GIS AND HYDROLOGICAL SIMULATION MODEL INTEGRATED FEASIBILITY STUDY OF IRRIGATION DEVELOPMENT UNDER SALINITY

By

MONIKA GHIMIRE

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Pokhara University

Kathmandu, Nepal

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Thesis Approved:

Dr. Art Stoecker

Thesis Adviser

Dr. Jeffrey Vitale

Dr. Chad Godsey

Dr. Sheryl A. Tucker

Dean of the Graduate College

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CHAPTER I

INTRODUCTION

Background:

Irrigation is defined as an application of water to crop land. Supply of irrigation water is crucial to increase crop production in many areas of the world. Irrigation water is obtained generally either from surface water sources like rivers, streams, creeks or from groundwater aquifers. The W.C Austin Project is a water supply project constructed by the Bureau of Reclamation in Greer, Kiowa, and Jackson Counties, Oklahoma. The principal features of the Austin Project are the Altus Dam, and the reservoir located 18 miles north of Altus. The Austin Project has been providing water storage for irrigation and flood control on the North Fork of Red River. The W.C Austin project has provided irrigation water to 48,000 acres of privately owned land south of Lake Altus since 1953. Lake Altus also provides water for municipal and industrial uses, fish and wildlife conservation, and other public recreational opportunities for the city of Altus. At present, Lake Altus has been losing its storage capacity due to sediment accumulation. A 2005 Bureau of Reclamation report estimated the annual capacity loss at 911 acre-feet while a

2007 study estimated annual capacity loss at 417 acre-feet per year (Bureau of Reclamation, 2008). Displacement of available reservoir capacity by sediment will diminish the project's capacity to supply water within 30 to 50 years. It is, therefore, necessary to augment the water supply of this project to maintain or enhance the current level of economic activities in the region.

The Cable Mountain Reservoir is one of the proposed alternatives to increase and augment the water supply of Lake Altus (Bureau of Reclamation, 2005). The proposed site is 40 miles downstream of Lake Altus and north of Headrick, Oklahoma (latitude: 34.6275° N, longitude: 99.1378° W, and elevation: 1,430 ft msl). According to the Bureau of Reclamation (2005), the projected reservoir capacity is 100,000 to 120,000 acre-feet which is more than required to replace the water loss from Lake Altus. Part of the project would be to supply, on average, 68,000 acre–feet of water annually to the existing Lugert Altus Irrigation District (LAID). The excess water can be used to irrigate arable lands at lower elevations of the reservoir in the Tillman Terrace area (TTA), the western part of Tillman County (34° 22' latitude and -99°: 4' longitude). The TTA lies in the Osage Plains physiographic province adjacent to the Red River in Tillman County. The expansion of irrigation to utilize excess water in the Cable Mountain Reservoir will not add any additional cost to its initial construction. Instead, its net benefits can be added to the initial net benefit of the Cable Mountain Reservoir. This study evaluates whether the net benefit of constructing the Cable Mountain Reservoir will be enhanced by considering the net benefit from adding this irrigation supply to the TTA.

Construction of the Cable Mountain Reservoir is dependent on a project to prevent loading of up to 400 tons of salt per day on the Elm Fork which is upstream of the proposed reservoir. The source of salt to the Elm Fork and North Fork (downstream of the reservoir) are the three canyons Kaiser, Robinson, and Salton that flow into the river within half a mile of each other. The water currently is not used due to its high salt content. Daily electrical conductivity (EC) samples collected during a low flow year (between October 2009 and September 2011) from Elm Fork of the Red River indicated an average EC of 45.8 mmhos cm^{-1} with daily measurements ranging from 5.6 to 150 mmhos cm^{-1} (USGS, 2012).

The Tillman Terrace ground water basin is a primary means of water discharges to the rivers and streams. When the water table in the basin is higher than the river, water is discharged to the North Fork of the Red River. Water flows from the river to the aquifer when the water table in the aquifer is lower than the river which causes ground water pollution. The aquifer has been extensively used for various purposes like public water supply, irrigation, mining, and domestic purposes. A hydrological survey conducted by Oklahoma Water Resources Board (OWRB) in 1974 concluded that if present level of ground water uses continues, the aquifer would deplete within 10 to 20 years (Osborn, 2002). Though in recent years the water level in the aquifer has been rising due to more than average precipitation, the high rate of pumping water from the aquifer not only depletes the groundwater but also causes salinity problems in the aquifer because the saline river water will replenish the aquifer.

Study Site Description:

The study area occupies the TTA, the western part of Tillman County, and a portion of Kiowa County (Fig. 1). Tipton, Davidson, and Frederick are the major cities in the area with populations of 847, 315, and 3,940 respectively (US Census Bureau, 2010). The North Fork of the Red River lies to the west of the TTA and the Red River lies to the south. Its ground water basin covers approximately 290 square miles of area. The altitude of land surfaces ranges from 1,131 to 1,396 ft.

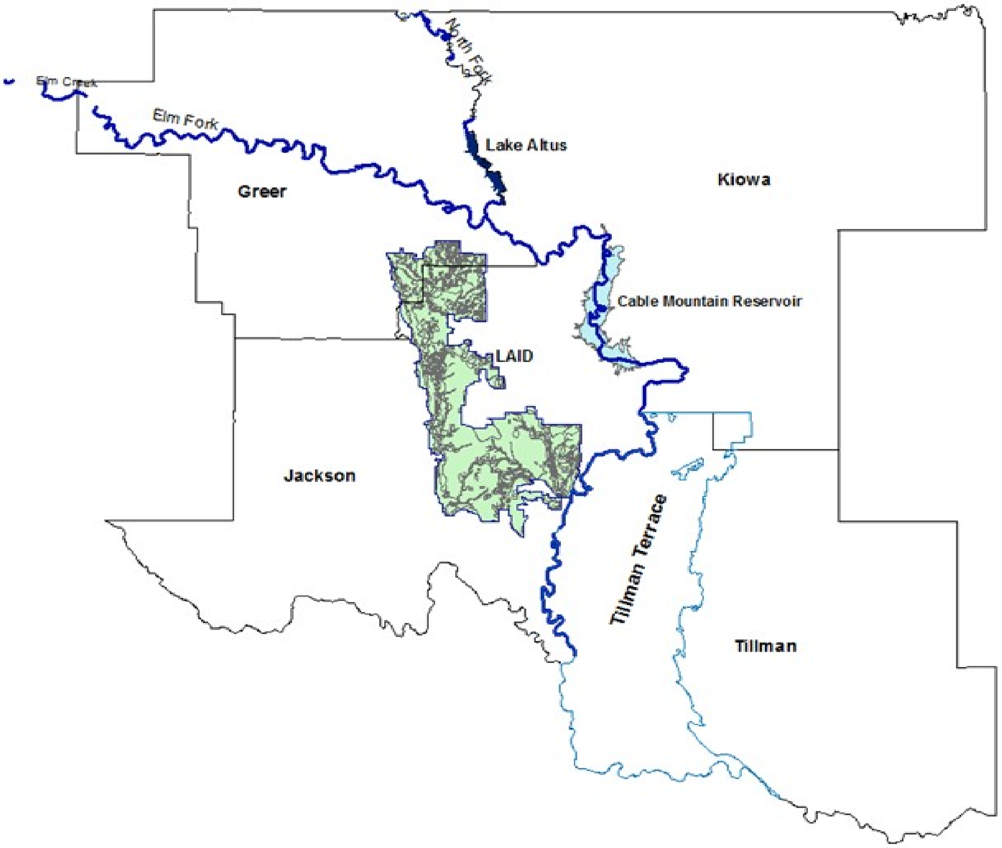

Fig. 1. Map Showing Tillman Terrace, Cable Mountain Reservoir, LAID, Lake Altus, Elm Fork, and North Fork.

The major soil types in the area are Tipton, Hardeman and Grandfield association which are comprised of loamy and sandy soils. The area is characterized by a dry sub-humid climate with long, hot summers and mild winters. The mean annual precipitation of the study area from 1971 -2000 was 30.78 inches (Oklahoma Climatological Survey, 2011). The land use in Tillman Terrace is predominantly cropland and pasture. Cotton is the major crop in the area. Other dominant crops are wheat, alfalfa, and peanuts. The five year average of harvested acres and yields of dryland and irrigated cotton from 1971 to 2005 in Tillman and Kiowa Counties are provided in Tables 1 and 2. Table 1 shows that dryland cotton harvested acres are declining in recent years. Harvested cotton acres in Kiowa County were 7,240 during 2001-05 while the total acreage was 50,780 during 1976-80. Total cotton acreage in Tillman County was 97,210 during 1981-85 and decreased to 21,080 acres during 1996-00. However, higher productivity was observed for recent years in both counties. No harvested irrigated cotton acres have been reported in Kiowa County (Table 2) since 1995. Total irrigated cotton acreages have been declining in recent years as compared to 1980s. However, harvested irrigated and dryland cotton acres in Tillman county increased in a period from 2001-05 as compared to 1996-00. Higher productivity was achieved in Tillman County in recent years.

Table 1. Five year average of harvested acres and yields of dryland cotton from 1971 to 2005 in Tillman and Kiowa Counties.

	Harvested acres			Yield (lb/acre)	
Period	Kiowa	Tillman	Total	Kiowa	Tillman
1971-75	48,226	53,850	102,076	250	275
1976-80	50,780	87,990	138,770	217	257
1981-85	45,140	97,210	142,350	241	195
1986-90	40,806	91,250	132,056	252	267
1991-95	38,860	89,960	128,820	218	235
1996-00	13,740	21,080	34,820	257	205
2001-05	7,240	46,600	53,840	380	390

Source: National Agricultural Statistics Service (NASS), USDA.

Table 2. Five year averages of harvested acres and yields of irrigated cotton from 1971 to 2005 in Tillman and Kiowa Counties.

	Harvested acres			Yield (lb/acre)	
Period	Kiowa	Tillman	Total	Kiowa	Tillman
1971-75	1,848	4,990	6,838	364	386
1976-80	5,220	20,030	25,250	472	454
1981-85	3,080	18,140	21,220	497	457
1986-90	2,544	15,970	18,514	532	497
1991-95	100	4,160	4,260	115	435
1996-00	-	4,220	4,220	-	603
2001-05	-	8,300	8,300	-	830

Source: National Agricultural Statistics Service (NASS), USDA

Objectives:

The general objective of this study was to identify the economic feasibility of developing pressurized irrigation system from the Cable Mountain Reservoir to the Tillman Terrace area.

The specific objectives of the study were to:

1. Identify the area of land with irrigation capability.
2. Determine the length, route, and cost of pipeline.
3. Determine the net returns of irrigation with increased crop yield.

CHAPTER II

LITERATURE REVIEW

Potential Irrigable Areas:

Potential irrigable areas can be classified based on soil characteristics, soil types, slope, and other factors. The irrigation potential for the area is determined by the irrigation water requirement of the soil and water availability (FAO, 1997). Hailegebriel (2007) and Meron (2007) used slope of the soil, soil types, land cover/use, water resources, and climate factors to assess irrigation suitability. In this study, slope and irrigation capability classes of the soil types determine their potential for irrigation.

Geographic Information System:

There is a spatial and temporal variation in the irrigation water requirements due to the effect of weather, local climate, soil, and cropping factors. Traditional analytical techniques cannot address spatial and temporal variability in irrigation (Knox and Weatherfield, 1999). This necessitates the use of a spatial data management tool like a Geographic Information System (GIS) for diverse ranges of application in effective water resource management. Geographic Information Systems can be used to integrate spatially distributed data of many variables, including climate, soil, and water distribution to produce soil class, profile map, crop map, and map for crop requirements (Todorovic and Steduto, 2003).

Application of GIS with respect to irrigation requires detailed information on soil type, agro climate, land use pattern, irrigation practices, and availability of water (Knox and Weatherfield, 1999). The attributes of GIS for storing, manipulating, and analyzing spatial data can be used to project irrigable areas and to estimate water demands (Rao, Brownee, and Sarma, 2004). The use of satellite images in conjunction with GIS is a powerful and an effective tool to identify irrigable areas and cropping patterns (Su 2000; El-Magd and Tanton, 2003). These studies suggest that GIS is an important tool to remotely sense the irrigable areas and manage the irrigation water efficiently. GIS can be used to identify the potentially irrigable areas and determine pipeline routes.

Pressurized Irrigation System:

A pressure piped irrigation system is a network installation consisting of pipes, fittings, and other devices properly designed and installed to supply water under pressure from the source of water to the irrigable area over the most convenient route. A pressurized irrigation system utilizes small to large flows of water very efficiently when compared to traditional surface irrigation methods.

In open canal distribution networks, the water losses are estimated at up to 40 percent in unlined ditches and up to 25 percent in lined canals (Phocaides, 2007). These losses are due to seepage and leakage in gates, spillways, etc. In piped systems, no such losses occur. As a result, water losses can be minimized and an irrigation efficiency of 75-95 percent can be achieved. In open canals, the irrigation application efficiency ranges from 45 to 60 percent. The operation and maintenance needed in the piped systems is minimal and range from one-tenth to one-quarter of that required for open canals. However, external energy is required to distribute the water and operate the pressurized irrigation system.

Hydrological Simulation Model:

The EPANET software (EPA, 2011), developed by Environmental Protection Agency's Water Supply and Water Resource division, models piped water distribution systems. It is a windows 95/98/NT/XP program that simulates the hydraulic and water quality behavior within pressurized networks of pipeline. The software calculates the head loss in every pipe and node using the Hazen-William's Head loss formula and also estimates the water pressure for all nodes and pipes of the irrigation system.

EPANET can be utilized to optimize a demand network layout by choosing the most economic pipe sizing and selecting the layout at the same time. In the network design optimization process, the following costs of the irrigation system should be considered (Planells et al, 2000):

a) Cost of network
b) Cost of pumping plant
c) Energy cost

Environmental Policy Integrated Climate:

The Environmental Policy Integrated Climate (EPIC) simulation model is a research tool commonly used to determine the response of crop yields to environmental factors. It is used to simulate crop yield, crop water use, and the relation between yield and crop water use like evapotranspiration and water use efficiency (Ko, Peccinni, and Steglich, 2009). Crop yields are simulated using EPIC once planting and harvesting dates are determined (Tan and Shibasaki, 2003). The simulated yield from EPIC depends on several factors like rainfall, amount of irrigation water, soil salinity, and irrigation water salinity. These factors are used to calculate the returns from irrigation. The parameter estimates for the crop yield response function in response to the salinity of surface water and soil salinity using the simulated yield from EPIC were used in this study (Choi, 2011).

