Appendix 1 – Water and Wastewater' Rates

1.1 Athens – Clarke, GA

UNIFIED GOVERNMENT OF ATHENS-CLARKE COUNTY, GEORGIA

FEE SCHEDULE FOR WATER AND WASTEWATER SERVICES[1]
Adopted by ordinance- 06/03/2003.

([1]Athens-Clarke County reserves the right to change the charges for water and wastewater service upon passage of an ordinance.)

CHARGES FOR USING THE SYSTEM

WATER (Effective with the first billing cycle in July 2003)

The water charge is computed as the sum of the base charge, based on meter size, and the unit charge, based on consumption.

Consumption (Per 100 cubic feet)

Residential	$2.00
Non-Residential	$1.73

Base Charge by Meter Size

Size		Size	
5/8" or 3/4"	$5.95	3"	$30.59
1"	$6.60	4"	$40.10
1½"	$8.20	6"	$90.23
2"	$23.19	8"	$117.53

WASTEWATER (Effective with the first billing cycle in July 2003)

The wastewater charge is computed as the sum of the base charge and the unit charge, based on consumption.

Consumption	Residential	Non-Residential
Per 100 cubic feet	$1.54	$1.54
Base Charge	$5.60	$5.60

- Residential wastewater volume is equal to eighty percent (80%) of the water volume unless approved differently by the Public Utilities Director.
- Non-residential wastewater volume is equal to the water volume unless approved differently by the Public Utilities Director.

WASTEWATER SURCHARGE RATES

Parameter	Concentration (mg/l)	Charge (per 1,000 lbs.)
BOD_5	251 – 500	$46.00
	501 – 750	$92.00
	751 – 1000 (maximum allowed)	$138.00
TSS	251 – 500	$103.00
	501 – 750 (maximum allowed)	$135.00
Oil and Grease	101 – 150	$80.00
	151 – 200 (maximum allowed)	$160.00

- An industrial cost recovery charge on processed wastewater is computed by the Athens-Clarke County Public Utilities Department.

CHARGES TO ESTABLISH SERVICE

CONNECTION FEES (Effective 02/01/87)

Meter Size	Water Connection Fee	Wastewater Connection Fee
3/4"	$270.00	$380.00
1"	$450.00	$630.00
1½"	$900.00	$1,270.00
2"	$2,700.00	$3,800.00
3"	$4,725.00	$6,650.00
4"	$9,450.00	$13,300.00
6"	$18,900.00	$26,600.00

TAP AND METER CHARGES (Effective 07/01/90)

3/4" water meter	$165.00
3/4" water stub	$210.00
1" water meter	$310.00
1" water stub	$225.00

1½" water meter	$450.00
1½" water stub	$300.00
2" water meter	$2,900.00
2" water stub	$350.00

4" sewer stub	$240.00*
6" sewer stub	$250.00*
8" sewer stub	$285.00*
Paving cuts – minimum	$275.00**
Bullheads – minimum	$100.00**

- Sizes larger than those listed are calculated by the Public Utilities Director.
- Add $100.00 for installations requiring DOT right-of-way encroachment permit.

*Plus casing & manhole.

**Plus additional amounts as determined by the Public Utilities Director based on actual labor, material and equipment charges.

1.2 Gainsville, GA

City of Gainesville

Water and Sewer Rates and Policies

JANUARY 2005

PAYMENTS

Payments are due within 20 days of the bill date. Checks may be mailed to:

City of Gainesville
757 Queen City Parkway, SW
Gainesville, GA 30501

Cash, check and credit card payments may also be made in the Customer Account Services Department located on the first floor of the Public Utilities Administration Building at 757 Queen City Parkway, SW. Our convenient drive-through windows are open from 7:00 AM to 6:00 PM Monday through Friday. Inside windows are open from 8:00 AM to 5:00 PM. Credit card payments can be made by phone by calling 770-535-6878, Monday through Friday from 7:00 AM to 6:00 PM.

When the office is closed, your payment plus the remittance section of the bill may be placed in one of the envelopes provided for your convenience, and dropped in the *Night Deposit Box* located on the drive through side of the building. The City of Gainesville is not responsible for **cash** deposited in this manner.

WATER TAP/METER, CONNECTION & ADMINISTRATIVE FEES

TAP SIZE	Tap & Meter	Connect	Admin	Total
3/4-Inch	$527	$888	$26	**$1,441**
1-Inch	$591	$2,219	$66	**$2,876**
1½-Inch	$1,300	$4,439	$133	**$5,872**
2-Inch	$1,390	$7,102	$213	**$8,705**
3-Inch	$6,287	$14,204	$426	**$20,917**
4-Inch		$22,194	$665	---
6-Inch		$44,389	$1,331	---
8-Inch		$71,022	$2,130	---

4 to 8-Inch Tap & Meter Fees are charged at actual cost for time and materials and require a fully-executed Agreement to Pay at time application for service is made.

