ESTIMATION OF THE COST OF BUILDING A WATER TREATMENT PLANT AND RELATED FACILITIES FOR KAW CITY, OKLAHOMA

BY

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ABBREVIATION

CWSs	Community Water Systems
DEQ	Department of Environmental Quality
ECLS	Environmental Complaints and Local Services
EPA	Environmental Protection Agency
GPD /gpd	gallon per day
GPM / gpm	gallon per minute
GWR	Ground Water Rule
GWSs	Ground Water Systems
$KMnO_4$	Potassium permanganate
MCL	Maximum Contamination Level
NCWSs	Non-Community Water Systems
NF	Nanofiltration
NTNCWSs	Non-Transient Non-Community Water Systems
OSDC	Oklahoma State Department of Commerce
PWSs	Public Water Systems
SDW	Safe Drinking Water
SDWA	Safe Drinking Water Act
SDWRs	Secondary drinking water standards or regulations
TDS	Total Dissolved Solids
TNCWSs	Transient Non-Community Water Systems
USACE	United States Army Corps Engineers
WQD	Water Quality Department

I.

CHAPTER I

INTRODUCTION

I.1 Overview of quality of drinking water use in Oklahoma

The U.S. Geological Survey estimated that there were approximately one million cubic miles of ground water within one-half mile of the Earth's surface, which is 30 times the volume in the fresh water bodies in earth's surface. In the U.S., many locations rely on ground water for consumption. This is true especially in areas with limited amounts of rainfall and water resources. It is also estimated that about 51 percent of U.S. population rely on groundwater for domestic uses (U.S.EPA, 2008). Biologically, ground water may contain a variety of organisms, including bacteria, viruses, protozoans, and other pathogens. Minerals contained in the groundwater include manganese, nitrogen, calcium, potassium and others. Drinking water that contains high nitrate concentration poses a risk of methemoglobinemia, a condition that interferes with oxygen transport in the blood of infants (U.S. EPA, 2004). The federal drinking water standard for nitrate is 10 mg/l, which EPA defines as the maximum contaminant level (MCL) to prevent methemoglobinemia (U.S. EPA, 2006).

The main objective of Oklahoma Water Quality Department (OWQD) is to maintain clean water for Oklahoma by ensuring that state and federal regulations are being met at facilities that produce and distribute public drinking water as well as facilities of transporting, storing and discharging the wastewater U.S. EPA. (2008). Moreover, it is also the responsibility of the Oklahoma Water Quality Department to ensure that the quality of rivers, streams and lakes in Oklahoma will be maintained by enforcing State and Federal water quality regulation U.S. EPA. (2004). The Oklahoma Department of Environmental Quality (DEQ) is responsible of making sure that their public water supplies meet the standard of the Safe Drinking Water (SDW).

It is difficult to determine the safeness and quality of drinking water. However, the taste, appearance, and odor of drinking water can affect its quality. The test for presence of iron, manganese, and pH in water should be done when the water has a Yellow or Brown, Black flake, tarnished silverware, stomach ache diarrhea color (Smolen et al) Http://osufacts.okstate.edu. The Congressional 1996 SDWA amendment requires that water suppliers should provide consumers an annual drinking water quality report beginning in 1999.

EPA is promulgating the ground water rule (GWR) to provide for increased protection against microbial pathogens in public water systems (PWSs) that use ground water sources. Their main concern is about ground water systems (GWSs) that are susceptible to fecal contamination. It estimated that over 100 million people use ground water from community water systems (CWSs) while about 14 million people use ground water from non-community water systems (NCWSs) in the US (U.S.EPA, 2007). According to (Smolen et al): Http://osufacts.okstate.edu most of the Oklahoma groundwater meets the SDWA standard without treatment. However, problems may occur in areas where there are high concentration of minerals like nitrate, manganese, lead, and fluoride.

Primary and secondary standards are two types of drinking water standards that must be met for health reason. Primary drinking water standard includes limits on contaminants that have health dangers when exceeded. Secondary drinking water standards or regulations (SDWRs) are mainly aesthetic standards related to the odor, taste and appearance of the water and its cosmetic effects on skin or tooth discoloration. The state secondary contaminants and their standards requirement in drinking water are odor, 3 threshold odor number; color, 15 (color units); and manganese 0.05 mg/l. Other secondary contaminants and their standards are aluminum, is 0.05 to 0.2 mg/l; chloride, is 250mg/l; pH is to be between 6.5 and 8.5; and zinc, less than 5mg/l (U.S. EPA, 2009). The U.S. EPA is expected to establish MCLs for trihalomethanes (THMs), requiring that they must be less than 0.005mg/l for individual THMs compounds; and less than 0.05mg/l for total trihalomethanes (UEC Water Plan, chapter 9 pp.99).

1.2 The Overview of supply of groundwater in Kaw City

Construction of Kaw Lake by the US Army Corps of Engineers (USACE) was completed in 1976. The present day site of Kaw City is 1.75 miles from the old site which covered by the lake. Federal Law required that the government to provide water to people when they are relocated but it does not require government to allow for increasing water consumption (demand) due to growth of population or increased in economic activities (Engineering Report, 2006). The city has only 61 acre-feet of groundwater rights allocated by Oklahoma Water Resources Board at the time of relocation of the city.

The amendment of Oklahoma Groundwater laws that regulates or rules the use of groundwater in Oklahoma recognized the city’s water right to 61 acre-feet or 456 gallons of groundwater annually at the previous city location but cannot guarantee the Corps to develop or construct new well. The USACE granted permission to withdraw 815.2 acre-feet of groundwater annually without cost to the city on January 2000. The city also has the right to apply for 2 acre-feet of groundwater annually for each of the 437.6 acre-feet of the old location as the state law required. The wells of the city are pumping at their maximum capacity. The city needs to install new well or renovate the old wells in order to secure 815.2 acre-feet of water yearly but the city does not have funds to complete it.

The city has relied on the wells designed by U.S. Army Corps as their main source of water. However, one of the wells has collapsed. The capacity of the remaining wells is not enough to meet their demand. In 1990's the city attempted to restore the abandon collapsed well but it was not fruitful. The current water demand is 50 gpm and the volume of the wells is inadequate to solve the current city's demand, the corps facilities and satisfy induced tourism demand for water.

Table I-1 shows the increase population growth by less than 20 people since 1990. This described that the current increase in demand for water in the city is not because of induced population but rather increase in the economic activities. Though the population of the city is increasing, but the rate of increase is low. Table I.1 shows population data from 1990 to the projected 2010 population.

Table I-1. Population Data of Kaw City 1990 - 2009 and 2010 projection

Year	Population
1990	365
1995	369
2000	372
2001	374
2002	374
2003	376
2004	377
2005	378
2006	379
2007	380
2008	381
2009	382
2010	382

Source: OSDC (2000): Profile of General Demography

The water tower of the city has the capacity of 250,000 gallons, which supplies the city during the weekdays. But the city faces water shortage due to tourism activities during weekends. Also, the leakages of the pipeline underneath the lake, which cannot be repaired because of the lake, also decrease the water supply from the Washunga bay well to the city.

1.3 The Description of the City

Kaw City is located at latitude 96.85^{0}W and Longitude 36.76^{0}N. It covers about 5.5 square miles of the Kay County of Oklahoma and is 62.8 miles from Tulsa, Oklahoma and 76.2 miles from Wichita, Kansas. Of the 5.5 square miles size of Kaw City, the land covers 2.7 square miles and water covers 2.8 square miles (USGS, 2008). Figure 1-1 shows the satellite map of Kaw City. The cities, which are close to Kaw City, are Ponca City, Newkirk and Shidler. According to US Census of population, in the first

5 years of the last decade the population in Kaw City has increased by 2.6%. Out of the total population in the city, 57% are females and 43% are males. The population of the city is 372 and the projected population of Kaw City in 2030 is 400 people (OSDC, 2000). The Kaw Lake is their main source of the water in drought. U.S. Army Corps Engineers (USACE) designed wells, which provided groundwater to supply the city with a current capacity of only 50 gpm. The wells are located at Washunga Bay. The pumping station is located about half mile away from the city. The total water capacity delivered from the pumping station to the city is approximately 72,000 gpd. The pipeline crossing the lake is 8 inches in diameter.

Most of the pipeline within Kaw City for delivery of water to the customers ranges from 4” to 8” in diameter. DIP (ductile iron pipe) used in the city but the exact date of the installation is unknown. The reservoir is located near the Kaw Nation Environmental Department.

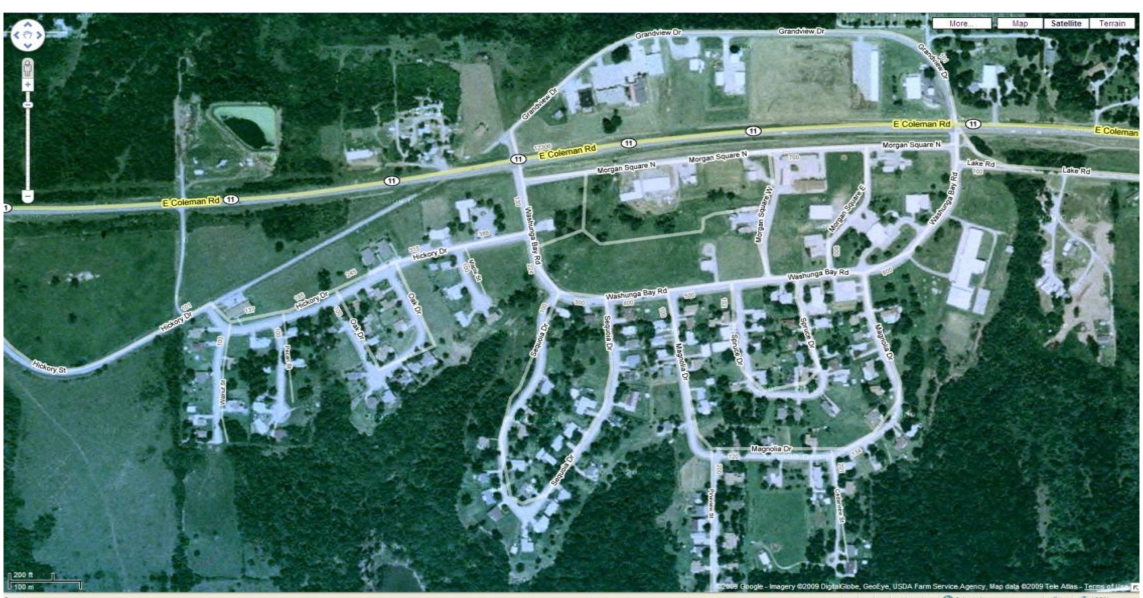

Figure I-1. Satellite Map of Kaw City Source: http://maps.google.com/maps

1.4 The Overview of Demand for Water in Kaw City

The problem of taste due to a high level of the minerals such manganese, iron, zinc, and other elements will not permit people to use the water comfortably without treatment though these minerals are not hazardous to human health. Raw drinking water in Kaw City does not meet the U.S. EPA secondary standard for manganese. The demand for water (groundwater) increases as the population and economic activity of the city increases.

Table 1-2 describes the monthly consumption (demand) of water in Kaw City from 2001 to 2008. Throughout the 8 years, water consumption level is very high in August as compare to other months with of average of 4,003,175 gallons and standard deviation of 883,561 gallons. However, the highest monthly consumption during the 8 years was in October 2002. The total water used per year and average water used per year in Kaw City in 2001 was 33,412,800 gallons and 2,784,400 gallons per year respectively. The per capita demand for water was 64,300 gallons per year (which is equivalent to 178 gallons per day or 7.4 gallons per hour). In 2008, the estimated total water consumed was 30,379,100 gallons per year, the per capita water demanded was 82,110 gallons per year which was equivalent to 9.5 gallons per day (ODEQ, monthly operational report 2001-2008).

Table I-2. The Monthly Water Consumption of Kaw City (2001-2008) ('000')

Months	2001	2002	2003	2004	2005	2006	2007	2008	Mean
January	2528	1772	2263	2240	2290	2305	2633	2232	2283
February	1514	1719	1825	2438	2294	1834	2333	1924	1985
March	2620	2102	1636	2174	1937	2445	1498	2305	2090
April	2240	2405	1538	2694	2589	2384	1675	2127	2206
May	2523	2706	1648	3671	3575	2404	1556	2120	2526
June	3018	3091	1862	528	2927	3512	2044	2257	2405
July	4987	3927	2588	4557	3744	4068	3259	3253	3798
August	4456	4552	2306	3700	3180	4272	4656	4904	4003
September	2652	4287	2068	2806	2732	3377	2627	4366	3114
October	2856	6964	1745	2635	3311	3514	2350	1690	3133
November	2138	2145	1515	2276	2372	2857	1953	1204	2057
December	1882	2047	877	2347	2235	1755	2170	1999	1914
Total Year	33413	37716	21871	32064	33186	34728	28753	30379	31514
Mean	2784	3143	1823	2672	2766	2894	2396	2532	

Source: ODEQ, Monthly operational report

Figure I-2 describes the monthly demand for water in Kaw City for 2001. The highest monthly consumption of water was 4,987,000 gallons in July while the lowest consumption was 1,513,500 gallons in February. The consumption of water was high from May to August summer season. Consumption increases during the summer because of heat and an influx of tourist in the community. However, between November and February, the demand was low because of the winter season which does not attract tourists to travel. In addition, during the week days, the demand for the water would be solely for the people in the Kaw City.

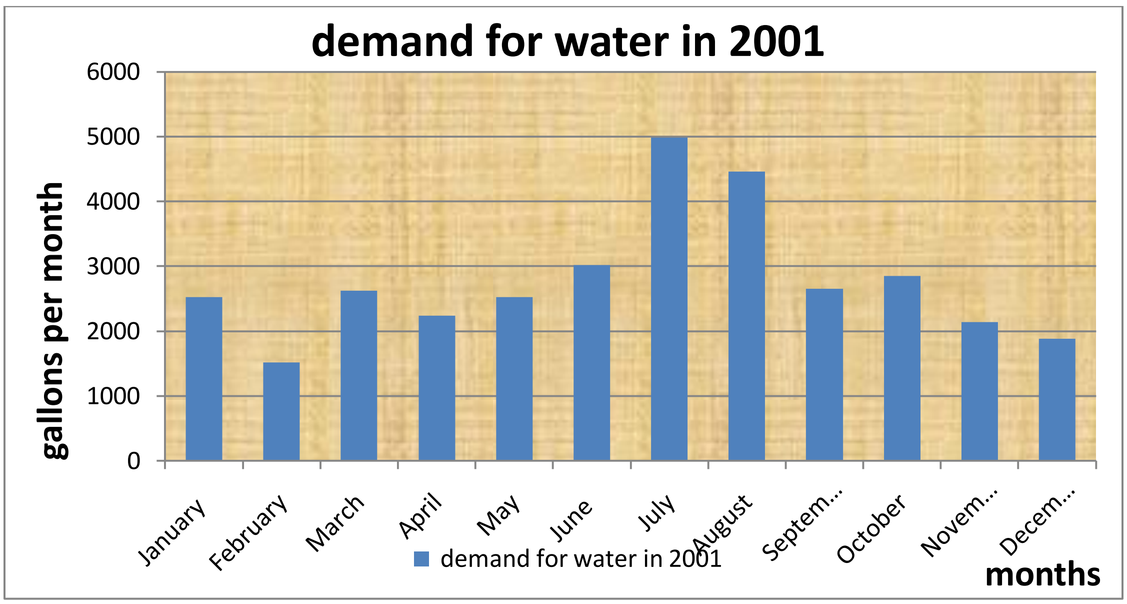

Figure I-2. Water Consumption of Kaw City in 2001 Source: ODEQ Monthly operational report

Figure I-3 also describes the monthly consumption of water in Kaw City 2008. The maximum monthly consumption of water was 4,903,500 gallons in of August. The minimum consumption was 1,203,500 gallons in November. The consumption of water was high from May to August. The range between the maximum and minimum monthly consumption was 3,700,000 gallons in 2008. The average and standard deviation of water consumption for the community was 2,531,590 and 1,094,860 gallons per month respectively. From October to February, the water consumption level is low because of the winter season which is not attractive for tourism.

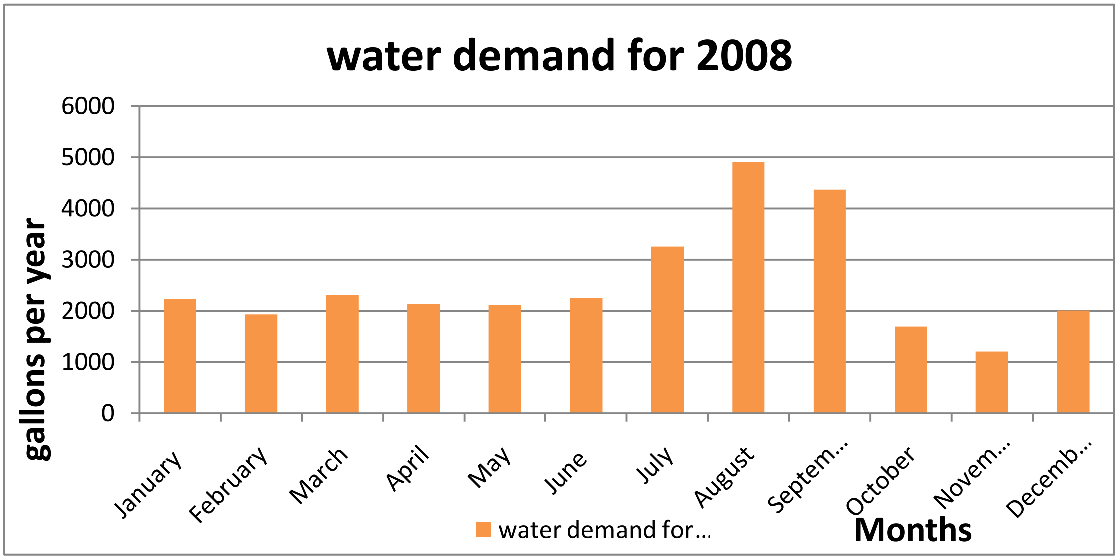

Figure I-3. Water Consumption of Kaw City in 2008 Source: ODEQ Monthly operational report

Figure I-4 describes the annual demand for water in Kaw City from 2001 to 2008. The highest yearly consumption of water was 37,715,600 gallons in 2002. The lowest consumption was 21,870,500 gallons in 2003. Annual water the consumption varies from year to year. It may depend on the number of tourists who visit during the summer season.

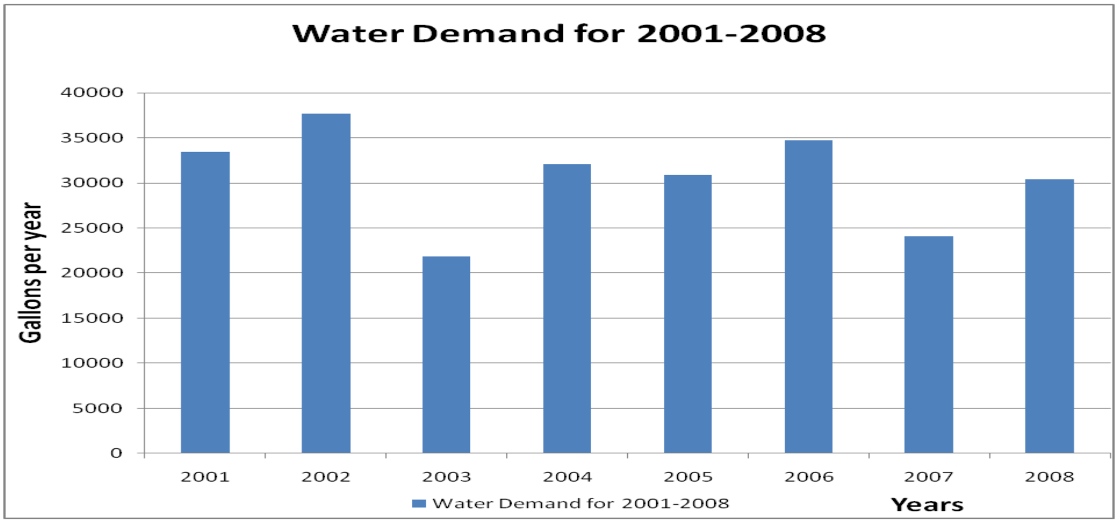

Figure I-4. Water Consumption of Kaw City (2001-2008), Source: ODEQ Monthly operational report

1.5 Statement of Problem

The city of Kaw City in Kay County has had water problems since the 1990's because of the collapse of one of its wells and from the poor taste of the groundwater. The poor taste is attributed to high levels of minerals such as manganese and iron in groundwater. Tests found that total dissolved solids, Turbidity, Hardness are 637mg/l, 0.76 NTU and 514mg/l respectively. In addition, Barium was 0.265 mg/l, iron was 0.071 mg/l and manganese was 0.121mg/l Chapman (2003). These chemicals (Total dissolved solids, manganese and Hardness) are above the Oklahoma Environmental Secondary Standard. Table I-3 shows the analysis of the untreated water and the levels that EPA and the State require after water treatment.

Table I-3. Organic Compound level in groundwater before and after treatment

Chemicals/Organic compound	Test from the well on the bridge no. 3 (2000).	EPA and State Standard/ primary required level in (units)
Total dissolved solids	637 mg/l*	500 mg/l
Turbidity	0.76 NTU	Surface water standard 95% must be < 0.5
iron	0.071 mg/l	0.3 mg/l
manganese	0.121 mg/l*	0.05 mg/l
Barium	0.265 mg/l	2 mg/l
Hardness	514 mg/l*	Existing hardness is only 154 mg/l

*indicates the Exceeds Secondary Standard **Source: Chapman &Associates (2003)**

The city wants to find a way to solve the problem of the poor taste of the water in the city. Kaw City also wants to investigate the possibility of providing water to Shidler. Accordingly, the city has requested assistance in estimating the cost of establishing a new well, new water treatment plant, and the necessary extension of pipelines. Because of the presence of Kaw Lake, there is additional tourist demand for water especially during summer weekends.

To increase the quality of water to solve high demand for water problem in the city and provide quality drinking water for domestic and other uses to meet the U.S. EPA and Safe Drinking Water Standard, then there is a need to develop a comprehensive solution by building water treatment plant and use best treatment systems to treat the water for drinking. The purpose of water treatment is to condition, change and remove the contaminants, to supply safe and good tasting drinking water acceptable to consumers or users Spellman (2003). The base water demand for Kaw City alone is assumed to be 60 gpm or 86,000 gallon per day. The base water demand for Kaw City and Shidler is assumed to be 150 gpm. The size of treatment plant to supply both cities would be 216,000 (150*60*24) gpd. It would boost the economic activities of Kaw City by increasing tourism. It is necessary examine the costs and benefits of the construction of a treatment plant and other facilities. It is, therefore, important to determine the total cost of supply of water from a new at the "monitoring well site" and determines which size and type of treatment plant will be more efficient.

Because of economies of size, an analysis of the cost of a treatment plant to serve both Kaw City and Shidler will be considered. Increasing the capacity of the treatment plant and supply to serve these cities may be more economically viable than building a small capacity to serve only Kaw City. Due to the nature of the chemical compounds in the groundwater, two main treatment systems considered are nanofiltration (reverse osmosis) and an enhanced conventional (Aeralator®) system to remove manganese. The Aeralator® system developed by Siemens is the specific evaluated.

1.6 Objectives of the Study

The general of objective of this study is to determine and compare the cost of building alternative water treatment plant facilities in Kaw City. Specific objectives of this research include:

1. To determine the cost of capital investment and annual capital cost of the two possible sizes and types treatment plants.
2. To determine the annual operating cost of each size and water treatment plants.
3. To determine the cost of a new well and the cost of the necessary transmission line from the well to the treatment plant (greenhouse site) an from treatment plant to the existing pipeline at Washunga bay
4. To compare the discounted amortized capital cost and plus the amortized operating cost for two sizes and two types of treatment plant
5. To determine the cost of replacing the entire Kaw City distribution pipeline

II.

CHAPTER II

LITERATURE REVIEW

2.1 The General Overview of Demand and supply of groundwater

A common problem is that a system designed for a current population may have inadequate capacity and/or operating pressures to meet higher future demands resulting from population and economic growth according to Filion (2009). His study found the type of property, size of garden and areas were related to household water demand. His study differs from the current study in that household gardens were positively related to demand. In this study the main determinant of demand will be size of the population and households in the area.

In addition, (Schleich and Hillenbrand, 2008; Fox, et al 2009) report that per capita water demand was a function of economic, environmental and social characteristics based on a study of 600 water supply areas. The household income had a positive relationship with water demand. Moreover, household size also had a significant effect on water consumption. They found that age of the population had an impact on water demand. Adults may use more water for bathing and hygienic purposes. Factors such as warmer climate, age, and household income increase water demand whereas increased prices for water and reduced household size are inversely related to water demand. Fox et al (2009) and Schleich and Hillenbrand (2008) used economic, environmental and social factors as determinants of demand for water. In this study, population and tourism activity would be used to determine the amount of water consumption and to estimate the cost of the treatment plant facility the cost of and treating the water.

Ground water is considered the best form of natural water. In some cases it does not need treatment for drinking or other domestic uses. Relative to surface water, it has the less contamination and turbidity because of its natural filtration. However, at times it contains contaminants because some minerals such as manganese, calcium, iron, magnesium and other compounds dissolve in it due to the nature of the soil or geographically area (Sarai 2006).

The Safe Drinking Water Act defines a Public Water Supply (PWS) as a system that provides water to serve 32,150,000 people or more via piping or other constructed conveyances to the public for human consumption. The goal of Oklahoma Water Plan is to provide safe and dependable water supply for people and information so that water providers, policy-makers, and water users can make informed decisions concerning the use and management of water resources (Dillon, 2007). The Safe Drinking Water Act has increased interest in analysis of how drinking water is handled before it is delivered to the consumer. A comprehensive analysis of the Interim Primary Drinking Water Regulations promulgated under the Act indicates that their economic effect on large water systems will be less, but that there may be potentially serious economic effects on small systems Clark and Stevie (1981). High unit costs are generally associated with small systems and if a small system is forced to install expensive treatment technology, it is conceivable that per capita costs could more than double Clark (1978). A frequently suggested option to minimize the cost of water supply is to develop regional water utilities consisting of a group of large systems or one or more systems combined with a larger system.

According to Hutson (2007), residential water use varies from household to household. Therefore, a public-supply system is designed to serve households with a common pattern of use that depends on factors such as water rates, water-conservation programs, lot size, customer affluence, climate, and topography. Water transmission and distribution systems are necessary because they provide water to meet basic human needs, and to protect humans in public emergencies. The water distribution system should be able to meet the demands placed on it at all times and at satisfactory pressure Spellman (2003).