Salinity

Salinity is one of the most severe environmental factors limiting the productivity of agricultural crops. The salinity problem occurs when irrigation water contains some amount of soluble salts that accumulates in the soil over time and reduces crop yields (FAO, 1976). After evaporation and transpiration water loss, plants leave these salts in the soil. Soil salinity and the use of irrigation water containing soluble salts is one of the major considerations in irrigation. Most crops are sensitive to salinity caused by high concentrations of salts in the soil. In the crop yield response function, salinity is an important variable to determine optimum amount of irrigation water to apply over time. Annual salinity cost to agriculture is estimated to be about $ 12 billion which is expected to increase as soils are further affected (Gnassemi et al., 1995). Besides this enormous financial cost of production, the salinity problem may impact infrastructure, water supplies, and the social structure and stability of communities. Selection of salt tolerant crops such as barely, cotton, and sugar beets can be done to increase production in saline soils.

Mathematical Optimization Model:

Yaron and Bresler (1970) used a linear programming model to derive the optimal quantity-quality combinations under different levels of irrigation and initial soil salinity. Comparing the empirical estimates of the marginal rate of substitution of water salinity for quality with the cost of the water quantity and quality ratio, the study concluded that an increase in the quantity of irrigation water applied increased the maximum permissible chloride concentration. Econometric estimates of yield response and salt accumulation in the soil under saline conditions with experimental data for alfalfa and cotton were provided by Dinar and Knapp (1986). The crop yield increased as water quantity increased and salt concentration decreased. In addition, they combined the estimated response functions and dynamic soil salt relations with an economic decision model to determine water applications for any give prices and initial soil salinity which maximize the net present value of profits. Profits increased as crop prices increased and decreased as irrigation water prices and initial soil salinity increased. Contrary to their expectation, they found that profits increased as the initial soil salinity increased within a range of salinity EC levels from 4 to7 for alfalfa.

Dinar *et al* (1991) provided statistical estimates of crop-water response functions with various levels of salinity. Feinerman (1994) estimated the response function to soil salinity of potatoes in a single-farm framework. The study used a switching regression to estimate a piecewise linear response function. Crop yield was dependent on average soil salinity below a certain critical threshold, and then decreased linearly with increased salt. A set of production functions were estimated relating wheat yield to initial soil salinity, and water quantity and quality (Datta *et al* 1998). They used the functions to find optimal water application for given irrigation water quality, reuse of drainage water, reduction in income from using saline drainage water mixed at various rates with good quality water. They suggested that yield was not simply related to the average initial soil salinity but also to the salinity in the applied irrigation water.

Kiani and Abbasi (2009) investigated crop response to both soil water content and soil salinity and estimated linear, Cobb-Douglas, quadratic, and transcendental functions. They found that both soil water content and soil salinity affected crop yield.

Capital Budgeting and Net Present Value:

Cost-benefit analysis of an irrigation project is an essential practical tool for decision making since development and maintenance costs of irrigation infrastructures are of great concern. Mostly, costs and benefits of a project are valued using market prices. The response of the crop yield to different irrigation applications can be simulated to determine the marginal production and the economic value of irrigation applications. The direct benefit from the irrigation project can then be estimated using irrigation response to yield functions. The value of irrigation is determined by multiplying the yield of product price and subtracting the cost of the increased farmers' inputs (Prest and Turvey 1965). The costs and benefits of a project, expressed in monetary terms, needs to be adjusted according to the expected changes in prices of inputs and output including future interest rate.

Capital budgeting is the process which determines the longterm profitability of any project. It projects whether long term investment is expected to generate cash flows over several years. Investment opportunities in long term assets expected to produce benefits for multiple years are analyzed using capital budgeting techniques (CBTs). A survey conducted by Schall, Sundem, and Geijsbeek (1978) showed that sophisticated CBTs are being practiced. The survey mentioned that over 86 percent of the firms used either internal rate of return (IRR) or net present value (NPV) or both in 1978 while Klammer (1972) reported that discounting methods like IRR or NPV were used by 57 percent of the firms in 1970. Bennouna, Meredith, and Marchant (2010) also noted that NPV and IRR are currently favored by the majority of firms as they move towards the adoption of sophisticated CBTs.

Net present value is defined as the difference between the present value of cash inflow and cash outflow. NPV is one of the decision rules of capital budgeting. NPV analysis is sensitive to the reliability of future cash inflows that an investment or project will yield. In other words, present value of future income is the NPV if the incomes are measured after the capital costs. Investment is acceptable when NPV is positive or the present value of benefits exceeds the present value of costs.

CHAPTER III

METHODS AND PROCEDURES

Determining Potential Irrigable Areas:

The study area is the southwestern part of Kiowa County and TTA of western Tillman County which is shown in Fig. 2. A Geographic Information System was used to determine the irrigable areas. The following maps were used for analysis (Geospatial Data Gateway, USDA):

1. Soil Survey Geographic Database (SSURGO) for Tillman and Kiowa counties
2. United States Geological Survey National Elevation Dataset (USGS NED) 10-meter digital elevation files for Tillman and Kiowa counties
3. County outlines
4. Township and aerial photo files for Tillman and Kiowa counties

The Natural Resources Conservation Services (NRCS) -SSURGO database (NRCS, 2010) provides the map of soil types and area in acres of Tillman and Kiowa counties. Land is classified according to suitability of soil quality for potential agricultural output. These land categories are I, II, III, IV, V, VI, VII, and VIII. Class I to VIII represents progressively greater limitations and narrower choices for agriculture. Class I and Class II were selected as irrigation land capability classes for determining the most productive soils to irrigate. Class I soils have few limitations while class II have moderate limitations. There are land capability subclasses. Land capability subclasses are denoted by codes e, w, s, and c. which are related with erosion problems, wetness problems, root zone limitations, and climatic limitations respectively. Irrigable soil types are defined by selecting subclass e and w. Subclasses e and w were added to class codes and I, IIe and IIw classes are considered as potential irrigated soil classes (National Soil Survey Handbook, USDA). NRCS-SSURGO database also divides soil into prime or non-prime categories according to average slopes, and a dry land capability rating.

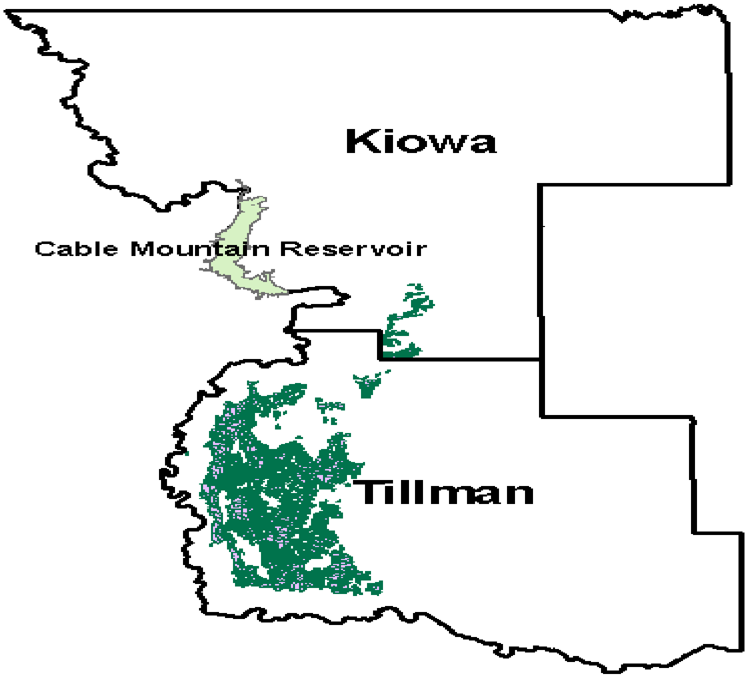

Fig. 2. Potential irrigable areas in Tillman and Kiowa counties. The dark green patches in Tillman Terrace represent potential irrigable soils.

The township shape file of Tillman and Kiowa counties were clipped with the SSURGO database to get the soil in each township and sections of the counties in ArcMap. The USGS NED 10-meter elevation files (USGS, 2010) were used to determine 10 m slope of the irrigable areas and to make contour lines at 10 m intervals. The raster elevation files of Tillman and Kiowa counties were joined and then converted to a shape file. The shape file was then intersected with SSURGO soil database file, the township, and the counties outline files. Then a large shape file was generated with soil types (prime and non-prime, dry land capability, irrigated capability (I and II)), and their area with a common 10-m slope and elevation. Because class codes I and II are considered suitable as irrigation land capability class, class I and II (Ie and IIe) were chosen for this study (Fig. 3). The acres of each soil type covered by each of the individual pivots and their section identification are presented in Appendix 5.

The acres and soil types with slopes less than 3 percent were used. The elevation shape file was again intersected with the clipped soil section map with slope of 3 percent or less. The obtained intersected shape file was filtered to retain the areas with elevation less than 1,430 mean feet sea level (mfsl) since elevation of the Cable Mountain Reservoir is 1,430 mfsl. The irrigable soil type areas less than 10 acres were removed on an assumption that it would be uneconomical to irrigate those small areas. The areas and slopes were determined using ArcMap version 9.3 GIS software (ESRI, Redlands, California, USA, 2011). The projection was NAD 1983, UTM Zone 14N. The measurements used in the analysis were based on the GIS calculations made with the shape files. Ten meter elevation and SSURGO soils data files (USGS, 2010) were downloaded for each county.

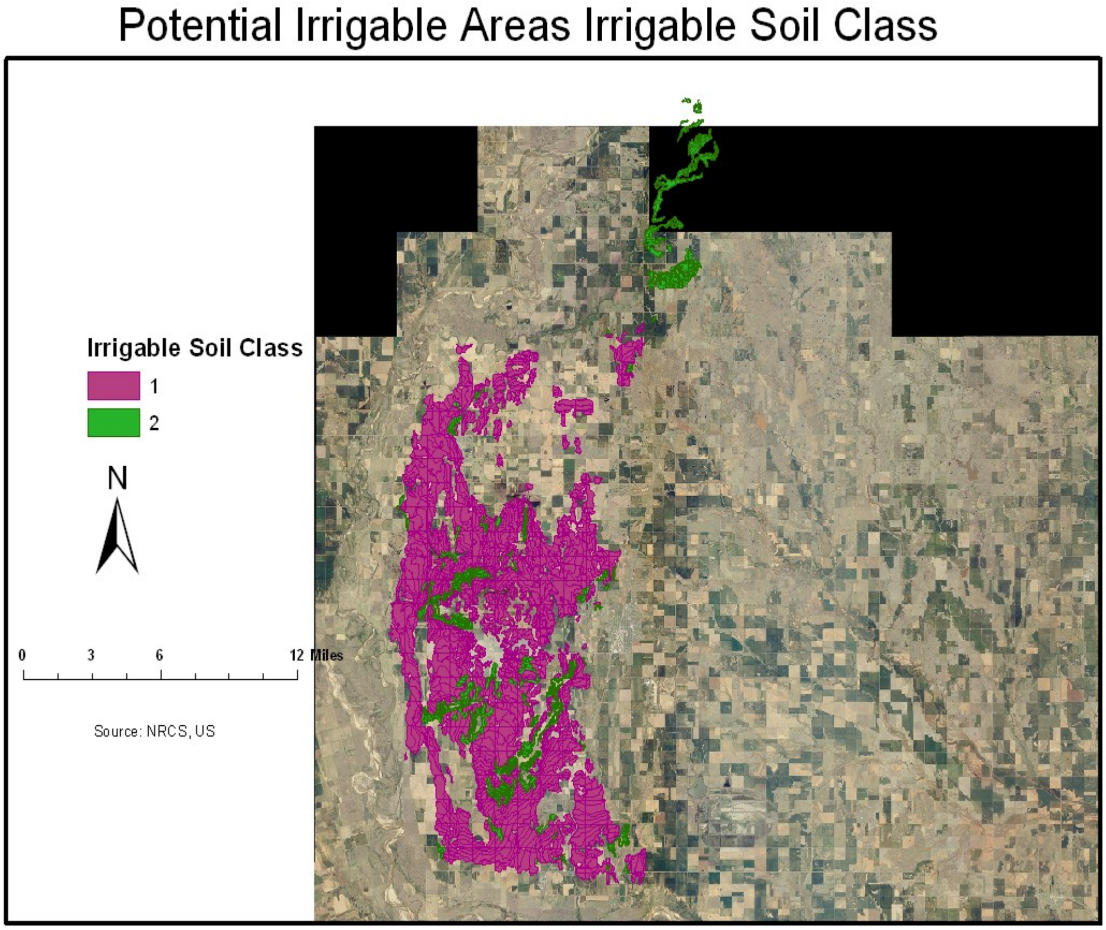

Fig. 3. A representation of irrigable soil class of selected potential irrigable areas in Tillman terrace area.

Pipeline Network Design of the Irrigation System:

Areas and shapes of the field with different soil types were identified and a pipeline network was designed using ArcMap. The elevation of irrigable areas was identified and used for the calculation of head pressure and pressure required to deliver the water into the field. Global Mapper was used to create XYZ files which include elevation of every pivot node of the pipeline (Global Mapper, Blue Marble Geographics, Maine, USA, 2011).

Pivot irrigation was chosen as the irrigation system for the area and the areas feasible for pivot irrigation were selected. The “buffer” tool in ArcGIS was used to create pivot circles with radius of a quarter mile. The settlement areas, railway tracks, and gullies in the irrigable areas might represent physical obstacles for an irrigation system. Areas with these features were not included as irrigable areas. The editor in ArcGIS was used to draw the pipeline network to provide irrigation for each pivot circle. The pipeline route was designed to follow the maximum elevation level from the Cable Mountain Reservoir to the TTA in a way that it minimizes the pumping cost of the irrigation system.

Data:

The data for calculating fixed cost of the project is categorized as follows:

Cost of Pipes and Valves:

The cost per linear foot for different sizes of pipes, and valves were obtained from RS Means Construction Data, 2009 which includes labor cost, material cost, and total cost of pipe and valve.

Cost of Earthwork:

The cost of earthwork depends on pipe size. So, the earthwork cost for different pipe sizes was determined. The earthwork to set the pipeline includes trenching to lay the pipeline, backfilling, and packing cost.