SEWER TAPPPING FEES

For a 6-inch service line serving a single dwelling or commercial unit the cost is **$745.**

***Sanitary sewer service lines over 6-Inches shall be charged an additional fee at actual cost per inch.**

SEWER TAP, CONNECTION & ADMINISTRATIVE FEES

METER SIZE (Inches)	*6" Tap	Connect	Admin	Total
¾-Inch	$745	$1,725	$51	**$2,521**
1-Inch	$745	$4,313	$129	**$5,187**
1½-Inch	$745	$8,625	$258	**$9,628**
2-Inch	$745	$13,800	$414	**$14,959**
3-Inch	$745	$27,600	$828	**$29,173**
4-Inch	$745	$43,126	$1,293	**$45,164**
6-Inch	$745	$86,252	$2,587	**$89,584**
8-Inch	$745	$138,002	$4,140	**$142,887**

INDUSTRIAL SURCHARGES
(Charges Per mg/l)

	250-500	501-700	701-900	900+
BOD	$0.0014	$0.0028	$0.0056	$0.0112
TSS	$0.0009	$0.0018	$0.0036	$0.0072
	101-125	126-150	151-175	176+
FOG	$0.0035	$0.007	$0.014	$0.028
	7-11	12-15	16-20	21+
PHOS	$0.014	$0.028	$0.056	$0.112
	40-75	76-100	101-135	136+
TKN	$0.004	$0.008	$0.016	$0.032

ADDITIONAL INFORMATION

The property owner must provide his/her own cutoff valve. Using the turn off at the meter is not permissible.

Each lot, tract or parcel of land to be served by the city water system, within or without the city limits, shall be served by its own individual water meter.

A water meter cannot be moved or transferred from the original lot, tract or parcel of land it was purchased to serve and remains the property of the City of Gainesville.

A water meter can be relocated on the same lot, tract or parcel after making application and paying the cost estimate prepared by the Public Utilities Department.

Note for City of Gainesville Residents:

Your utility bill will include monthly charges for:
Trash Removal—$15.00
Landfill—$3.35
Recycling—$3.30

In the case of multi-unit accounts, these fees will be charged for each unit.

For questions concerning these fees, please call the Solid Waste Division of the Public Works Department at 770-532-0493.

If you have a question about your bill, our Customer Service Representatives can be reached at 770-535-6878, 7 AM through 6 PM Monday through Friday.

For questions about purchasing a new water or sewer tap, please call the Engineering & Planning Division at 770-535-6892 between the hours of 8 a.m. and 5 p.m. Monday through Friday.

For other information on water and sewer service, to report broken water mains, etc. call 770-535-6881.

1.3 Rockdale, GA

About Rockdale County Government

Water Business Operations Division

The Rockdale Water Resources Business Operations and Meter Reading division handles customer service, billing of water and wastewater (sewer) services and meter reading. Cash, check, credit card (Visa and MasterCard), or bank draft are accepted as forms of payment.

Hours of operation: 8:00 a.m. to 5:00 p.m., Monday through Friday
Payments may be deposited in drop-box 24 hours a day

Address/Location
Directions
Contact Phone Numbers
Bills/Past Due Notices
Water and Wastewater Rates
Water and Wastewater Volume Rates
Rate/Fee Description

Address:
958 Milstead Avenue, Room 101, Conyers, Georgia 30012
Rockdale County Administration & Services Building
Across the street from the Rockdale County Courthouse
After hours drop box available at this location

Industrial Surcharge:

Allowable Limit	Cost Per Pound
BOD>250 mg/L	$ .24
TSS>250 mg/L	$ .24
Ammonia>20 mg/L	$ .21
Phosphorus>10 mg/L	$3.19

Computation:
Excess Chemical Factor X Liter Factor (8.34) X Effluent (MGD)
X Per Pound Charge X # of Days

Industrial surcharge includes any direct allocated expenses for any industrial pretreatment program maintained by Rockdale County.

Appendix 2 – Sensitivity Analysis Assumptions

I) Initial situation (using average level of pollutants of our Pilot Plant)

CREDITS		$	units	DEBITS	$	units
Cost of energy		$0,0429	Kwatt/hour	Price of filtration units	$20.000,00	membranes (150 m2 kit)
					$42.000,00	pump & tank (hard unit)
Cost of water		$1,7300	per 100 cubic feet	Annual Interest Rate	8,00%	
	+	$23,1900	/month base charge			
Cost of sewage		$1,5400	per 100 cubic feet	Insurance premium	$18.056,00	
	+	$5,6000	/month base charge			
				Wages (labor)	$9,270	/hour
OG (mg/L) per 1000 lbs		$160,0000	(max= 151-200 mg/L)			
TSS (mg/L) per 1000 lbs		$0,0000	(min= 251-500 mg/L)	Cleaner	$1,886	/ L (or $ 392.60 per 55 gal drum)
BOD (mg/L) per 1000 lbs		$138,0000	(max= 751-1000 mg/L)			