2.2 Alternative Water treatment system

The groundwater which is the main source of water in Kaw City and in Oklahoma as whole needs to be treated with the best technical treatment system for the safety of users. A groundwater source of water is described as pure even without treatment. However, because some organic compounds dissolve in groundwater, it may need be treated to meet the Safe Drinking water standards. Previously, only chlorination, and sedimentation were used in treating water for distribution to consumers. However these methods were not best for removing high level of total organic compounds. It became clear that chlorination was not effective when treating cloudy water and only controlled pathogenic bacteria (Sarai 2006).

The goal of water treatment in late 1960s was to distribute adequate supplies of water safe from bacteria (McGivney and Kamawura 2008). By the 1990s goals were expanded to include control of protozoa and disinfection process byproducts, distribution and noncorrosive water, and disposal of treatment residues. With population increases and increasing demand for water for industrial growth, there need to be advances in water treatment technology so that systems can distribute water over thousands of miles (McGivney and Kamawura 2008).

2.2.1 Nanofiltration (Reverse Osmosis) as an alternative Water Treatment Systems

Currently, nanofiltration (NF)/(reverse osmosis) is the treatment system considered as the best system for removal of organic compounds from groundwater for human consumption and other use. Water quality considered is poor when TDS concentrations are greater than 1000 mg/l and/or sulfate concentrations greater than 300 mg/l (Turner et al. 1997). NF has proven to be an effective method for removal of dissolved solids as well as all viruses and bacteria (Lozier et al. 1997). It is an effective method for removal of total organic carbon to at least 1mg/l. NF can reduce calcium, magnesium and sodium by 92 percent, 90 percent and 76 percent respectively (Turner et al 1997).

Clean water does not necessary mean it is portable for human consumption since it may contain inorganic compounds such as manganese, iron and others and microbacterias. Small amount of organic compounds in the water may not be harmful but excess amounts may have harmful effects on humans.

NF is a crossflow, pressure driven process characterized by membranes pore size corresponding to molecular weight cutoff of approximately 200 –1000 dalton, and operating pressures of 150–500 psi. NF is primarily used to separate low molecular weight organics and multivalent chemicals from monovalent chemicals and water

(Yacubowicz and Yacubowicz 2005). NF separation incorporates membrane with pore sizes and operating pressures, in between those for ultrafiltration and reverses osmosis. They are typically operated at pressures in the range of 70 to 200 psi. NF membranes prevent the passage of a portion of the total dissolved solids (TDS) and they remove dissolved organic matter occurring in natural waters such as groundwater (Mourato, 2006). NF membranes have smaller pores which range from 0.005 microns to 0.001 microns and can remove large molecular weight molecules. It is an economic advantage to apply nanofiltration in small and medium sized plants when the concentration of particles (suspended solid concentration) is relatively high (Gumerman et al, 1979).

Water treatment processes consist of course screening, disinfection, fluoridation, adjustment of pH, and lime softening before distribution was used in previous years (Baker, et al 2008; Sethi and Wiesner, 2000).

NF has found increased use in environmental-based applications including materials recovery, water and wastewater treatment, separation, and clarification. Because of the capability of effective removal of dissolved organic compounds, NF membranes are of considerable interest in potable water treatment, especially in meeting the water quality standards promulgated under the current and anticipated rules for disinfection by-products (Sethi and Wiesner 2000). Unlike conventional water treatment units, NF unit can also remove micropolutants such as pesticides and endocrine disruptors and reduce the total organic carbon (TOC) of water. This helps to minimize the formation of disinfection by-products (Geraldes et al, 2008).

Figure II-1 compare the characteristics of nanofiltration and reverse osmosis removal capabilities during processing. Both remove organic molecules, almost all viruses, some natural organic matter and a range of salts. NF removes divalent ions, which make water hard, so nanofiltration is used to soften hard water whereas reverse osmosis also removes monovalent ions, which explains why reverse osmosis is used in desalination. The green arrow indicates that the particle is small enough to pass through the filter, whereas the deflected orange arrow showed that the filter prevents the particle from passing through the filter.

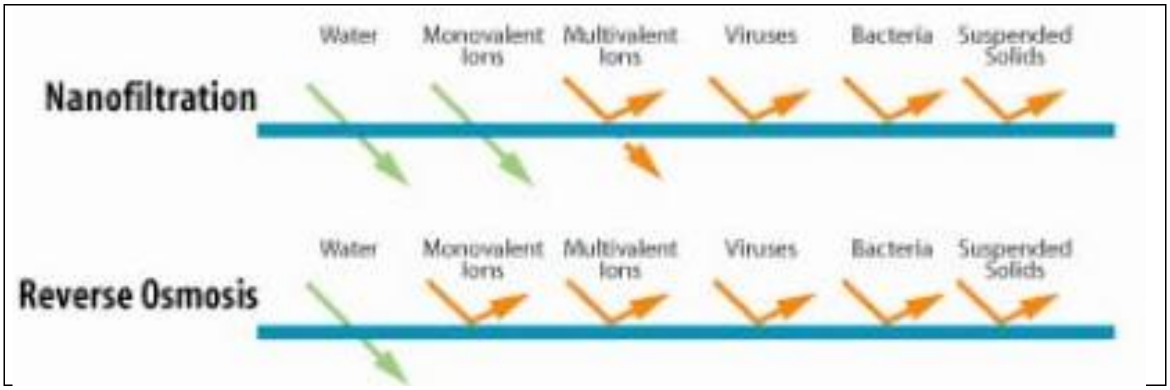

Figure II-1. Size of Materials That Are Removed By Various Separation Processes;
Source: http://www.kochmembrane.com/sep_uf.html

Table II-1. Optimal operating conditions of the applied membranes

Type	Operating pH	Operating Pressure (×105 psi)	Optimal Operating Pressure (×105 psi)	Maximum operating temperature (°C)	Molecular weight cut-off for uncharged organic molecules
NF	2-11	5-35	5-27	50	150-300 moles
RO	4-9	13-55	7-40	50	*

*Applied filtration of monovalent ion solutions, **source: Csefalvay et al, (2008)**

Table II-1 distinguishes the optimal operating condition between the using of nanofiltration and reverse osmosis in treatment system. The optimal operating pH of nanofiltration ranges from 2-11 whereas reverse osmosis is 4-9. Moreover, the optimal operating pressure of reverse osmosis is 13-35 psi while nanofiltration is 5-35 psi. The molecular weight cut-off for charged organic molecules ranges from 150-300 moles but reverse osmosis removes monovalent and multivalent ion from solution. Both have a common operating temperature of 50^0C.

2.3 Estimation of Cost

The best systems among the various alternative water treatment systems that meet standard may be selected on the basis of minimum cost, including construction, capital, maintenance and operating and cost associated with plant maintenance cost over a designated planning horizon.

2.3.1 Capital Cost

Capital costs are the costs for the physical assets of the project. Capital costs are part of the fixed component of the total cost. They are normally incurred one time but also include cost of rehabilitation or replacement of equipments during the life of the system. Capital costs are estimated for equipment, materials, construction and other assets. Capital costs can be estimated using a recently developed model (Sethi, 1997; Sethi and Wiesner, 2000) that divides water system costs into major cost components. These categories include pipes and valves, membranes, pumps, electrical and instrumentation, tanks, frames, and miscellaneous items (including buildings, electrical supply, treated water storage and pumping, etc.) (Sethi and Wiesner, 2000). Total construction cost includes all costs related to construction contract, overhead and profit of the contractor Kawamura (2000).

Generally, there are economies of size so as the capacity of the system increases the unit cost of capital declines. Therefore, the per gallon capital cost of water treatment plant for only Kaw City with capacity of 86,000 gpd may be higher than combined systems for Kaw City and Shidler with capacity of 216,000 gpd. Some of existing low-pressure membrane water treatment plants is indeed small, with capacities less than 3,800 m^3/d (1-mgd). Therefore, for large treatment plants, the annualized capital costs may become similar to the operating costs. “Amortized capital costs per unit of production decreases with plant capacity due to economies of scale” Sethi and Wiesner (2000).

2.3.2 Operating Cost

Operating costs are the variable cost components in the project cost. It is the cost incurred in running the day-to-day business or a project. For a water treatment plant, operating costs include costs for chemicals, maintenance, energy, taxes, and insurance. Labor costs are based on the manpower needed and the average salary. The manpower requirements for each design can be calculated according to EPA documentation (USEPA, 1971).

According to Sethi and Wiesner (2000), operating costs can be systematically calculated for the energy utilized by pumps, for membrane replacement, and for chemicals. Costs related to other components, like concentrate disposal and labor, are highly dependent on factors such as geography, scale, and application of the membrane process. Operation and maintenance costs of water treatment plant normally consist of labor, supervision and administration, power, chemicals, maintenance, repairs, and miscellaneous supplies and services. Additional factors that can influence the maintenance and operation cost are the policy of the owners, the complexity of the system, the local environment and weather. Operating cost can also be increased due to continuing inflationary trend of labor, power and equipments Kawamura (2000).

2.3.3 Distribution Cost

Water is delivered to consumers through transmission pipelines and distribution mains. Trunk lines are the major pipelines used to deliver water. They connect the treatment plant to the pumping station and to the distribution system. The distribution works include the meters, pipelines, and storage facilities (water tanks or reservoir) necessary to convey the water from the transmission system to the consumer Clark and Stevie (1981). As a result, the cost of distribution depends upon the quantity consumed by individuals at various distances from the plant.

2.4 Anticipated Contribution

The result of this study will assist the Kaw tribe and Kaw City in planning for their water treatment plant and for the distribution of the water to the customers in the city and the cities around it. The results will also give the insight of the power needed to supply certain amount (gallon) of water per day and per minute (gallons per day or gallons per minute). It will enable city to project the number of water (gallons per day) for future increase in population, cost of equipment like pipes, installation cost and maintenance cost. Moreover, the study will help the city to choose the best or most cost effective treatment system.

In addition, the study will help Kaw City and Shidler to solve the long term water problem as a result of poor taste of water and high amount of minerals in the water and water shortage in the city especially during weekends due to tourism activities in the area.

III.

CHAPTER III

METHODS AND PROCEDURES

3.1 Data Collection

The data used to estimate costs for distribution for water, the capital, operation cost for water treatment plants and the pattern of water demand in Kaw City were collected from various sources. The data on costs of water treatment systems were obtained from manufacturers. The costs for pipeline materials and installation were obtained from Means Construction Cost Estimates (RSMeans, 2009).

The data on the layout of the city pipelines including the diameter, the length of the pipe and the materials like fire hydrant collected from drawings were provided by the city engineer, which provided an in-depth layout of the existing pipelines in the city and the one connecting Shidler. The treatment plant and monitoring well design are also obtained from the City Engineer through the Department of Environment, Kaw Nation.

The estimated current and projected populations of the city were obtained from the website, http://www.census.gov, and Oklahoma Department of Commerce (OSDC 2000).

3.2 Data Details

The study would require detailed information on cost for trench, pipe, and energy. The study also requires knowledge of effect of specific variables such as diameter of the pipe, width and depth of the trench, horsepower, distance of the pipeline on overall capital and operating cost. The main areas of the estimation include the well and pipelines to the treatment plant and the distribution system. In each area, costs are divided into fixed or capital and operating or variable cost.

3.3 Method Used to Estimate of Cost of Water Treatment Systems

The possible alternative treatment systems will be considered with each has two different sizes. For example one size of the nanofiltration (reverse osmosis) treatment plant systems will serve a population of four hundred (400), (Kaw City only) and the other larger size will serve approximately one thousand people (1000) (both Kaw City and Shidler). Because of economics of scale, a plant that will serve both Kaw City and Shidler may be more economically viable. The cost estimates in this study will be summarized in three main categories namely capital cost, operating cost and distribution cost in a form of description, unit, quantity, unit cost and total cost.

3.3.1 Estimation of Investment and Annual Capital Cost

Capital costs are mainly for construction cost, engineering cost and cost of treatment equipment. Once installed these become the fixed component of cost. Capital costs are expected to be incurred mostly at the beginning of the planning process and in future years when the equipment are replaced or renovated. Capital cost can be calculated as the sum of material cost and equipment cost, trench cost, fixed pipe cost and contingency cost. Contingency is a proportion of construction cost estimated as a lump sum cost. The proportion of the contingency depends on the contractor or the estimator of the project but usually ranges from 2% to 5% Roberts (2008).

The estimation of equipment cost is based on the size, type and quantity of equipment needed to complete the project. The cost of equipment is estimated by multiplying the quantity of equipment by its current price and summing. The cost of equipment is a major part of the total capital cost for a water treatment system. In addition, some of the equipment can be rented or leased Roberts (2008). The materials for water treatment entail pipes, fire hydrants and valves. This category also includes membranes, pumps, electrical components, instrumentation, tanks frames, and miscellaneous items such as buildings, electrical supply, and treated water storage. Some cost data from previous years can be adjusted using the Engineering News Record's Construction Cost Index (ENR CCI) ratio. The ENR CCI value is determined by averaging the index values. For example, to update a representative cost of 2002 (ENR CCI value 6538), the cost of 2002 would be multiplied by the ratio of 7872 over 6538. The ENR CCI values are based on material and labor construction costs of all major cities across the US. The index measures the amount of money it would cost to purchase a theoretical quantity of services and goods in one year, as opposed to another. The approach of accounts for the individual economies of scale related to different equipment and facilities, and thereby considered an overall economy of scale for the entire water treatment and delivery system Sethi and Wiesner (2000).

3.3.1.1 Estimation of Pipe Cost and Trench Cost

The pipe cost is part of fixed component of cost. Pipe cost is a function of its diameter. Mathematically,

FPC = IP*(Dia)*MF………… (1)

where FPC = the Fixed Pipe cost, Dia =Diameter of the pipeline and MF = Mortgage factor, IP= Investment Cost of pipe as a function of its diameter.

Trench cost is the cost of excavating the trench to lay pipes. The trench cost is a function of width and depth of the trench. Regulations to insure worker safety greatly increase the cost of trenches greater than 5 feet. The larger the size of the pipe, greater the width of the trench will be. The depth of the trench varies associated with the size of the diameter of the pipe. T_i is Trench Cost, Di= the depth. The model (for trenches less than 5 feet in depth) is:

$$T_i = a + bD_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

T_i is the cost of trenching

D_i is the depth of the trenching which varies with the cost of pipe.

a and b are the parameters of the model and are estimated using regression technique. Budgets were first constructed based on different trench depths. Regression was used to estimate trenching cost as a function of depth. Since the width of the trench was held constant, it did not have effect on the ordinary least squares (OLS) estimation of the trench cost. R^2 will be calculated to show the goodness of fit of the depth in relation to unit cost of the pipe.

In addition, the total cost of excavation and backfill and packing was included in the cost of the trench, packing, and backfill. Trenching cost can be expressed as the sum of the cost for backfill, packing, trench cost and total operating cost

$$ExB_f = T_i + P_i + B_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where ExB_f is the Total cost of Excavation and backfill

T_i is the trenching cost, ***P_i*** the cost of packing on the sides of the pipe in the trench**,** ***B_i*** is cost of backfilling

3.3.1.2 Building Cost for Water Treatment Plant

The building was rectangular with 14 ft high where two windows on the building. The building had interior partitions for laboratory, lavatory and office. The rule was that large building cost per square-foot is less than small building because larger structures are more efficient to build than smaller building. The cost of the building was estimated by multiplying the unit cost by the quantity of the equipment and materials. RSmeans Construction Cost data provided cost information for a series of building materials and equipment and cost of the square foot of the exterior and roofing structure of the building, which makes it easy to get accurate unit cost of the material and equipment. The estimation was categorized into unit, quantity, unit cost and total cost of the materials and equipment.

3.3.1.3 Estimation of the Cost of Drilling a Well

The necessary depth of drilling a well for Kaw City can be estimated based on the depths of a previous monitoring well drilled by CRC & Associates Engineering Company, Tulsa, OK (2002). The monitoring well is located at the north of Kaw Lake near Washunga Bay. This study would use information from the drilling log provided by the Engineers to determine the cost of the drilling in the same location. The estimation of the cost of well will be in current prices based on the descriptive features given by the Engineers. The cost of the drilling of the well is part of the capital cost.

In this estimation, certain features of drilling of the well such as the length of the hole and diameter (size) of the hole taken into consideration. However, the diameter of the hole is 8”, the depth of the hole from the casing to the bottom cap level is 120’ and the casing diameter is 4” (CRS & Associates, Inc). Therefore, it is assumed that the length of the pipe (specifically PVC 4”) will be 120 feet (120’). To estimate the cost of drilling a well accurately, the quantity of each equipment and material will be multiplied by the current prices from the Means Construction cost data (RSMeans, 2009).

3.3.2 Estimation of Treatment Plant Operating Cost

Plant operation cost is the variable part of the cost of the treatment plant. It comprises of chemical cost, energy cost, staff, maintenance, monitoring and labor cost. Operating cost can be calculated as the sum of the above stated costs. It is cost incurred in running of day-to-day activities. Labor cost can be calculated base on the number of hour per work. It will be estimated base on the current wage of the labor per hour. In estimating operation cost, there are general assumptions, which should be considered:

a. The number of operation hours in a year is 365 hours (365*1=365 hours) for Aeralator® systems and (3*365) hour for Nanofiltration (NF) system

b. The unit cost of electricity use during the operations. This has significant effects on the cost of operations. The unit cost electricity is taken to be $0.108 per kw/h.

c. The capacity of the treatment plant of 150gpm for Kaw City and Shidler and 60gpm for only Kaw City.

d. The unit cost of potassium permanganate use to control odor, and taste in the water is $1.60/lb.

e. The unit cost of chlorine use to kill bacteria in the water is \$0.50/lb.

<u>3.3.2.1 Chemical Cost</u>

Chemical costs are for those chemicals used in the water treatment plant. However, this cost estimating depends on the quantity of the chemical use during treatment process and the price of the chemical per pound. When the price per pound of the chemical increases definitely the cost will increase. In the estimation of chemical cost, there is some baseline assumption that should follow:

a). The unit cost of chlorine (in \$) should be clearly stated. The unit cost of chlorine is \$0.50/lb. This cost will give the cost of the chlorine that will be use in treatment of water base on the quantity of the chlorine use. The chlorine is the important chemical as far as treatment of water is concern which is use to kill bacteria in water.

b). Another assumption is the cost of the potassium permanganate ($KMnO_4$) used during the treatment is \$1.60/lb. Potassium permanganate ($KMnO_4$) is used primarily to control taste and odors, remove color, control biological growth in treatment plants, and remove iron and manganese.

c). The third item to be considered is the unit cost of the antiscalant or scale inhibitor. The unit cost is assumed to be \$1.15/lb. The scale inhibitors specifically develop to manage the problems associated with hard water, specifically hardness salts and the formation of scale in a wide range of commercial and industrial process environments.

The chemical cost is based on P_i= unit cost of $KnMnO_4$, (Potassium permanganate), Q_i= quantity of $KnMnO_4$, δi = unit cost of antiscalant or Scale inhibitor, S_i=quantity of antiscalant or scale of inhibitor, α_i=unit cost of chlorine and C_i is quantity of Chlorine.

Total chemical cost (C_N) is calculated as

$C_N = P*Q + \delta_i * S_i + \alpha_i * C_i$ ……………… ***(4a) for nanofiltration treatment system***

$C_N = P*Q + \alpha_i * C_i$………………………..***(4b) for Aeralator® treatment system***

3.3.2.2 Energy Cost

The energy cost is the cost of energy needed to run the machines or treatment plant and other facilities. The energy cost for pumping can be estimated with the use of both water horsepower and the brake horse power method. In estimating energy cost, the following assumptions are made:

a. Pump efficiency should be range from 50-85% efficiency. Pumping efficiency is water horsepower divided by brake horsepower. Mathematically, *Pump efficiency = Whp/Bhp* (Spellman 2003)

b. The efficiency of the electric motor efficiency is also ranging from 80-95%. Motor efficiency is the quotient of Bhp to Mhp where Mhp is Motor horsepower. Algebraically, *Motor efficiency = Bhp/Mhp.* Spellman (2003).

Blake Horsepower (Bhp) is defined as the hydraulic horsepower supplied to the pump from the motor. It depends on the water horsepower. It can be calculated as

$$Bhp = \frac{GPM*Head\ (pr)}{3960*Peff*Meff} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ (5)$$

where ***GPM*** is gallon per minute, ***Peff*** is Pumping efficiency, ***Meff*** is Motor efficiency and Head (pr) is the pressure flow.

Water Horsepower *(Whp=GPM*Head/3960)* is the theoretical power required to pump a given volume of water from the well Spellman (2003). Therefore, the head loss is estimated as

$$\textbf{Head Loss} = \frac{10.51*(GPM/C)^{\wedge}2 * Dist}{(Dia)^{\wedge}4.87} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(6)$$

Dia is the diameter of the pipe, ***Dist***= distance of the pipe in feet, ***C***= coefficient of roughness for type of pipe.

EC is Energy Cost (Pumping Cost), *GPM* is gallon per minute, *Hd* is head loss, *Peff* is Pump efficiency, *Meff* is motor efficiency, *KwBhp* is kilowatt per brake horse power, *hpy* is hour per year, and *pelec* is electricity cost

$$EC= \frac{\{(GPM*Hd)*Kwbhp*hpy*pelec\}}{3960*Peff*Meff} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

3.3.2.3 Labor Cost

The labor cost is the function of hours of working and the cost of the labor. The total labor cost can be calculated by multiplying the current labor cost and working hours, plus the worker's compensation (insurance) and payroll tax Isherwood (1999). The payroll tax and insurance were the percentage of the labor cost. It assumed that the unit wage rate of the labor to be $20.00/hr and 365 hours of labor was by Aeralator® treatment system and (3*365=1,095) hours of labor by nanofiltration system.

3.3.3 Determination of Annual Economic Cost

In this study, the annual economic cost of treatment systems are expressed as the total annual capital cost and combination with operating cost of treated water produced.

Total investment capital costs are amortized over the design life of the plant to get total annual fixed capital cost (Sethi et al 2000, Beck et al 2004). The cost per unit of thousand gallon day was estimated as the total annual economic cost divided by the total design flow rate multiplied by 1000.

$$\textit{Annual Economic Cost} = (C_{con} + C_{eng} + C_{eqp} + Cont.)(A/C) + C_{op} \ldots\ldots\ldots\ldots (8)$$

where C_{con} is the construction cost, C_{eng} is the Engineering cost, C_{eqp} is the Equipment cost, C_{op} is the Operating cost and (A/C) is the amortization factor or capital recovery factor, estimated as the function of the interest rate for the capital investment cost, i_c and the life span of the plant, LS:

$$(A/C) = \frac{i_c*(1+i_c)^{LS}}{(1+i_c)^{LS}} \ldots\ldots\ldots\ldots (9)$$

However, the cost per thousand gallons a day (CPT) of treated water was expressed as:

$$CPT = \left(\frac{(C_{con} + C_{eng} + C_{eqp} + Cont.)(A/C) + C_{op}}{Qdes}\right)*1000 \ldots\ldots\ldots\ldots (10)$$

where Q_{des} is the capacity of water treated

5.4 Description of the Treatment Systems Considered and Implications for Cost

3.4.1 Description and Method of Aeralator® Treatment System

The Aeralater® water treatment process is designed to remove high levels of iron and or manganese from water. The Aeralator® water treatment system is divided into three main sections: aeration, detention and filtration (four filter cells). The system has been described as three in one system because it performs three functions in single unit as shown in Figure III-1. The Type II AERALATER® is considered as a modified conventional treatment system for Kaw City.

The Aeralater® water treatment system is a complete self-contained filter plant for treating water. It combines aeration, detention, and filtration functions. The treatment processes involved aeration, iron and manganese oxidation (with the oxidant added at inlet piping to the AERALATER® system), detention and gravity filtration (with four filter cells). Water from the well (groundwater) would enter the top of the unit and pass through inlet hole (PVC pipe) to the aeration section. After aeration, water moves to the detention area where oxidation and flocculation of iron and/or manganese oxidation occurs. A static mixer is mounted in between aeration and detention in order to speedup oxidation process. The probes in the detention tank are used to control the operation of the pumps, and chemical feeders to control reaction speed.

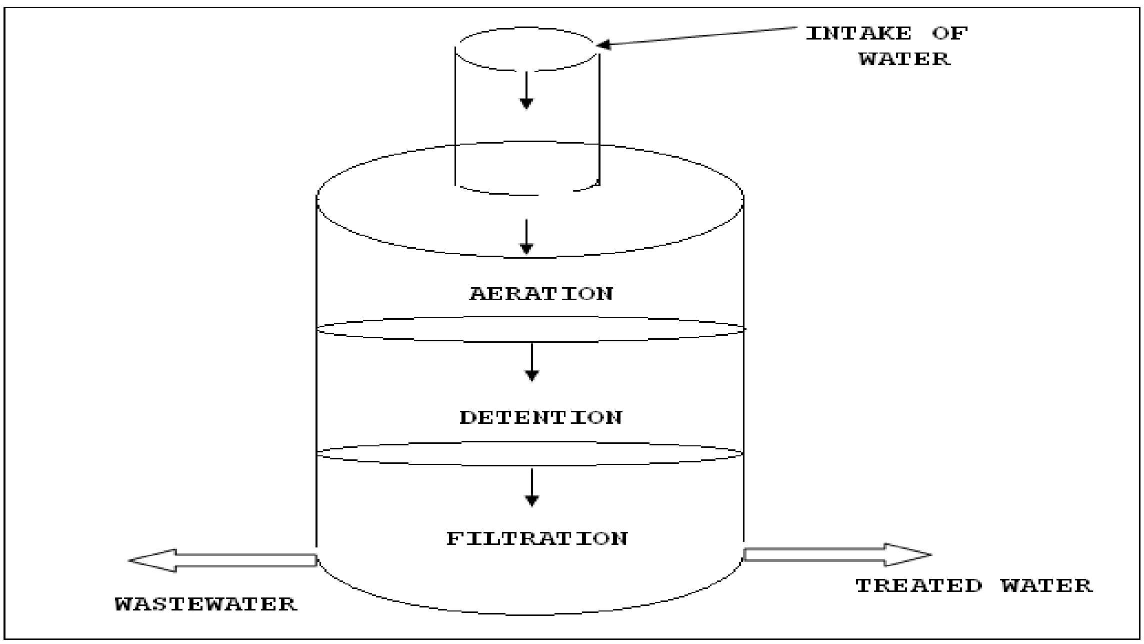

Figure III-1. The Flow System of Aeralator® Treatment Process

The oxidized iron and manganese water is distributed to the four filter cells through a simple piping arrangement. The filtered water passes through at a low pressure rate. These filters contain an Anthra/sand media to remove the manganese. This media is advertised as an alternative to greensand. After the raw water has passed through these processes, multiplates with low headloss are used to collect the filtered water. A similar process is used to automatically backwash the filters and remove the wastewater. The filtered water is then pumped to the elevated storage tank by high service pump. The water loss by the system is assumed to be 1 percent (Sorg 2008).