Trenching, Backfilling and Packing Cost:

Trenching is a type of excavation in the ground for the purpose of laying the pipeline as a conveyance system to deliver the irrigation water. The trenches of 5 feet or deeper have to be excavated with certain slope for the safety of the workers and durability of the trench (Occupational Safety and Health Administration (OSHA), United States Department of Labor). The slope of the trench also depends on soil types. The OSHA guidelines categorize different soil types (A to C) from most stable to least stable and design the size of the trenches with a run over rise method or a degree system for different soil types as shown in Table 3.

Table 3. Slope of trench walls for different soil types assumed in trench design.

S.N.	**Soil type**	**Rise over run**	**Wall slope**
1	Stable rock	-	90 degree
2	A	Three quarter of a unit run to one unit of rise	53 degree
3	B	One to one ratio	45 degree
4	C	One and one half to one	34 degree

Source: OSHA, US Department of Labor

The depth of the trench was assumed to be equal to the diameter of the pipeline plus 4.5 feet for bedding and filing of trenches. The width of the trench in the bottom was equal to the diameter of pipeline added with 1.5 feet of filling space between two sides of the trench walls and the pipe. The width of the trench at the top was equal to diameter of pipeline at the bottom plus slope width of the trench.

The cost of trenching was estimated for variable sized trenches with a regression model using data on costs for specific depths and width of trenches from Means (2009). The dependent variable was cost of trenching ($/cubic feet) and the independent variables were width of the trench (ft), depth of the trench (ft), and square of the depth of the trench (ft^2). The costs of trenching for larger and smaller pipelines were different. Larger wall slopes are required for larger trenches (depth > 5 ft.) and smaller wall slopes are required for smaller trenches. Due to this reason, different cost estimation models were used for large and small trenches. Total earthwork cost was calculated as a sum of trenching, backfilling, and packing costs.

Finally, pipe cost and total earthwork were summed as total piping cost. As pipe is onetime cost its replacement is not required within the 50 year planning period. The total costs were then annualized for equal payment over a 50-year of planning period of irrigation system. A discount rate of four percent was used to annualize the total piping costs. A spreadsheet was used to develop the cost for purchase and installation cost of alternative diameters pipes from 6 through 120 inches, using data on the cost of pipe, excavation, and backfilling using estimates from Means (2009).

Cost of Pumps and Pivot Irrigation System:

The cost of pumps for different water demand was obtained from Berkley pumps and Enterprise Budgets, Oklahoma State University and the cost of pivot irrigation system was obtained from Enterprise Budgets, Oklahoma State University.

The pumps and irrigation systems have to be replaced at the end of their respective economic lives over the 50-year planning period. A pivot system has an average life of 17 years. The cost of pivot is discounted at 1st, 17th and 35th year at the four percent discount rate. The cost of a pump, with a 20,000 hour of life span, is calculated based on annual use of pump. For example, a pivot operating at 600 gallons per minute applying approximately 18 acre-inches of water on an average have life of 10-12 years. The present values of pumps were discounted at four percent on 1st, 11th, 21st, 31st and 41st year. The present values of fixed costs were subtracted from the estimated present value of revenue from irrigated cotton.

Water Demand:

The water demand (gallons/minute) at each pivot is required to determine the head or pressure required, diameter, and the cost of pipelines. The water demand is considered as 600 gpm for an unrestricted irrigation system and 800 gpm for a scheduled irrigation system for 543 pivot circles each of 125.6 acres.

Energy Cost:

Energy cost in this study involves the cost of energy for pumping water to the fields. The pressure of at least 35 PSI for each individual pivot is obtained by adjusting the pumps in the required areas of the irrigation system. The energy cost for pumping was estimated with the use of both water horse power and brake horse power method as described in Keller and Bliesner (1990).

$$Bhp = \frac{GPM * Head\,(ft)}{3960 * Peff * Meff} \tag{1}$$

where GPM is gallons per minute, $Peff$ is pumping efficiency, $Meff$ is motor efficiency and $Head\ (ft)$ is the pressure flow.

The head loss for water moving through a level pipe was calculated using Hazen William's formula (Jensen, 1983).

$$Head\,loss\,(ft) = \frac{10.46(GPM\,/\,C)^{1.85} * Length}{D^{4.87}} + Elevation\ change + Delivery\,head \tag{2}$$

where C is retardation constant which is 120 for steel or aluminum, 140 for Cement Asbestos, and 150 for plastic, and D is pipe inside diameter (Inches)

Energy cost (EGC) was calculated using the following formula (Keller and Bliesner, 1990):

$$EGC = \frac{\{(GPM * Hd) * Kwbhp * hyp * pelec\}}{3960 * Peff * Meff} \tag{3}$$

where Hd is head in feet, $KwBhp$ is kilowatt per brake horse power, hpy is hours per year, and $pelec$ is electricity cost per kwh.

Pipeline and Pump Designs:

EPANET software models water flow and pressure loss in distribution systems to help with sizing the pipeline, and determining the pump location for minimizing energy cost. The pipe diameters and the node elevations have to be entered in the model. GIS provided the estimate of the length of pipes. The pipe size were iteratively increased and decreased to obtain optimum pipe size. An example of input file for EPANET is provided in Appendix 9. The pumps were chosen according to the pressure requirement to deliver water demanded in each pivot according to output of EPANET. Four different designs of irrigation systems were developed. Design 1A allows irrigation to all the pivots simultaneously at once. Design 1B was intended to schedule the irrigation alternately to the north and the south of laterals of Design 1A irrigation system. Design 2 divides the irrigable land into the two areas while Design 3 divides the irrigable land into four areas. In Design 2 and 3, the irrigation system was scheduled to irrigate one area at a time. The outlines of pipeline network in EPANET for scheduled and non-scheduled irrigation systems (Design 1A, 1B, 2, and 3) are shown in Figs. 4, 5, 6, and 7 respectively.

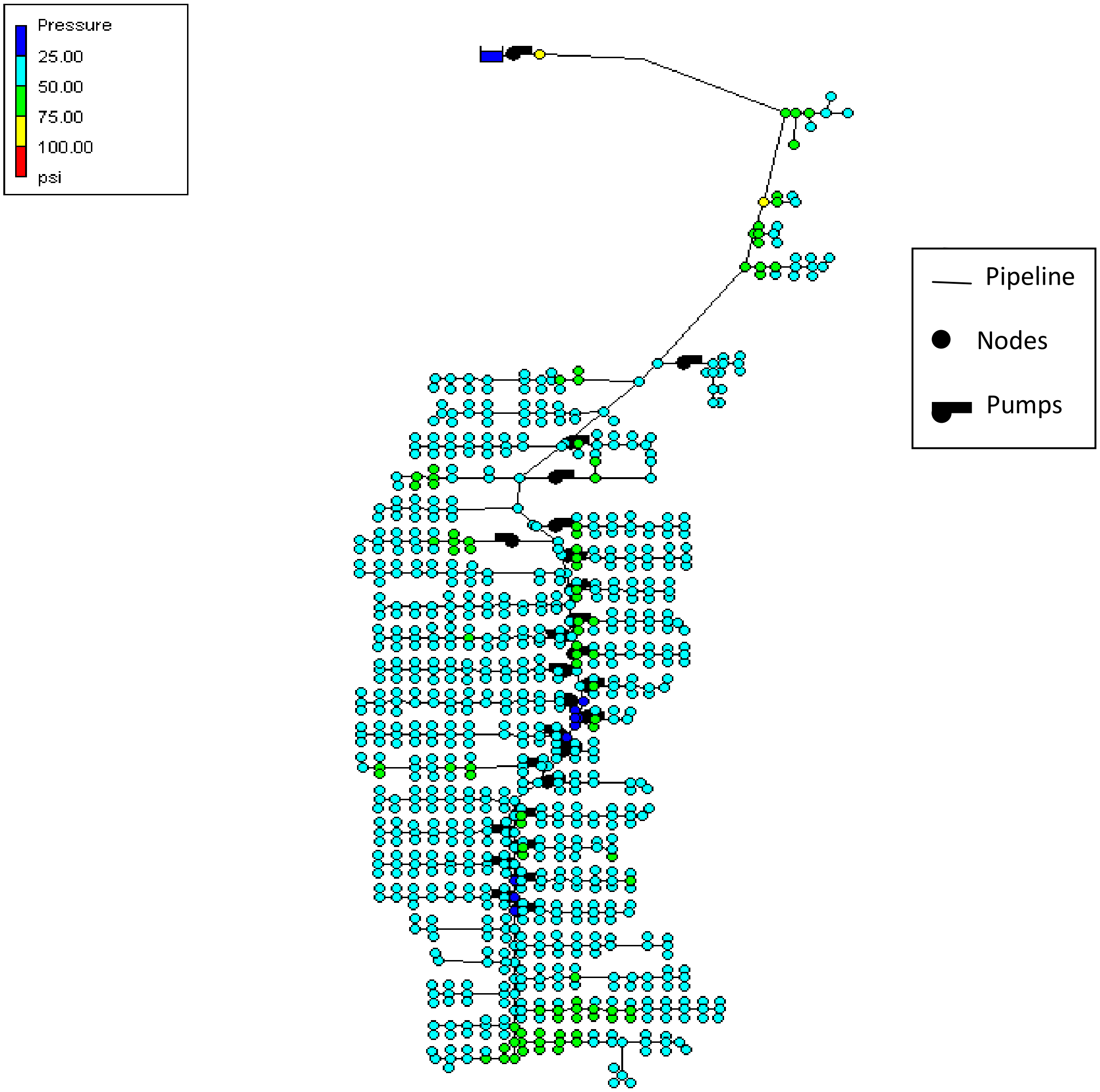

Fig. 4. An outline of EPANET pipeline networks with reservoir and pumps representing pressures at different points for non-scheduled irrigation system (Design 1A). Lines represent the pipeline while the nodes represent the junction between the pipelines.

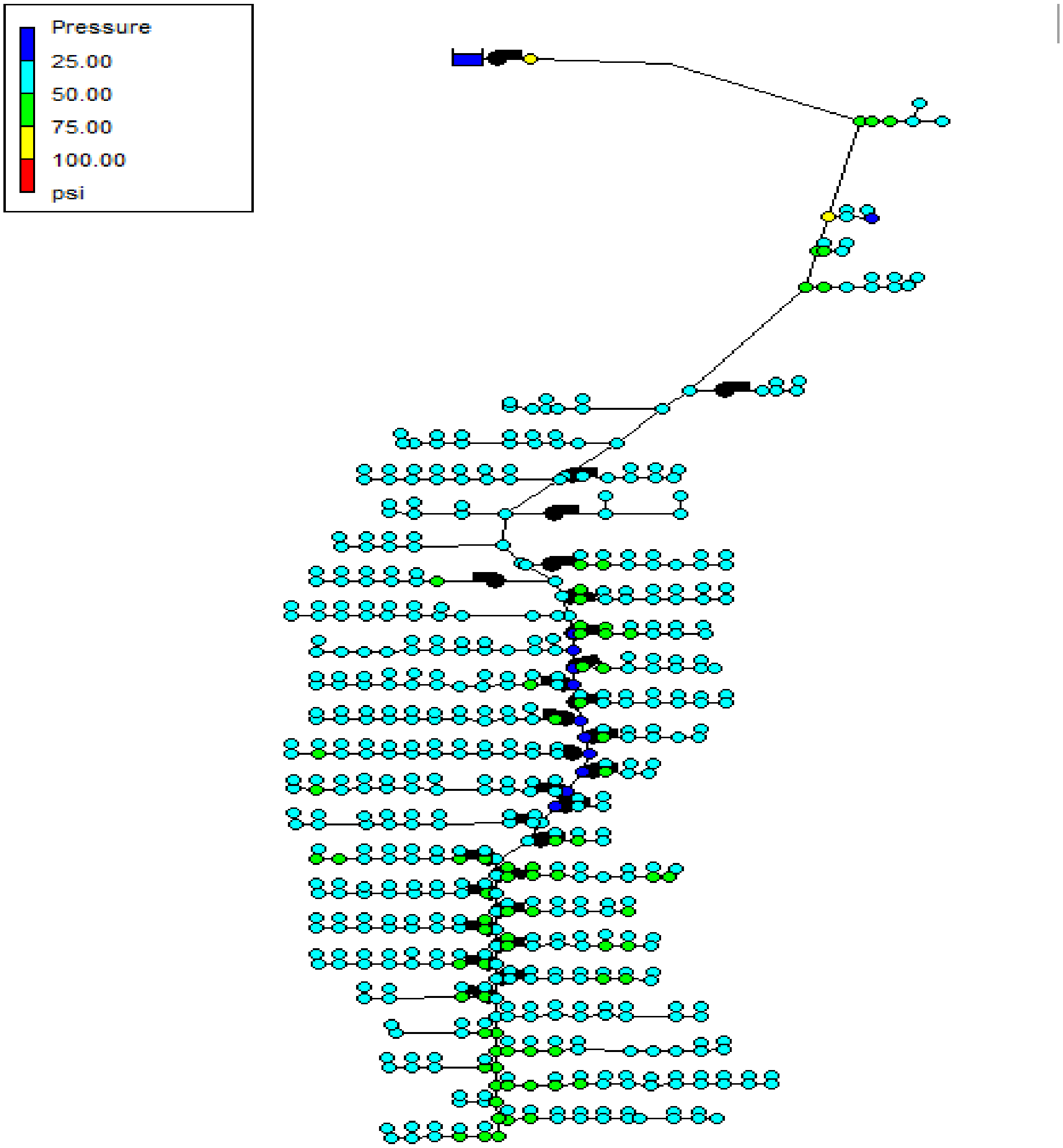

Fig. 5. An outline of EPANET pipeline network with pressure at different points for Design 1B irrigation system.