II) Initial situation with 5% increase on DEBITS ITEMS

CREDITS		$	units	DEBITS	$	units
Cost of energy		$0,0429	Kwatt/hour	Price of filtration units	$21.000,00	membranes (150 m2 kit)
					$44.100,00	pump & tank (hard unit)
Cost of water		$1,7300	per 100 cubic feet	Annual Interest Rate	8,40%	
	+	$23,1900	/month base charge			
Cost of sewage		$1,5400	per 100 cubic feet	Insurance premium	$18.958,80	
	+	$5,6000	/month base charge			
				Wages (labor)	$9,734	/hour
OG (mg/L) per 1000 lbs		$160,0000	(max= 151-200 mg/L)			
TSS (mg/L) per 1000 lbs		$0,0000	(min= 251-500 mg/L)	Cleaner	$1,980	/ L
BOD (mg/L) per 1000 lbs		$138,0000	(max= 751-1000 mg/L)			

III) Initial situation with 10% increase on DEBITS ITEMS

CREDITS		$	units	DEBITS	$	units
Cost of energy		$0,0429	Kwatt/hour	Price of filtration units	$22.000,00	membranes (150 m2 kit)
					$46.200,00	pump & tank (hard unit)
Cost of water		$1,7300	per 100 cubic feet	Annual Interest Rate	8,80%	
	+	$23,1900	/month base charge			
Cost of sewage		$1,5400	per 100 cubic feet	Insurance premium	$19.861,60	
	+	$5,6000	/month base charge			
				Wages (labor)	$10,197	/hour
OG (mg/L) per 1000 lbs		$160,0000	(max= 151-200 mg/L)			
TSS (mg/L) per 1000 lbs		$0,0000	(min= 251-500 mg/L)	Cleaner	$2,075	/ L
BOD (mg/L) per 1000 lbs		$138,0000	(max= 751-1000 mg/L)			

IV) Initial situation with 15% increase on DEBITS ITEMS

CREDITS		$	units	DEBITS	$	units
Cost of energy		$0,0429	Kwatt/hour	Price of filtration units	$23.000,00	membranes (150 m2 kit)
					$48.300,00	pump & tank (hard unit)
Cost of water		$1,7300	per 100 cubic feet	Annual Interest Rate	9,20%	
	+	$23,1900	/month base charge			
Cost of sewage		$1,5400	per 100 cubic feet	Insurance premium	$20.764,40	
	+	$5,6000	/month base charge			
				Wages (labor)	$10,661	/hour
OG (mg/L) per 1000 lbs		$160,0000	(max= 151-200 mg/L)			
TSS (mg/L) per 1000 lbs		$0,0000	(min= 251-500 mg/L)	Cleaner	$2,169	/ L
BOD (mg/L) per 1000 lbs		$138,0000	(max= 751-1000 mg/L)			

V) Initial situation with 20% increase on DEBITS ITEMS

CREDITS		$	units	DEBITS	$	units
Cost of energy		$0,0429	Kwatt/hour	Price of filtration units	$24.000,00	membranes (150 m2 kit)
					$50.400,00	pump & tank (hard unit)
Cost of water		$1,7300	per 100 cubic feet	Annual Interest Rate	9,60%	
	+	$23,1900	/month base charge			
Cost of sewage		$1,5400	per 100 cubic feet	Insurance premium	$21.667,20	
	+	$5,6000	/month base charge			
				Wages (labor)	$11,124	/hour
OG (mg/L) per 1000 lbs		$160,0000	(max= 151-200 mg/L)			
TSS (mg/L) per 1000 lbs		$0,0000	(min= 251-500 mg/L)	Cleaner	$2,263	/ L
BOD (mg/L) per 1000 lbs		$138,0000	(max= 751-1000 mg/L)			

VI) 5% increase on CREDITS ITEMS over Initial situation

CREDITS		$	units	DEBITS	$	units
Cost of energy		$0,0450	Kwatt/hour	Price of filtration units	$20.000,00	membranes (150 m2 kit)
					$42.000,00	pump & tank (hard unit)
Cost of water		$1,8165	per 100 cubic feet	Annual Interest Rate	8,00%	
	+	$24,3495	/month base charge			
Cost of sewage		$1,6170	per 100 cubic feet	Insurance premium	$18.056,00	
	+	$5,8800	/month base charge			
				Wages (labor)	$9,270	/hour
OG (mg/L) per 1000 lbs		$168,0000	(max= 151-200 mg/L)			
TSS (mg/L) per 1000 lbs		$0,0000	(min= 251-500 mg/L)	Cleaner	$1,886	/ L (or $ 392.60 per 55 gal drum)
BOD (mg/L) per 1000 lbs		$144,9000	(max= 751-1000 mg/L)			