3.4.2 Description of Nanofiltration Water Treatment System

The nanofiltration system used has two-stage array system. The system was constructed by Fluid Processes Inc. and the spiral-wound membranes supplied by Hydranautics. The first stage consisted of two parallel pressure vessels, each consist of three membrane elements. The second stage consists of one pressure vessel containing three membrane elements Hem (2008). The system assumed to set to operate at 75 percent recovery, which means that only 75 percent of intake water enters the distribution system while 25 percent enters into wastewater stream. Before the nanofiltration, the water filtered through cartridge filter or greensand filters oxides manganese and to prevent the plugging of the membrane module with particles.

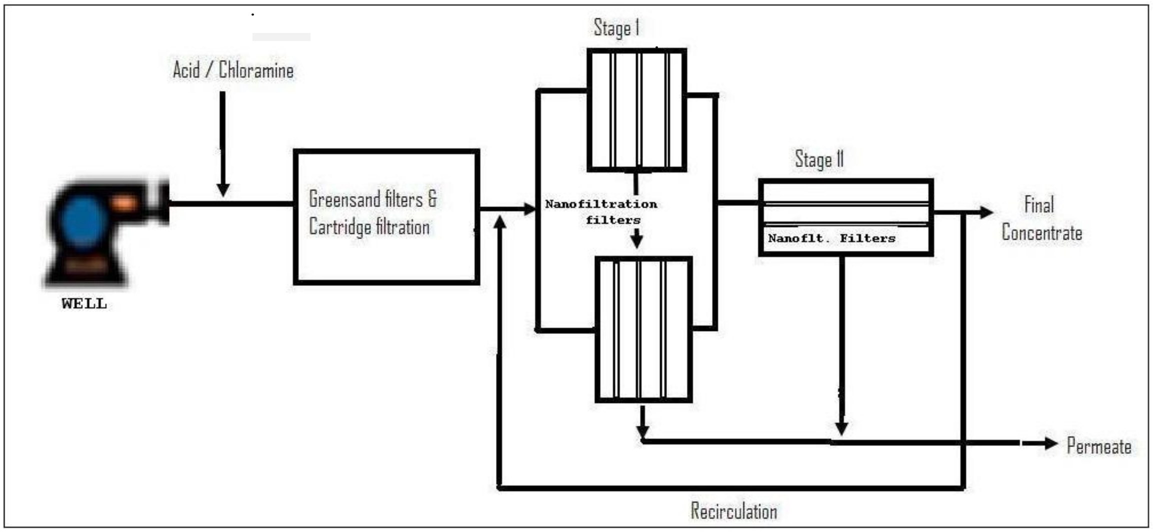

Figure III-2. Design of Nanofiltration Treatment Process

Acid will be introduced into the nanofiltration feed line to keep the pH between 5.6 and 5.8 to enable solubility of carbonates to minimize inorganic scaling. Chloramines would be injected at a set rate and concentration to prevent biofouling (formation of a biological slime or biofilm that can be avoided by feeding chlorine into the feed water). Because the nanofilter membranes do not tolerate free chlorine, chloramines would be used. Chloramines are defined as chlorine that exists in a chemical combination with ammonia in water. Chloramines were made by mixing sodium hypochlorite with ammonium sulfate. Chloramines controlled such that no more than 0.1 mg/l of free chlorine applied to the membranes. The goal residual in the permeate stream will be one mg/l of chloramines.

3.5 Simulation of the Water Treatment System Using EPANET

EPANET software was used to create a pipeline diagram since the Kaw City does not have digital pipeline map. A modified version of EPANET called EPANET-Z (Zonium Solutions) (http://www.zonums.com/epanetz.html) was used which has Google and Yahoo maps as the background. Parameters such as length of the pipeline, elevation of the nodes and equipment like pumps are added into the model of the distribution system. The distribution system of Kaw City, distributes water from the tower through the city. Figure III-3 shows the map of the study site with the locations of the proposed site of the well and treatment and their elevations and endpoint of the existing plant. Figure III-4 therefore shows the distribution systems of the entire Kaw City and the location of the elevated water tank.

In EPANET–Z's toolbar, the pipe and link icons used to create link and endpoint (junction) of the pipe. More precisely, the node forms the endpoint of the pipeline and the link forms the pipe.

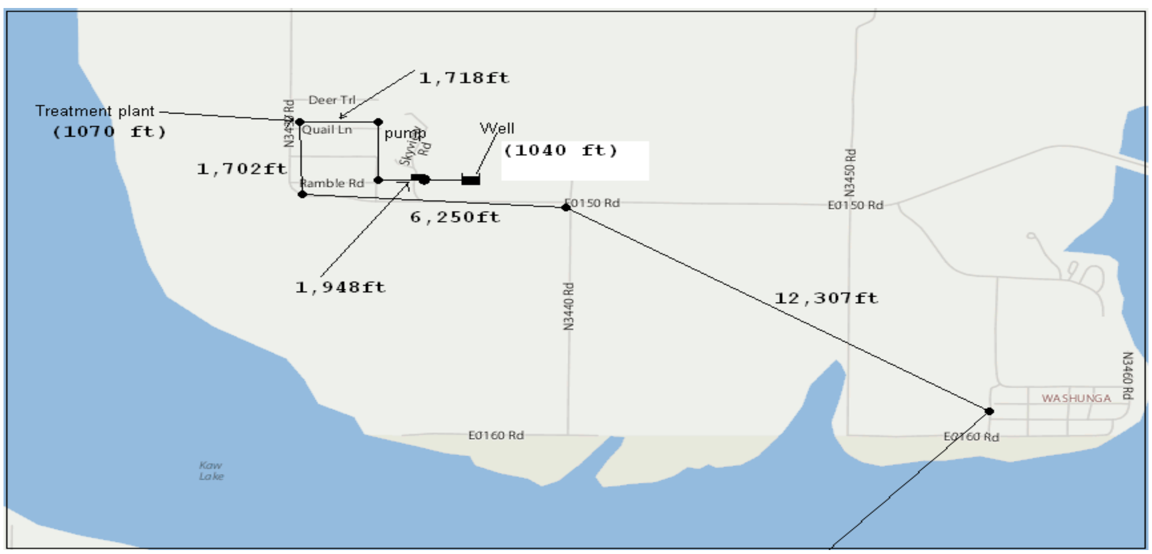

Figure III-3. The network system of the pipeline the Monitoring well to propose "Greenhouse" the treatment plant and from the treatment plant to the Exiting Pipeline at Washunga Bay

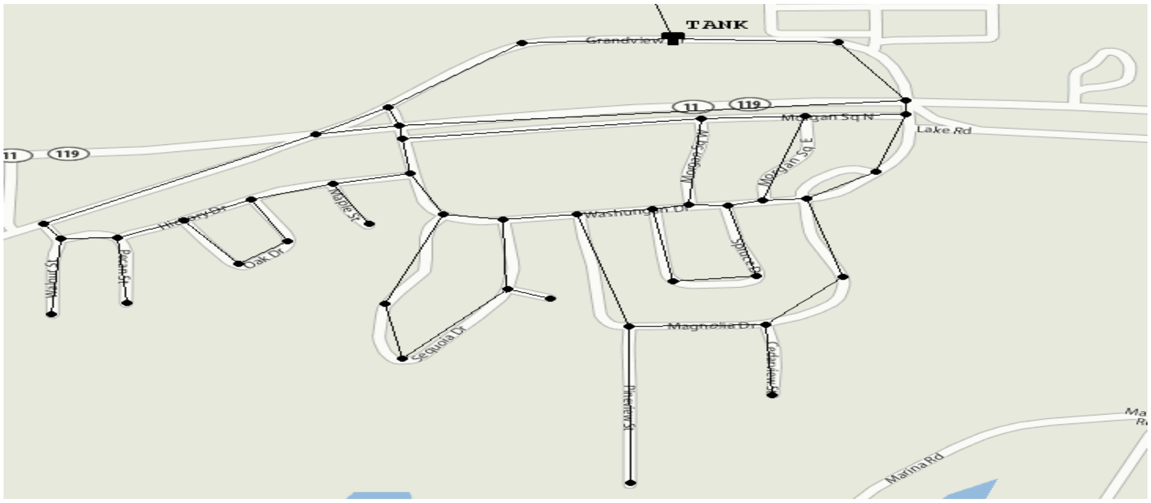

Figure III-4. The Replacement Pipeline Layout for Kaw City

The main tower (tank) and the pump are located in the model in addition to the pipelines and the nodes. Then EPANET-Z will save the data in an *.inp file by exporting the network (pipeline layout).

The elevation of each node was estimated by overlaying the pipeline file on a USGS 1/3 second elevation map in the GIS software program, Globalmapper©. An xyz file is exported from Globalmapper©. The elevations from this file were added to the node identification section of the EPANET input (.inp) file using the Notepad text editor

The elevations values were in meters but were converted to feet. In GlobalMapper©, the measure icon can be used to calculate the distance (length) of the pipelines. This procedure was used repeatedly until all the measurements finished. In areas where there were large elevations changes between nodes, it was necessary to use Pythagoras's theorem to estimate the length of the pipeline between nodes. Alternatively, a tread measurement method can be applied. Globalmapper© was used to create a cross section from one node to another. The trend was used to measure the undulating cross section and multiple by the scale of the cross section to get the exact distance.

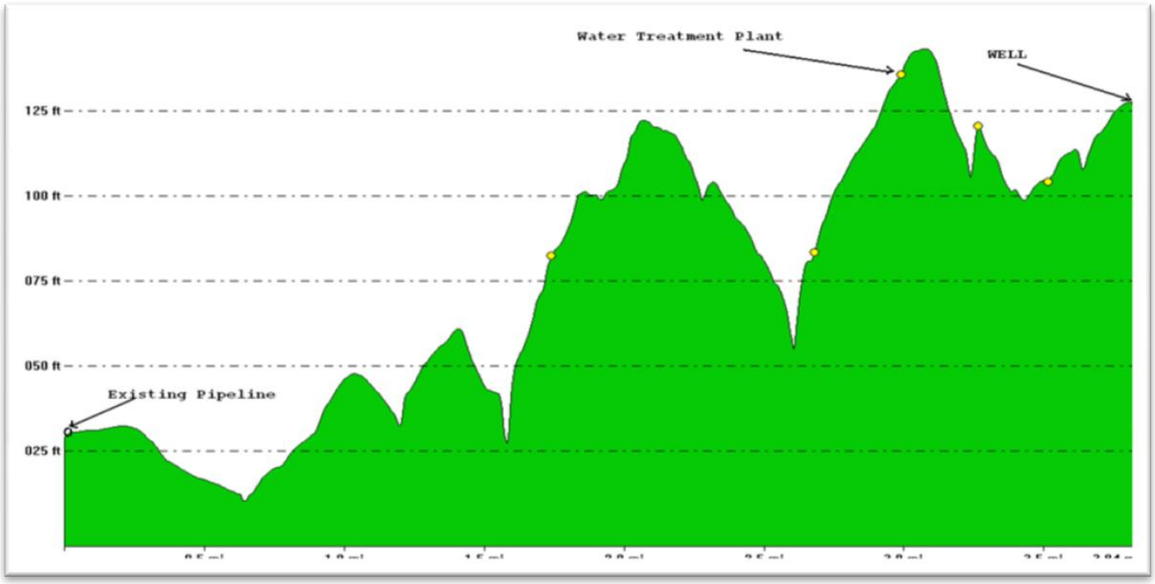

Figure III-5. The Cross Section from the Existing pipeline at Washunga Bay to the Treatment Plant and from Treatment Plant to the Monitoring Well at Greenhouse

CHAPTER IV

RESULTS AND ANALYSIS

4.0 Introduction

This chapter explains the results and findings of the study. Under this study, there were three main objectives. The first objective was to determine the cost of capital investment and the annual capital cost of two possible types and sizes of water treatment plants. The second objective was to determine the annual cost of operating of the treatment systems. The third objective was to compare the discounted amortized capital cost plus the amortized operating cost for two sizes and two types of treatment plants. Another objective was to determine the cost of replacing the distribution pipeline in Kaw City.

Other costs will be explained shortly in addition to the main objectives. These include the cost of buildings for the two different treatment plants. The cost of the transmission line from the Monitoring well to the treatment plant potentially located at the old green house site and then from the treatment plant to the existing pipeline at Washunga Bay was also estimated from the cost of materials plus the cost of excavation. The estimated cost of the layout of the entire Kaw City pipeline was based on the materials required and pipeline excavation cost in the city

4.1 Estimation of Cost of Building of Alternative Water Treatment Plant Systems

4.1.1 Estimation of Cost of a Building to House the two Sizes of Nanofiltration (NF) Treatment Systems.

The estimation of the cost of treatment plant building was based on the size of the building and other facilities in the building. The size of the building to house an 86 thousand gpd nanofiltration system was 40 feet length by 25 feet width with 1,000 square feet for Kaw City only. The size of the building to house the 216 thousand gpd system was slightly larger being 45 feet in length by 30 feet in width with 1,350 square feet for both Kaw City and Shidler. The two buildings have common descriptions and the only thing differs is the length of the building. The costs of the two buildings are presented in terms of the foundation, slab floor, structural steel enclosure, interior finishes, and heating, ventilation and air conditioning (HVAC). Table IV-1 shows the cost of building nanofiltration treatment plant of the size of 40 feet by 25 feet width with 1000 square feet which is designed to house the 86 thousand gpd treatment plant. The cost of perimeter of foundation was estimated to be $22,650 or $22.65/square foot. The steel reinforcing for floor slabs cost $9.29/cubic yard of cement with a total cost of $232.

Table IV-1. Cost of Nanofiltration Building (40 feet X 25 feet) Dimension

Descriptions (40ft x 25ft)	units	unit cost ($)	quantity	Invest. Total Cost	Annual Cost
Structural concrete with normal weight (sand, portland cement and water, 3500psi) for floor and foundation	CY	$114	25	$2850	$156
Steel Reinforcing for Floor or slab (40'x 35' x .5')'	CY	$9.29	25	$232	$13
Perimeter of Foundation	sqft	$22.65	1000	$22,650	$1,241
Pre-Engineered Steel Building (Clear span rigid 26 ga. Colored roofing and siding 25' to 40' wide, 14' eves height	SF	$19.64	1000	$19,640	$1,076
Controls & Instrumentation	Lump sum	$3,450	1	$3,450	$189
Heat Generating Systems (6KW, 20.5 MBH)	SF	$6.60	1000	$6,600	$362
Cooling Generating Systems (water cooled, compressor, standard control, 5 ton)	SF	$4.72	1000	$4,720	$259
Steel door, half glass, steel flame with paint, 2'-8" X 6'-8"	EA	$1,045	3	$3,136	$172
Partitions (incl. base, no door, painted steel, no plumbing)	EA	$1,056	4	$4,224	$231
Exterior Windows (including frame, screen, and grilles)	EA	$1,564	2	$3,128	$171
Exterior Doors	EA	$493	2	$985	$54
Water closet, elongated tank, wall hung, all set)	EA	$1,940	2	$3,880	$213
lavatory systems	EA	$1,144	2	$2,288	$125
Light and Wiring	SF	$2.51	1000	$2,510	$137
Transformer, oil filled, 15kv with taps, 480V	EA	$9,385	1	$9,385	$514
TOTAL				**$89,678**	**$4,912**

The total cost of the structural concrete with sand, Portland cement and water was estimated to be $2850 or $114/cubic yard. The pre-engineered Steel building (including exterior enclosure and roofing) was estimated to cost $19,640 or $19.64/square feet. The investment cost of fittings for water closets and lavatory systems were estimated to be $3,880 and $2,288 respectively. The two water closets and lavatory systems were used which assumed that one for men and other for women. The investment cost of interior steel doors for the partitions and exterior doors were estimated to be $3,136 and $985 respectively while their amortized cost was estimated to be $177/yr and $54/yr respectively. The lighting and wiring were estimated to cost $2510 with an annual repayment cost of $137. The control and instrumentation systems and heat generating systems were estimated to cost $3,450 and $6,600 with annual repayment costs of $189 and $352 respectively. The cooling system was estimated to be cost $4,720 with an annual fixed cost of $259.

The investment cost of internal partition of the building was estimated to be $4,224 with an annual fixed cost of $231. The investment and annual fixed cost of electrical transformer for the building was estimated to be $9,385 and $514 respectively. The total investment cost of the 1000 square feet building of nanofiltration (NF) treatment plant was estimated to be $89,678 or $89.68 cost per square foot.

Assuming the lifespan of the building is fifty years and the discount rate is 5 percent, the capital recovery factor (CRF) or annual amortized cost per dollar is $0.05. Therefore, the annual fixed (repayment) cost was calculated to be $4,912.

Table IV-2 gives the cost of the building for the larger NF treatment plant (45 feet by 35 feet width or 1350 square feet). The building was designed to house the 216 thousand gpd treatment plant. The investment and annual fixed cost of structural concrete with sand, water and Portland cement and steel reinforcing of floor slabs were estimated to be ($3,762 and $307) and ($206 and $17) respectively. Additionally, the estimated investment and amortized cost of the perimeter of foundation cost $30,578 and $1,675 respectively. The investment cost of pre-engineered steel building was estimated to be $24,030 with an amortized cost of $1,316/yr.

Moreover, the investment cost of the heat and cooling generating systems were estimated to be $8,910 and $6,372 respectively with corresponding annual fixed costs of $488 and $349. The investment and amortized costs of the building light and wiring were estimated to be $3,389 and $186/yr respectively. The total investment and annual fixed of the building were estimated to be $107,822 and $5,906/yr. The cost per square foot of the building was estimated to be $79.87.

Table IV-2. Cost of Nanofiltration Building (45 feet x 30 feet) Dimension

Descriptions (45ft x 30ft)	**units**	**unit cost ($)**	**quantity**	**Invest. Total Cost**	**Annual Cost**
Structural concrete with normal weight (sand, Portland cement and water, 3500psi)	CY	114	33	$3,762	$206
Steel reinforcing of Floor or slab	CY	$9.29	33	$307	$17
Perimeter of Foundation	SF	$22.65	1350	$30,578	$1,675
Pre-Engineering Steel Building (Clear span rigid 26 ga. Colored roofing and siding 50' to 35' wide, 14' eves height	SF	$17.80	1350	$24,030	$1,316
Controls & Instrumentation	Lump sum	$3,450	1	$3,450	$189
Heat Generating Systems (6KW, 20.5 MBH)	SF	$6.60	1350	$8,910	$488
Cooling Generating Systems (water cooled, compressor, standard control, 5 ton)	SF	$4.72	1350	$6,372	$349
Steel door, half glass, steel flame with paint, 2'-8" X 6'-8"	EA	$1,045	3	$3,136	$172
Partitions (incl. base, no door, painted steel, no plumbing)	EA	$1,056	4	$4,224	$231
Exterior Windows (including frame, screen, and grilles)	EA	$1,564	2	$3,128	$171
Exterior Doors	EA	$493	2	$985	$54
water closet, elongated tank, wall hung, all set)	EA	$1,940	2	$3,880	$213
lavatory systems	EA	$1,144	2	$2,288	$125
Light and Wiring	SF	$2.51	1350	$3,389	$186
Transformer, oil filled, 15kv with taps, 480V	EA	$9,385	1	$9,385	$514
TOTAL				**$107,822**	**$5,906**

Both the investment and amortized cost of the structural concrete, heating and cooling generating systems, steel reinforcing of floor slabs, perimeter of foundation and lighting and wiring of the building of capacity of 216 thousand gpd were higher than for the 86 thousand gpd building. This is due to the size of the building. However, both the investment and annual fixed cost per square foot of the 216 thousand gpd building were lower than 86 thousand gpd treatment plant building. As the size of the building increases, the cost per foot of the building decreases.

4.1.2 Estimation of Cost of a Building to House the two Sizes of Aeralator® Treatment Plant Systems.

The estimated total cost of the 86,000 gpd Aeralator® treatment plant building is presented in Table IV-3. The size of the building for the Aeralator® water treatment plant was 30 feet length by 25 feet in width or 750 square feet. The estimated investment cost of the structural concrete at $114/cubic yard was $2,166 with an annual fixed cost of $119. With the unit cost of $9.29/cubic yard or $ 22.65/square foot, the investment cost of steel reinforcing of floor slab and the perimeter of the foundation of the building were cost $177 and $16,988 and the amortized cost of $10/yr and $931/yr respectively. Because of the vertical structure of the Aeralator® system, it requires special foundation to be placed on it to avoid sinking into the floor

Table IV-3. Cost of Aeralator® Building (30 feet X 25 feet) Dimension

Descriptions (30' x 25')	**Units**	**unit cost ($)**	**quantity**	**Total invest. cost**	**Ann. fixed cost**
Structural concrete with normal weight (sand, portland cement and water, 3500psi)	CY	114	19	2166	**$119**
Steel Reinforcing of Floor slab	C.Y	$9.29	19	$177	**$10**
Perimeter of Foundation	SF	$22.65	750	$16,988	**$931**
Aeralator® plant Foundation 12 feet x 12 feet x 8 inch	SF	$22.65	144	$3,262	**$179**
Pre-Engineering Steel Building (Clear span rigid 26 ga. Colored roofing and siding 25' to 40' wide, 14' eave height	SF	$20.85	750	$15,638	**$857**
Controls & Instrumentation	Lump sum	$3,450	1	$3,450	**$189**
Heat Generating Systems (6KW, 20.5 MBH)	SF	$6.60	750	$4,950	**$271**
Cooling Generating Systems (water cooled, compressor, standard control, 5 ton)	SF	$4.72	750	$3,540	**$194**
Wood door, flush wood flame with paint, 2'-8" X 6'-8"	EA	$1,045	3	$3,136	**$172**
Partitions (incl. base, no door, painted steel, no plumbing)	EA	$1,056	4	$4,224	**$231**
Exterior Windows (including frame, screen, and grilles)	EA	$1,564	2	$3,128	**$171**
Exterior Doors	EA	$493	2	$985	**$54**
water closet, elongated tank, wall hung, all set)	EA	$1,940	2	$3,880	**$213**
lavatory systems	EA	$1,144	1	$1,144	**$63**
Light and Wiring	SF	$2.51	750	$1,883	**$103**
Transformer, oil filled, 15kv with taps, 480V	EA	$9,385	1	$9,385	**$514**
Total Cost of the building				**$77,933**	**$4,269**

Therefore, the investment cost of the system special foundation was estimated to be $3,262 and annual repayment cost of $179.

With a unit cost of $20.85/square foot, the pre-engineered steel building including roofing and exterior structural was estimated to be $15,638 with an amortized cost of $857. The cost of the control and instrumentation was estimated to be $3,450. The investment and annual fixed costs of the heating and cooling systems of the building were estimated to be $4,950 and $3,540 and $271 and $194 respectively. The investment and annual fixed cost of partitions in the building for the office, lavatory and laboratory were estimated to be $4,224 and $231 respectively. The investment cost and annual repayment for light and wiring was estimated to be $1,883 and $103 respectively. The total investment and amortized costs of the entire building were estimated to be $77,933 and $4,269 respectively. The cost per foot of the total building was estimated to be $103.91/square foot.

Table IV-4 gives the cost of building for the 216 thousand gpd treatment which is 40 feet length by 25 feet width or 1000 square feet. This would house the treatment plant to supply both Kaw City and Shidler. The descriptive features of the two buildings are the same but they have cost differences in some features due to variation of size. The investment and annual fixed cost lighting and wiring cost were estimated to be $2,510 and $137 respectively. The initial and amortized costs for the heating and cooling units were estimated to be $6,600 and $4,720 and $362 and $259. Using the Means (2009) square foot cost of $20.85, the investment cost of the Pre-Engineered steel building including roofing, with roof and exterior siding 25 feet length by 40 feet width and 14 feet high was estimated to be $20,850 with an amortized cost of $1,142. The estimated investment cost of the steel reinforcing of floor slabs was $214 and annual fixed cost of $12. With 1000 square feet and unit cost per foot of $22.65, the estimated investment cost of perimeter of the foundation was $22,650 and annual repayment cost of $1,241.

Table IV-4. Cost of Aeralator® Building (40 feet X 25 feet) Dimension

Descriptions (40' x 25')	**Units**	**unit cost ($)**	**quantity**	**Total invest. cost**	**Ann. fixed cost**
Structural concrete with normal weight (sand, portland cement and water, 3500psi)	CY	114	23	2622	$144
Steel Reinforcing of Floor or slab	C.Y	$9.29	23	$214	$12
Perimeter of Foundation	SF	$22.65	1000	$22,650	$1,241
Aeralator® plant Foundation 12 feet x 12 feet x 8 inch	SF	$22.65	144	$3,262	$179
Pre-Engineering Steel Building (Clear span rigid 26 ga. Colored roofing and siding 25' to 40' wide, 14' eave height	SF	$20.85	1000	$20,850	$1,142
Controls & Instrumentation	Lump sum	$3,450	1	$3,450	$189
Heat Generating Systems (6KW, 20.5 MBH)	SF	$6.60	1000	$6,600	$362
Cooling Generating Systems (water cooled, compressor, standard control, 5 ton)	SF	$4.72	1000	$4,720	$259
Wood door, flush wood flame with paint, 2'-8" X 6'-8"	EA	$1,045	3	$3,136	$172
Partitions (incl. base, no door, painted steel, no plumbing)	EA	$1,056	4	$4,224	$231
Exterior Windows (including frame, screen, and grilles)	EA	$1,564	2	$3,128	$171
Exterior Doors	EA	$493	**2**	$985	$54
water closet, elongated tank, wall hung, all set)	EA	$1,940	2	$3,880	$213
lavatory systems	EA	$1,144	1	$1,144	$63
Light and Wiring	SF	$2.51	1000	$2,510	$137
Transformer, oil filled, 15kv with taps, 480V	EA	$9,385	1	$9,385	$514
Total Cost of the building				**$92,759**	**$5,081**

The total investment and annual fixed cost of the building were estimated to be $92,759 and $5,081. The cost per foot of the investment and annual fixed cost were estimated to be $92.76 and $5.08 respectively. However, the investment cost per foot of the building to house water treatment plant of capacity of 86 thousand was $103.91 is higher than the $92.76 cost per foot for the 216 thousand treatment plant. The difference between the costs per foot for the two buildings was estimated to be $11.15 or 10.7 percent. Again as the size of the building increases, the cost per foot of the building decreases.