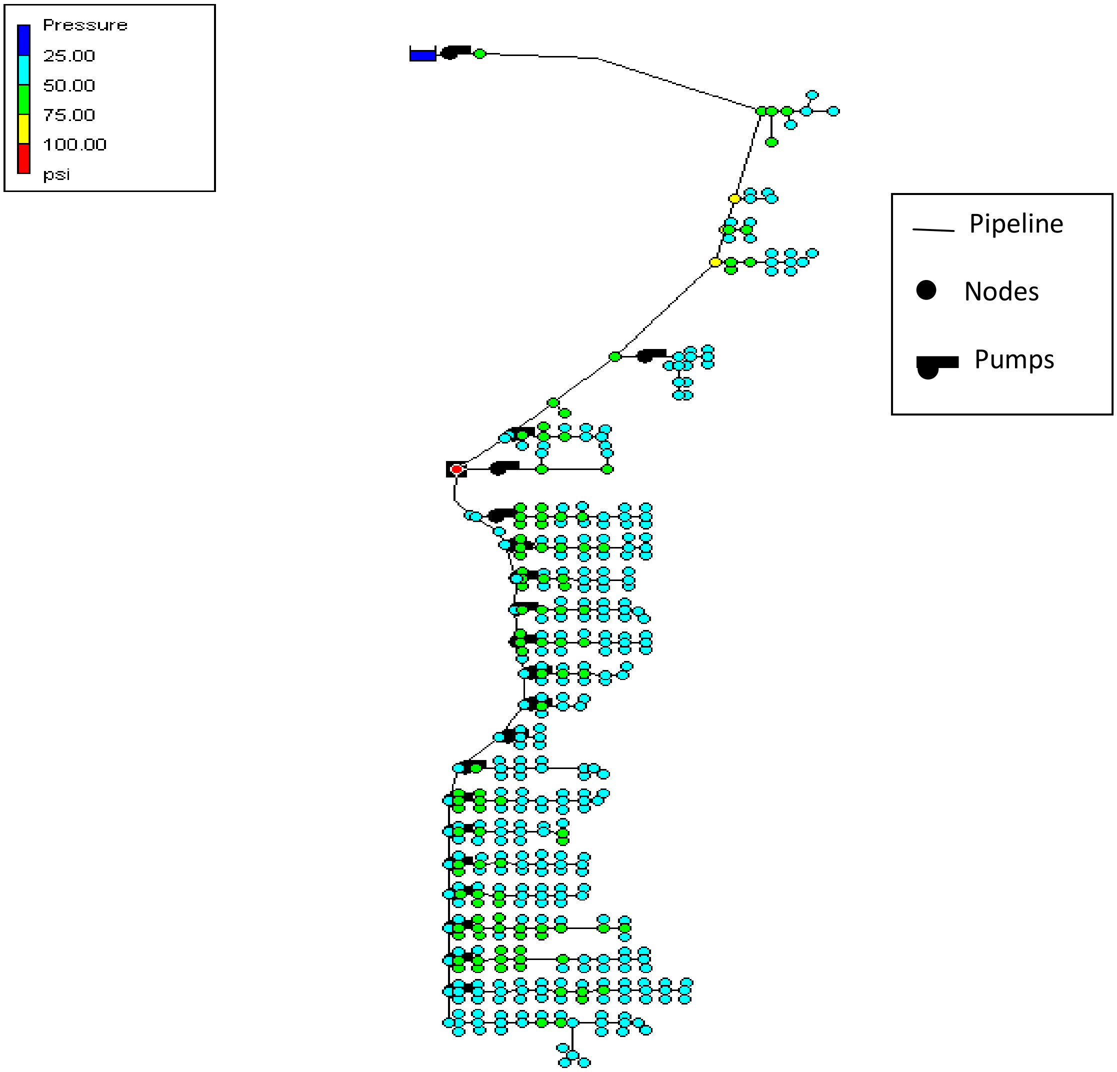

Fig. 6. An outline of EPANET pipeline networks with reservoir and pumps representing pressures at different points for 2-sides scheduled irrigation system (Design 2).

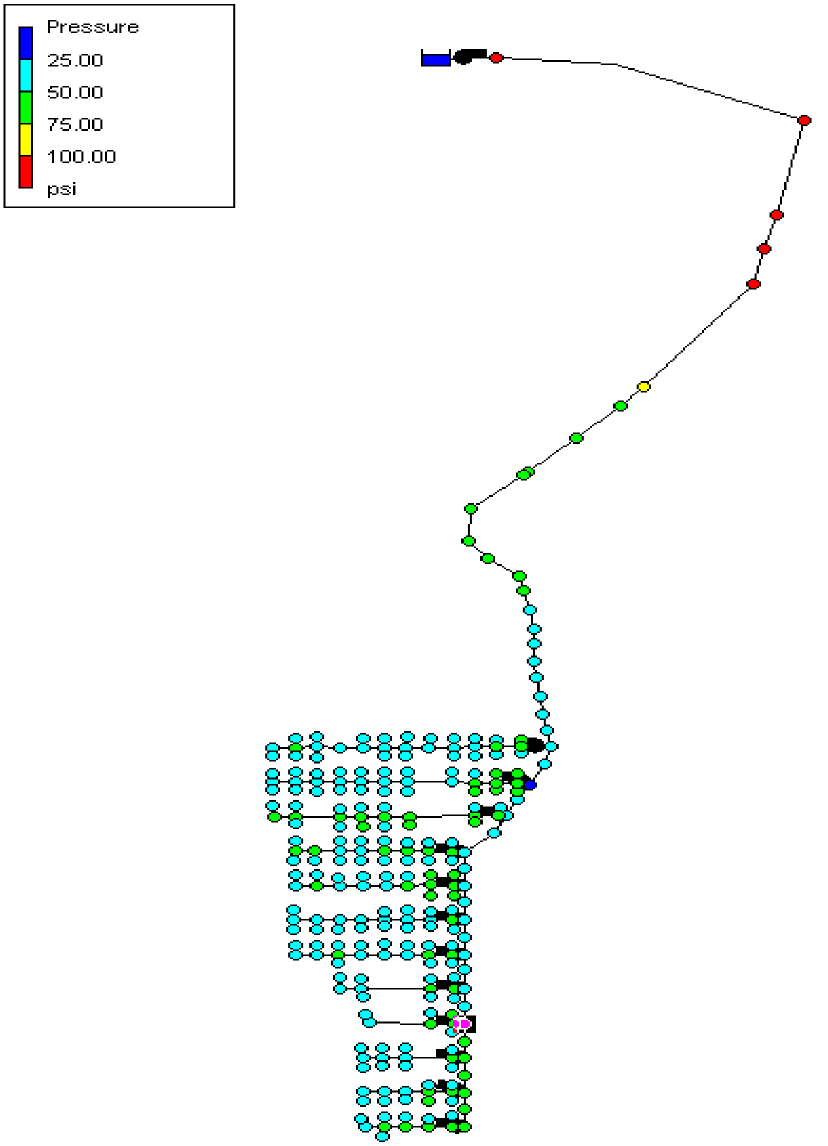

Fig. 7. An outline of EPANET pipeline networks with reservoir and pumps representing pressures at different points for a part of four area scheduled irrigation system (Design 3).

Sizing of Pipeline:

The pipeline size was obtained for minimal annual cost of pipes and pumping cost. The minimum annual cost involves a tradeoff between pipe size and energy cost. A standard capital recovery factor was used to annualize the cost of the pipe. The annual capital cost for pipeline and the annual pumping costs were added together to get the size of pipeline with minimal annual cost. As the diameter of pipe increases, the total cost of the pipe increased but the energy required for pumping the water through the pipe decreased (Appendix 6, Appendix 7, and Appendix 8). Figure 8 shows that lateral pipeline had a total water demand of 9,000 GPM with 600 GPM for each individual pivot. The optimum diameter of pipeline for 9,000 GPM of water demand was 30 inches as it yielded the minimum annual cost of pipeline and pumping. The water demand decreased to 7,800 GPM in the next lateral pipe for which the optimum diameter was 24 inches. In the same way, pipe size of next lateral was reduced as water demand in the pipe decreases. This contributes to decrease the cost of pipeline to some extent. Irrigating the north of the lateral pipeline at one time and south the other time further decreases the water demand in the lateral pipeline in which even smaller pipes would be sufficient to meet the water demand.

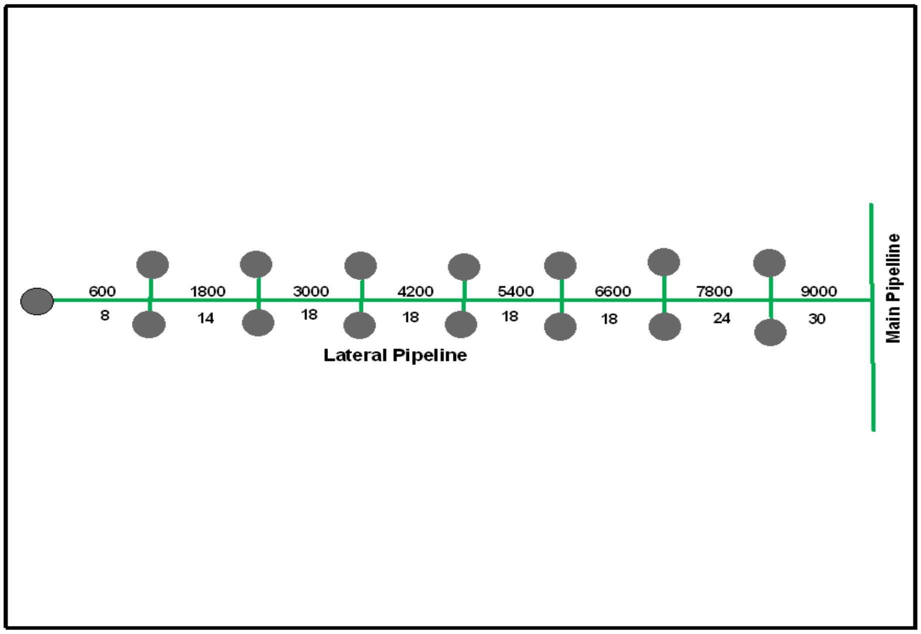

Fig. 8. A representation of lateral pipe sizing and designing according to water demand.

Crop Yield Response Function:

Crop yield response functions have been determined based on simulated yield from EPIC (Choi, 2011). The crop yield response functions for different soil types were used in the analysis. The quadratic yield function for each individual soil type is:

$$\mathrm{Y_{st}} = \mathrm{a_0} + \mathrm{a_1 W_{st}} + \mathrm{a_2 S_{st}} + \mathrm{a_3 NR_{st}} + \mathrm{a_4 W_{st}^2} + \mathrm{a_5 S_{st}^2} + \mathrm{a_6} \frac{\mathrm{S_{st}}}{\mathrm{W_{st}}} \tag{4}$$

where W_{st} is the total water (i.e. sum of irrigation and rainfall) applied (ac-feet), S_{st} is the quantity of salt in the irrigation water (tons/ac-ft), plus the salt in the soil profile $\frac{S_{st}}{W_{st}}$ is the amount of total salt (soil irrigation) divided by the total amount of water (irrigation plus rain fall) per acre, and NR_t is the precipitation in the non-growing season (feet). The coefficient estimates for crop yield response function, soil salinity response function at harvest and dynamic soil salinity function at planting for different soil types are provided in Appendix 1, Appendix 2, and Appendix 3, respectively. An example of yield for different soil types for Design1A irrigation system at 0.76 acre-ft. of irrigation water and at an EC level of 1.5 mmhos cm^{-1} is provided in Appendix 4.

Net Present Value Estimation:

The Net Present Value (NPV) for a 50-year period was calculated for each individual pivot circles as a sum of NPVs for individual soil types with in the pivot circle. The NPV is calculated using the following formula:

$$max_{Irr}\, NPV = \sum_{t=1}^{T} \frac{1}{(1+r)^t} \sum_{s=1}^{n} \{ A_s (P \cdot Y_t - C_{irr} \cdot Irr - C_o) \} \tag{5}$$

Subject to,

$$Y_t = a_0 + a_1 W_{st} + a_2 S_{ht} + a_3 NR_{st} + a_4 W_t^2 + a_5 S_{st}^2 + a_6 \frac{S_{st}}{W_{st}} \tag{6}$$

$$S_{ht} = b_0 + b_1 Irr_{st} + b_2 Irr_{ECt} + b_3 S_{pt} + b_4 R_{gst} W_{st} \tag{7}$$

$$W_{st} = \left(R_{gt} + Irr_{st}\right) \tag{8}$$

$$S_{st} = (S_{ht} + Irr_{ECt}) \tag{9}$$

$$S_{pt} = c_0 + c_1 S_{ht-1} + c_2 R_{wt-1} \tag{10}$$

where Y_t is yield (lbs/acre) in soil year t, A_s is the acreage of a soil type s in the individual irrigation circles (number of soils differ for each pivot circle), P is the price of cotton lint ($/lb), W_{st} is the total water applied i.e. sum of growing season rainfall and irrigation, S_{st} is the total salt i.e. sum of salt in soil and salt in irrigation water, S_{ht} is soil salt at harvest year t, Irr_{st} is irrigation water applied, Irr_{ECt} is salt applied with irrigation water, S_{pt} is soil salt at planting, R_{gt} is growing season rainfall, S_{pt} is soil salt at planting, S_{ht-1} is soil salt at previous harvest, R_{wt-1} is non-season (winter) rainfall, C_{irr} is the irrigation cost ($/acre-feet), C_o is the operation cost and, r is the discount rate. The irrigation water applied each year is that quantity of water which maximizes the NPV of the soil types in each pivot circle.

Dryland Cotton

Table 4. Dryland cotton variable cost per acre for 125 acres.

125 acres farmed				
Production	**Units**	**Price**	**Quantity**	**$/Acre**
Cotton Lint	Lbs	0.54*	390	210.60
Cotton Seed	Cwt	4.77	5.56	26.52
Other Income	Dollars	18.54	1	18.54
Total Receipts				255.66
Operating Inputs	**Units**	**Price**	**Quantity**	**$/Acre**
Seed	Acre	12.76	1	12.76
Fertilizer	Acre	20.43	1	20.44
Pesticide	Acre	27.12	1	27.12
Growth Regulators/Harvest Aids	Acre	7.52	1	7.52
Crop Insurance	Acre	9.91	1	9.91
Annual Operating Capital	Dollars	0.083	73.89	6.10
Machinery Labor	Hrs.	8	2.03	16.24
Machinery Fuel, Lube, Repairs	Acre	92.04	1	92.04
Ginning/Processing	Acre	37.61	1	37.61
Other Expense	Acre	16.02	1	16.02
Total Operating Costs				245.76
Returns Above Total Operating Costs				$ 9.90
Fixed Costs	**Units**	**Rate**		**$/Acre**
Machinery/Irrigation Interest at	Dollars	0.09		47.81
Total Fixed Costs				47.81
Total Costs (Operating + Fixed):				293.57
Returns Above All Specified Costs				$ (37.91)

*Price of cotton from normalized (Source: ERS, 2011)
Source: Enterprise Budgets, Oklahoma State University

The profitability of dryland cotton was assessed to determine the scenario without the irrigation system in the future. The net returns from dry land cotton are subtracted from the net returns of irrigated cotton, to find out the net agricultural benefits by implementing irrigation practices.