VII) 10% increase on CREDITS ITEMS over Initial situation

CREDITS		$	units	DEBITS	$	units
Cost of energy		$0,0472	Kwatt/hour	Price of filtration units	$20.000,00	membranes (150 m2 kit)
					$42.000,00	pump & tank (hard unit)
Cost of water		$1,9030	per 100 cubic feet	Annual Interest Rate	8,00%	
	+	$25,5090	/month base charge			
Cost of sewage		$1,6940	per 100 cubic feet	Insurance premium	$18.056,00	
	+	$6,1600	/month base charge			
				Wages (labor)	$9,270	/hour
OG (mg/L) per 1000 lbs		$176,0000	(max= 151-200 mg/L)			
TSS (mg/L) per 1000 lbs		$0,0000	(min= 251-500 mg/L)	Cleaner	$1,886	/ L (or $ 392.60 per 55 gal drum)
BOD (mg/L) per 1000 lbs		$151,8000	(max= 751-1000 mg/L)			

VIII) 15% increase on CREDITS ITEMS over Initial situation

CREDITS		$	units	DEBITS	$	units
Cost of energy		$0,0493	Kwatt/hour	Price of filtration units	$20.000,00	membranes (150 m2 kit)
					$42.000,00	pump & tank (hard unit)
Cost of water		$1,9895	per 100 cubic feet	Annual Interest Rate	8,00%	
	+	$26,6685	/month base charge			
Cost of sewage		$1,7710	per 100 cubic feet	Insurance premium	$18.056,00	
	+	$6,4400	/month base charge			
				Wages (labor)	$9,270	/hour
OG (mg/L) per 1000 lbs		$184,0000	(max= 151-200 mg/L)			
TSS (mg/L) per 1000 lbs		$0,0000	(min= 251-500 mg/L)	Cleaner	$1,886	/ L (or $ 392.60 per 55 gal drum)
BOD (mg/L) per 1000 lbs		$158,7000	(max= 751-1000 mg/L)			

IX) 20% increase on CREDITS ITEMS over Initial situation

CREDITS		$	units	DEBITS	$	units
Cost of energy		$0,0515	Kwatt/hour	Price of filtration units	$20.000,00	membranes (150 m2 kit)
					$42.000,00	pump & tank (hard unit)
Cost of water		$2,0760	per 100 cubic feet	Annual Interest Rate	8,00%	
	+	$27,8280	/month base charge			
Cost of sewage		$1,8480	per 100 cubic feet	Insurance premium	$18.056,00	
	+	$6,7200	/month base charge			
				Wages (labor)	$9,270	/hour
OG (mg/L) per 1000 lbs		$192,0000	(max= 151-200 mg/L)			
TSS (mg/L) per 1000 lbs		$0,0000	(min= 251-500 mg/L)	Cleaner	$1,886	/ L (or $ 392.60 per 55 gal drum)
BOD (mg/L) per 1000 lbs		$165,6000	(max= 751-1000 mg/L)			

Appendix 3 – Limdep Outputs

I) LINEAR MODEL

--> DSTAT;Rhs=BODR,CODR,OGR,TSSR,ANNUAWTP;Output=3$

Descriptive Statistics

All results based on nonmissing observations.

Variable	Mean	Std.Dev.	Minimum	Maximum	Cases
BODR	2204.77926	39.4276150	2080.65256	2316.63425	1000
CODR	3131.79554	45.5378181	2978.14528	3268.49190	1000
OGR	363.195715	5.24182640	344.710817	379.083477	1000
TSSR	2.49087677	.950394488E-01	2.17990106	2.84780546	1000
ANNUAWTP	286688.343	1678.66784	281384.428	291302.001	1000

Matrix COV.MAT. has 5 rows and 5 columns

	BODR	CODR	OGR	TSSR	ANNUAWTP
BODR	.1554537D+04	-.3187300D+02	.5783657D+01	.1113727D+00	.6542044D+05
CODR	-.3187300D+02	.2073693D+04	-.1291722D+02	.1874063D+00	-.1963151D+04
OGR	.5783657D+01	-.1291722D+02	.2747674D+02	-.2835030D-01	.1577233D+04
TSSR	.1113727D+00	.1874063D+00	-.2835030D-01	.9032497D-02	.3289497D+01
ANNUAWTP	.6542044D+05	-.1963151D+04	.1577233D+04	.3289497D+01	.2817926D+07

Correlation Matrix for Listed Variables

	BODR	CODR	OGR	TSSR	ANNUAWTP
BODR	1.00000	-.01775	.02798	.02972	.98844
CODR	-.01775	1.00000	-.05411	.04330	-.02568
OGR	.02798	-.05411	1.00000	-.05691	.17925
TSSR	.02972	.04330	-.05691	1.00000	.02062
ANNUAWTP	.98844	-.02568	.17925	.02062	1.00000