4.2 Determination of the Capital Cost of Nanofiltration treatment Systems for Kaw-City

The cost of the two treatment systems were divided into two groups that is Capital cost (which comprises construction cost, building cost and all which incurred before the operation of the system) and Operating cost (cost incurred on day to day activities or running the of treatment plant). The total capital cost has two sections namely capital investment cost and annual fixed cost. The capital investment cost is the cost incurred in the construction of the treatment without discounting. Annual fixed cost of capital is the discounting cost or annual repayment cost.

4.2.1 Estimated Capital Cost of Nanofiltration treatment Systems Plant of two sizes

The design cost assumed to be 0.91 percent of the construction cost and bidding phase cost was assumed to be 0.81% of the construction cost. Table IV-5 presents estimated investment capital cost and annual fixed cost of 86 thousand gpd nanofiltration plant assumed to supply only Kaw City. The construction cost of the plant included building cost, cost of drilling a well, a six inch pipeline cost from the well to the treatment plant, trenching cost and resident inspection. The investment cost of the building, as discussed above, was estimated to be $89,656 or $89.66 per square foot. The annual fixed cost of the building was $4,912. The annual fixed cost per thousand was $0.16 gallon of water treated. The investment cost for trenching including backfilling and packing was estimated to be $9,307 for 1506 cubic feet.

The annual fixed cost of the trenching was $510. With the unit cost of pipeline of $5.98, the total investment of the raw pipeline was estimated to be $30,402. The annual fixed cost was estimated to be $1,665. The cost of drilling and establishing the well was estimated to be $9,094.12 with the annual fixed cost of $498. In the course of execution of the project, there should be monitoring and inspecting. The cost of the inspection and monitoring was estimated to be $5,000. The total cost of construction was $143,484 or 40 percent of the total investment cost and annual cost of $7,860 or $0.25/1000 gal of treated water.

Table IV-5. Estimated Capital Cost of Nanofiltration Plant of 86 Thousand GPD at Greenhouse Site

Descriptions	**units**	**unit cost($)**	**quantity**	**Initial Cost**	**Rate(%)**	**annual FC**	**Ann. FC/1000**
Construction							
Building	sq. ft	$90	1000	$89,680		$4,912	0.16
Cost of drilling Well	ft	$9,094	1	$9,094		$498	0.02
6" Raw Water Pipeline from well to treatment plant	ft	$6	5084	$30,402		$1,665	0.05
Trenching (incl backfilling, packing) 2' Width, 4' Depth	CY	$6	1506	$9,307		$510	0.02
Resident Inspection	lump sum	$5,000	1	$5,000		$274	0.01
Total Construction				$143,484	41.7	$7,860	0.25
Equipment							
Chlorine Contact Chamber	ea	$12,000	1	$12,000		$657	0.02
Greensand Pressure Filtration (80 gpm)	ea	$27,765	1	$27,765		$1,521	0.05
Nanofiltration Manufacturing Model (80gpm)	ea	$120,000	1	$120,000		$6,573	0.21
Well pump, motor and control	Hp	$8,310	1	$8,310		$455	0.01
Pressure Pump to force water through the filters	Hp	$2,995	1	$2,995		$164	0.01
Waste Water Pump	Hp	$1,987	1	$1,987		$109	0.00
Total equipment				$173,057	50.3	$9,479	0.30
Engineering Cost							
Design @ .91% Construction	percent	$1,306	1	$1,306		$72	0.00
Bidding Phase @.8% Construction	percent	$1,148	1	$1,148		$63	0.00
Engineering during construction	lump sum	$11,561	1	$11,561		$633	0.02
O&M Manual	lump sum	$2,720	1	$2,720		$149	0.00
Groundwater Rights							
Other Engineering and Surveying	lump sum	$2,500	1	$2,500		$137	0.00
DEG Permit to construct WTP	lump sum	$1,000	$1	$1,000		$55	0.00
Land Acquisition							
Total Engineering Cost				$20,235	5.9	$1,108	0.04
Contingencies (5% 0f construction cost)	lump sum	$7,174	1	$7,175	2.1	$393	0.01
TOTAL FIXED (CAPITAL) COST				$343,950		$18,840	0.60

The equipment cost covered the cost of chlorine contact chamber, pressure filtration, Nanofiltration unit, and well pumps, motor and controls. The total investment cost of the equipment was estimated to be $173,057 and the annual amortized cost of the total equipment was estimated to be $9,479 or 50 percent of the total cost investment. The annual fixed cost per thousand gallons was $0.60. The unit cost of the chlorine contact chamber was $12,000 with an annual fixed cost of $657. The investment costs of the nanofiltration module and pressure filtration unit was estimated to be $120,000 and $27,765 respectively with annual fixed costs of $6,573 and $1,521 respectively.

The engineering cost included costs for the design, bidding, O&M manual, engineering during construction, groundwater rights, engineering and surveying costs, and Department of Environmental Quality (DEQ) permits. The design and bidding phase of the investment costs were estimated to be $1,306 and $1,148, which were 0.91% and 0.8% of the construction cost respectively. Land acquisition and groundwater rights required no cost because the city has their own land and groundwater rights, so the costs of these items are zero.

Moreover, the O&M manual cost was estimated at $2,720. The engineering portion of total investment cost of $20,235 represented 6 percent of the total investment cost. The cost of other expenses or contingency costs were estimated to be $7,174 per year which is 5 percent of the construction and 2.1 percent of the total capital cost. Total capital cost was estimated to be $343,950. The annual repayment fixed cost is $18,840 or $0.60/1000 gallon of treated water.

Table IV-6 presents the estimated capital investment cost and annual fixed cost for the 216,000 gal/day nanofiltration treatment plant assumed to supply water to both Kaw City and Shidler. The total investment of the building was estimated to be $107,825 or $79.89 per square foot. The total cost of the pipe and trenching from the well to the treatment were estimated to be $30,402 and $9,307 or $5.98 and $1.78 per linear foot respectively. The annual repayment cost of the pipe and the trenching were estimated to be $1,665 and $510. The investment cost and annual fixed cost of drilling the well that would supply water were estimated to be $9,094 and $498 respectively. Moreover, the total construction investment cost was estimated to be $161,628. This represents 30.6 percent of the total capital investment cost. The annual fixed cost or amortized capital cost was estimated to be $8,853 or $0.11/1000 gal of water treated.

Table IV-6. Estimated Capital Cost of Nanofiltration Plant of 216 Thousand GPD at Greenhouse Site.

Descriptions	units	unit cost($)	quantity	Initial Cost	Rate(%)	Total FC	TotalCost/ 1000
Construction							
Building (45' x 30')	sq. ft	$79.87	1350	$107,825		$5,906	$0.07
Cost of drilling Well	ft	$9,094	1	$9,094		$498	$0.01
6" Raw Water Pipeline from well to treatment plant	ft	$6	5084	$30,402		$1,665	$0.02
Trenching (incl backfilling, packing) 2' Width, 4' Depth	CY	$6	1506	$9,307		$510	$0.01
Resident Inspection	lump sum	$5,000	1	$5,000		$274	$0.00
Total Construction				**$161,628**	**30.6**	**$8,853**	**$0.11**
Equipment							
Chlorine Contact Chamber 150gpm	ea	$16,000	1	$16,000		$876	$0.01
Pressure Filtration(greensand filters) 150gpm	ea	$69,414	1	$69,414		$3,802	$0.05
Nanofiltration	ea	$240,000	1	$240,000		$13,146	$0.17
Well pump, motor and control150gpm 12hp	ea	$8,310	1	$8,310		$455	$0.01
Pressure Pump to force water through the filters	ea	$2,995	1	$2,995		$164	$0.00
Waste Water Pump	ea	$1,987	1	$1,987		$109	$0.00
Total equipment				**$338,706**	**64.0**	**$18,553**	**$0.24**
Engineering Cost							
Design @ .91% Construction	percent	$1,471	1	$1,471		$81	$0.00
Bidding Phase @.8% Construction	percent	$1,293	1	$1,293		$71	$0.00
Engineering during construction	lump sum	$11,561	1	$11,561		$633	$0.01
O&M Manual	lump sum	$2,720	1	$2,720		$149	$0.00
Groundwater Rights							$0.00
Other Engr and Surveying	lump sum	$2500	1	$2,500		$137	$0.00
DEG Permit to construct WTP	lump sum	$1,000	1	$1,000		$55	$0.00
Land Acquisition							
Total Engineering Cost				**$20,545**	**3.9**	**$1,125**	**$0.01**
Contingencies (5% 0f construction cost)	lump sum	$8081	1	$8,081	1.5	$443	**$0.01**
TOTAL FIXED (CAPITAL) COST				**$528,960**		**$28,975**	**$0.37**

The equipment cost covered the chlorine contact chamber, greensand pressure filtration, nanofiltration manufacture model, and pumps. The unit cost of the greensand pressure filtration for 80 gpm capacity was estimated to be $69,414. The annual fixed cost was estimated to be $3,802. The cost per thousand gallons of water supply was estimated to be $0.05 gallon. The investment costs for the well pump and additional pump to add pressure water through the filters were estimated to be $8,310 and $2,995 respectively. The amortized cost of the well pump and pressure pump were estimated to be $455 and $164. The total cost of equipment estimated at $338,706 represents 64 percent of the total investment capital cost or $18,553 per year. For each thousand gallons of water supply, the equipment cost was estimated to be $0.05/1000 gallon of water treated. The total engineering cost was estimated to be $20,545 or 3.9 percent of the total investment capital cost.

Other expenses or a contingency cost at 5 percent of construction cost was estimated to be $8,081 of 1.5 percent of the investment capital cost. The total investment capital cost was $528,960. With a fifty year period and a 5 percent interest rate, and the CRF of $0.05, the total capital fixed cost was estimated $28,975 and the unit cost per thousand gallons of water treated was $0.37/1000 gallon.

The investment cost of the 86,000 gal/day and 216,000 gal/day treatment plants were estimated to be $343,950 and $528,960 respectively with annual capital fixed costs of $18,840 and $28,975 respectively. The quantity of water to be treated was more than doubled but the cost difference of total investment of the capacities was $185,010/yr (approximately 35%), which means there are cost economies. However, the cost of 86 thousand gpd was $60/1000 gallon and the cost with the 216 thousand gpd plant was estimated to be $0.37/1000. As the quantity of water treated from a given plant increased, the cost per gallon treated decreases.

4.2.2 Annual Operating Cost of Nanofiltration Treatment System Plant of Two different Sizes

Table IV-7 shows the details of estimated operating costs for the 86,000 gpd Nanofiltration treatment plant to treat water for Kaw City. This treatment system has number of pumps due to high pressure needed during processing. The operating cost entailed utilities, chemicals, labor, administration, and replacement costs. The utility cost included the cost of the well control systems, pumping from the well, the HVAC, treatment plant pumps (booster, high service and wastewater lift station), and the greensand filtration system.

Table IV-7. Estimated Operating Cost of an 86,000 Gallon per Day Nanofiltration Water Treatment System at the Greenhouse Site

Descriptions	units	unit cost($)	quantity	Total Cost	Total Cost/1000	Rate (%)
Utilities						
Well Control System (@ .15KWH, 2920 hrs/yr) 0.15*2920	Kwh	$0.11	438	$47	$0.00	
Running well pump, 5.0hp, 0,747 Kw/hp, 3784 hrs/yr,80GPM (3784*5.0*0.747)	Kwh	$0.11	14133	$1,526	$0.05	
Heating, Ventilation and Air Condition(HVAC),.001 sqft x 1000sq ft x 2920hr/yr	Kwh	$0.11	2920	$315	$0.01	
Booster Pump 4.8hp, 78gpm, 0.747 Kw/hp, 3784 hrs/yr (3784*4.8*0.747)	Kwh	$0.11	13568	$1,465	$0.05	
Greensand Controls, nano controls @ 0.4Kw/h, 2920hrs/yr	Kwh	$0.11	1168	$126	$0.00	
High Service Pump, 60gpm (3.6hp *0.747kw/hp*3784hr/yr)	Kwh	$0.11	10176	$1,099	$0.03	
Waste Water Lift Station Pump(1hp, 365 days, 15gpm, 0.747 Kw/hr	Kwh	$0.11	1636	$177	$0.01	
Total Utilities				**$4,756**	**$0.15**	**11.8**
Chemicals						
Chlorine, 31.536 MG/yr @ (4 mg/l water treated)	Mg/yr	$0.50	477	$239	$0.01	
Scale inhibitor 31.536MG/yr @ (2mgl water treated)	Mg/yr	$1.15	239	$275	$0.01	
KnMnO4, 31.536MG/yr, @ (3.95mgl water treated)	Mg/yr	$1.60	471	$754	$0.02	
Total Chemicals				**$1,268**	**$0.04**	**3.1**
Administration and Operations						
Certification Fees	lump sum	$150	1	$150	$0.00	
Dues & Subscriptions	lump sum	$150	1	$150	$0.00	
Insurance	lump sum	$1,200	1	$1,200	$0.04	
Laboratory	lump sum	$500	1	$500	$0.02	
Office Supplies	lump sum	$450	1	$450	$0.01	
Miscellaneous Supplies	lump sum	$531	1	$531	$0.02	
Vehicle	lump sum	$645	1	$645	$0.02	
Postage and Freight	lump sum	$349	1	$349	$0.01	
Legal and Audit	lump sum	$249	1	$249	$0.01	
Telephone	lump sum	$400	1	$400	$0.01	
Administration and Operations				**$4,623**	**$0.15**	**11.4**
Labor						
Payroll Taxes (6.25% of operate and maintain)	percent	$1,369	1	$1,369	$0.04	

Table IV-7. Estimated Operating Cost of an 86,000 Gallon per Day Nanofiltration Water Treatment System at the Greenhouse Site

Descriptions	units	unit cost($)	quantity	Total Cost	Total Cost/1000	Rate (%)
Health Insurance 1.5% of Operate and maintenance of WTP	percent	$329	1	$329	$0.01	
Salary and Wages	hours	$20	1095	$21,900	$0.69	
Total Labor Cost				**$23,597**	**$0.75**	**58.4**
Replacement Costs						
pump	hp	$4,750	1	$4,750	$0.15	
Filters	ea	$278	5	$1,390	$0.04	
Total Replacement Cost				**$6,140**	**$0.19**	**15.2**
Total Annual Operating Cost				**$40,384**	**$1.28**	

With a unit electrical cost of 0.11kw/h, the annual cost of the well control system and for pumping from the well to the treatment plant was estimated to be $47 and $1,526 respectively. The annual cost of operating the HVAC, booster pumps, greensand controls, nano controls were estimated to be $315, $1,465 and $126 respectively. The annual cost for pumping from the treatment plant to the water tower and operating the wastewater pump were $1,099 and $177 respectively. The total utility cost for the 86 thousand gpd nanofiltration system was estimated to be $4,756/yr or $0.15/1000 gallon of water treated which represents 11.8 percent of total annual operating cost.

The 86 thousand gallon per day plant is expected to use chlorine at a rate of 477mg/yr of quantity of chlorine require and unit at $0.05/lb, the total cost of chlorine was estimated $238.73/yr or $0.01/1000 gallon of water treated. The cost of $KMnO_4$ required for oxidizing the iron and manganese in the water was estimated to be $754/yr or $0.02/1000 gal of water treated. The antiscalant or scale inhibitor, which controls scaling during processing, was estimated to be $275/yr for 471 mg/yr or $0.01/1000 gal of treated water. The total cost for the above chemicals is $1,268/yr or $0.04/1000 gal of water treated. The administration and operation costs included insurance, telephone, certification fees, legal and auditing and other costs. The cost for administration and operation, which represent 11.4 percent of the annual operating, cost. The labor cost included the base salary plus payroll tax (6.125% of wages and salary), and health insurance (1.5% of the wages and salary). The cost of health insurance was estimated to be $329/yr or $0.01/1000 gallon of water treated. The payroll taxes were placed at $1,369/yr or $0.04/1000 gallon of water treated. With a wage rate of $20/hr and if 1095 hours per are required, the total labor cost would be $21,900/yr or $0.69/1000 gal of water treated. Therefore, the total labor cost was then estimated to be $23,597yr or $0.75/1000 gallon. Some of the equipment for the treatment system needs to be periodically replaced during the 50 year planning horizon. The needed replacements included pumps and filters. The cost for these items were estimated to be $6,140/yr or $0.19/1000 gal of water treated. The total annual operating cost estimated to be $40,384/yr or $1.28/1000 gallon of water treated and the cost of $673/gpm of treated water.

Table IV-8 shows the estimated operating cost of the 216 thousand gpd nanofiltration treatment plant. The total cost of utility for this size of plant was estimated to be $13,547/yr or $0.17/1000 gallon of water treated. This represents 23.8 percent of the annual operating cost.

The cost of chlorine, applied at the rate of 1512 mg/gal, at $0.50/lb, was estimated to be $756 or $0.01/1000 gal of water treated. The system was estimated to require 1493mg/gal of $KMnO_4$ at the unit rate of $1.60/lb. the estimated cost of $KMnO_4$ was $2,389/yr or $0.03/1000 gal of water treated. The antiscalant was estimated to cost $869/yr or $0.01/1000 gal. Total chemical cost was estimated to be $4,014.20/yr or $0.05/1000 gal, which represents 7.1 percent of the annual operating cost. The cost of administration and operation of 216 gpd reverse osmosis/ nanofiltration treatment plant was assumed the same as that of capacity of 86, 000 gal/day represent 8.1 percent of the total cost per year.

Table IV-8. Estimated Operating Cost of the 216,000 GPD Nanafiltration Water Treatment System at Greenhouse site

Descriptions	units	$ unit cost	Quantity	Total Cost	rate (%)	TC/1000
Utilities						
Well Control System (@ .15KWH, 2920 hrs/yr) 0.15*2920	Kwh	$0.11	438	$47		$0.00
Running well pump, 15.5hp, 190GPM, 0.747 Kw/hp, 3784 hrs/yr, 190GPM (3784*15.5*0.747)	Kw/h	$0.11	43813	$4,732		$0.06
Heating, Ventilation and Air Condition(HVAC),.001 sqft x 1000sq ft x 2920hr/yr	Kwh	$0.11	2920	$315		$0.00
Booster pump 15.1hp, 0.747Kw/h, 187GPM, 3784hrs/yr (15.1*3784*0.747)	Kw/h	$0.11	42682	$4,610		$0.06
Greensand Controls, nano controls @ 0.4Kw/h, 2920hrs/yr	Kwh	$0.11	1168	$126		$0.00
High Service Pump (10.9hp *0.747kw/hp*3784hr/yr, 150GPM)	Kw/h	$0.11	30810	$3,328		$0.04
Waste Water Lift Station Pump(2.2hp, 365 days, 37.5 GPM, 0.747 Kw/hr, 2190Hrs/yr	Kw/h	$0.11	3599	$389		$0.00
Total Utilities				**$13,547**	**23.8**	$0.17
Chemicals						
Chlorine, 99.864 MG/yr @ (4 mg/l water treated)	Mg/yr	$0.50	1512	$756		$0.01
Scale inhibitor 99.864MG/l @2mgl water treated)	Mg/yr	$1.15	756	$869		$0.01
KnMnO4 99.864MG/yr, @ (3.95mg/l water treated)	Mg/yr	$1.60	1493	$2,389		$0.03
Total Chemicals				**$4,014**	**7.1**	$0.05
Administration and Operations						
Certification Fees	lump sum	$150	1	$150		$0.00
Dues & Subscriptions	lump sum	$150	1	$150		$0.00
Insurance	lump sum	$1,200	1	$1,200		$0.02
Laboratory	lump sum	$500	1	$500		$0.01
Office Supplies	lump sum	$450	1	$450		$0.01
Miscellaneous Supplies	lump sum	$531	1	$531		$0.01
Vehicle	lump sum	$645	1	$645		$0.01
Postage and Freight	lump sum	$349	1	$349		$0.00
Legal and Audit	lump sum	$249	1	$249		$0.00
Telephone	lump sum	$400	1	$400		$0.01
Total Administration and Operations				**$4,623**	**8.1**	$0.06
Labor						
Salary and Wages	hours	$20	1095	$21,900		$0.28

Table IV-8. Estimated Operating Cost of the 216,000 GPD Nanafiltration Water Treatment System at Greenhouse site

Descriptions	units	$ unit cost	Quantity	Total Cost	rate (%)	TC/1000
Health Insurance 1.5% of Salary and Wages	percent	$329	1	$329		$0.00
Payroll Taxes (6.25% of Salary and Wages)	percent	$1,369	1	$1,369		$0.02
Total Labor Cost				**$23,597**	**41.5**	$0.30
Replacement Costs						
Pumps	ea	$9,675	1	$9,675		$0.12
Filters	ea	$278	5	$1,390		$0.02
Total Replacement Cost				**$11,065**	**19.5**	$0.14
Total Annual Operating Cost				**$56,846**		$0.72

The labor cost, which represents 41.5 percent of the total operating cost estimated to be $23,597/yr or $0.30/1000 gallon of water treated. The replacement cost of pumps and filters was estimated to be $11,065/yr or $0.14/1000 gal or 19.5 percent of the operating cost. Total annual operating cost was estimated to be $56,846/yr or $0.72/1000 gal and $379/gpm of water treated.

4.3 Determination of the Cost of the Aeralator® Treatment Systems

4.3.1 Total Capital Cost of Treatment Systems Plant of two sizes

Table IV-9 presents the estimated investment capital and annual fixed cost for the 86,000 gal/day Aeralator® treatment plan. The cost of the 750 square foot building was estimated to be $77,933 or 103.91 per square foot. With a 50 year life, the annual fixed cost of the building was $4,269. The cost per thousand gallons of water treated was estimated to be $0.14. The cost of the building for the Aeralator® is less than the cost for the Nanofiltration building due to its smaller size. The cost of trenching including backfilling and packing was estimated to be $9,307 with the unit cost of $1.78 per linear foot. The unit cost of 6 inches pipe was estimated to be $5.98/ft or $30,402. The annual fixed cost of the pipe was estimated to be $1,665. The total construction cost of the plant was estimated to be $131,736 or 48.5 percent of the total cost. The annual fixed cost was $7,216 or $0.23/1000 gallons treated.

The equipment cost includes the Aeralator® system combines an air/backwash for enhanced media cleanliness with 60 gpm capacity and 6” diameter, valves which controls backwash and inlet waste water, induced draft blower, instrumentation and controls and pumps and motors. The MULTIWASH©, which is main equipment of the system, had investment cost of $76,000. The cost of control valves for the system was estimated to be $2,940.

Table IV-9. Estimated Capital Cost of Aeralator® Plant of 86,000GPD at Greenhouse Site

Descriptions	**units**	**$ unit cost**	**quantity**	**Initial Total Cost**	**Rate($)**	**Annual Fixed Cost**	**Annual Cost/1000**
Construction							
Building	sq ft	103.91	750	$77,933		$4,269	$0.14
Cost of drilling Well	ft	9094	1	$9,094		$498	$0.02
6" Raw Water Pipeline from well to treatment plant	ft	5.98	5084	$30,402		$1,665	$0.05
Trenching (incl backfilling, packing) 2' Width, 4' Depth	CY	6.18	1506	**$9,307**		$510	$0.02
Resident Inspection	lump sum	5000	1	$5,000		$274	$0.01
Total Construction				$131,736	48.3	$7,216	$0.23
Equipment							
MULTIWASH combined air/water backwash for enhanced media cleanliness (80 gpm, 6" diameter)	ea	76000	1	$76,000		$4,163	$0.13
Valve (Control, Backwash Waste Valve,Filter inlet Valve)	ea	2940	9	$26,460		$1,449	$0.05
Induced Draft Blower	ea	251.5	1	$252		$14	$0.00
Instrumentation and Control	lump sum	3450	1	**$3,450**		$189	$0.01
Well pump, motor and control	Hp	8310	1	$8,310		$455	$0.01
Total Equipment				$114,472	42.0	$6,270	$0.20
Engineering Cost							
Design @ .91% Construction	percent	1198	1	$1,199		$66	$0.00
Bidding Phase @.8% Construction	percent	1053	1	$1,054		$58	$0.00
Engineering during Construction	lump sum	11561	1	$11,561		$633	$0.02
O&M Manual	lump sum	2720	1	$2,720		$149	$0.00
Groundwater Rights							
Other Engineering and Surveying	lump sum	2500	1	$2,500		$137	$0.00
DEQ Permit for water line							$0.00
DEQ Permit to construct WTP	lump sum	1000	1	$1,000		$55	$0.00
Land Acquisition							
Total Engineering				**$20,034**	**7.3**	**$1,097**	**$0.03**
Contingencies (5% 0f construction cost)	**lump sum**	**$6586**	**1**	**$6586**	**2.4**	**$361**	**$0.01**
Total Fixed (Capital) Cost				**$272828**		**$14,945**	**$0.47**

The estimated cost of total investment equipment cost was $114,472 and annual fixed cost of $6,270 represents 42 percent of the investment cost. The engineering cost, which represents 7.3 percent of the investment, cost estimated lump sum of $20,034. Cost of other expenses or contingency represents 2.4 percent of the investment cost costs, was estimated to be $6,587. The total investment capital cost, which is a summation of all the components, was estimated to be $272,828. With the 50 years payment period, fixed interest of 5 percent, and CRF of $0.05, the total annual repayment fixed cost was $14,945/yr and the cost per thousand gallons of water treated was estimated to be $0.47 gallon. With the capacity of 60 gpm of the treated water, the capital investment cost was estimated to be $4,547/gpm and the annual fixed capital cost was $249/gpm.

Table IV-10 shows cost estimation of investment capital cost and annual fixed cost of Aeralator® treatment plant of water capacity of 216 thousand gpd. This was designed to treat and supply water for both Kaw City and Shidler. The investment of cost of the building was estimated to be $92,760 or $93/sqft for the 1000 square feet building.