The average yield of dryland cotton for last five years (2001- 2005) in Tillman County was 390 lbs per acre (National Agricultural Statistics Service, 2010). On average dryland cotton production generates $ 256 revenue per acre for 54 cents cotton price (Table 4). The total operating cost and fixed cost for dryland cotton were $246 and $48 per acre, respectively (Table 4). With the cotton price of $0.54/pound of lint the returns above total operating cost was $10 while the returns above all costs (operating and fixed costs) was $-37.91 (Table 4). The dryland cotton production was only profitable if the cotton lint price was $0.65 or more per pound (Table 5). Though dryland cotton production was not profitable below $0.65 cotton price per pound, the NASS statistics showed that dryland cotton acreage is increasing in the TTA. This indicates that producers are making profits as they are more likely to get a price higher than $0.65 per pound of lint of cotton.

Table 5. Dryland net returns per acre for different prices of cotton.

	Price of Cotton/lb				
Dry Land Returns	**54 cents**	**65 cents**	**70 Cents**	**75 cents**	**90 cents**
Net Returns above Variable Costs					
Returns per acre	$10	$53	$72	$92	$150
Net Returns above Total Costs					
Returns per acre	-38	$5	$24	$44	$102

CHAPTER IV

FINDINGS

Potential Irrigable Soil Types and Areas:

The irrigable areas were selected to allocate the irrigation water and also to determine the optimal quantity of irrigation water for the area. The green areas in Fig. 2 show the potential irrigable areas. The area of potentially irrigable soils totaled 67,868 acres (Table 6). Tipton Sandy Loam and Tipton Loam are the dominant soil types within the area. There were some soils which were not designated as irrigable, but which producers are irrigating. The circles shown in the aerial map in Fig. 9 indicate pivot irrigation currently exists in the area but the areas are not designated as irrigable areas according to NRCS soil classification. There are approximately 45 pivot circles where producers are irrigating though soils are not classified as irrigable. The major soil types and their areas for the non-irrigable areas but being irrigated are given in Table 7. As people would like to continue irrigation, these areas were also included in potential irrigable areas for the region. Other features in Fig. 9 are the potential irrigable areas as designated by NRCS.

Table 6. Total irrigable areas of different soil types.

S.N	Soil type	Description	Total Area (Acres)
1	Ab	Abilene Loam	6,556
2	CaB	Carey Silt Loam 1-3 percent Slope	722
3	TcB	Tillman Clay Loam 1 to 3 percent slope	1,264
4	TdB	Tillman Hinkle Complex 1 to 3 percent slope	837
5	TpA	Tipton Fine Sandy Loam 0 to 1 Percent Slope	24,200
6	TpB	Tipton Fine Sandy Loam 1 to 3 Percent Slope	4,245
7	TtA	Tipton Loam 0 to 1 Percent Slope	27,954
8	TtB	Tipton Loam 1 to 3 Percent Slope	2,091
	Total		**67,868**

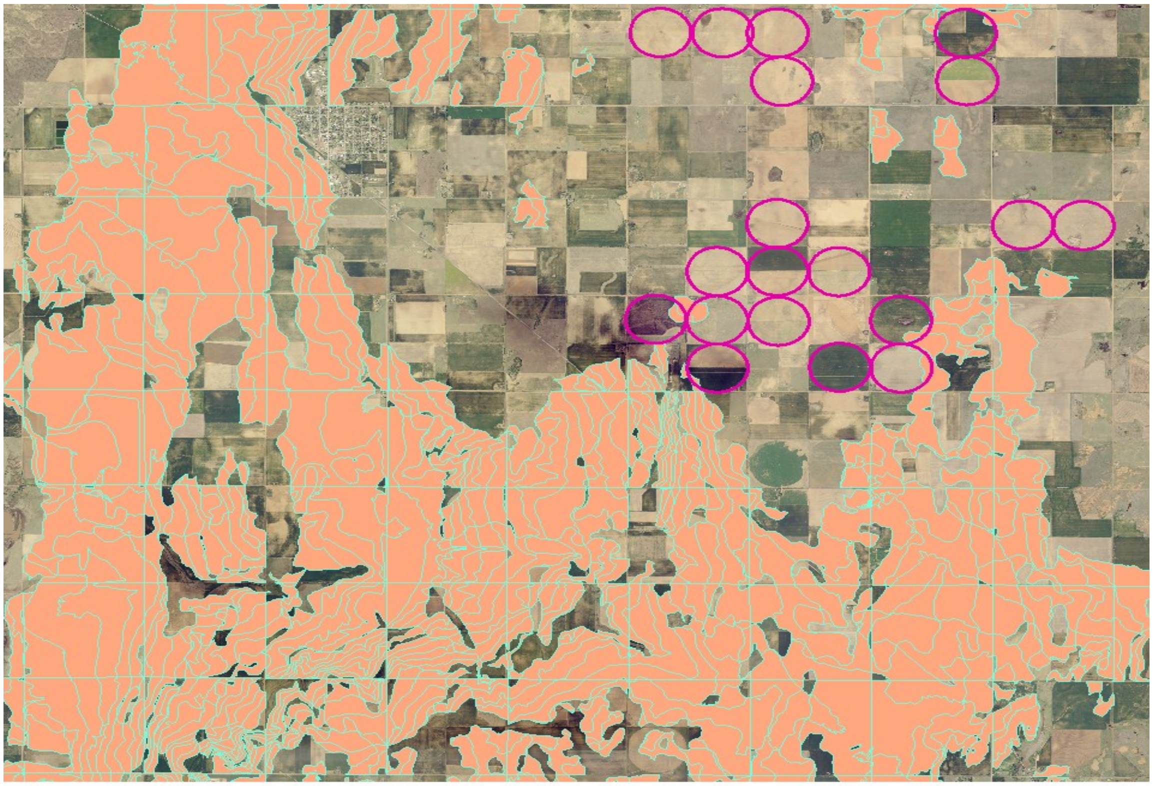

Fig.9. Potential irrigable areas (orange patches) and non-irrigable areas but currently under pivot irrigation (circles) (NRCS, 2010).

Table 7. Total areas of non-irrigable soils but being irrigated by producers.

S.N	Soil Type	Description	Areas
1	DeB	Devol loamy fine sand	844
2	DeC	Devol loamy fine sand	332
3	GnA	Grandfield and Grandmore loamy fine sands	606
4	GnB	Grandfield-Grandmore complex	1,841
5	HaA	Devol fine sandy loam	926
6	HaB	Hardeman fine sandy loam	330
7	LdC	Jester loamy fine sand	158
8	TtA	Tipton loam	159
	Total		**5,196**

Irrigation Pipeline:

Pipeline networks with pivot circles are shown in Fig. 10. Most of the irrigable areas were covered by 543 pivot circles. There can be up to four pivot circles with an area of 125.6 acres in each section of land. Figure 11 shows outline of main, lateral, and final pipelines from the reservoir to Tillman Terrace. Irrigation water flows through the main pipeline (north to south) from the reservoir to the lateral pipelines (east to west). Each lateral pipeline is connected with final pipelines which deliver water to the individual pivots in the fields. The length of main pipeline, lateral and final pipelines were 41, 133, and 151 miles, respectively. The size for main pipeline ranges from 48 inches to 120 inches, lateral ranges from 12 to 36 inches, and final pipes from 8 to 10 inches (Table 8).

Table 8. Length and size range of main, lateral and final pipelines.

Pipelines	**Length(ft)**	**Length(miles)**	**Size Rage (inches)**
Main	217,922	41	48 to120
Lateral	699,782	133	12 to 36
Final	802,407	152	6 to 10

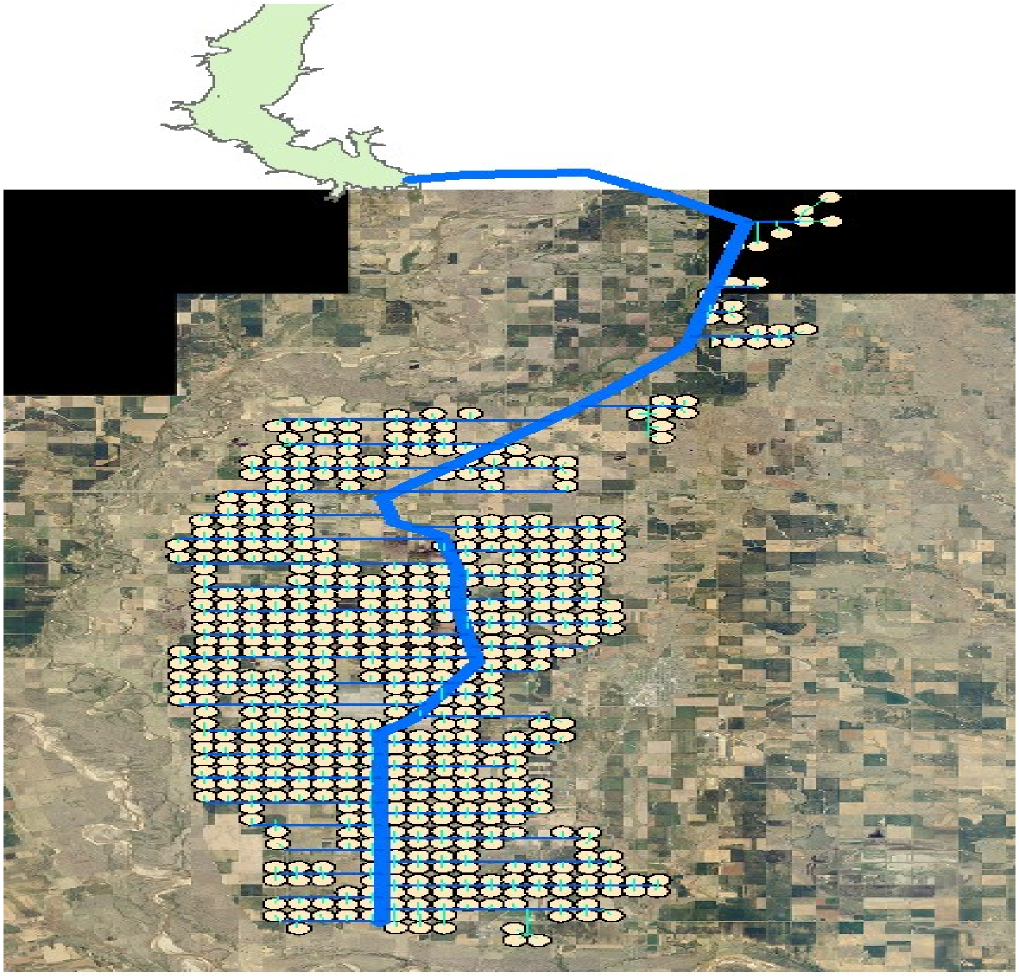

Fig. 10. Pipeline network with the pivot circles in different sections of land overlaid on 10 meter aerial NRCS photo map (Source: NRCS, 2010). White circles in the figure represent pivot irrigation.

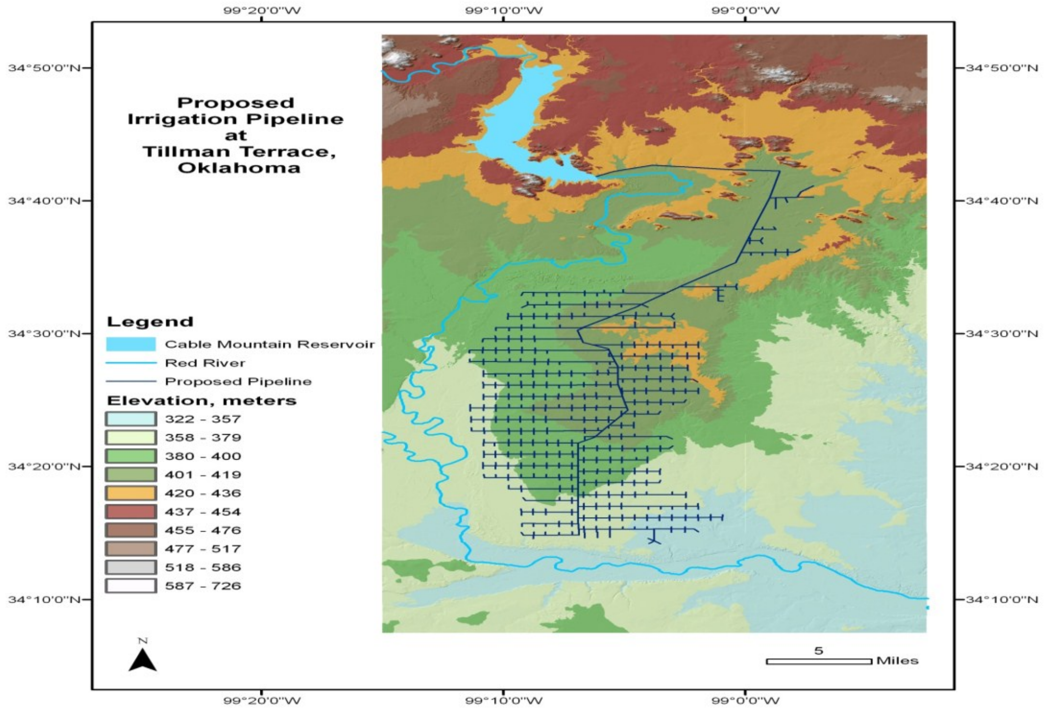

Fig. 11. Outline of pipeline from the reservoir to Tillman Terrace with main, lateral, and final pipelines. North-South line is main pipeline and East-West lines are lateral pipelines overlaid on the elevation file.

Cost of Piping:

Trenching and Pipeline Cost:

The following regression model was obtained for determining the cost of trenching for main pipeline (trenching depth >5 ft):

$$C = -7.33 + 6.97\,W - 1.46D + 0.48D^2$$

where C= cost of trenching, W= width of trench (ft), D= depth of trench (ft), D^2= square of the depth of trench (ft^2). Data for specific widths and depths were taken from Means (2009).

Total pipe costs, trenching costs, and total annualized costs at 4 percent discount rate for 50 years period for larger pipes are provided in Table 9. Diameter of pipes ranged from 24 to 120 inch. As the size of pipeline increases, total piping costs also increased. Total pipe costs per linear foot ranged from \$151 (24-inch) to \$1,925 (120-inch). Total earthwork cost increased with increasing pipe size ranged from \$70 per linear foot for a 24-inch diameter pipe to \$271 for 120-inch pipe. Total cost was calculated as sum of total pipe cost and total earthwork cost which ranged from \$221 to \$2,196 per linear foot. The cost per year was calculated with the excel pmt function for 50-year at four percent discount rate was \$10 per foot for 24-inch diameter pipe and reached upward to \$102 per foot for the 120-inch pipe.