--> Regress; Lhs=ANNUAWTP; Rhs=ONE,BODR,CODR,OGR,TSSR; HET $

```
+-----------------------------------------------------------------------+
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = ANNUAWTP Mean=   286688.3433    , S.D.=    1678.667837    |
| Model size: Observations =    1000, Parameters =   5, Deg.Fr.=    995 |
| Residuals:  Sum of squares= 14.21487180    , Std.Dev.=          .11953 |
| Fit:        R-squared= 1.000000, Adjusted R-squared =         1.00000 |
| Model test: F[  4,    995] =********,    Prob value =          .00000 |
| Diagnostic: Log-L =     707.7947, Restricted(b=0) Log-L =   -8844.1941 |
|             LogAmemiyaPrCrt.=   -4.243, Akaike Info. Crt.=     -1.406 |
| Autocorrel: Durbin-Watson Statistic =   1.91293,    Rho =       .04354 |
| Results Corrected for heteroskedasticity                              |
| Breusch - Pagan chi-squared =     3.4181, with   4 degrees of freedom |
+-----------------------------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	176657.1042	.43327635	********	.0000	
BODR	41.90280800	.95419195E-04	********	.0000	2204.7793
CODR	-.1718137183E-04	.82092700E-04	-.209	.8342	3131.7955
OGR	48.58221683	.70283750E-03	********	.0000	363.19571
TSSR	-.7576127948E-03	.40353712E-01	-.019	.9850	2.4908768

II) DOUBLE - LOG MODEL

--> DSTAT;Rhs=LNBODR,LNCODR,LNOGR,LNTSSR,LNWTP;Output=3$

Descriptive Statistics

All results based on nonmissing observations.

Variable	Mean	Std.Dev.	Minimum	Maximum	Cases
LNBODR	7.69822292	.178850966E-01	7.64043685	7.74787066	1000
LNCODR	8.04925610	.145474022E-01	7.99905600	8.09208397	1000
LNOGR	5.89483777	.144368750E-01	5.84270585	5.93775644	1000
LNTSSR	.911903739	.383130710E-01	.779279491	1.04654868	1000
LNWTP	12.5661339	.585514807E-02	12.5474771	12.5821158	1000

Matrix COV.MAT. has 5 rows and 5 columns

	LNBODR	LNCODR	LNOGR	LNTSSR	LNWTP
LNBODR	.3198767D-03	-.4580961D-05	.7340193D-05	.2020291D-04	.1035028D-03