Table IV-10. Estimated Capital Cost of Aeralator® Plant of 216,000 GPD at Greenhouse Site

Descriptions	units	$ unit cost	quantity	Invt. Total Cost(TC)	Rate(%)	annual FC	Annual Cost/1000
Construction							
Building (40' x 25')	sq ft	$93	1000	$92,760		$5,081	$0.06
Cost of drilling Well	ft	$9,094	1	$9,094		$498	$0.01
6" Raw Water Pipeline from well to treatment plant	ft	$6	5084	$30,402		$1,665	$0.02
Trenching (including backfilling, packing) 2' Width, 4' Depth	CY	$6	1506	$9,307		$510	$0.01
Resident Inspection	lump sum	$5,000	1	$5,000		$274	$0.00
Total Construction				**$146,564**	**45.3**	**$8,028**	**$0.10**
Equipment							
MULTIWASH combined air/water backwash for enhanced media cleanliness (150 gpm, 6" diameter)	ea	$111,000	1	$111,000		$6,080	$0.08
Valve (Control, Backwash Waste Valve, Filter inlet Valve)	ea	$2,940	9	$26,460		$1,449	$0.02
Induced Draft Blower	ea	$252	1	$252		$14	$0.00
Instrumentation and Controls	lump sum	$3,450	1	$3,450		$189	$0.00
Well pump, motor and controls	ea	$8,310	1	$8,310		$455	$0.01
Total Equipment				**$149,472**	**46.2**	**$8,188**	**$0.10**
Engineering Cost							
Design @ .91% Construction	percent	$1,334	1	$1,334		$73	$0.00
Bidding Phase @.8% Construction	percent	$1,173	1	$1,173		$64	$0.00
Engineering during Construction	lump sum	$11,561	1	$11,561		$633	$0.01
O&M Manual	lump sum	$2,720	1	$2,720		$149	$0.00
Groundwater Rights							
Other Engineering and Surveying	lump sum	$2,500	1	$2,500		$137	$0.00
DEQ Permit to construct WTP	lump sum	$1,000	1	$1,000		$55	$0.00
Land Acquisition							
Total Engineering				**$20,287**	**6.3**	**$1,111**	**$0.01**
Contingencies (5% 0f construction cost)	**lump sum**	**$7,328**	**1**	**$7,328**	**2.3**	**$401**	**$0.01**
Total Fixed (Capital) Cost				$323,650		$17,729	$0.22

The total construction cost represents 45.3 percent of the total investment capital cost. Total construction cost was estimated to be $146,564 or $8,028 per year. Again, the construction cost per thousand gallons of water treated of the capital cost was estimated to be $0.08.

The Aeralator® system cost $111,000 for a system of capacity of 216,000 gpd. The cost of Aeralator® system differs in terms of capacity. The cost difference between the two Aeralator® systems was about 31.5 percent. The investment of the well pumps, motors and controls was estimated to be $8,310 and annual repayment cost of $3,052. The investment in equipment for the 216 thousand gallon per day was estimated to be $149,472 with an annual fixed cost of $8,188 or $0.10/1000 gallons of water treated. The total capital cost for 216 thousand gpd Aeralator® treatment plant was estimated to be $323,650 with an annual fixed cost of $17,729. The cost per thousand gallon of water treated was estimated to be $0.0.22.

4.3.2 Annual Operating Cost of Aeralator® Treatment System of Two Sizes

Table IV-11 gives the analysis of the estimated operating cost of the 86,000 gallons per day Aeralator® treatment plant. This system differs from nanofiltration because it operates at lower pressure. It also more automated and required fewer labor hours to operate the plant. The utility cost consist of cost of well control system, running well pump, HVAC, high service pump, and Greensand/Athra sand controls and Aeralator® controls. The unit cost of utility was based on the assumption that electricity cost $0.11/kwh. The costs of operating the well pump and the high service pump, (which pumps from the plant to the water tower) were estimated to be $1,130/yr and $1,099/yr. In addition, the HVAC and Greensand/ Athrasand controls and Aeralator® controls cost $30/yr and $16/yr respectively. The utility cost was estimated $2,280/yr or 10.9 percent of the total operating cost.

The chemicals required applying under this treatment system are chlorine and $KMnO_4$. The Aeralator® treatment system is not expected form scales during processing so the cost of chemicals do not include the cost of a scale of inhibitor. The assumed cost for chlorine was $0.50/lb and the assumed of $KMnO_4$ was $1.60/lb. Given the respective treatment rates of 477mg/gal, the cost of chlorine was $239/yr or $0.01/1000 gallon and the cost of $KMnO_4$ was $754/yr or $0.02/1000 gallon of the water treated. The total of chemical cost was estimated $993/yr or $0.03/1000 water treated which represents 4.7 percent of the operating cost per year. The administration and operation cost was calculated as 22.1 percent of the operating cost. This cost included expenses for vehicles, legal and audit, insurance, certification fees, laboratory and other costs. Administration and operating cost were estimated to be $4,623/yr or $0.15/1000 gallon of treated water.

Table IV-11. Estimated Operating Cost of the 86,000 Gallon Per Day Aeralator® Water Treatment System at Greenhouse site

Descriptions	Units	$ unit cost	quantity	Total Cost(TC)	Rate (%)	TC/1000
Utilities						
Well Control System (@ .15KWH, 365 hrs/yr) 0.15*365	kw/H	$0.11	54.75	$6		$0.00
Running well pump, 3.7hp, 61GPM, 0.747 Kw/hp, 3784 hrs/yr (3784*3.7*0.747)	kw/H	$0.11	10459	$1,130		$0.04
Heating, Ventilation and Air Condition (HVAC) .001 sqft x 750sq ft x 365hr/yr	kw/H	$0.11	273	$30		$0.00
High Service Pump 3.6hp, 60GPM, (3.6hp *0.747kw/hp*3784hr/yr)	kw/H	$0.11	10176	$1,099		$0.03
Greensand/ Anthra sand Controls, Aeralator controls @ 0.4Kw/h, 365hrs/yr	kw/H	$0.11	146	$16		$0.00
Total Utilities				**$2,280**	**10.9**	$0.07
Chemicals						
Chlorine, 31.536 MG/yr @ (4 mg/l water treated)	mg/yr	$0.50	477	$239		$0.01
KnMnO4, 31.536MG/yr @ (3.95mg/l water treated)	mg/yr	$1.60	471	$754		$0.02
Total Chemicals				**$993**	**4.7**	$0.03
Administration and Operation						
Certification Fees	lump sum	$150	1	$150		$0.00
Dues & Subscriptions	lump sum	$150	1	$150		$0.00
Insurance	lump sum	$1,200	1	$1,200		$0.04
Laboratory	lump sum	$500	1	$500		$0.02
Office Supplies	lump sum	$450	1	$450		$0.01
Miscellaneous Supplies	lump sum	$531	1	$531		$0.02
Vehicle	lump sum	$645	1	$645		$0.02
Postage and Freight	lump sum	$349	1	$349		$0.01
Legal and Audit	lump sum	$249	1	$249		$0.01
Telephone	lump sum	$400	1	$400		$0.01
Total Administration and Operation				**$4,623**	**22.1**	$0.15
Labor						
Salary and Wages (1hrs/day of $ 20 rate)	Hrs	$20	365	$7,300		$0.23

Table IV-11. Estimated Operating Cost of the 86,000 Gallon Per Day Aeralator® Water Treatment System at Greenhouse site

Descriptions	Units	$ unit cost	quantity	Total Cost(TC)	Rate (%)	TC/1000
Health Insurance of 1.5% of Salary and Wages	Percent	$110	1	$110		$0.00
Payroll Taxes of (6.125% of Salary and Wages)	Percent	$456	1	$456		$0.01
Total Labor Cost				**$7,866**	**37.6**	$0.25
Replacement Costs						
pump	Hp	$4,312	1	$4,312		$0.14
Filters	Ea	$278	3	$834		$0.03
Total Replacement Cost				**$5,146**	**24.6**	$0.16
Total Annual Operating Cost				**$20,908**		$0.66

The cost of labor, which is very significant in determining operating cost, is the function of labor hours and unit cost per hour. Due to the presence of more automated controls for Aeralator® system, it required only hour of labor per day. The total cost assumed 365 hours per year at $20/hr. Payroll taxes and health insurance were estimated to be 6.25 and 1.5 percent of wage and salary costs. The wages and salary of the labor operating the plant were estimated to be $7,300/yr or $0.09/1000 gallon of water treated. The estimated cost of health insurance and payroll taxes of the proportion of 1.5 percent and 6.125 percent of the wages and salary are $110 and $447 respectively. The total labor cost of $7857/yr represents 37.6 percent of total operating cost or $0.10/1000 gallon of water treated.

The replacement costs are for replacement of filters and pump that have a shorter lifespan than the treatment plant. The replacement cost of $5,146/yr, represents 24.6 percent of total costs. The annual operating cost of the 86,000 gpd Aeralator® treatment plant systems was estimated to be $20,908/yr. The cost per thousand gallons of water treated was estimated to be $0.66.

Table IV-12 presents the annual operating cost of the 216,000 Gallon per Day Aeralator® treatment plant system. The total utilities costs included those for the well control systems, the well pump, the high service pump, the greensand/Athrasand sand controls, and the heating and cooling for the treatment building. The estimated cost of running well pumps and HVAC of the system were $3,389/yr or $0.04/1000 and $30 respectively.

Table IV-12. Estimated Operating Cost of Aeralator® Water Treatment System of 216,000 gallons per day capacity of Monitoring well at Greenhouse site

Descriptions	units	$ unit cost	quantity	Total Cost	rate(%)	TC/1000
Utilities						
Well Control System (@ .15KWH, 365 hrs/yr) 0.15*365	Kw/h	$0.11	55	$6		$0.00
Running well pump, 11.1hp, 0,747 Kw/hp,152GPM, 3784 hrs/yr (3784*11.1*0.747)	Kw/h	$0.11	31376	$3,389		$0.04
Heating, Ventilation and Air Condition (HVAC) .001 sqft x 750sq ft x 365hr/yr	Kw/h	$0.11	274	$30		$0.00
High Service Pump 10.9hp, 150GPM (10.9hp *0.747kw/hp*3784hr/yr)	Kw/h	$0.11	30810	$3,328		$0.04
Greensand/ Anthra sand Controls, Aeralator controls @ 0.4Kw/h, 365hrs/yr	Kw/h	$0.11	146	$16		$0.00
Total Utilities				**$6,767**	**21.6**	**$0.09**
Chemicals						
Chlorine, 99.864 MG/yr @ (4 mg/l water treated)	Mg/yr	$0.50	1512	$756		$0.01
KnMnO4 99.864MG/l @ (3.95mg/l water treated)	Mg/yr	$1.60	1493	$2,389		$0.03
Total Chemicals				**$3,145**	**10**	**$0.04**
Administration and Operations						
Certification Fees	lump sum	$150	1	$150		$0.00
Dues & Subscriptions	lump sum	$150	1	$150		$0.00
Insurance	lump sum	$1,200	1	$1,200		$0.02
Laboratory	lump sum	$500	1	$500		$0.01
Office Supplies	lump sum	$450	1	$450		$0.01
Miscellaneous Supplies	lump sum	$531	1	$531		$0.01
Vehicles	lump sum	$645	1	$645		$0.01
Postage and Freight	lump sum	$349	1	$349		$0.00
Legal and Audit	lump sum	$249	1	$249		$0.00
Telephone	lump sum	$340	1	$400		$0.01
Total Administration and Operations				**$4,623**	**14.7**	**$0.06**
Labor						
Salary and Wages (2hrs/day of $ 20 rate)	hrs	$20	365	$7,300		$0.09
Health Insurance of 1.5% of Salary and Wages	percent	$110	1	$110		$0.00
Payroll Taxes (6.125% of Salary and Wages)	percent	$447	1	$447		$0.01

Table IV-12. Estimated Operating Cost of Aeralator® Water Treatment System of 216,000 gallons per day capacity of Monitoring well at Greenhouse site

Descriptions	units	$ unit cost	quantity	Total Cost	rate(%)	TC/1000
Total Labor Cost				**$7,857**	**25**	**$0.10**
Replacement Costs						
pump	hp	$8,150	1	$8,150		$0.10
Filters	ea	$278	3	$834		$0.01
Total Replacement Cost				**$8,984**	**28.6**	$0.11
TOTAL OPERATING COST				**$31,376**		**$0.40**

The high service pump and Aeralator® controls were estimated to cost $3,328/yr and $16/yr respectively. The total utility cost was estimated to be $6,767/yr or $0.09/1000 and account for 21.6 percent of total operating cost.

It was assumed that 1512mg/l of chlorine and 1493mg/l of $KMnO_4$ were required to treat each gallon of water based on the concentration of iron and manganese in the water. The unit cost of $KMnO_4$ was $1.60/lb and 1,493 mg/yr were required. The cost of $KMnO_4$ was then estimated to be $2,389/yr or $0.03/1000 gallon of water treated. The cost of chlorine of a unit cost of $0.50/lb and 1512mg/yr were required. The cost of chlorine was calculated to be $756 or $0.01/1000 gallon of water treated. The administration and operation cost of the system was $4,563/yr. or 14.7 percent of the total operating cost. Replacement costs were estimated to be $8,984/yr or $0.11/1000 gallon of water treated. The operating cost of the system was estimated to be $31,367/yr or $0.4/1000 gallon of water treated. With the capacity of 150gpm of water treated, the total operating cost was estimated to be $209/gpm.

4.4 Cost of Energy for Distributing Water within Kaw City

The cost of distributing water from the treatment plant to the Kaw City was one of the aspects of the study that need attention. After the treatment of water, the next issue that will come in mind was how to distribute the water to the various places. Moreover, the cost of distribution of water from the plant to the city depends on the pipe size and the distance.

The energy cost which depends on the total head, water horsepower (whp) and brake horsepower (bhp). The diameter of the pipe under consideration was 6 inches (6") and the distance of 25344 feet. The energy cost of pumping water from the treatment to the tower was estimated to be $2,346/yr with the total head of 163 psi and 36 hp. However, there is an inverse relationship between the size of the pipe and energy cost. As the size of the pipe increases, the total head (pressure) of distributing water decreases.

4.5 Comparison of Amortized Capital Cost and Amortized Operating Cost of the two treatment Systems

This section of the study analyzed the comparison between the two treatment plant systems and the two different sizes of capacity of 60 gpm for only to be supply Kaw City and the 150 gpm capacity to supply both Kaw City and Shidler. The amortized (annual fixed) capital cost calculated as the product of CRF of $0.05 and the total investment capital cost of the interest rate of 5 percent and repayment period of 50 years.

4.5.1 Comparison of Annual Capital Cost and Operating Cost of Aeralator® and Nanofiltration treatment system of capacity of 60 gallons per minute or 86000 gallons per day

Table IV-13 gives the comparison of the two treatment plant system Aeralator® and NF of the capacity of 60 gpm or 86,000 gallon per day. Under the estimated capital cost, the construction cost of the NF was $7,860/yr which was higher than Aeralator® system of $7,216/yr and due to the cost of building, which depends on the size of the building of the two treatment plants and the difference of $644/yr (approximately 8.2%). The equipment cost of Aeralator® systems was $6,270 less than equipment cost of NF of $9,479and the cost difference was $3,209 (approximately 34%).

The lump sum engineering cost of NF treatment system was estimated to be $1,108 which was 1 percent higher than Aeralator® treatment system of $1,097. This cost difference was as a result of the cost of design and bidding phase which was proportion of construction cost meaning as the cost of construction increases, the cost of design and bidding phase increases and vice versa. The cost of amortized capital Aeralator® and NF treatment plant were estimated to be $14,945/yr and $18,841/yr respectively. However, the cost difference of capital was estimated to be $3,896/yr (approximately 20.7%). The cost per thousand gallons of water treated for the NF and Aeralator® treatment systems were $0.60 and 0.47 respectively.

The labor cost for the Aeralator® was $7,866/yr and for the NF was $23,597/yr. This was a difference of $15,731 (approximately 66.7%) though both treatment plant systems are automatic but NF plant required more labor. The difference in utility costs between the two systems was $2,476/yr (approximately 52.1%). The utility cost of Aeralator® system was estimated to be $2,280/yr while the utility cost for the NF plant was $4,756/yr. The utility cost differs due to the high pressure requires in the process of treating water.

The total chemical cost of an 86 thousand gpd Aeralator® plant was estimated to be $993/yr and while chemical costs for the NF plant were estimated to be $1,268/yr. The chemical costs for NF treatment were higher mainly due to the cost of antiscalant, which controls the scaling form in the pipes during processing. The difference was estimated to be $275/yr (approximately 21.7%). The total operating cost of NF treatment plant was $40,384/yr whereas Aeralator® plant estimated $20,908/yr. This was a difference of $19,476/yr (approximately 48.2%). The estimated cost per gpm of water treated of operating cost of Aeralator® and NF cost $348/yr and $673/yr respectively. Additionally, the cost per thousand of the treated water Aeralator® and NF cost $0.66 and $1.28 respectively and cost difference of $0.62 (approximately 48.2 percent).

Table IV-13. Comparison of Annual Capital Cost and Operating Cost of 86,000 Gallon per Day Aeralator® and Nanofiltration Treatment Systems

Capacity	Aeralator® 60gpm	Nanofiltration 60gpm	Diff in cost %	diff in cost
CAPITAL COST				
Construction	$7,216	$7,860	8.2	$644
Equipment	$6,270	$9,479	34	$3,209
Engineering	$1,097	$1,108	1	$11
Contingencies	$361	$393	8.2	$32
Total Capital Cost	**$14,945**	**$18,841**	**20.7**	**$3,896**
Cost per thousand water treated	$0.47	$0.60	20.7	$0.12
Cost per gpm water treated	$249	$314.02	20.7	$65
OPERATING COST				
Labor	$7,866	$23,597	66.7	$15,731
Utilities	$2,280	$4,756	52.1	$2,476
Chemicals	$993	$1,268	21.7	$275
Administration &Operations	$4,623	$4,623	0.0	$0
Replacement Cost	$5,146	$6,140	16.2	$994
Total Operating Cost	**$20,908**	**$40,384**	**48.2**	**$19,476**
Cost per thousand water treated	$0.66	$1.28	48.2	$0.62
Cost per gpm water treated	$348	$673	48.2	$325
Total Estimated Cost	**$35,852**	**$59,225**	**39.5**	**$23,372**
Cost per thousand water treated	$1.14	$1.88	39.5	$0.74
Cost per gpm water treated	$598	$987	39.5	$390

The total annual cost of the Aeralator® treatment plant was estimated to be $35,852/yr while the total cost of the NF treatment plant system was estimated to be $59,225/yr. This was a 39.5 percent difference in annual cost. The cost per thousand gallons of treated water from the Aeralator® treatment system plant was estimated to be $1.14 while that from the NF plant was $1.88 of water treated. This was a difference of $0.74 per 1000 gallons. It is vividly shown that it is more expensive of using NF water treatment plant than Aeralator® water treatment plant of the capacity of the 86,000 gallon per day. However the water quality from the NF/RO system will be higher and taste may be preferred over that from the Aeralator® system. Therefore, when the city decides to treat water to supply only Kaw City, then it economically reasonable to use Aeralator® treatment plant system which has low cost unless the citizens are willing to pay an additional $0.74 of cost per thousand and $390 gpm of water treated for taste and quality reasons.

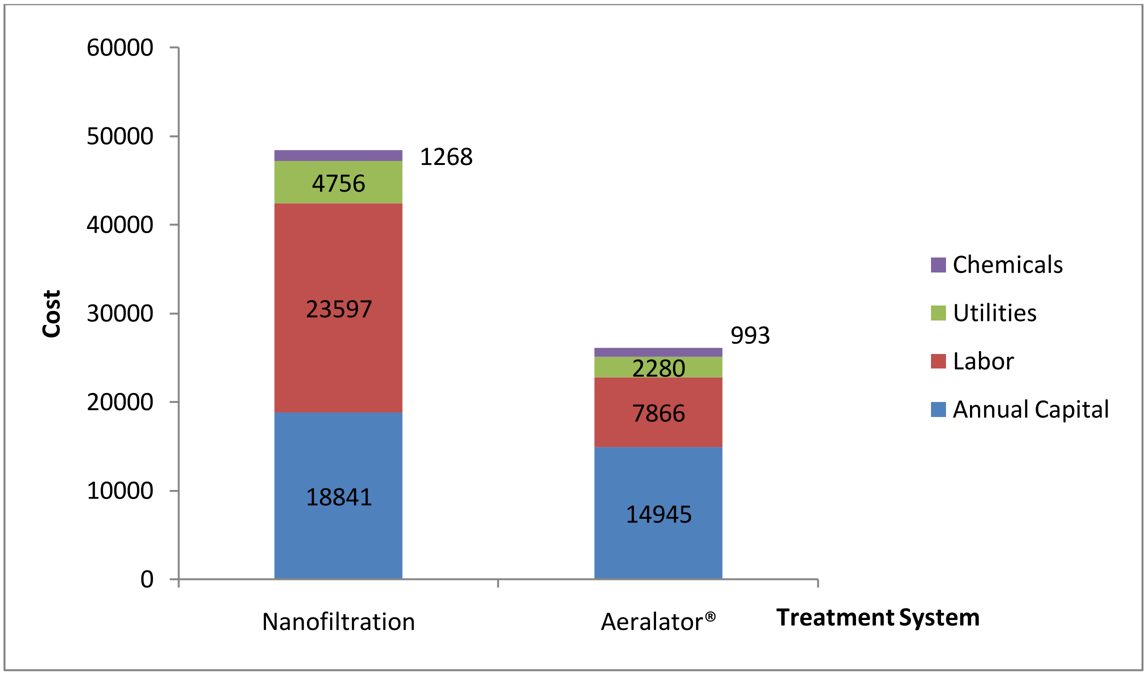

Figure IV-1. The Estimated Total Cost of Nanofiltration and Aeralator® Treatment Systems of 86 Thousand GPD

Figure 6 and 7 explains the estimated total annual cost and estimated annual cost per thousand of nanofiltration and Aeralator® systems and difference between the costs of the system respectively. The cost of annual capital of nanofiltration was higher than Aeralator® system because of the cost of equipment. The cost of utilities of the Aeralator® system is cheaper than nanofiltration as a result of low pressure required for nanofiltration. The chemical costs of the two systems were differed because of the cost of the antiscalant which catered for the formation of scaling in pipeline during the treatment process. The cost of labor of nanofiltration system was higher than Aeralator® system because the labor hours required operating system was different. Though both the systems were automatic but needed different hours.

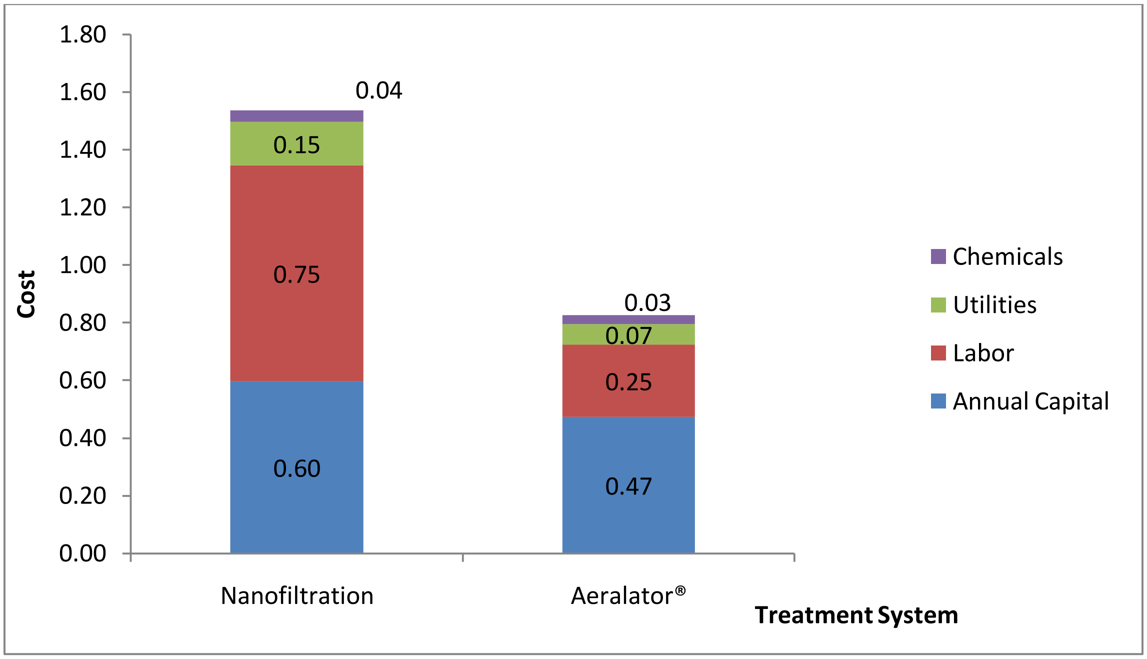

Figure IV-2. The Estimated Cost per Thousand GPD of Nanofiltration and Aeralator® Treatment Systems of 86 Thousand GPD

The estimated total cost per thousand of annual capital of the nanofiltration was increased by $0.13. The labor cost of the nanofiltration was 66.7 percent increased more than Aeralator® systems. It was clear indication that the estimated cost per thousand of the nanofiltration is higher than Aeralator® system.

4.5.2 Comparison of Annual Capital Cost and Operating Cost of Aeralator® and Nanofiltration treatment system of capacity of 216 thousand gallons per day

Table IV-14 presents the comparison of the cost of NF and Aeralator® treatment plants system but the same treated water capacity of 150 gpm. The construction cost of the Aeralator® plant was estimated to be $8,028/yr and NF was $8,853/yr (approximately 9.3 percent). The cost difference was as result of different size of the building and the cost of building was based on the size. The cost of equipment of the NF was estimated to be $18,553/yr as compared to Aeralator® treatment plant of $8,188/yr (approximately

55.9%) because NF required many pumps due to high pressure needed in processing. The total annual capital fixed cost of Aeralator® was estimated to be $17,728. The cost of gallon per minute of Aeralator® treatment plant was $118 and cost per thousand of water treated cost $0.22. The capital cost of NF was $28,974/yr or $0.0.37/1000 gallon of treated water and $193 was estimated to be annual cost of gallon per minute of water treated

The labor cost of the NF and Aeralator® treatment was estimated to be $23,597/yr and $7,866/yr respectively. The labor cost difference was estimated to be $15,731/yr, which is very high because the two systems required different labor hours in operation. The total utility cost of NF and Aeralator® treatment plant was estimated to be $13,547/yr and $6,767/yr respectively. The cost difference of utility was estimated to be $6,780/yr (approximately 50 percent). The annual cost of chemical of NF and Aeralator® treatment plants was estimated to be $3,145/yr and $4,014/yr and the cost difference was $869/yr (approximately 27.7 percent). Moreover, the total operating cost of Aeralator® and NF treatment system plant of the capacity of 150 gpm was estimated to be $31,385/yr and $56,846/yr respectively and the cost difference of $25,461/yr (approximately 44.8 percent). The cost per gpm and thousand of NF were estimated to be $379/yr and $0.72/yr respectively and Aeralator® system were estimated to be $209/yr and $0.40/yr respectively.