The regression model to estimate the cost of trenching for smaller pipelines (< 5 ft deep) was: $C = -13.33 + 4.28W - 2.13D + 0.33D^2$

The total piping cost (earthwork and pipeline cost) and its total annualized cost for smaller pipelines are presented in Table 10. Diameter of pipes ranged from 6 to 18 inches. Total pipe costs ranged from \$8 for 6-inch to \$55 for 18-inch pipes. Total earthwork cost increased with increasing pipe size ranged from \$8 to \$16. Total cost (pipe cost + earthwork cost) ranged from \$16 to \$71. The 50-year annualized cost at 4 percent discount rate ranged from \$0.7 (6-inch pipe) to \$3.3 (18-inch pipe) per linear foot.

Table 9.The initial and annualized cost of pipes and trenching for larger pipelines at 4 percent discount rate.

Diameter (in)	**Total Pipe cost/ft**	**Depth (ft)**	**Top width (ft)**	**Bottom width (ft)**	**Cub. yard/ft**	**Trenching cost/ft**	**Pack cost/ft^3**	**Backfill cost/ft^3**	**Total Earthwork cost**	**Total cost/ft**	**Annualized cost/ft**
24	$151	7	17	4	3	$59	$6	$5	$70	$221	$10
36	$193	8	20	5	3	$72	$9	$7	$88	$281	$13
48	$271	9	23	6	5	$85	$11	$9	$105	$376	$18
60	$410	10	26	7	6	$98	$14	$11	$123	$533	$25
72	$490	11	29	8	7	$111	$18	$14	$143	$633	$29
84	$655	12	33	10	9	$131	$22	$18	$171	$826	$38
96	$930	13	36	11	11	$144	$27	$21	$192	$1,122	$52
108	$1,250	14	43	16	15	$185	$36	$28	$249	$1,499	$70
120	$1,925	15	46	17	17	$198	$41	$32	$271	$2,196	$102

Source: RS Means Facilities Construction Cost Data

Table 10. The initial and annualized cost of pipes and trenching for six to eighteen inch pipelines at 4 percent discount rate.

Diameter (in)	**Pipe cost/ft**	**Top Width (ft)**	**Bottom width (ft)**	**Depth (ft)**	**Cub yard/ft**	**Trenching cost/ft**	**Pack cost/ft^3**	**Backfill cost/ft^3**	**Total earthwork cost**	**Total cost/ft**	**Total annualized cost/ft**
6	$8	4.3	2	4.5	0.5	$6	$1	$1	$8	$16	$0.7
8	$12	4.3	2	4.7	0.5	$7	$2	$1	$9	$21	$1.0
10	$23	4.4	2	4.8	0.6	$7	$2	$1	$10	$33	$1.5
12	$30	5.5	3	5	0.8	$12	$3	$1	$16	$45	$2.1
14	$30	5.6	3	5.2	0.8	$11	$3	$1	$15	$45	$2.1
16	$45	5.7	3	5.3	0.9	$11	$3	$1	$16	$60	$2.8
18	$55	5.8	3	5.5	0.9	$11	$3	$2	$16	$71	$3.3

Source: RS Means Facilities Construction Cost Data

Sensitivity Analysis of Annual Pipeline Costs to Interest Rates

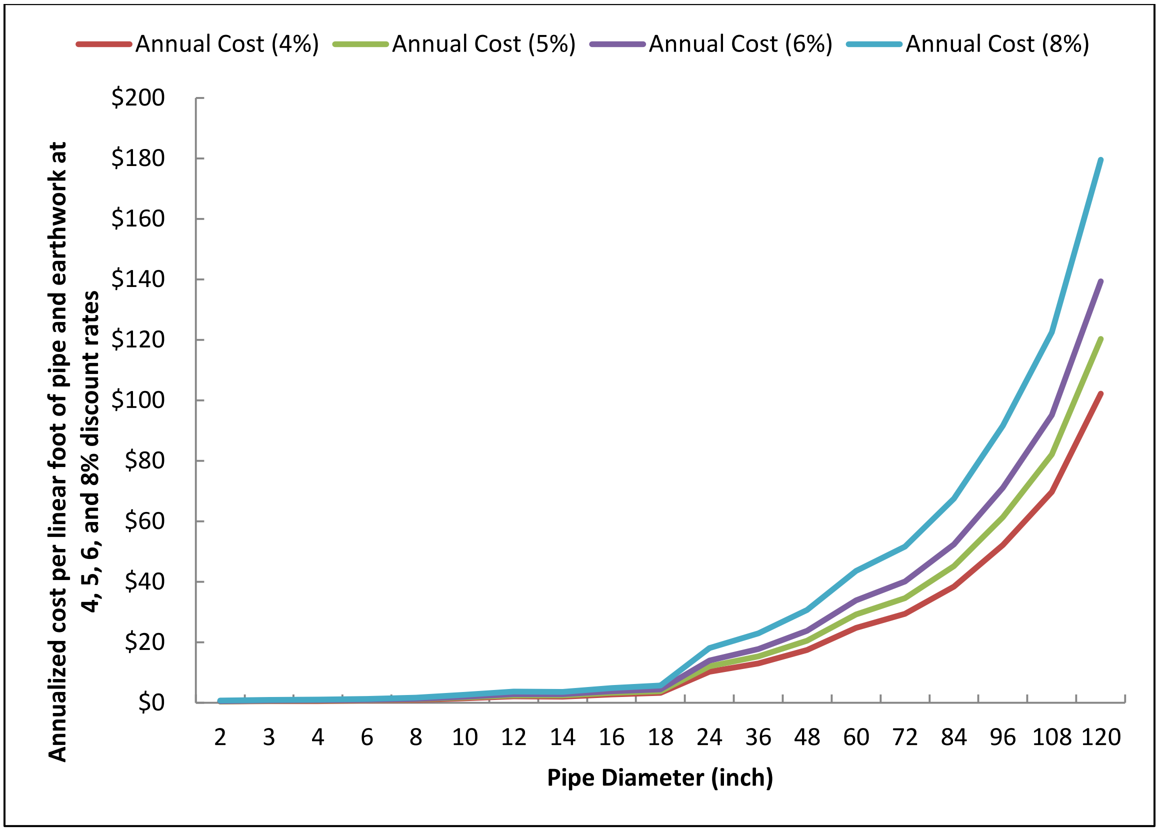

Fig. 12. Sensitivity analysis for the annualized cost of pipeline and earthwork at discount rates of four, five, six and eight percent.

The sensitivity analysis was performed for the annualized cost of pipeline and earthwork at discount rates of four, five, six and eight percent (Fig. 12). Increasing the discount rates from four percent to five percent and five percent to six percent increased the cost by 17 percent on an average. Increasing the discount rate from six percent to eight percent increased the average cost by 29 percent. When the discount rate increased from four percent to six percent and from four percent to eight percent the average annualized cost was increased by 36 percent and 76 percent, respectively.

Irrigation System Designs:

In EPANET software, the pipeline diameters were iteratively increased or decreased until the size of pipeline with minimum cost was determined that gave the pressure required at different nodes of the pipeline. The pumps were added to low pressure points to meet the minimum pressure of 35 PSI for each pivot system operation. This produced different irrigation system designs that would deliver the water to every pivot. Major four designs were evaluated in this study. Design 1A allowed all producers to irrigate simultaneously while Design 1B scheduled the irrigation alternately to the north and south of each lateral of the Design1A irrigation system. Design 2 divided the irrigable land into two areas alternating irrigation in east and west of main pipeline. Design 3 divided the irrigable land into four areas to allow producers to irrigate one area at a time. Design 1A had individual pivot demand of 600 gpm, and Design 1B, 2 and 3 had individual pivot demand of 800 gpm. The four designs were evaluated in terms of the annual fixed and variable costs.

Variable Costs:

The variable costs include inputs costs (minus the revenue from seeds), pumping costs, labor and interest on non-irrigation equipments, and other related costs. The non-irrigation variable cost of irrigated cotton production is tentatively $496 per acre (Table 11). The annual pumping cost is approximately $50 per acre foot for all four designs.

Table 11. The non-irrigation variable cost of irrigated cotton production and pivot irrigation.

Budget Items	**Cost**
Seed	$21.23
Fertilizer	$59.96
Pesticide	$41.60
Growth Regulators/Harvest Aids	$28.86
Crop Insurance	$9.91
Annual Operating Capital	$11.23
Machinery Labor	$21.12
Irrigation Labor	$1.52
Machinery Fuel, Lube, Repairs	$107.23
Ginning/Processing	$110.33
Other Expense	$22.34
Other Fixed Cost	$137.40
Returns from seed	$77.00
Total overall variable cost	**$496**

Source: Enterprise Budgets, Oklahoma State University.

Design 1A Irrigation System:

This design was for the unrestricted irrigation system with the demand of 600 gpm for each 543 pivot circles. This design used main pipelines from 48 to 120 inches, lateral pipelines from 12 to 36 inch, and final pipelines of 8 to 10 inches. The total water demand was 325,800 gpm and fixed cost per acre was $399 at a four percent discount rate (Table 12).

Table 12. Fixed costs of Design 1A irrigation system.

Cost	**Total Annualized Cost (4 %)**	**Cost/ Acre**
Cost of pipe and earthwork	$23,332,017	$343
Cost of pumps and motors	$394,697	$6
Cost of pivot irrigation system	$3,412,362	$50
Total	**$27,139,077**	**$399**

Sensitivity Analysis of Annual Fixed costs to Interest Rates:

Sensitivity analysis in Table 13 showed that the total annualized fixed cost per acre increased by 17 percent from $399 to $467 when the discount rate was increased from four to five percent. Likewise, when the discount rate was increased from four to six percent the annualized fixed cost per acre increased by 35 percent. It increased by 74 percent when the discount rate rose from four to eight percent.

Table 13. Fixed costs of Design1A irrigation system at different discount rates.

Cost **Discount Rate**	**Cost/Acre (4%)**	**Cost/Acre (5%)**	**Cost/ Acre (6%)**	**Cost/ Acre (8%)**
Cost of pipe and earthwork	$343	$401	$464	$596
Cost of pumps and motors	$6	$7	$8	$10
Cost of pivot irrigation system	$50	$59	$68	$88
Total	**$399**	**$467**	**$540**	**$694**

Net Present Value and Optimal Irrigation Water:

With an annualized fixed cost of $399 and total annual variable cost of $550 of the irrigation system, the cotton lint price should be 75 cents or more per pound to make Design 1A irrigation system economically feasible. A cotton price less than 75 cents per pound resulted in a negative NPV for the Design 1A irrigation system (Fig. 13). The figure shows that NPV increases with increase in cotton price and decreases with increase in EC levels.

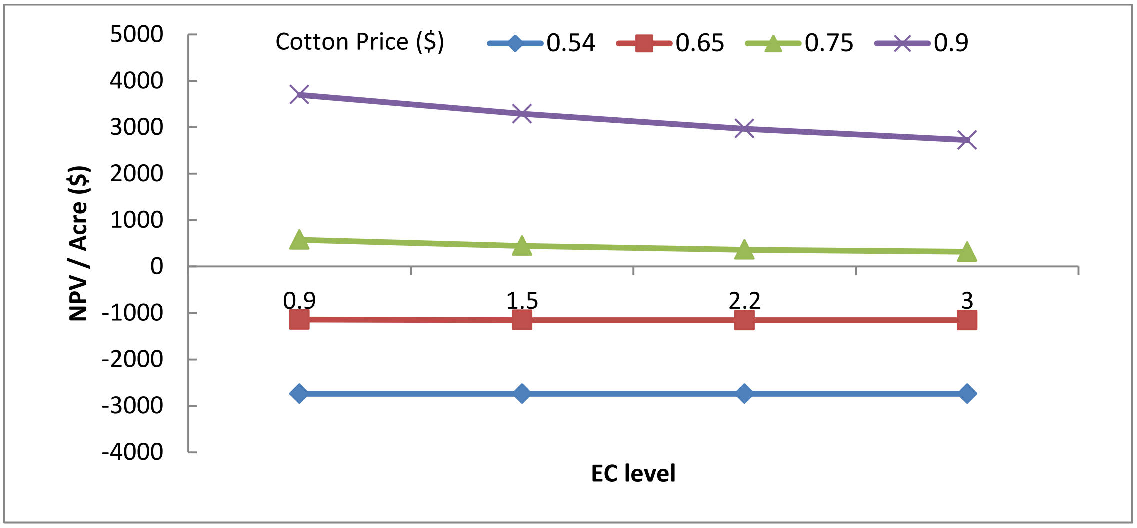

Fig. 13. NPV for different water EC levels at different cotton prices per pound for Design 1A irrigation system.

The aggregate NPVs per acre above returns of dryland cotton for the non-scheduled irrigation system for cotton lint prices of 75 and 90 cents were $402 (Table 14) and $3,189 (Table 15), respectively for an EC value of 1.5 mmhos cm^{-1}. At this level of EC, the total NPVs for 68,000 acres of land at cotton price of 75 and 90 cents were approximately $30 million (Table 14), and $225 million (Table 15), respectively. The average NPVs for a 125.6-acre system were approximately $56,000 for 75 cents and $413,000 for 90 cents of cotton price. The sensitivity of the fluctuation in the NPV of the system to EC was also analyzed. The result showed that an increase in EC would decrease the NPV per acre and the optimal amount of irrigation water to maximize NPV.

For Design 1A, a decrease in EC from 1.5 to 0.9 mmhos cm^{-1} increased NPV by 32 and 11 percent for cotton lint prices of 75 and 90 cents per pound, respectively. The optimum quantity of irrigation water increased by 60, and 35 percent for 75 and 90 cents of cotton prices, respectively. The increase in EC level also decreased the total irrigation water for the irrigation system and increasing the price of cotton increased the total irrigation water linearly (Fig.14).