LNCODR	-.4580961D-05	.2116269D-03	-.1134872D-04	.2468758D-04	-.2190711D-05
LNOGR	.7340193D-05	-.1134872D-04	.2084234D-03	-.3067875D-04	.1520057D-04
LNTSSR	.2020291D-04	.2468758D-04	-.3067875D-04	.1467891D-02	.4652069D-05
LNWTP	.1035028D-03	-.2190711D-05	.1520057D-04	.4652069D-05	.3428276D-04

Correlation Matrix for Listed Variables

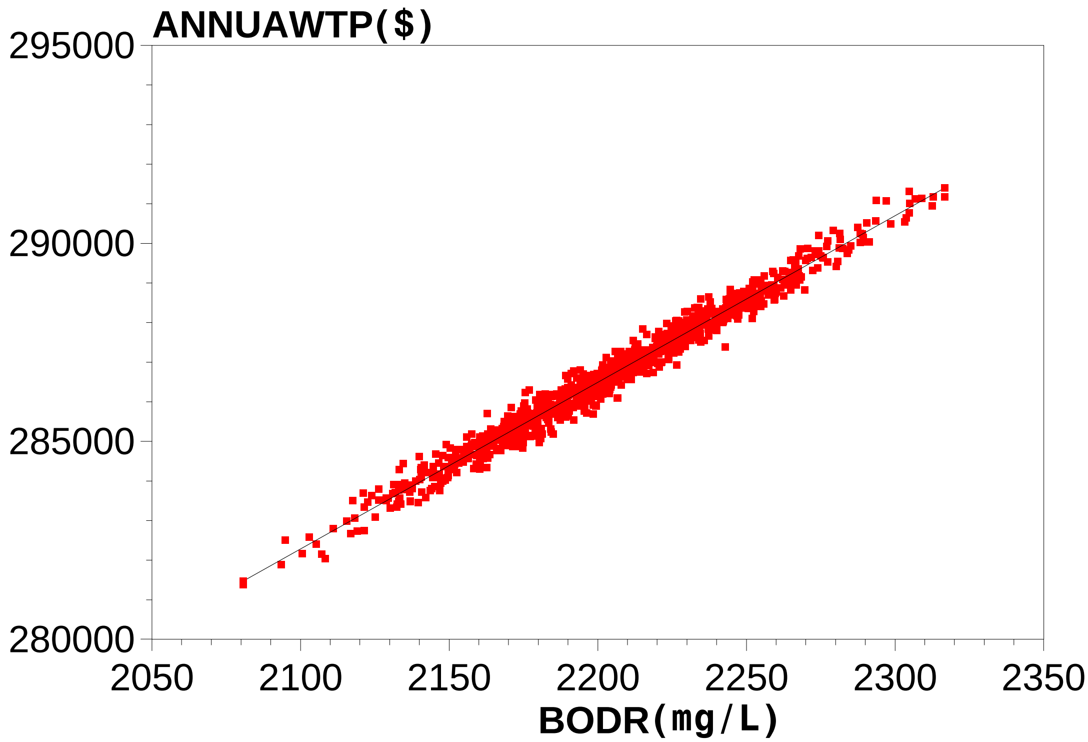
	LNBODR	LNCODR	LNOGR	LNTSSR	LNWTP
LNBODR	1.00000	-.01761	.02843	.02948	.98838
LNCODR	-.01761	1.00000	-.05404	.04429	-.02572
LNOGR	.02843	-.05404	1.00000	-.05546	.17982
LNTSSR	.02948	.04429	-.05546	1.00000	.02074
LNWTP	.98838	-.02572	.17982	.02074	1.00000

--> Regress; Lhs=LNWTP; Rhs=ONE,LNBODR,LNCODR,LNOGR,LNTSSR; HET $

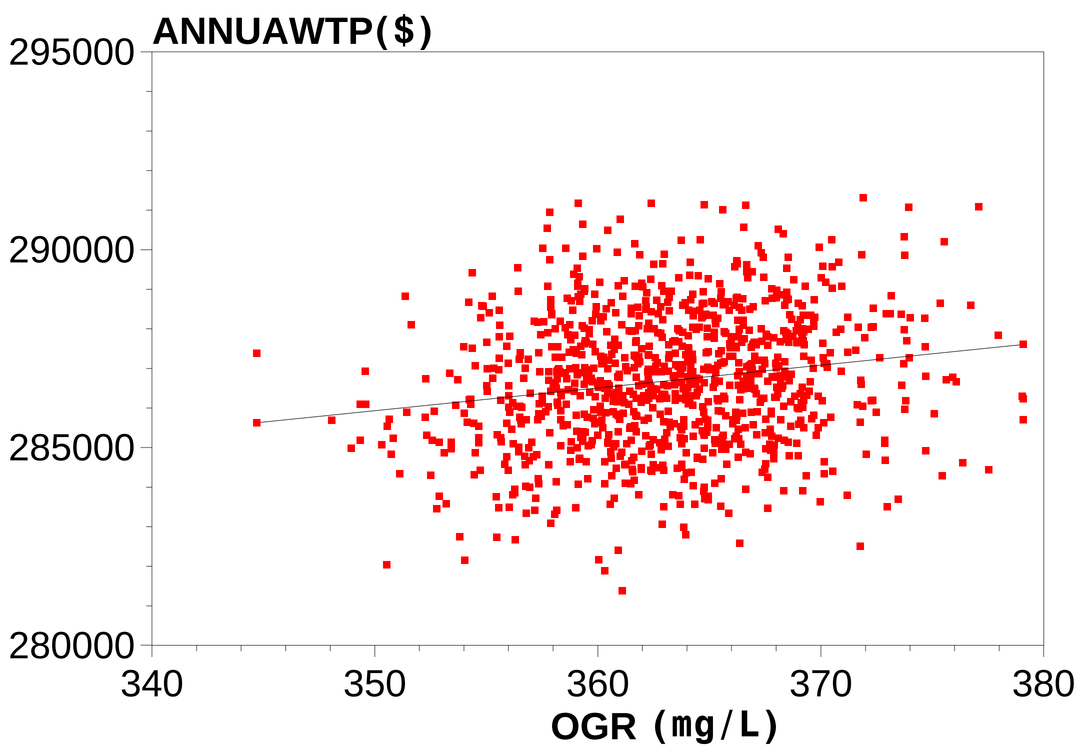
```
+-----------------------------------------------------------------------+
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = LNWTP    Mean=   12.56613387    , S.D.=   .5855148073E-02 |
| Model size: Observations =    1000, Parameters =   5, Deg.Fr.=    995 |
| Residuals:  Sum of squares= .2394329151E-05, Std.Dev.=         .00005 |
| Fit:        R-squared=  .999930, Adjusted R-squared =          .99993 |
| Model test: F[  4,    995] =********,    Prob value =          .00000 |
| Diagnostic: Log-L =    8506.1428, Restricted(b=0) Log-L =   3721.9957 |
|             LogAmemiyaPrCrt.=  -19.840, Akaike Info. Crt.=    -17.002 |
| Autocorrel: Durbin-Watson Statistic =   1.90951,    Rho =      .04524 |
| Results Corrected for heteroskedasticity                              |
| Breusch - Pagan chi-squared =     4.9851, with   4 degrees of freedom |
+-----------------------------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	9.723689176	.16723951E-02	5814.230	.0000	
LNBODR	.3221551169	.17775122E-03	1812.393	.0000	7.6982229
LNCODR	-.7848124624E-04	.93408803E-04	-.840	.4008	8.0492561
LNOGR	.6158487282E-01	.11915521E-03	516.846	.0000	5.8948378
LNTSSR	.2376405758E-04	.39343492E-04	.604	.5458	.91190374