Table IV-14. Comparison of Annual Capital Cost and Operating Cost of Aeralator® and Nanofiltration treatment system of capacity of 150 gallons per minute or 216,000 gallons per day

Capacity	Aeralator 150gpm	Nanofiltration 150gpm	Diff in cost %	diff in cost
CAPITAL COST				
Construction	$8,028	$8,853	9.3	$825
Equipment	$8,188	$18,553	55.9	$10,366
Engineering	$1,111	$1,125	1.3	$14
Contingencies	$401	$443	9.3	$41
Total Capital Cost	**$17,728**	**$28,974**	38.8	$11,246
Cost per thousand water treated	**$0.22**	**$0.37**	38.8	$0.14
Cost per gpm water treated	**$118**	**$193**	38.8	$75
OPERATING COST				
Labor	$7,866	$23,597	66.7	$15,731
Utilities	$6,767	$13,547	50.0	$6,780
Chemicals	$3,145	$4,014	21.7	$869
Administration &Operations	$4,623	$4,623	0.0	$0
Replacement Cost	$8,984	$11,065	18.8	$2,081
Total Operating Cost	**$31,385**	**$56,846**	44.8	$25,461
Cost per thousand water treated	**$0.40**	**$0.72**	44.8	$0.32
Cost per gpm water treated	**$209**	**$379**	44.8	$170
Total Estimated Cost	**$49,113**	**$85,821**	42.8	$36,707
Cost per thousand water treated	**$0.62**	**$1.09**	42.8	$0.47
Cost per gpm water treated	**$327**	**$572**	**42.8**	**$245**

In all, the total annual costs of Aeralator® was estimated to be $49,113/yr and NF was $36,707/yr and cost difference approximately 42.8 percent. The cost of per thousand gallons per minute of water treated of NF was estimated to be $1.09 and $572 respectively. However, the cost of gpm and thousand of Aeralator® treatment plant cost $327/yr and $0.62/yr of water treated. Since the cost of NF is higher than cost of the Aeralator® treatment plant, it is economically viable for the city to adopt the Aeralator® treatment plant system when they decide to supply water for Kaw City and Shidler and save cost of $0.47/yr and $245/yr of cost of thousand and gpm water treated respectively or if they can bear extra cost to opt for NF to get better taste of the water.

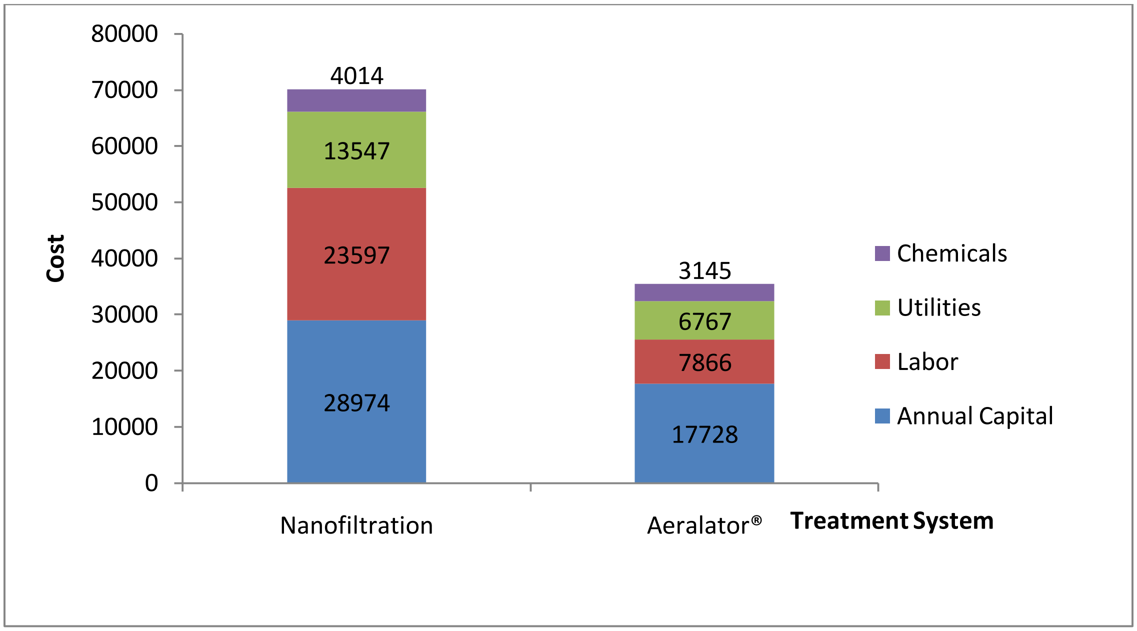

Figure IV-3. The Estimated Total Cost of Nanofiltration and Aeralator® Treatment Systems of 216 Thousand GPD

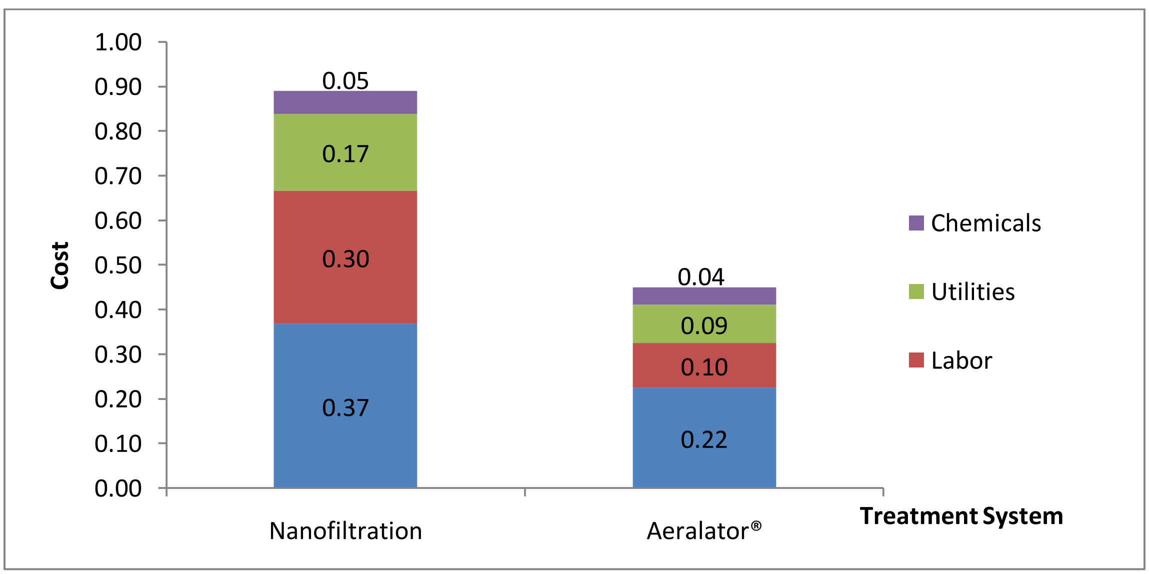

Figure IV-4. The Estimated Total Cost per Thousand GPD of Nanofiltration and Aeralator® Treatment Systems of 216 Thousand GPD

Figure 8 and 9 gives the visual interpretation of the cost difference between the nanofiltration and Aeralator® system of capacity of 216 thousand gallons per day. The total cost per thousand of utilities of the nanofiltration was $0.08 higher than the Aeralator® because of Aeralator® needs low pressure to force the water through the system. However, the estimated total annual cost and an estimated total annual cost per thousand of the nanofiltration system were below $70,000 and $0.09/yr respectively.

Moreover, the estimated total annual cost per thousand and total annual cost of aeralator® system were estimated to be below $0.05/yr and $40,000/yr respectively. It is however viable to treat water using Aeralator® to avoid extra cost. The total annual capital cost was increased by 40 percent against the Aeralator® system. In addition, the cost per thousand of estimated total utilities of the nanofiltration was 47 percent higher than that of the Aeralator® system. In nutshell, all the estimated cost showed that the cost of the nanofiltration was more costly than the Aeralator® system.

4.5.3 Comparison of Annual Capital Cost and Operating Cost of Aeralator® treatment system of capacity of 216,000 gallons per day and 86 Thousand gallons per day

Table IV-15 presents the annual capital cost and operating cost of Aeralator® treatment plant of two different capacities of 86 thousand gallons per day and 216 thousand gallon per day. The construction cost of the systems had cost difference of $812/yr (approximately 10.1 percent). However, the cost of construction the capacity of 60 gpm and 150 gpm was estimated to be $7,216/yr and $8,028/yr respectively.

The equipment costs of the systems differed by the capacity therefore as the capacity of the water treated increased, the cost of equipment also increased. The total annual equipment cost of capacity of 60 gpm was estimated to be $6,270 was less than the cost of the capacity of 150 gpm, which was estimated to be $8,188, and cost difference was estimated to be $$1,917/yr (approximately 23.4 percent).

Table IV-15. Comparison of Annual Capital Cost and Operating Cost of Aeralator® treatment system of capacity of 216,000 gallons per day and 86000 gallons per day

Capacity	Aeralator® 60gpm	Aeralator® 150gpm	Diff in cost %	diff in cost
CAPITAL COST				
Construction	$7,216	$8,028	10.1	$812
Equipment	$6,270	$8,188	23.4	$1,917
Engineering	$1,097	$1,111	1.2	$14
Contingencies	$361	$401	10.1	$41
Subtotal	**$14,945**	**$17,728**	15.7	$2,784
Cost per thousand water treated	**$1.31**	**$0.61**	-116.7	-$0.71
Cost per gpm water treated	**$691**	**$319**	-116.7	-$372
OPERATING COST				
Labor	$7,866	$7,866	0.0	$0
Utilities	$2,280	$6,767	66.3	$4,488
Chemicals	$993	$3,145	68.4	$2,152
Administration &Operations	$4,623	$4,623	0.0	-$0.21
Replacement Cost	$5,146	$8,984	42.7	$3,838
Subtotal	**$20,908**	**$31,385**	33.4	$10,477
Cost per thousand water treated	**$0.66**	**$0.40**	-66.5	-$0.26
Cost per gpm water treated	**$348**	**$209**	-66.5	-$139
Total	**$35,853**	**$49,113**	27.0	$13,261
Cost per thousand water treated	$1.98	$1.00	-96.8	-$0.97
Cost per gpm water treated	$1,039	$528	-96.8	-$511

The total engineering cost of capacity of 60 gpm and 150 gpm differed by $14 approximately 1.2 percent as result of cost of design and bidding phase which was proportion of construction. The total annual capital cost of the plant of the capacity of 60 gpm was estimated to be $14,957/yr or $0.47/1000 gallon of water treated and $249 gpm of water treated. Cost of the annual capital of 150 gpm capacity was $17,728 or $0.22/1000 gallon and cost of gallon per minute was $118/gpm of treated water. The annual capital cost difference was estimated to be $2,784 (approximately 15.7 percent).

The cost of the replacement cost of the capacity of 60 gpm and 150 gpm was estimated to be $5,146/yr and $8,984/yr with cost difference of 42.7 percent. The costs of utility of the treatment plants based on the energy required pumping the water to various places. However, the bigger capacity of 150 gpm was estimated to be $6,767/yr higher than 60 gpm capacity was $2,280/yr. The cost difference between the two capacities was estimated to be $4,488/yr (approximately 66.3 percent). The labor cost of the two treatment plants are the same.

The quantity of the chemical needed to treat water was based on the quantity of water treated. The more the quantity of water to be treated, the more the quantity of chemicals required. However, the cost of chemical of capacity of 150 gpm was estimated to be $3,145/yr, which was higher than the capacity of 60 gpm of $993/yr, and cost difference was estimated to be $2,152/yr (approximately 68.4%). The total operating cost of the two systems was estimated to be $20,908/yr of capacity of 60 gpm or $0.66/1000 gallon of water treated and $0.40/1000 gallon of capacity of 150 gpm. The operating cost of gallon per minute of 150gpm was $209 and $348/yr was cost of the capacity of the 60 gpm.

In conclusion, the total cost of the systems was estimated to be $35,852/yr of capacity of 60 gpm or $1.14/1000 gallon and cost of gallon per minute was $598. Also, the cost of the capacity of 150 gpm was estimated to be $49,113/yr or $.62/1000 gallon and the cost of the gallon per minute was estimated to be $327. The cost per thousand and cost per minute of capacity of 150 gpm were estimated are lower than the cost of the 60 gpm. It is therefore necessary and viable to treat water to supply both Kaw City and Shidler instead of Kaw City only. Due to economies of size, it is more economically sensible to supply to both Kaw City and Shidler and save the cost of \$0.26/yr and \$139/yr of cost per thousand and gpm respectively.

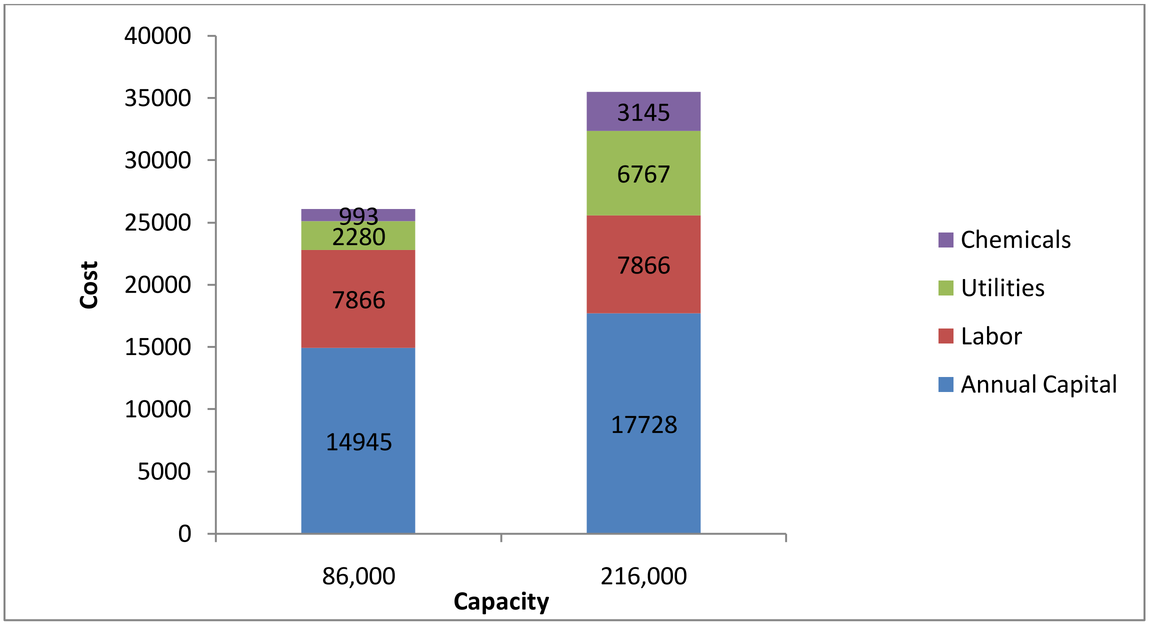

Figure IV-5. The Estimated Total Cost of Aeralator® treatment system of capacity of 216,000 gallons per day and 86000 gallons per day

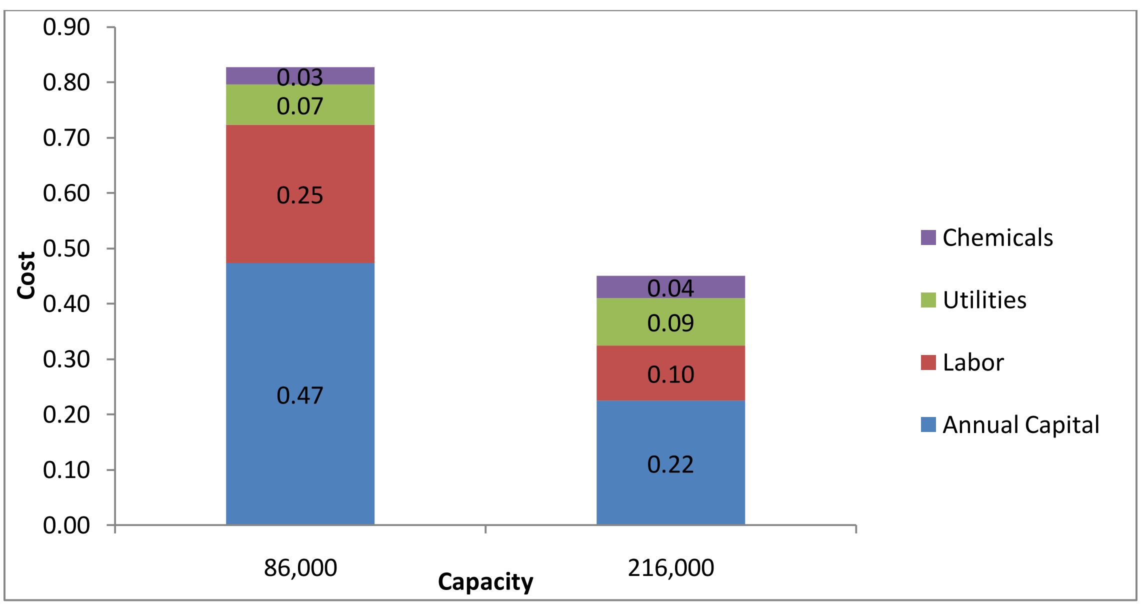

Figure IV-6. The Estimated Total Cost per Thousand of Aeralator® treatment system of capacity of 216,000 gallons per day and 86000 gallons per day

Figure 10 and 11 therefore give further visual explanations of the cost difference between the aeralator® system of 86 thousand and 216 thousand capacity. The estimated total annual cost of the 216 thousand capacities higher than the capacity of the 86 thousand, which were estimated to be above $35,000 and $25,000 respectively. The estimated total cost of 216 thousand capacities was increased by about $7,000/yr and it was as a result of cost equipment, chemical and utilities. The total cost per thousand of 86 thousand capacities was more costly than the 216 thousand due to the economies of the size of the treating and supplying of water. Therefore, it more cost effective to supply water to both Kaw City and Shidler to at lower cost.

4.5.4 Comparison of Annual Capital Cost and Operating Cost of Nanofiltration treatment system of capacity of 216,000 gallons per day and 86,000 gallons per day

Table IV-16 presents the comparison of annual capital cost and operating cost of the NF treatment plant of different of 60 gpm or 86 thousand gallons per minute and 150 gpm or 216 thousand gallons per minute respectively. The equipment cost of the 60 gpm NF unit was estimated to be $9,479/yr and $18,553/yr for the 150 gpm unit. The cost difference between the systems was estimated to be $9,074/yr (approximately 49 percent). The annual capital costs of the 60 gpm and 150 gpm plants was estimated to be $18,841/yr or $0.60/1000 gallon and $28,974/yr or $0.37/1000 gal of water treated respectively. Moreover, the estimated cost of gallon per minute of treated water was estimated to be $314 and $193 of capacity of 60 gpm and 150 gpm respectively.

The labor cost of NF system, (three hours per day) of both capacities, was estimated to be $23,597/yr. The replacement cost was estimated to be $4,140/yr for the 60 gpm and $11,065/yr for the 150 gpm plants. The cost difference between the sizes was estimated to be $4,925/yr (approximately 44.5 percent). The utility costs were estimated to be $4,756/yr for the 60 gpm and $13,547/yr for the 150 gpm plants. The cost difference between the two capacities was estimated to be $8,791/yr (approximately 64.9 percent).

Table IV-16. Comparison of Annual Capital Cost and Operating Cost of Nanofiltration treatment system of capacity of 216,000 gallons per day and 86000 gallons per day

Capacity	Nanofiltration 60gpm	Nanofiltration 150gpm	Diff in cost %	diff in cost
CAPITAL COST				
Construction	$7,860	$8,853	11.2	$993
Equipment	$9,479	$18,553	49	$9,074
Engineering	$1,108	$1,125	1.5	$17
Contingencies	$393	$443	11.2	$50
Subtotal	**$18,841**	**$28,974**	35.0	$10,133
Cost per thousand water treated	**$1.59**	**$0.78**	-104	-$0.81
Cost per gpm water treated	**$838**	**$411**	-104	-$427
OPERATING COST				
Labor	$23,597	$23,597	0.0	$0
Utilities	$4,756	$13,547	64.9	$8,791
Chemicals	$1,268	$4,014	68.4	$2,747
Administration &Operations	$4,623	$4,623	0.0	$0
Replacement Cost	$6,140	$11,065	44.5	$4,925
Subtotal	**$40,384**	**$56,846**	29.0	$16,463
Cost per thousand water treated	**$0.66**	**$0.72**	8.1	$0.06
Cost per gpm water treated	**$348**	**$379**	8.1	$31
Total	**$59,225**	**$85,821**	31.0	$26,596
Cost per thousand water treated	**$1.98**	**$1.50**	-31.6	-$0.47
Cost per gpm water treated	**$1,039**	**$790**	-31.6	-$249

Chemical costs were estimated to be $1,268/yr for 60 gpm and estimated to be $4,014/yr for the 150 gpm size with a $2,747/yr (approximately 68.4 percent). The total operating costs of the 60 gpm and 150 gpm units were estimated to be $40,384/yr ($0.66/1000 gallon) and $56,846/yr ($0.72/1000 gallons) respectively.

The total cost of the 60 gpm and 150 gpm systems were estimated to be $59,225/yr or $1.88/1000 gallon and $85,821/yr or $1.09/1000 gallons respectively. The cost difference was estimated to be $26,596/yr (approximately 31 percent). Moreover, the total cost of gallon per minute of the capacity of 86,000 gpd and 216,000 gpd were estimated to be $987/yr and $572/yr respectively. Because of economy of size, it is more efficient for the city to supply water to both Kaw City and Shidler to save cost of $0.47/1000 or $249/gpm than to supply only Kaw City.

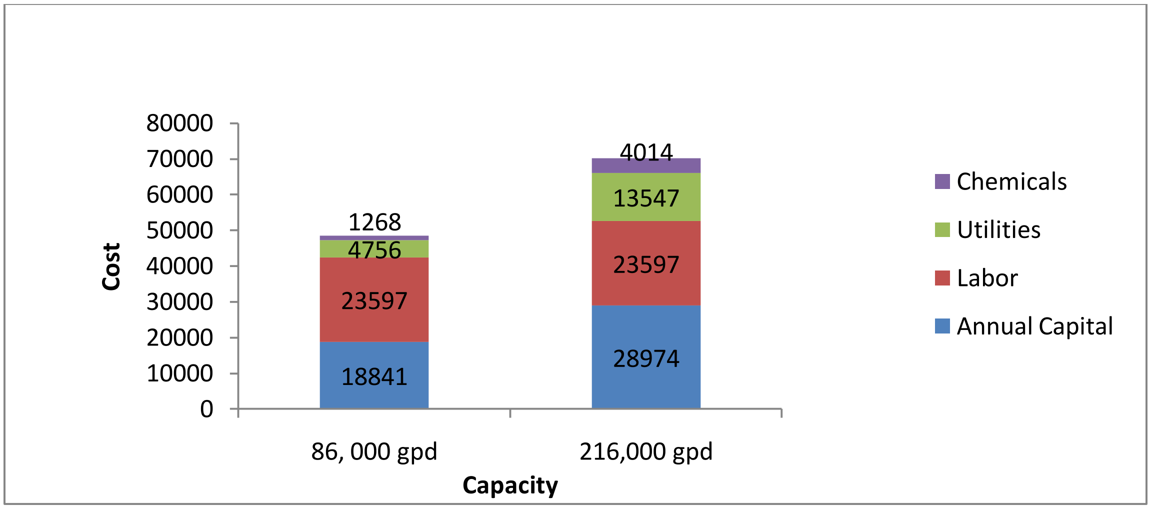

Figure IV-7. The Estimated Total Cost of Nanofiltration Treatment System of Capacity of 216,000 gallons per day and 86,000 gallons per day

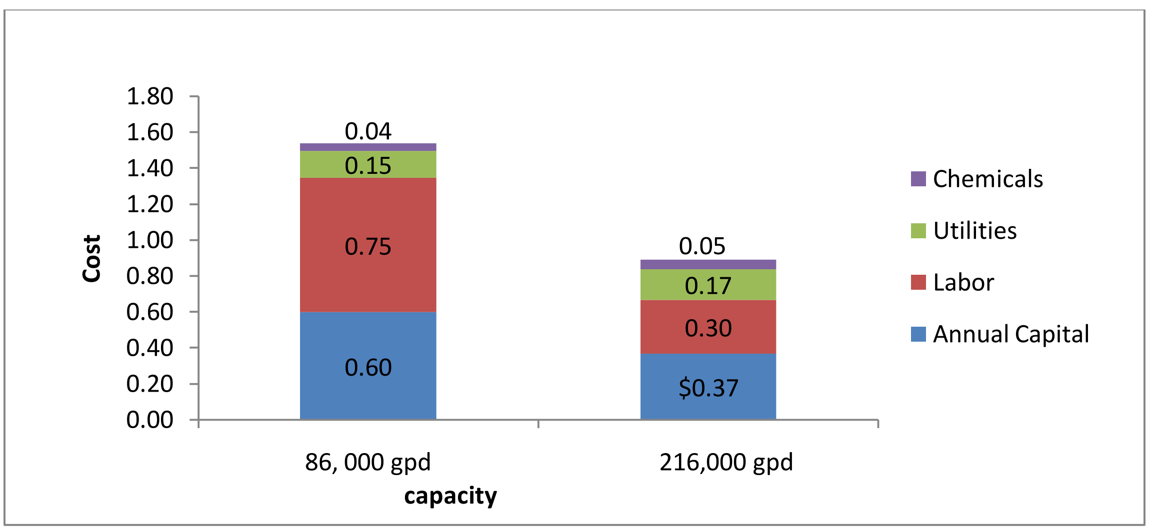

Figure IV-8. The Estimated Total Cost. per Thousand of Nanofiltration treatment system of capacity of 216,000 gallons per day and 86,000 gallons per day

Figure 12 and 13 also give the further interpretation of the estimated total cost of the nanofiltration system of the capacity of 216 thousand gallons per day and 86 thousand gallons per day. The estimated total cost of the 216 thousand capacities was estimated to be $70,000 and 86 thousand capacities was estimated to be above $50,000. The cost per thousand of estimated annual capital of 86 thousand was estimated to be 38.3 percent increased higher than Aeralator® system. The cost per thousand of chemical cost of the 86 thousand capacities was 20 percent higher than 216 thousand capacities. It is shown that the total cost of the 150 gallons per minute was higher than the 60 gallons per minutes. However, due to economies of size of the supply of water, the estimated cost of the 86 thousand gallons per minute was estimated to be higher than the 150 gallon per minute.