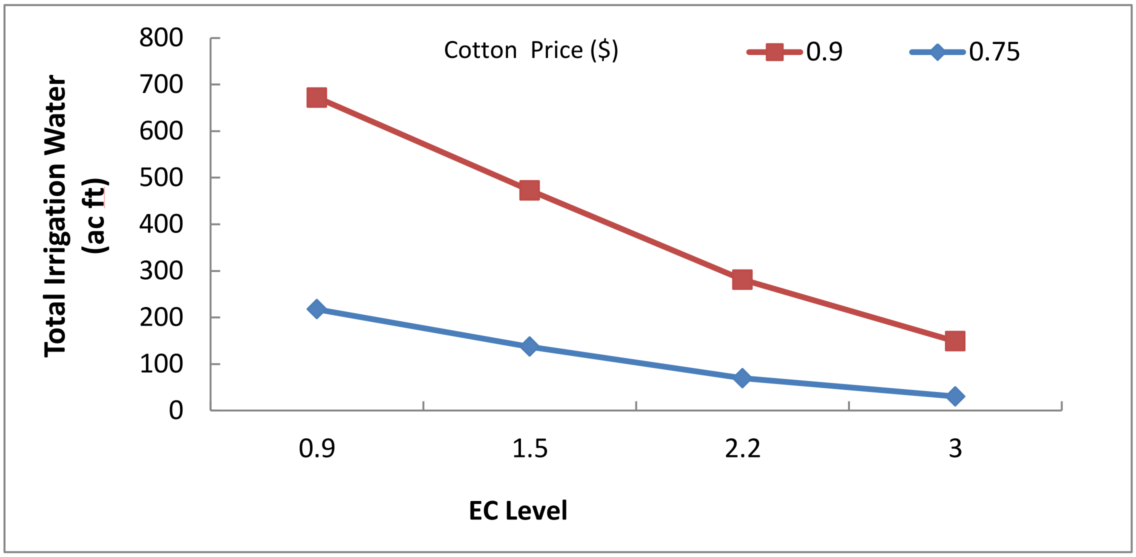

Fig 14. Total irrigation water per 125.6 acre irrigation system at different EC levels and cotton prices for Design 1A irrigation system.

Increasing the EC level from 0.9 to 1.5 mmhos cm^{-1} decreased the total irrigation water per 125.6 acres by 37 percent from 217.5 to 137.1 acre-feet for 75 cent cotton. An increase in EC value from 1.5 to 3.0 decreased the NPV by 31 and 18 percent for 75 and 90 cents of cotton prices, respectively. It also decreased the average optimum irrigation water by 78 percent for cotton prices of 75 cents and by 65 percent for cotton prices of 90 cents per pound.

Table 14. Aggregate net present value (NPV) of irrigated cotton for Design 1A at cotton price $0.75 at different levels of EC.

EC Level (mmhos cm^{-1})	**0.9**	**1.5**	**2.2**	**3**
Total NPV	$38,905,339	$30,391,486	$24553297	$21,585,240
Average NPV/125.6 acre	$71,649	$55,970	$45,218	$39,752
Average irrigation water (ft/acre)	0.40	0.25	0.13	0.06
Total irrigation water (ft)	216	137	70	30
NPV/ Acre above dryland returns	$534	$402	$320	$276

Table 15. Aggregate net present value (NPV) of irrigated cotton for Design 1A at cotton price $0.9 at different EC Levels.

EC Level (mmhos cm^{-1})	**0.9**	**1.5**	**2.2**	**3**
Total NPV	$252,422,563	$224,458,253	$199,760,168	$183,232,769
Average NPV/125.6 acre	$464,867	$413,367	$367,882	$337,445
Average irrigation water (ft./acre)	0.84	0.62	0.39	0.22
Total irrigation water (ft./ 125.6 acre)	454	336	212	118
NPV/ Acre above dryland returns	$3,599	$3,189	$2,868	$2,622

Design 1B Irrigation System:

This design was for the restricted irrigation system for instantaneous irrigation water supply. The Design 1A was modified for scheduling irrigation in Design 1B to the north of each lateral at one time and the south the other time. This scheduling reduces the size of pipe of the lateral pipeline as it would requires less amount of water at a certain time than the unrestricted design. The total water demand at a time was 217,600 gpm. Main pipelines of 36 to 108 inches, lateral pipelines of 12 to 30 inches, and final pipelines of 6 to 10 inches were used in this design. The annual fixed cost for 50 years decreased to $277 (Table 16) from $399 (Design 1A) per acre at four percent discount rate.

Table. 16. Fixed costs of Design 1B irrigation system.

Costs	**Total Annualized cost (4%)**	**Cost/acre**
Cost of pipe and earthwork	$15,278,034	$224
Cost of pivots	$3,412,362	$50
Cost of pumps and motors	$207,035	$3
Total	**$18,897,431**	**$277**

The sensitivity of discount rates to the cost of this system showed that increasing discount rate from 4 to 5, 6, and 8 percent increased the cost per acre foot by 18 percent, 36 percent, and 76 percent, respectively (Table 17).

Table 17. Annual cost per acre of Design 1B irrigation system for different discount rates.

Costs	**Cost/ Acre 4%**	**Cost/ Acre 5%**	**Cost / Acre 6%**	**Cost/ Acre 8%**
Cost of pipe and earthwork	$224	$263	$305	$393
Cost of pivots	$50	$58	$68	$88
Cost of pumps and motors	$3	$3	$4	$5
Total	**$277**	**$326**	**$377**	**$487**

Net Present Value and Optimal Irrigation Water:

With an annualized fixed cost of $280 and total annual variable cost of $550, Design 1B irrigation system was economically feasible for cotton prices above 70 cents. At 70 cents cotton this design was feasible for EC level less than and equal to 2.2 mmhos cm^{-1}. A cotton price less than 70 cents per pound resulted in a negative NPV for the Design 1B irrigation system (Fig. 15). The figure shows that NPV increases with increase in cotton price and decreases with increase in EC level linearly.

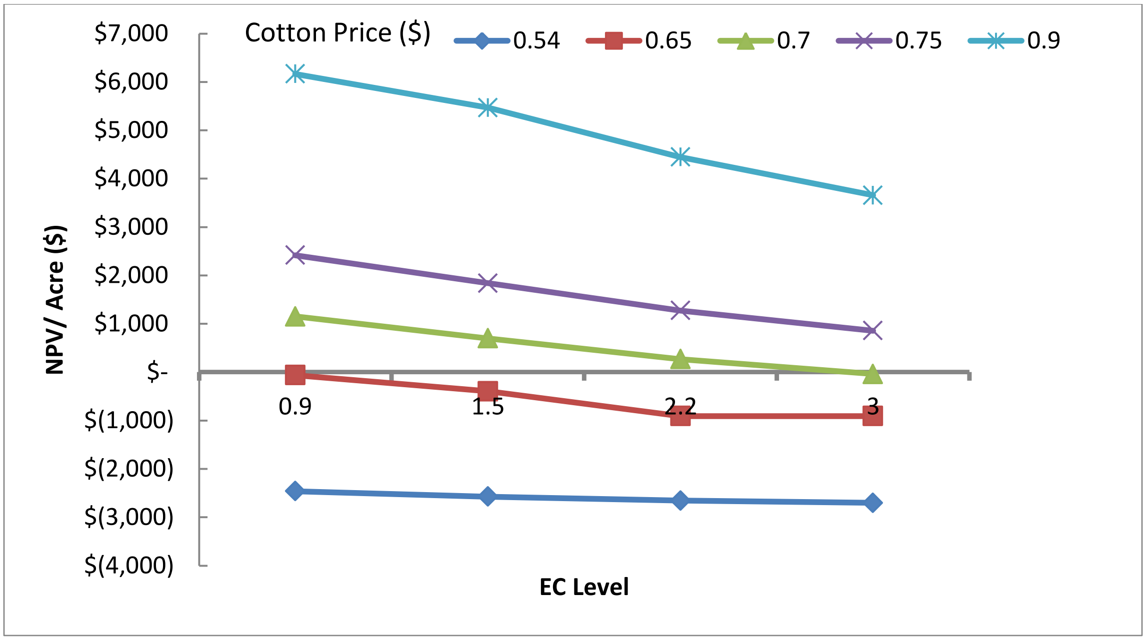

Fig . 15. NPV for different water EC levels at different cotton prices per pound for Design 1B irrigation system.

The aggregate NPVs per acre above dryland returns for the Design 1B irrigation system for cotton lint prices of 70, 75, and 90 cents were $674 (Table 18), $1,795 (Table 19), and $5,366 (Table 20), respectively for an EC value of 1.5 mmhos cm^{-1}. At this level of EC, the total NPVs for 68,000 acres of land at cotton price of 70, 75 and 90 cents were approximately $46 million (Table 18), $125 million (Table 19), and 367 million (Table 20), respectively. The sensitivity of the variability in the NPV and irrigation water use of the system to EC was also analyzed. The result showed that an increase in EC would decrease the NPV per acre and decrease the optimal average and total amount of irrigation water to maximize NPV.

Table 18. Aggregate NPV of irrigated cotton for Design 1B at price of cotton $0.7 per pound for different EC levels.

EC Level (mmhos cm^{-1})	**0.9**	**1.5**	**2.2**	**3**
Total NPV	$77,467,321	$46,978,340	$18,121,976	-$2,502,726
Average NPV/125.6 acre	$142,665	$86,516	$33,374	-$4,609
Average irrigation water (ft/acre)	1.1	0.8	0.5	0.3
Total irrigation water (ft/125.6acre)	574	439	290	172
NPV/Acre above dryland returns	$1,128	$674	$244	($62)

Table 19. Aggregate NPV of irrigated cotton for Design 1B at cotton price of $0.75 per pound for different EC levels.

EC (mmhos cm^{-1})	**0.9**	**1.5**	**2.2**	**3**
Total NPV	$162,560,744	$123,708,374	$85,685,646	$57,696,768
Average NPV/125.6 acre	$299,375	$227,824	$157,800	$106,256
Average irrigation water (ft/ acre)	1.2	0.9	0.6	0.4
Total irrigation water (ft/125.6acre)	645	501	337	204
NPV/Acre above dryland returns	$2,373	$1,795	$1,229	$813

Table 20. Aggregate NPV of irrigated cotton for Design 1B at price of cotton of $ 0.9 per pound for different EC levels.

EC (mmhos cm^{-1})	**0.9**	**1.5**	**2.2**	**3.0**
Total NPV	$414,591,644	$367,712,681	$299,118,775	$245,904,800
Average NPV/125.6 acre	$763,521	$677,187	$550,863	$452,863
Average irrigation water (ft/acre)	1.4	1.2	0.8	0.5
Total irrigation water (ft/125.6)	781	646	448	281
NPV/Acre above dryland returns	$6,064	$5,366	$4,346	$3,554

For Design 1B, an increase in EC from 0.9 to 1.5 mmhos cm^{-1} decreased NPV by 40, 24, and 12 percent for cotton lint prices of 70, 75 and 90 cents per pound, respectively. An increase in cotton price also increased the total water and increase in EC levels decreased the total water for the system (Fig. 16). The total water per 125.6 acre ranged from 174 to 574 acre feet for 70 cents cotton price (Table 18), 281 to 781 acre foot for 90 cents cotton price (Table 20). With an increase in EC level from 0.9 to 1.5 mmhos cm^{-1}, the average and total optimum quantity of irrigation water decreased by 23, 22, and 17 percent for cotton prices of 70, 75, and 90 cents, respectively. An increase in EC value from 1.5 to 2.2 decreased the NPV by 64, 32, and 19 percent for 70, 75, and 90 cents of cotton prices, respectively.

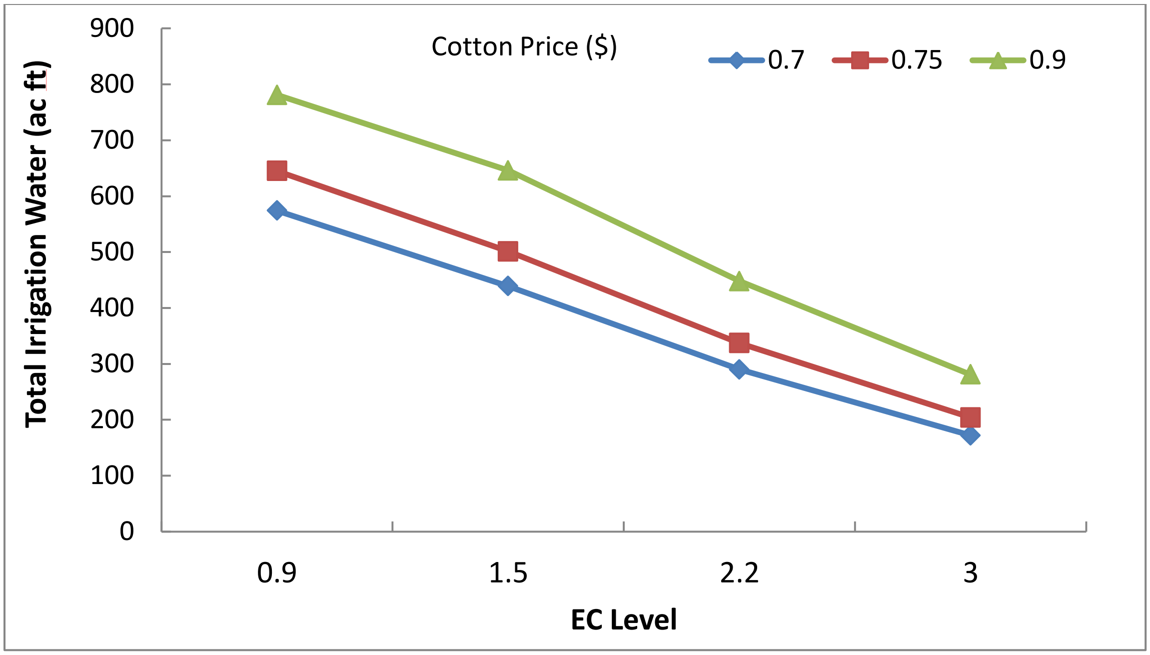

Fig 16. Total irrigation water per 125.6 acre irrigation system at different EC levels and cotton prices for Design 1B irrigation system.

Design 2 Irrigation System:

This design was also for the restricted instantaneous water supply by scheduling irrigation. The irrigation system was divided into two areas and irrigation was scheduled for one area at a time. Scheduling would require less water at one time so that the smaller pipes would be enough to meet the demand which ultimately lower the cost of the irrigation system. Main pipelines of 36 to 108 inches, lateral pipelines of 12 to 30 inches, and final pipelines of 6 to 10 inches were used in this design. The design was derived by iteratively changing pipeline sizes in EPANET. Water demand for each pivot was 800 gpm so that it would take less time to irrigate each section and so irrigation on the other area can be scheduled sooner. This design required 212,000 gallons of water per minute at a time. This scheduling has an annual fixed cost of $273 per acre at four percent discount rate (Table 21) which is approximately 32 percent less than that of Design 1A and three percent less than Design 1B.