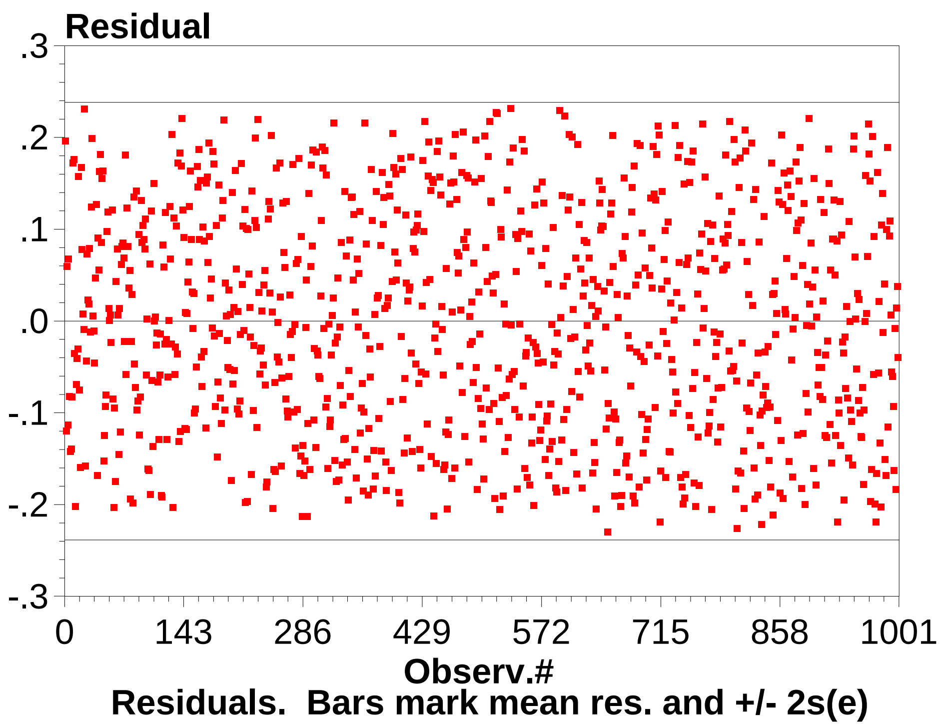
I) LINEAR MODEL



Appendix Figure 3.1. WTP vs. BOD reduction

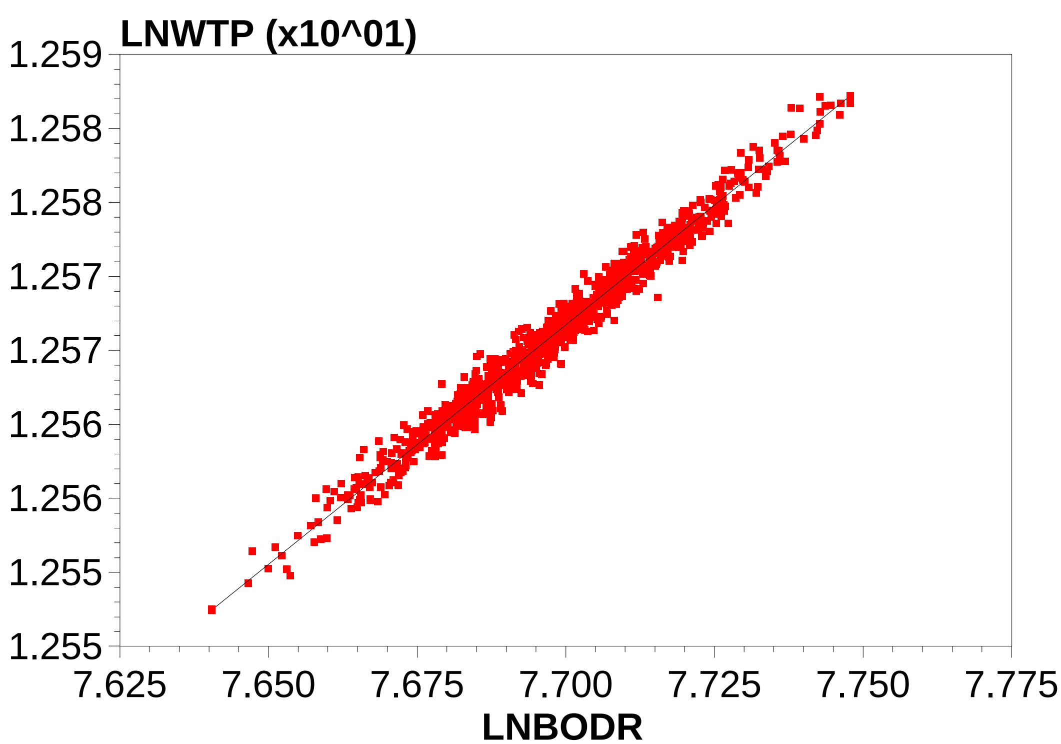


Appendix Figure 3.2. WTP vs. OG reduction

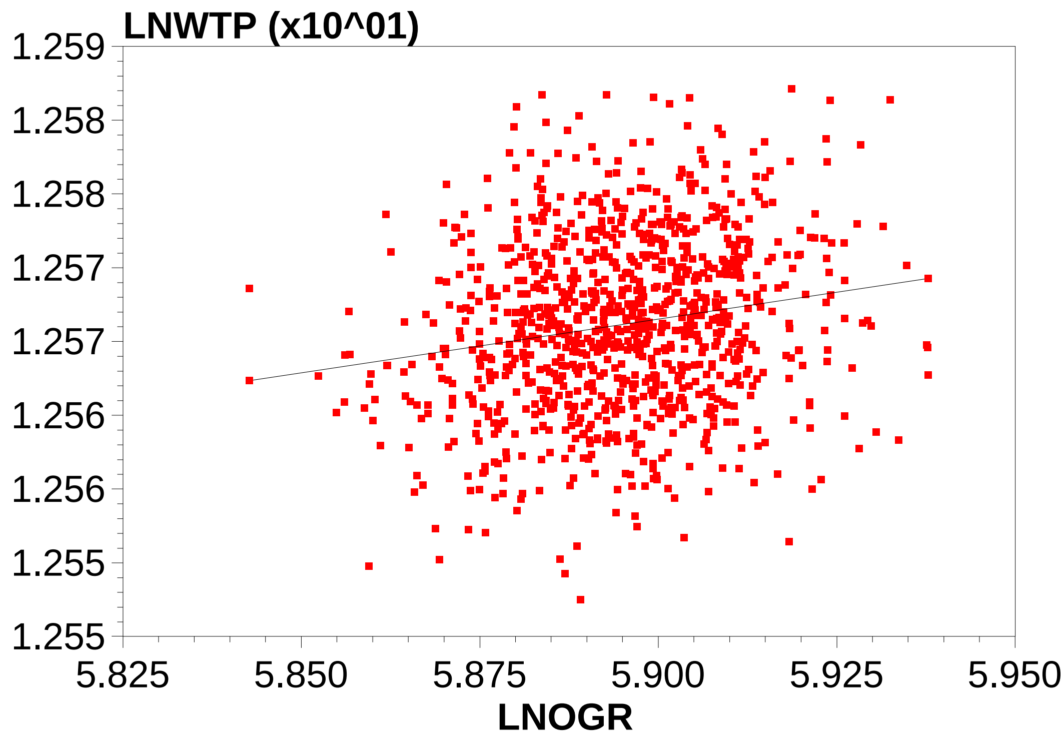


Appendix Figure 3.3. Linear Model's Residual Plot