4.6 Estimation of Cost of layout the Kaw City Pipeline System and the cost of pipeline from the plant to the existing pipeline

Table IV-17 gives the detailed cost of the layout of the pipeline system of entire Kaw City. For the better improvement of the distribution system of the city, there should be the need of replacing all the old pipes with required new pipes and sizes. The size of the city pipelines ranges from 4” to 8” size but the population of the city is even less than 400 people. The pipes were laid when the city was relocated by the US Army Corps Engineers for the construction of the Kaw Lake. Since the relocation of the city, no replacement of the pipelines had been done. The replacement cost of the city pipeline was based on the cost of trenching and the cost of the pipe. It assumed that the depth of the trench was 4 feet or 48 inches to prevent the water and the pipe from severe winter otherwise it would freeze

The cost estimation of the layout of pipelines of the city should have been included the cost of the pipeline underneath the lake to the city but it would be very difficult to construct it. The estimation was looked in two aspects of the cost components. The first component of the cost was the cost of the materials and other was the cost of the trenching. Three different pipe sizes were used where 6” pipe was the large size, which linked from the end of the lake to the storage tank and mains. The cost of the 6” pipe size was estimated to be $69,481 with the distance of 11,619ft and unit cost of $5.98/ft. With the unit cost of $3.91/ft and $3.06/ft and the distance of 10,200ft and 2,750ft, the cost of 4” and 3” pipe were estimated to be $39,883 and $8,414 respectively.

The excavation of the trenching of the entire was $93,115 with unit cost of $7.76/cubic yard and 24,569 feet of pipeline. The cost of backfilling, dressing and packing was estimated to be $14,050 with unit of cost of $1.93/cubic per yard. The total cost of the trenching for the city cost $304,033 represents 80.7 percent of the total estimated cost of entire layout of the city and the cost per foot of the trench cost $12.37/ft. However, the annual repayment fixed was estimated to be $16,654.

. The cost of materials excluded elevated storage tank because the existing storage tank for city of capacity of 250,000 gallons was enough for the city of the population of 400 people. The 27 (1-3 way) fire hydrants required for the city at $1,085 each were estimated to cost $29,295. The total cost of materials was estimated to be $72,917, which represents 19.3 percent of the total estimated cost of the layout and annual fixed cost was estimated to be $$3,994. The investment cost of the layout of the city was estimated to be $376,950 and $15.34/ft cost per foot of the investment cost.

The total annual fixed cost of the layout cost $20,648 with 5 percent interest, life expectancy of the material of 50 years and CRF of $0.05.

Table IV-17. Estimation of Cost of layout the Kaw City Pipeline System

Trenching and Equipment	units	unit cost	Quantity	Total Cost	Annual fixed Cost
Estimated Trenching cost of entire city					
6" PVC DR 18 pipe	ft	5.98	11619	$69,481	$3,806
4" PVC DR 18 pipe	ft	3.91	10200	$39,883	$2,185
3" PVC DR 18 pipe	ft	3.06	2750	$8,414	$461
6" Midco Joint Restraints	ea	$90.00	24	$2,160	$118
Line Markers	ea	$63.00	7	$441	$24
Installation and Testing (with the length of 24,569 ft)	ea	$1,875.00	8	$15,000	$822
Tracer Wire 6"	clf	$3.79	24569	$93,115	$5,101
Trench Excavation CY (with the length of 24,569 ft)	cu/yd	$7.76	7280	$56,490	$3,094
Backfill and dressing	cu/yd	$1.93	7280	$14,050	$770
Mobilization/demobilization	job	$5,000.00		$5,000	$274
Total Trenching				**$304,033**	**$16,654**
Materials					
1-6"x6"x6" Tee	ea	$86.95	15	$1,304	$71
1-3 way F.H.	ea	$1,085	27	$29,295	$1,605
1-6" C.I. Plug	ea	$82.45	4	$330	$18
1-6" H.E. Valve & box	ea	$1,185	11	$13,035	$714
1-4" C.I.Plug	ea	$46.50	2	$93	$5
1-4" 111/4 deg. Bend	ea	$37.63	1	$38	$2
1-6"x6"x4" Tee	ea	$251.50	2	$503	$28
1-4" H.E. Valve box	ea	$1,185	6	$7,110	$389
2-6"x6"x6" Tee	ea	$86.95	3	$261	$14
1-6" 22deg. Bend	ea	$78.20	1	$78	$4
1-6" 45 deg. Bend	ea	$65.68	2	$131	$7
1-6" 221/2 deg. Bend	ea	$78.20	3	$235	$13
Air Relief valve in vault	ea	$744.50	9	$6,701	$367
1-8"x8"x8" Tee	ea	$131.45	18	$2,366	$130
1-3/4" Corporation stop/Cock	ea	$172.00	4	$688	$38
3-6" 221/2 deg. Bend	ea	$87.15	2	$174	$10
2-6" 221/2 deg. Bends	ea	$78.45	2	$157	$9
1-6" 90 deg. Bend	ea	$64.96	1	$65	$4
2-6" 111/4 deg. Bends	ea	$67.05	1	$67	$4
1-6" 111/4 deg Bends	ea	$66.93	4	$268	$15

Trenching and Equipment	units	unit cost	Quantity	Total Cost	Annual fixed Cost
1-8" H.E. Valve & box	ea	$1,835	1	$1,835	$101
1-8" 221/2 Bends	ea	$117.25	2	$235	$13
1-8" C.I. Plug	ea	$95.45	1	$95	$5
1-8" 45 deg. Bends	ea	$122.43	2	$245	$13
2-8" 221/2 deg Bends	ea	$116.70	1	$117	$6
2-8" H. E.Valve &box	ea	$1,835	3	$5,505	$302
8"x6" Tee	ea	$296.45	5	$1,482	$81
2-6" 45 deg. Bends	ea	$65.68	1	$66	$4
3/4" Corporation stop/Cock	ea	$53.50	1	$54	$3
3-8" 111/4 deg	ea	$113.13	2	$226	$12
1-4" 45deg Bend	ea	$37.93	1	$38	$2
1-4" 221/2 deg	ea	$40.63	3	$122	$7
Total Material				**$72,917**	**$3,994**
Total Estimated Cost				**$376,950**	**$20,648**

Table IV-18 presents the cost of transmission line from the monitoring well at Greenhouse Site to the treatment plant and from the treatment plant to the existing pipeline. The cost of the post hydrant was estimated to be $1,408 and the installation and the testing of the transmission line of the length of 25,344ft was estimated as $15,000. The trenching cost of the line was estimated to $46,408 with the unit cost of $6 per cubic yard or $1.83 per linear feet.

The 6" gate valves, which prevent the backflow of water, were estimated to be $5,632. The mobilization and demobilization was estimated to be the lump sum of $500. The cost of 3 6" 90^0 bends pipe required to connect the pipes to foster the smooth flow of water were estimated to

cost $787 with the unit cost of $262. The total estimated investment cost of the transmission line was estimated to be $347,527 or $13.71 per foot. With the CRF of $0.05, the total annual repayment (fixed) cost was estimated to be $19,036/yr

Table IV-18. Cost of Transmission line (Pipeline) from Monitoring Well (Greenhouse) to Existing Pipeline with 25,344 feet length

Descriptions	units	Unit Cost	Quantity	Total Cost
6" Tees	Ea	$301	3	$902
6" M.J. Plug	Ea	$144	2	$288
6" Gate Values	Ea	$704	8	$5,632
Air Valve Assemblies	Ea	$1,101	5	$5,504
6" 90 Bends	Ea	$262	3	$787
12" Bore and Casing	Ea	$84	250	$20,875
Post Hydrant	Ea	$1,408	1	$1,408
Line Markers	Ea	$64	7	$448
6" Midco Joint Restraints	Ea	$90	24	$2,160
6" AWWA Pipe	ft	$5.98	25344	$151,559
Installation and Testing	ft	$1,875	8	$15,000
Tracer Wire 6"	ft	$4	25344	$96,055
Trench Excavation (incl backfilling, packing and dressing) CY	CY	$6	7509	$46,408
Mobilization/demobilization	job	$500	1	$500
Total				**$347,527**

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Summary and Conclusions

The Kaw City has relied on the well designed by U.S. Army Corps as their main source of water. In 1990's the city attempted to restore the abandon collapsed well but it was not fruitful. The problem of taste due to a high levels of the minerals such manganese, and iron will not permit people to use the water comfortably without treatment though these minerals are not very hazardous to human health.

The general objective of this study was to determine and compare the cost of building alternative water treatment plant facilities in Kaw City. Some of the specific objectives of the study were to determine the cost of capital investment and annual capital cost of two possible treatment plant and determine the cost of operating of the two treatment systems. Moreover, another objective was to compare the discounted amortized capital cost and plus the amortized operating cost for two sizes and two types of treatment plants and determine the energy cost of pumping water from the well to the city. The estimated cost of the layout of the entire Kaw city pipeline was based on the materials required and pipeline excavation cost in the city. The cost of the transmission line from the Monitoring well at Greenhouse to treatment plant and then to the existing pipeline at Washunga Bay was also estimated from the cost of materials the cost of excavation.

Estimation of the cost of treatment building based on specifically the size of the building assuming the buildings have common features. The annual total fixed cost of the 1000 square feet and 1,350 square feet buildings and their facilities of nanofiltration (NF) treatment plants estimated \$4,912 and \$5,906 respectively and cost per foot were estimated to be \$4.91 and \$4.37. Because of to structure of the Aeralator® treatment plant system, the annual total fixed cost of 750 square feet and 1000 square feet of the buildings were estimated to be \$4,269 and \$5,081 and \$5.69/sqft and \$5.08/sqft respectively. The costs per foot of smaller buildings were higher than the bigger building due to economies of size. As the size the building increases, the cost of the building decreases.

The cost of distributing water from the plant to the Kaw City was based on the energy and the pipe size. The estimates identified that the larger the pipe size, the lower the cost of energy. Therefore, there was an inverse relationship between energy cost and the size of the pipe.

The comparison of the two treatment plant system Aeralator® and NF of the capacity of 60 gpm analyzed that the cost of amortized capital Aeralator® and NF treatment plant were estimated to be \$14,945/yr and \$18,841/yr respectively and the cost difference was approximately 20.7%, which is high. The total operating cost of NF treatment plant was \$40,384/yr whereas Aeralator® treatment plant was estimated to be \$20,908/yr, which has difference of approximately 48.2%. The total economic cost of Aeralator® treatment plant was \$35,852/yr while the NF treatment system was

$59,225/yr and cost difference of $23,373/yr. The cost of NF treatment was more expensive than the Aeralator® treatment plant of the same capacity. Since the systems serve almost same purpose, it is economically more cost effective to use Aeralator® treatment plant to treat and supply water to the city, which has less economic cost instead of nanofiltration treatment plant.

For treatment plant of capacity of 150 gpm, the annual capital fixed cost of Aeralator® system was estimated to be $17,728/yr while NF was estimated to be $28,974/yr water of treated water. Moreover, the total operating cost of Aeralator® and NF treatment plant system of the capacity of 150 gpm were estimated to be $31,385/yr and $56,846/yr respectively. The annual economic costs of the two treatment system plants were estimated as $49,113/yr or $0.62/1000 gal of Aeralator® treatment plant and $85,821/yr or $1.09/1000 gal of NF treatment plant. The cost of treatment plant of capacity of 150gpm of water of NF was higher than cost of the Aeralator®, therefore it is economically viable to use Aeralator® treatment plant to minimize cost of $36,708/yr.

The capital fixed cost of the Aeralator® treatment plant of the capacity of 60 gpm was estimated to be $14,945/yr or $0.47/1000 gallon and $247/gpm. The cost of the annual capital of 150gpm capacity was $17,728 or $0.22/1000 gallon and cost of gallon per minute was $118/gpm of water treated. The total operating cost of the two capacities were estimated to be $20,908/yr of capacity of 60 gpm or $0.66/1000 gallon of water treated and $31,385/yr or $0.40/1000 gallon water treated of capacity of 150 gpm. The operating cost of gallon per minute of 150 gpm was $209/gpm and $348/gpm of the capacity of the 60 gpm. The total annual costs of the systems were estimated to be $35,852/yr of capacity of 60 gpm or $1.14/1000 gallon and cost of gallon per minute was

$598/gpm. The total annual cost of the capacity of 150 gpm was $49,113/yr or $0.62/1000 gal and the cost of the gallon per minute was estimated to be $327/gpm. The cost estimated emphatically identified that treating of water to supply both Shidler and Kaw City was cheaper than supply Kaw City alone. This cost difference gives better of explanation of the theory of economy of scale. As sufficient water being treated, the total cost of water treatment reduced.

The annual capital cost of Nanofiltration of the capacity of 60 gpm and 150 gpm were estimated to be $18,841/yr or $0.60/1000 gallon and $28,974/yr or $0.37/1000 gallon of water treated respectively. The estimated costs of gallon per minute of treated water were $314/gpm and $193/gpm of capacity of 60 gpm and 150 gpm respectively. Operating cost of the system of capacities of 60 gpm and 150 gpm were $40,384/yr or $0.66/1000 gallon and $56,846/yr or $0.72/1000 gallon of water treated respectively. In all, the total economic cost of the system with difference capacities of 60 gpm and 150 gpm were estimated to be $59,225yr or $1.88/1000 gallon and $85,821/yr or $1.09/1000 gallon of treated water respectively. The cost difference was estimated to be $26,596/yr. Moreover, the total economic cost of gallon per minute of the capacity of 86,000 gpd and 216,000 gpd were $987/gpm and $572/gpm respectively. However, it was concluded that the city should treat water to supply Kaw City and Shidler rather than supply only Kaw City since the cost gpm of water treated for two cities of $987/gpm less costly than only Kaw City of $572/gpm. Additionally, the city should supply water to both cities and serve cost of $415/gpm and $0.79/1000 gallon of water a year.

For the better improvement of the distribution system of water for the city, new pipes should replace the old pipes. The cost estimation of the layout of pipelines of the city should have been included in the cost of the pipeline underneath the lake to the city but it is very difficult to construct or replace the pipes crossing the lake. The investment cost of the layout of the entire city was estimated to be $376,950 and $15.34/ft was the cost per foot of the investment cost. The annual fixed cost of the layout of $20,648/yr and CRF of $0.05. The total estimated investment cost of the transmission line was estimated to be $347,527 and the cost per foot of the total investment cost is $13.71/ft. With the CRF of $0.05, the annual fixed cost of $19,036/yr.

5.2 Specific Recommendations

i) The economic cost of Aeralator® treatment plant of capacity of 60 gpm and 150 gpm was estimated to be $598/yr and $327/yr respectively. However, the annual economic cost of Aeralator® treatment plant system of 60 gpm was higher by $271/yr (approximately 45.2%). Due to economy of scale of treating and supply of water, it is economically more cost effective to supply water to both Kaw City and Shidler and serve cost of $271/yr of gpm and $0.52/1000 of water treated.

ii) It is more cost-effective also to supply water to Shidler and Kaw City than only Kaw City alone using the NF treatment plant system. The annual economic cost of NF of capacity gallon per minute of 60 gpm and 150 gpm was $987/yr and $572/yr and cost difference of $415/yr (approximately 42%). Since the annual economic cost between the two capacities was very high, it is economically reasonable to supply water of 150 gpm to serve cost of $415/yr of gpm and $0.79/1000 of water treated.

iii) The economic annual cost of NF and Aeralator® treatment plants of the capacity of 60 gpm were estimated to be \$987/yr and \$598/yr respectively and the cost difference of \$389/yr (approximately 39.2%). Therefore, the annual economic cost of Aeralator® treatment plant was cheaper than NF treatment plant. Since the two systems serve the almost the same purpose and efficient to treat raw water from chemicals contaminated through dissolve the soil, it is highly recommended the use of Aeralator® treatment plant due to lower cost of treatment of raw water and avoid spending cost of \$389/yr of gpm and \$0.74/1000 of water treated.

iv) It is highly recommended to use the Aeralator® treatment plant when the city decides to supply water to both Kaw City and Shidler. Since the annual economic cost of gallon per minute of the Aeralator® treatment plant was cheaper than NF treatment plant.

v) For better improvement of the distribution of water throughout city, the pipelines must be changed to be proportional to the population. The pipe sizes of the city were large because they were using the rural pipeline since they were relocated to the site. The change of the pipes would make smooth flow of the water and be more efficient.

vi) Aside from the cost of the treatment of the raw water, the NF treatment system is recommended if the city emphasis is only the removal of taste and improving quality of the water since one of the city's problems was taste of the water.

vii) Groundwater is a natural resource and it is limited. Therefore, if the city decides to put measures in place to protect their available resource, then the city should adopt the use of Aeralator® water treatment system instead of nanofiltration treatment system. Since the wastewater during treatment are 1% and 25% of Aeralator® and nanofiltration treatment system respectively.

5.3 Limitation and Suggestion for further Research

This study has comprehensive models for estimating the cost of annual capital, operating cost, energy cost and the transmission line. Base on the assumptions, the models may encounter uncertain estimations of operating cost of the treatment systems. However, the cost of the equipment and materials estimated using the RSMean construction data may differ from the real market cost.

The cost of chemicals of NF was higher than the Aeralator® treatment system because the cost of antiscalant, which would take care of scaling, based on the assumption that the NF treatment system form scales in the pipes during the processing. But the cost of antiscalant would depend on the amount of chemicals dissolved in the groundwater though the main chemical was the manganese. Therefore it would be difficult to estimate the exact of the antiscalant, then the real cost of antiscalant may be different from the estimated cost.

Additionally, the cost of drilling of the well may be different from real world cost because it was assumed that the depth of the well was 120 feet since the US Army Corps well of 67 feet depth was not fruitful. Therefore, the depth of the well may be higher or lower than that of 120 feet to get enough water and if so then the cost of drilling of the water would be different.

In term of future research, it would be interesting to apply to propose the model to re-estimate the effect of the distribution based on the old pipe crossing or underneath the lake. Also, re-estimate the cost of alternative treatment system (such as Microfiltration) to compare the cost with Aeralator® and NF treatment systems and find out which is more reliable and has minimum cost. Moreover, future researcher can re-estimate operating cost of treatment system using both chlorine and $KMnO_4$ and only $KMnO_4$ for treating of raw water and compare the cost which is more affordable. The analytical model could be modeled to estimate the willingness to pay of the cost of water treated and cost of treatment plant and related facilities.

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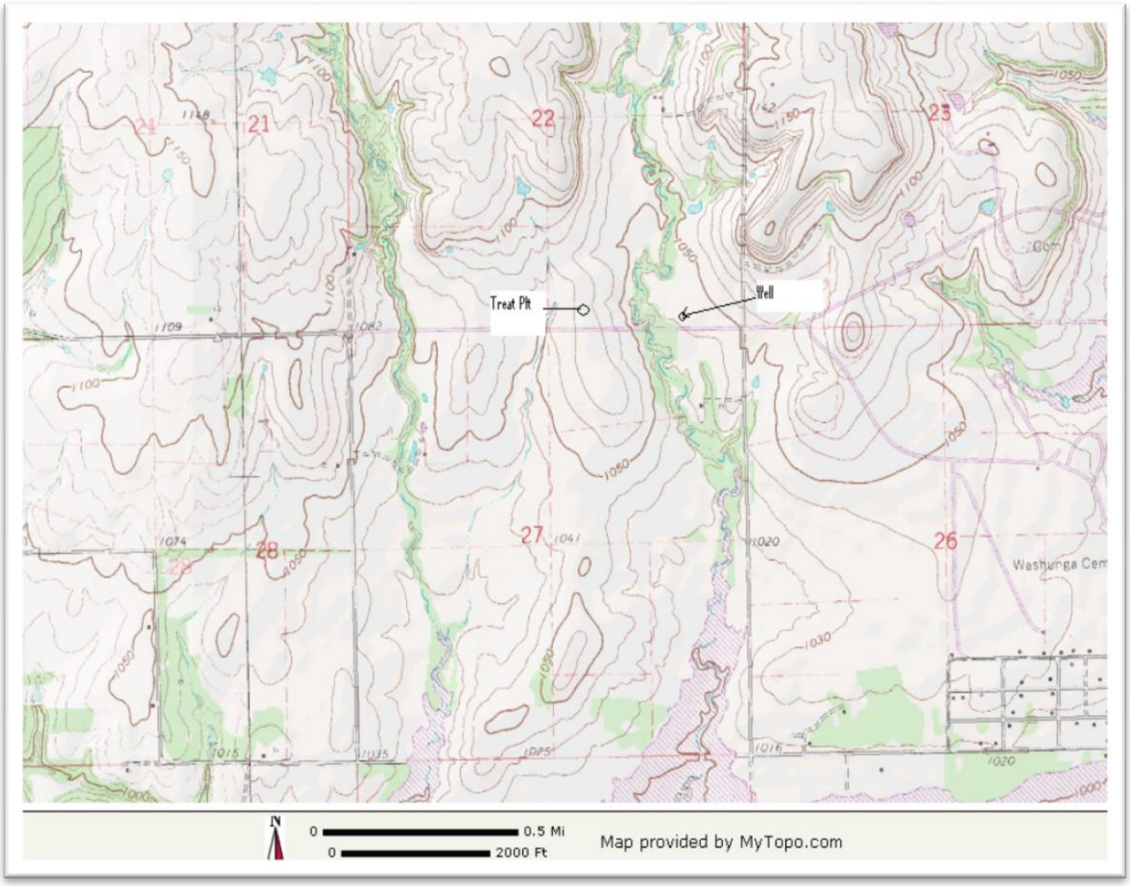
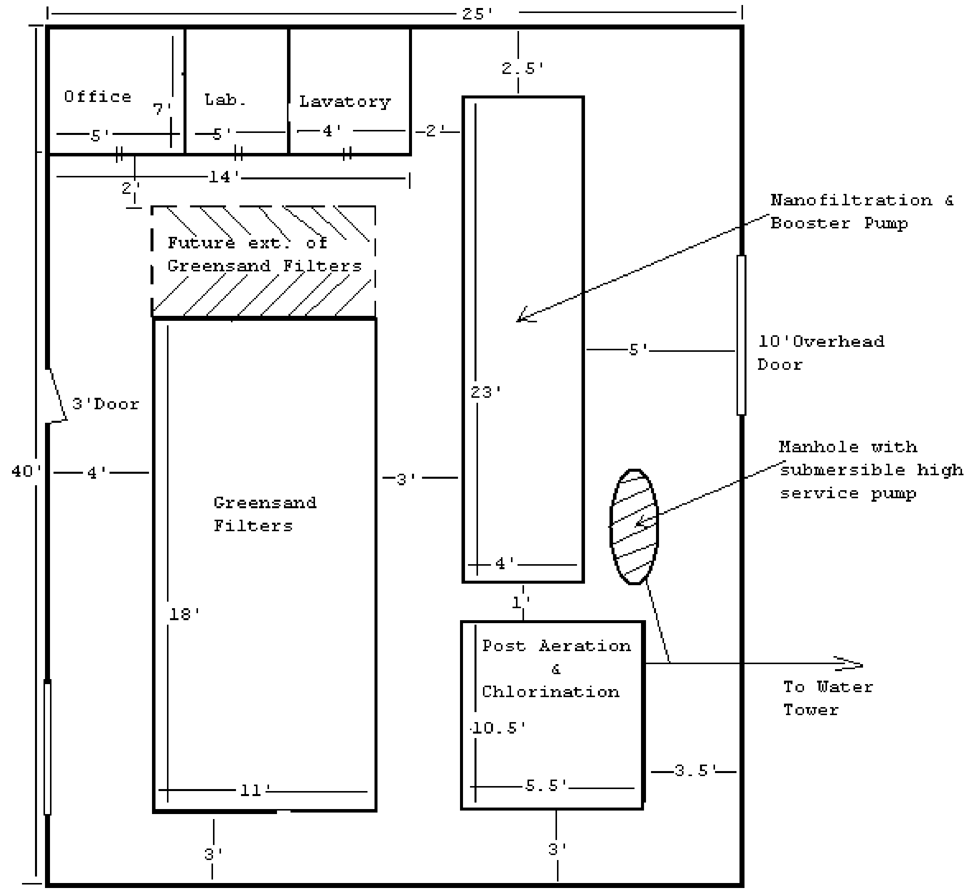
APPENDIX

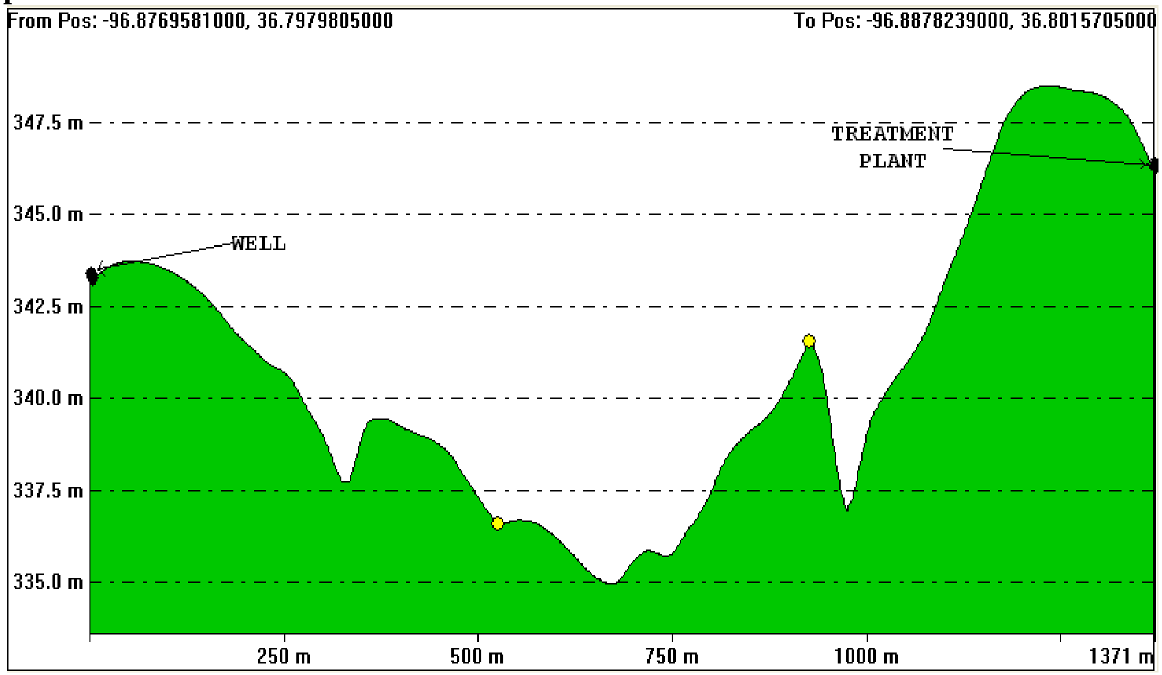
Appendix 1: Topography of the area of the existing pipeline, the treatment plant and the treatment plant to the well



Appendix 2: Nanofiltration building and foundation plan



Appendix 3. Cross section of the land from the monitoring well to water treatment plant



Appendix 4. Estimated Annual Economic Cost of Aeralator® Water Treatment Plant of Capacity of 60 gpm or 86,000 gallon per day

Descriptions	units	unit cost($)	quantity	Total Cost	Total Cost/1000	Rate (%)
Utilities						
Well Control System (@ .15KWH, 2920 hrs/yr) 0.15*2920	Kwh	$0.108	438	$47	$0.00	
Running well pump, 5.0hp, 0,747 Kw/hp, 3784 hrs/yr,80GPM (3784*5.0*0.747)	Kwh	$0.108	14133	$1,526	$0.05	
Heating, Ventilation and Air Condition(HVAC),.001 sqft x 1000sq ft x 2920hr/yr	Kwh	$0.108	2920	$315	$0.01	
Booster Pump 4.8hp, 78gpm, 0.747 Kw/hp, 3784 hrs/yr (3784*4.8*0.747)	Kwh	$0.108	13562	$1,465	$0.05	
Greensand Controls, nano controls @ 0.4Kw/h, 2920hrs/yr	Kwh	$0.108	1168	$126	$0.00	
High Service Pump, 60gpm (3.6hp *0.747kw/hp*3784hr/yr)	Kwh	$0.108	10175	$1,099	$0.03	
Waste Water Lift Station Pump(1hp, 365 days, 15gpm, 0.747 Kw/hr	Kwh	$0.108	1635	$177	$0.01	
Total Utilities				**$4,756**	**$0.15**	**11.8**
Chemicals						
Chlorine, 31.536 MG/yr @ (4 mg/l water treated)	Mg/yr	$0.50	477	$239	$0.01	
Scale inhibitor 31.536MG/yr @ (2mgl water treated)	Mg/yr	$1.15	239	$275	$0.01	
KnMnO4, 31.536MG/yr, @ (3.95mgl water treated)	Mg/yr	$1.60	472	$754	$0.02	
Total Chemicals				**$1,268**	**$0.04**	**3.1**
Administration and Operations						
Certification Fees	lump sum	$150	1	$150	$0.00	
Dues & Subscriptions	lump sum	$150	1	$150	$0.00	
Insurance	lump sum	$1200	1	$1,200	$0.04	
Laboratory	lump sum	$500	1	$500	$0.02	
Office Supplies	lump sum	$450	1	$450	$0.01	
Miscellaneous Supplies	lump sum	$531	1	$531	$0.02	
Vehicles	lump sum	$645	1	$645	$0.02	
Postage and Freight	lump sum	$349	1	$349	$0.01	
Legal and Audit	lump sum	$249	1	$249	$0.01	
Telephone	lump sum	$400	1	$400	$0.01	
Administration and Operations				$4,623	$0.15	11.4
Labor						
Payroll Taxes (6.25% of operate and maintain)	percent	$1368	1	$1,369	$0.04	

Appendix 4. Estimated Annual Economic Cost of Aeralator® Water Treatment Plant of Capacity of 60 gpm or 86,000 gallon per day

Descriptions	units	unit cost($)	quantity	Total Cost	Total Cost/1000	Rate (%)
Health Insurance 1.5% of Operate and maintenance of WTP	percent	$328	1	$329	$0.01	
Salary and Wages	hours	$20	1095	$21,900	$0.69	
Total Labor Cost				**$23,597**	**$0.75**	**58.4**
Replacement Costs						
pump	hp	$4750	1	$4,750	$0.15	
Filters	ea	$278	5	$1,390	$0.04	
Total Replacement Cost				**$6,140**	**$0.19**	**15.2**
Total Annual Operating Cost				**$40,384**	**$1.28**	
CAPITAL COST						
Construction						
Building	sq. ft	$89.68	1000	$4,912	$0.16	
Cost of drilling Well	ft	$9094	1	$498	$0.02	
6" Raw Water Pipeline from well to treatment plant	ft	$5.98	5084	$1,665	$0.05	
Trenching (including backfilling, packing) 2' Width, 4' Depth	CY	$6.18	1506	$510	$0.02	
Resident Inspection	lump sum	$5000	1	$274	$0.01	
Total Construction				**$7,860**	**$0.25**	**41.7**
Equipment						
Chlorine Contact Chamber	ea	$12000	1	$657	$0.02	
Greensand Pressure Filtration (80 gpm)	ea	$27765	1	$1,521	$0.05	
Nanofiltration Manufacturing Model (80gpm)	ea	$120000	1	$6,573	$0.21	
Well pump, motor and control	Hp	$8310	1	$455	$0.01	
Pressure Pump to force water through the filters	Hp	$2995	1	$164	$0.01	
Waste Water Pump	Hp	$1987	1	$109	$0.00	
Total equipment				**$9,479**	**$0.30**	**50.3**
Engineering Cost						
Design @ .91% Construction	percent	$1305	1	$72	$0.00	
Bidding Phase @.8% Construction	percent	$1147	1	$63	$0.00	
Engineering during construction	lump sum	$11561	1	$633	$0.02	
O&M Manual	lump sum	$2720	1	$149	$0.00	
Groundwater Rights						
Other Engineering and Surveying	lump sum	$2500	1	$137	$0.00	

Appendix 4. Estimated Annual Economic Cost of Aeralator® Water Treatment Plant of Capacity of 60 gpm or 86,000 gallon per day

Descriptions	units	unit cost($)	quantity	Total Cost	Total Cost/1000	Rate (%)
DEG Permit to construct WTP	lump sum	$1000	1	$55	$0.00	
Land Acquisition						
Total Engineering Cost				**$1,108**	**$0.04**	**5.9**
Contingencies (5% 0f construction cost)	lump sum	$7174	1	$393	$0.01	2.1
TOTAL FIXED (CAPITAL) COST				**$18,840**	**$1.18**	
TOTAL ECONOMIC COST				**$59,225**	**$2.46**	

Appendix 5. Estimated Annual Economic Cost of Aeralator® Water Treatment Plant of Capacity of 150 gpm or 216,000 gallon per day

Descriptions	**units**	**unit cost**	**quantity**	**Total Cost**	**rate(%)**	**TC/1000**
Utilities						
Well Control System (@ .15KWH, 365 hrs/yr) 0.15*365	Kw/h	$0.11	54.75	$5.9		$0.00
Running well pump, 11.1hp, 0,747 Kw/hp,152GPM, 3784 hrs/yr (3784*11.1*0.747)	Kw/h	$0.11	31376	$3,389		$0.04
Heating, Ventilation and Air Condition (HVAC) .001 sqft x 750sq ft x 365hr/yr	Kw/h	$0.11	273.75	$30		$0.00
High Service Pump 10.9hp, 150GPM (10.9hp *0.747kw/hp*3784hr/yr)	Kw/h	$0.11	30810	$3,328		$0.04
Greensand/ Anthra sand Controls, Aeralator controls @ 0.4Kw/h, 365hrs/yr	Kw/h	$0.11	146	$16		$0.00
Total Utilities				**$6,767**	**21.6**	**$0.09**
Chemicals						
Chlorine, 99.864 MG/yr @ (4 mg/l water treated)	Mg/yr	$0.50	1512	$756		$0.01
KnMnO4 99.864MG/l @ (3.95mg/l water treated)	Mg/yr	$1.60	1493	$2,389		**$0.03**
Total Chemicals				**$3,145**	**10.0**	**$0.04**
Administration and Operations						
Certification Fees	lump sum	$150	1	**$150**		$0.00
Dues & Subscriptions	lump sum	$150	1	$150		$0.00
Insurance	lump sum	$1,200	1	$1,200		$0.02
Laboratory	lump sum	$500	1	$500		$0.01
Office Supplies	lump sum	$450	1	$450		$0.01
Miscellaneous Supplies	lump sum	$531	1	$531		$0.01
Vehicles	lump sum	$645	1	$645		$0.01
Postage and Freight	lump sum	$349	1	348.63		$0.00
Legal and Audit	lump sum	$249	1	248.82		$0.00
Telephone	lump sum	$340	1	$400		$0.01
Total Administration and Operations				**$4,623**	**14.7**	**$0.06**
Labor						

Appendix 5. Estimated Annual Economic Cost of Aeralator® Water Treatment Plant of Capacity of 150 gpm or 216,000 gallon per day

Descriptions	units	unit cost	quantity	Total Cost	rate(%)	TC/1000
Salary and Wages (2hrs/day of $ 20 rate)	hrs	$20	365	$7,300		$0.09
Health Insurance of 1.5% of Salary and Wages	percent	$110	1	$110		$0.00
Payroll Taxes (6.125% of Salary and Wages)	percent	$456	1	$456		$0.01
Total Labor Cost				**$7,866**	**25.1**	**$0.10**
Replacement Costs						
pump	hp	$8,150	1	$8,150		$0.10
Filters	ea	$278	3	$834		$0.01
Total Replacement Cost				**$8,984**	**28.6**	**$0.11**
TOTAL OPERATING COST				**$31,385**		**$0.40**
CAPITAL COST						
Construction						
Building (40' x 25')	sq ft	$92.76	1000	$5,081		$0.06
Cost of drilling Well	ft	$9094	1	$498		$0.01
6" Raw Water Pipeline from well to treatment plant	ft	$6	5084	$1,665		$0.02
Trenching (including backfilling, packing) 2' Width, 4' Depth	CY	$6	1506	$510		$0.01
Resident Inspection	lump sum	$5,000	1	$274		$0.00
Total Construction				**$8,028**	**45.3**	**$0.10**
Equipment						
MULTIWASH combined air/water backwash for enhanced media cleanliness (150 gpm, 6" diameter)	ea	$111,000	1	$6,080		$0.08
Valve (Control, Backwash Waste Valve, Filter inlet Valve)	ea	$2,940	9	$1,449		$0.02
Induced Draft Blower	ea	$252	1	$14		$0.00
Instrumentation and Controls	lump sum	$3,450	1	$189		$0.00
Well pump, motor and controls	ea	$8,310	1	$455		$0.01
Total Equipment				$8,188	46.2	$0.10

Appendix 5. Estimated Annual Economic Cost of Aeralator® Water Treatment Plant of Capacity of 150 gpm or 216,000 gallon per day

Descriptions	units	unit cost	quantity	Total Cost	rate(%)	TC/1000
Engineering Cost						
Design @ .91% Construction	percent	$1,334	1	$73		$0.00
Bidding Phase @.8% Construction	percent	$1,173	$1.00	$64		$0.00
Engineering during Construction	lump sum	$11,561	1	$633		$0.01
O&M Manual	lump sum	$2,720	1	$149		$0.00
Groundwater Rights						
Other Engineering and Surveying	lump sum	$2,500	1	$137		$0.00
DEQ Permit to construct WTP	lump sum	$1,000	1	$55		$0.00
Land Acquisition						
Total Engineering				**$1,111**	**6.3**	**$0.01**
Contingencies (5% 0f construction cost)	lump sum	**$7,328**	**1**	**$401**	**2.3**	**$0.01**
Total Fixed (Capital) Cost				**$17,729**		**$0.22**
TOTAL ECONOMIC COST				**$49,114**		**$0.62**

Appendix 6. Estimated Annual Economic Cost of Nanofiltration Water Treatment Plant of Capacity of 150 gpm or 216,000 gallon per day

Descriptions	units	$ unit cost	quantity	Total Cost	rate (%)	TC/1000
Utilities						
Well Control System (@ .15KWH, 2920 hrs/yr) 0.15*2920	Kwh	$0.11	438	$47		$0.00
Running well pump, 15.5hp, 190GPM, 0.747 Kw/hp, 3784 hrs/yr, 190GPM (3784*15.5*0.747)	Kw/h	$0.11	43813.04	$4,732		$0.06
Heating, Ventilation and Air Condition(HVAC),.001 sqft x 1000sq ft x 2920hr/yr	Kwh	$0.11	2920	$315		$0.00
Booster pump 15.1hp, 0.747Kw/h, 187GPM, 3784hrs/yr (15.1*3784*0.747)	Kw/h	$0.11	42682.38	$4,610		$0.06
Greensand Controls, nano controls @ 0.4Kw/h, 2920hrs/yr	Kwh	$0.11	1168	$126		$0.00
High Service Pump (10.9hp *0.747kw/hp*3784hr/yr, 150GPM)	Kw/h	$0.11	30810.46	$3,328		$0.04
Waste Water Lift Station Pump(2.2hp, 365 days, 37.5 GPM, 0.747 Kw/hr, 2190Hrs/yr	Kw/h	$0.11	3599	$389		$0.00
Total Utilities				**$13,547**	**23.8**	**$0.17**
Chemicals						
Chlorine, 99.864 MG/yr @ (4 mg/l water treated)	Mg/yr	$0.50	1511	$756		$0.01
Scale inhibitor 99.864MG/l @2mgl water treated)	Mg/yr	$1.15	755	$869		$0.01
KnMnO4 99.864MG/yr, @ (3.95mg/l water treated)	Mg/yr	$1.60	1493	$2,389		$0.03
Total Chemicals				**$4,014**	**7.1**	**$0.05**
Administration and Operations						
Certification Fees	lump sum	$150	1	$150		$0.00
Dues & Subscriptions	lump sum	$150	1	$150		$0.00
Insurance	lump sum	$1,200	1	$1,200		$0.02
Laboratory	lump sum	$500	1	$500		$0.01
Office Supplies	lump sum	$450	1	$450		$0.01
Miscellaneous Supplies	lump sum	$531	1	$531		$0.01
Vehicles	lump sum	$645	1	$645		$0.01
Postage and Freight	lump sum	$349	1	$349		$0.00
Legal and Audit	lump sum	$249	1	$249		$0.00
Telephone	lump sum	400	1	$400		$0.01
Total Administration and Operations				**$4,623**	**8.1**	**$0.06**
Labor						

Appendix 6. Estimated Annual Economic Cost of Nanofiltration Water Treatment Plant of Capacity of 150 gpm or 216,000 gallon per day

Descriptions	**units**	**$ unit cost**	**quantity**	**Total Cost**	**rate (%)**	**TC/1000**
Salary and Wages	hours	$20	1095	21900		$0.28
Health Insurance 1.5% of Salary and Wages	percent	$329	1	$329		$0.00
Payroll Taxes (6.25% of Salary and Wages)	percent	$1,369	1	$1,369		$0.02
Total Labor Cost				**$23,597**	**41.5**	**$0.30**
Replacement Costs						
Pumps	ea	$9,675	1	$9,675		$0.12
Filters	ea	$278	5	$1,390		$0.02
Total Replacement Cost				$11,065	19.5	$0.14
Total Annual Operating Cost				**$56,846**		$0.72
CAPITAL COST						
Construction						
Building (45' x 30')	sq. ft	$80	1350	$5,906		0.07
Cost of drilling Well	ft	$9,094	1	$498		0.01
6" Raw Water Pipeline from well to treatment plant	ft	$6	5084	$1,665		0.02
Trenching (including backfilling, packing) 2' Width, 4' Depth	CY	$6	1506	$510		0.01
Resident Inspection	lump sum	$5,000	1	$274		0.00
Total Construction				**$8,853**	**30.6**	**0.11**
Equipment						
Chlorine Contact Chamber 150gpm	ea	$16,000	1	$876		0.01
Pressure Filtration(greensand filters) 150gpm	ea	$69,414	1	$3,802		0.05
Nanofiltration	ea	$240,000	1	$13,146		0.17
Well pump, motor and control150gpm 12hp	ea	$8,310	1	$455		0.01
Pressure Pump to force water through the filters	ea	$2,995	1	$164		0.00
Waste Water Pump	ea	$1,987	1	$109		0.00
Total equipment				**$18,553**	**64.0**	**0.24**
Engineering Cost						
Design @ .91% Construction	percent	$1470	1	$81		0.00
Bidding Phase @.8% Construction	percent	$1293.	1	$71		0.00
Engineering during construction	lump sum	$11561	1	$633		0.01
O&M Manual	lump sum	$2720	1	$149		0.00
Groundwater Rights						0.00

Appendix 6. Estimated Annual Economic Cost of Nanofiltration Water Treatment Plant of Capacity of 150 gpm or 216,000 gallon per day

Descriptions	units	$ unit cost	quantity	Total Cost	rate (%)	TC/1000
Other Engineering and Surveying	lump sum	$2500	1	$137		0.00
DEG Permit to construct WTP	lump sum	$1000	1	$55		0.00
Land Acquisition						
Total Engineering Cost				$1,125	3.9	0.01
Contingencies (5% 0f construction cost)	lump sum	$8081	1	$443	1.5	0.01
TOTAL FIXED (CAPITAL) COST				**$28,975**		**0.37**
TOTAL ECONOMIC COST				**$85,821**		**0.06**

Appendix 7. Estimated Annual Economic Cost of Nanofiltration Water Treatment Plant of Capacity of 60 gpm or 86,000 gallon per day

Descriptions	units	unit cost($)	quantity	Total Cost	Total Cost/1000	Rate (%)
Utilities						
Well Control System (@ .15KWH, 2920 hrs/yr) 0.15*2920	Kwh	$0.11	438	$47	0.00	
Running well pump, 5.0hp, 0,747 Kw/hp, 3784 hrs/yr,80GPM (3784*5.0*0.747)	Kwh	$0.11	14133	$1,526	0.05	
Heating, Ventilation and Air Condition(HVAC),.001 sqft x 1000sq ft x 2920hr/yr	Kwh	$0.11	2920	$315	0.01	
Booster Pump 4.8hp, 78gpm, 0.747 Kw/hp, 3784 hrs/yr (3784*4.8*0.747)	Kwh	$0.11	13568	$1,465	0.05	
Greensand Controls, nano controls @ 0.4Kw/h, 2920hrs/yr	Kwh	$0.11	1168	$126	0.00	
High Service Pump, 60gpm (3.6hp *0.747kw/hp*3784hr/yr)	Kwh	$0.11	10176	$1,099	0.03	
Waste Water Lift Station Pump(1hp, 365 days, 15gpm, 0.747 Kw/hr	Kwh	$0.11	1636	$177	0.01	
Total Utilities				**$4,756**	**0.15**	**$11.8**
Chemicals						
Chlorine, 31.536 MG/yr @ (4 mg/l water treated)	Mg/yr	$0.50	477	238	0.01	
Scale inhibitor 31.536MG/yr @ (2mgl water treated)	Mg/yr	$1.15	239	$275	0.01	
KnMnO4, 31.536MG/yr, @ (3.95mgl water treated)	Mg/yr	$1.60	471	$754	0.02	
Total Chemicals				**$1,268**	**0.04**	**$3.1**
Administration and Operations						
Certification Fees	lump sum	$150	1	$150	0.00	
Dues & Subscriptions	lump sum	$150	1	$150	0.00	
Insurance	lump sum	$1,200	1	$1,200	0.04	
Laboratory	lump sum	$500	1	$500	0.02	
Office Supplies	lump sum	$450	1	450	0.01	
Miscellaneous Supplies	lump sum	$531	1	530.75	0.02	
Vehicle	lump sum	$645	1	$645	0.02	
Postage and Freight	lump sum	$349	1	$349	0.01	

Appendix 7. Estimated Annual Economic Cost of Nanofiltration Water Treatment Plant of Capacity of 60 gpm or 86,000 gallon per day

Descriptions	**units**	**unit cost($)**	**quantity**	**Total Cost**	**Total Cost/1000**	**Rate (%)**
Legal and Audit	lump sum	$249	1	$249	0.01	
Telephone	lump sum	$400	1	$400	0.01	
Administration and Operations				**$4,623**	**0.15**	**$11.4**
Labor						
Payroll Taxes (6.25% of operate and maintain)	percent	$1,369	1	$1,369	0.04	
Health Insurance 1.5% of Operate and maintenance of WTP	percent	$329	1	$329	0.01	
Salary and Wages	hours	$20	1095	$21,900	0.69	
Total Labor Cost				$23,597	0.75	$58.4
Replacement Costs						
pump	hp	$4,750	1	$4,750	0.15	
Filters	ea	$278	5	$1,390	0.04	
Total Replacement Cost				**$6,140**	**0.19**	**$15.2**
Total Annual Operating Cost				**$40,384**	**1.28**	
CAPITAL COST						
Construction						
Building	sq. ft	$90	1000	$4,912	0.16	
Cost of drilling Well	ft	$9,094	1	$498	0.02	
6" Raw Water Pipeline from well to treatment plant	ft	$5.98	5084	$1,665	0.05	
Trenching (including backfilling, packing) 2' Width, 4' Depth	CY	$6.18	1506	$510	0.02	
Resident Inspection	lump sum	$5,000	1	$274	0.01	
Total Construction				**$7,860**	**0.25**	**41.7**
Equipment						
Chlorine Contact Chamber	ea	$12,000	1	$657	0.02	
Greensand Pressure Filtration (80 gpm)	ea	$27,765	1	$1,521	0.05	
Nanofiltration Manufacturing Model (80gpm)	ea	$120,000	1	$6,573	0.21	

Appendix 7. Estimated Annual Economic Cost of Nanofiltration Water Treatment Plant of Capacity of 60 gpm or 86,000 gallon per day

Descriptions	units	unit cost($)	quantity	Total Cost	Total Cost/1000	Rate (%)
Well pump, motor and control	Hp	$8,310	1	$455	0.01	
Pressure Pump to force water through the filters	Hp	$2,995	1	$164	0.01	
Waste Water Pump	Hp	$1,987	1	$109	0.00	
Total equipment				**$9,479**	**0.30**	**50.3**
Engineering Cost						
Design @ .91% Construction	percent	$1,306	1	$72	0.00	
Bidding Phase @.8% Construction	percent	$1,148	1	$63	0.00	
Engineering during construction	lump sum	$11,561	1	$633	0.02	
O&M Manual	lump sum	$2,720	1	$149	0.00	
Groundwater Rights						
Other Engineering and Surveying	lump sum	$2,500	1	$137	0.00	
DEG Permit to construct WTP	lump sum	$1,000	1	$55	0.00	
Land Acquisition						
Total Engineering Cost				**$1,108**	**0.04**	**5.9**
Contingencies (5% 0f construction cost)	lump sum	$7,174	1	$393	0.01	2.1
TOTAL FIXED (CAPITAL) COST				**$18,840**	**0.60**	
TOTAL ECONOMIC COST				**$59,225**	**1.88**	

Appendix 8. The Global Positioning Systems of the Locations of Kaw City

Location	latitude	longitude
177 & US11	**36.76729**	**-97.06219**
Kaw City	**36.76463**	**-96.88689**
Lake bridge	**36.76558**	**-96.81898**
Reservoir	**37.7665**	**-96.86342**
Groundwell	**36.76721**	**-96.85881**
Irrigation well	**36.7964**	**-96.8545**
Pot. Treat. Pt	**36.79642**	**-96.85841**
Newirk wells	**36.78977**	**-96.88277**

VITA

Atta-Asiamah, Ernest

Candidate for the Degree of

Master of Science

Thesis: ESTIMATION OF THE COST OF BUILDING A WATER TREATMENT PLANT AND RELATED FACILITIES FOR KAW CITY, OKLAHOMA

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Asokore Ashanti, Ghana on September 25, 1979, the son of Kofi Adom and Mary Boatemaa

Education: Graduated from T.I. Ahmadiyya High School, Asokore Ashanti, Ghana in December 1998; received a Bachelor Arts in Mathematics and Economics from the University of Cape Coast, Cape Coast, Ghana in June 2005. Completed the requirements for the Master of Science degree with a major in Agricultural Economics at Oklahoma State University, Stillwater, Oklahoma in May, 2010.

Experience: 1. Graduate Research Assistant, Oklahoma State University, Department of Agricultural Economics, January 2008 to present.
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Name: Atta-Asiamah, Ernest Date of Degree: May, 2010

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: ESTIMATION OF COST OF BUILDING A WATER TREATMENT PLANT AND RELATED FACILITIES FOR KAW CITY, OKLAHOMA

Pages in Study: 111 Candidate for the Degree of Master of Science

Major Field: Agricultural Economics

Scope and Method of Study: The city of Kaw City had water problem since the 1990's because of the collapse of the wells and the poor taste of the groundwater. The Aeralator® and NF treatment systems would be considered with each has two different sizes with an output of 60 gpm and 150 gpm of water treated assumed to supply Kaw City only and both Kaw City and Shidler respectively. The cost of investment capital was estimated by the sum and product of units cost and quantity of materials and equipment. The operating cost was estimated by summing the chemical, utilities, labor replacement and administration and operations. An amortization factor was used to determine the annual fixed capital cost with the design life of 50 years and rate of 5%. The cost per unit of thousand was determined as the total cost divided by the total design flow rate multiplied by 1000.

Findings and Conclusions: The cost of amortized capital Aeralator® and NF treatment plant of capacity of 60 gpm were estimated to be $14,945/yr and $18,841/yr. The total operating cost of NF treatment plant was $40,384/yr and Aeralator® treatment plant was estimated to be $20,908/yr. For treatment plant of capacity of 150 gpm, the annual capital fixed cost of Aeralator® system was estimated to be $17,728/yr while NF was estimated to be $28,974/yr water of treated water. Moreover, the total operating cost of Aeralator® and NF systems were estimated to be $31,385/yr and $56,846/yr respectively. The annual economic costs of the two treatment system plants were estimated to be $0.62/1000 gallon of Aeralator® treatment plant and $1.09/1000 gallon of NF treatment plant. The estimated costs of the NF were more costly than Aeralator® system. The investment cost of the layout of the entire city was estimated to be $15.34/ft of the investment cost. The annual fixed cost of the layout of $20,648/yr and CRF of $0.05. Due to economy of scale of treating and supply of water, it is economically more cost effective to supply water to both Kaw City and Shidler and serve cost.

Advisor Approval ______________ Dr. Art Stoecker ______________