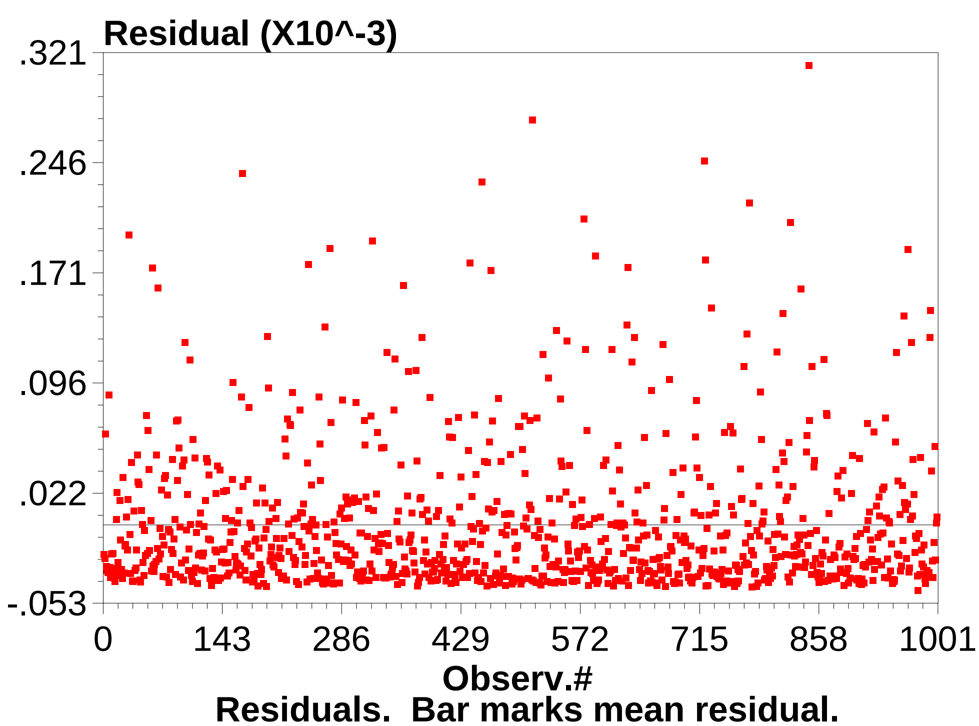
II) DOUBLE - LOG MODEL



Appendix Figure 3.4. LnWTP ($x10^{-1}$) vs. Ln (BOD reduction)



Appendix Figure 3.5. LnWTP ($x10^{-1}$) vs. Ln (OG reduction)



Appendix Figure 3.6. Double - Log Model's Residual Plot