Table 21. Fixed costs of Design 2 irrigation system.

Cost	**Total Cost**	**Cost/Acre**
Cost of pipe and earthwork	$14,689,813	$215
Cost of pumps and motors	$290,435	$4
Cost of pivot irrigation system	$3,412,362	$50
Cost of valves	$211,026	$3
Total	$3,913,823	$273

Sensitivity Analysis of Annual Fixed Costs to Interest Rates:

The result of sensitivity analysis of costs for Design 2 at different discount rates was is given in Table 22. A one percent increase in discount rate from 4 to 5 percent increased the annual cost of the irrigation system per acre approximately by 17 percent. Increasing the discount rate from four to six percent and four to eight percent increased the cost per acre by 36 percent and 75 percent, respectively.

Table 22. Annual Fixed costs of Design 2 irrigation system at different discount rates.

Cost	**Cost/Acre (4%)**	**Cost/Acre (5%)**	**Cost/Acre (6%)**	**Cost/Acre (8%)**
Cost of pipe and earthwork	$215	$253	$294	$378
Cost of pumps and motors	$4	$5	$6	$7
Cost of pivot irrigation system	$50	$59	$68	$88
Cost of valves	$3	$4	$4	$5
Total	$273	$321	$372	$479

Net Present Value and Optimal Irrigation Water:

At an annualized fixed cost of \$273 and total variable cost of \$550 per acre, Design 2 irrigation system was only feasible for the cotton price above 70 cents per pound (Fig. 17). At cotton price of 70 cents this design was feasible for EC levels less than 2.2 mmhos cm^{-1}.

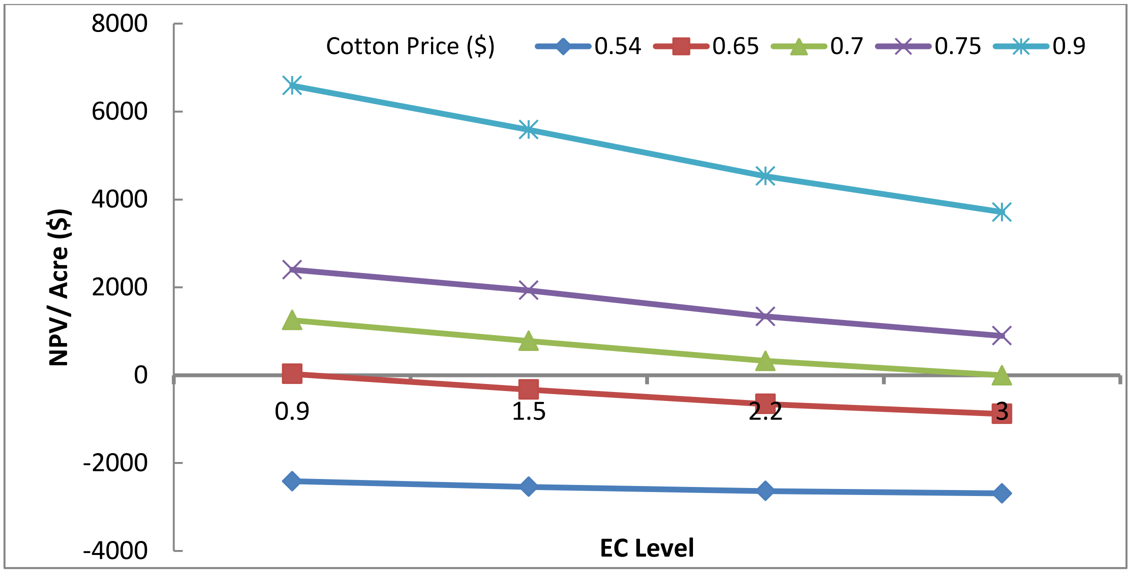

Fig. 17. NPV for different water EC levels at different cotton prices for Design 2 irrigation system.

Aggregate total NPVs, NPVs per acre and average optimal quantity of irrigation water at different EC levels for Design 2 at cotton prices of 70, 75, and 90 cents are presented in Table 23, 24, and 25, respectively. The average NPVs per acre above dryland cotton at EC level of 1.5 mmhos cm^{-1} for this scheduled irrigation system were \$755 (Table 23), \$1,887 (Table 24), and \$5,484 (Table 25) at the cotton prices of 70, 75, and 90 cents per pound, respectively. At an EC of 1.5 mmhos cm^{-1}, the total NPVs for

68,000 acres of land at cotton price of 70, 75, and 90 cents were approximately $52 million (Table 23), $129 million (Table 24), and $375 million (Table 25), respectively. The total water per 125.6 acres ranged from 180 to 594 acre-feet for a cotton price of 70 cents (Table 23), 212 to 663 acre-feet for a cotton price of 75 cents (Table 24), and 288 to 826 acre-feet for a cotton price of 90 cents (Table 25).

Table 23. Aggregate NPV of irrigated cotton for Design 2 at the price of cotton $0.7 per pound for different EC levels.

EC Level (mmhos cm^{-1})	**0.9**	**1.5**	**2.2**	**3**
Total NPV	84,426,767	$52,429,273	$21,858,011	($178,039)
Average NPV/125.6 acre	$155,482	$96,555	$40,254	($328)
Average irrigation water (ft/acre)	1.1	0.8	0.56	0.33
Total irrigation water (ft/125.6)	594	456	302	180
NPV/Acre above dryland returns	$1,231	$755	$300	($28)

Table 24. Aggregate NPV of irrigated cotton for Design 2 at cotton price of $0.75 per pound for different EC levels.

EC (mmhos cm^{-1})	**0.9**	**1.5**	**2.2**	**3**
Total NPV	$163,589,347	$129,892,665	$89,989,453	$60,422,953
Average NPV/125.6 acre	$301,270	$239,213	$165,726	$111,276
Average irrigation water (ft/acre)	1.22	0.95	0.64	0.39
Total irrigation water (ft/125.6)	663	517	349	212
NPV/Acre above dryland returns	$2,355	$1,887	$1,293	$854

Table 25. Aggregate NPV of irrigated cotton for Design 2 at price of cotton \$0.9 per pound for different EC levels.

EC (mmhos cm^{-1})	**0.9**	**1.5**	**2.2**	**3.0**
Total NPV	\$443,274,771	\$375,608,518	\$304,758,898	\$249,579,827
Average NPV/125.6 acre	\$816,344	\$691,728	\$561,250	\$485,426
Average irrigation water (ft/ acre)	1.52	1.21	0.84	0.53
Total irrigation water (ft/ 125.6 acre)	826	659	458	288
NPV/Acre above dryland returns	\$6,491	\$5,484	\$4,430	\$3,609

The average optimal quantity of irrigation water per acre to maximize NPV at an EC level of 1.5 mmhos cm^{-1} were 0.8, 0.95, and 1.21 acre-feet at the cotton prices of 70, 75, and 90 cents, respectively. The increase in EC value from 1.5 to 2.2 mmhos cm^{-1} decreased the irrigation water by 34 percent for 70 cents cotton, 32 percent for 75 cents cotton, and 30 percent for 90 cents cotton. The average irrigation water use was reduced when EC level was increased (Fig. 18).

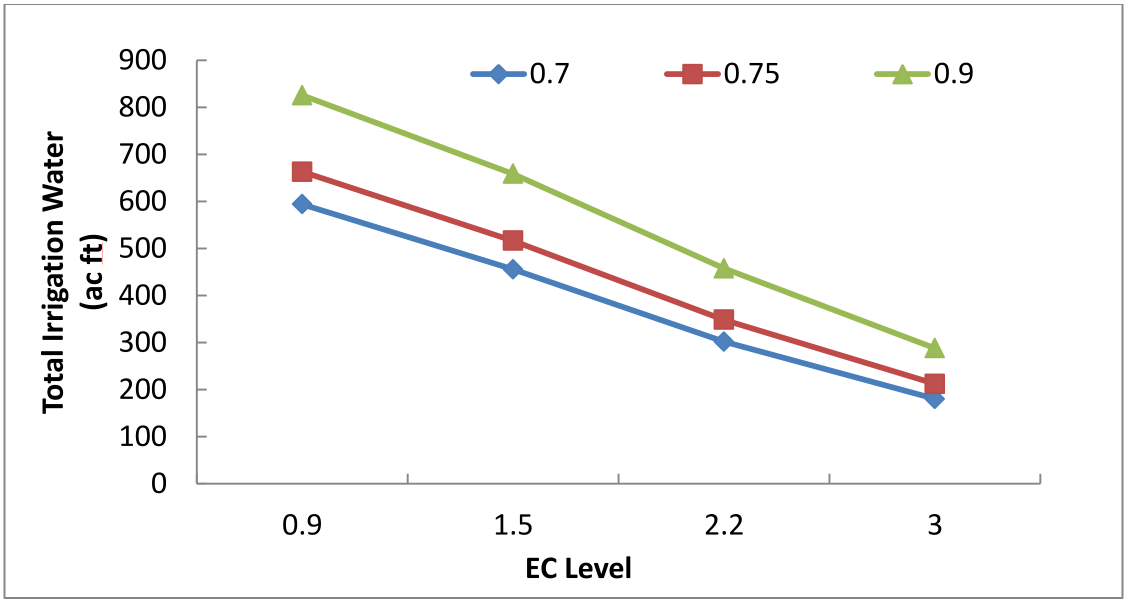

Fig.18. Total irrigation water per 125.6 acre foot for different EC levels and cotton prices for Design 2 irrigation system.

A decrease in the EC level from 1.5 to 0.9 mmhos cm^{-1} increased the NPV per acre by 63 percent and the average optimum irrigation water by 38 percent at cotton price of 70 cents. It increased the NPV by 25 percent and average optimum irrigation water increased by 15 percent at cotton price of 75 cents. Similarly, the NPV increased by 18 percent and the average optimum irrigation water increased by 27 percent at the cotton price of 90 cents. An increase in EC level from 1.5 to 2.2, and 3 decreased both the NPV and the optimum quantity of irrigation water. Increasing the EC level to 3 from 1.5 mmhos cm^{-1} decreased NPV by 103 percent (for 70-cent cotton), 55 percent (for 75-cent cotton), and 34 percent (for 90-cent cotton). In the same way, the average optimum quantity of irrigation water decreased by approximately 55 percent for both 90 and 75 cents of cotton prices.

Design 3 Irrigation System:

This design was also for the restricted instantaneous irrigation supply. In this design, the irrigation system was divided into four areas. At one time, only one area would be irrigated. This reduced the water demand and lead to a further reduction in pipeline size as compared to other designs. Water demand of 800 gpm per pivot for this design requires a total 108,600 gallons of water per minute to irrigate an area. Main pipelines of 36 to 84 inches, lateral pipelines of 12 to 24 inches, and final pipelines of 6 to 10 inches were used in this design. The annualized fixed cost at a four percent discount rate for this design was $223 per acre (Table 26) which is approximately 44 percent less than that of Design 1A, 19 percent less than Design 1B, and 18 percent less than that of Design 2.

Similar to Design 2, a one percent increase in discount rate from 4 to 5 percent increased the annual cost of the irrigation system per acre approximately by 17 percent. Increasing the discount rate from four to six percent and four to eight percent increased the cost per acre by 36 percent and 75 percent, respectively (Table 27).

Table 26. Fixed cost of Design 3 irrigation system.

Cost	**Total Annualized Cost (4 %)**	**Cost/ Acre**
Cost of pipe and earthwork	$11,422,383	$167
Cost of pumps and motors	$170,525	$3
Cost of valves	$211,026	$3
Cost of pivot irrigation system	$3,412,362	$50
Total	**$15,216,296**	**$223**

Table 27. Annual per acre fixed costs of Design 3 irrigation system at different discount rates.

Cost	**Cost/ Acre (4%)**	**Cost/ Acre (5%)**	**Cost/Acre (6%)**	**Cost/Acre (8%)**
Cost of pipe and earthwork	$167	$197	$228	$294
Cost of pumps and motors	$3	$3	$3	$4
Cost of valves	$3	$4	$4	$5
Cost of pivots	$50	$59	$68	$88
Total	$223	$263	$304	$392

Net Present Value and Optimal Irrigation Water:

With an annualized fixed cost of $223 and total variable cost of $550, the Design 3 irrigation system was feasible for the cotton price above 65 cents per pound (Fig. 19). At 65 cents this design was feasible for EC levels less than and equal to 1.5 mmhos cm^{-1}. The total irrigation water use per 125.6 acre was reduced when EC level was increased and rose when cotton price increased (Fig. 20).

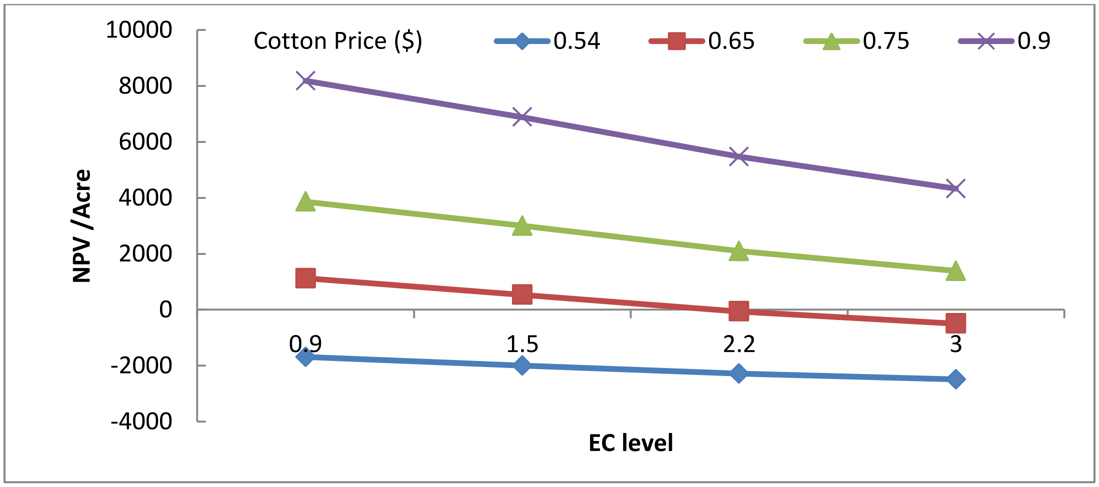

Fig. 19. NPV for different water EC levels at different cotton prices for Design 3 irrigation system.

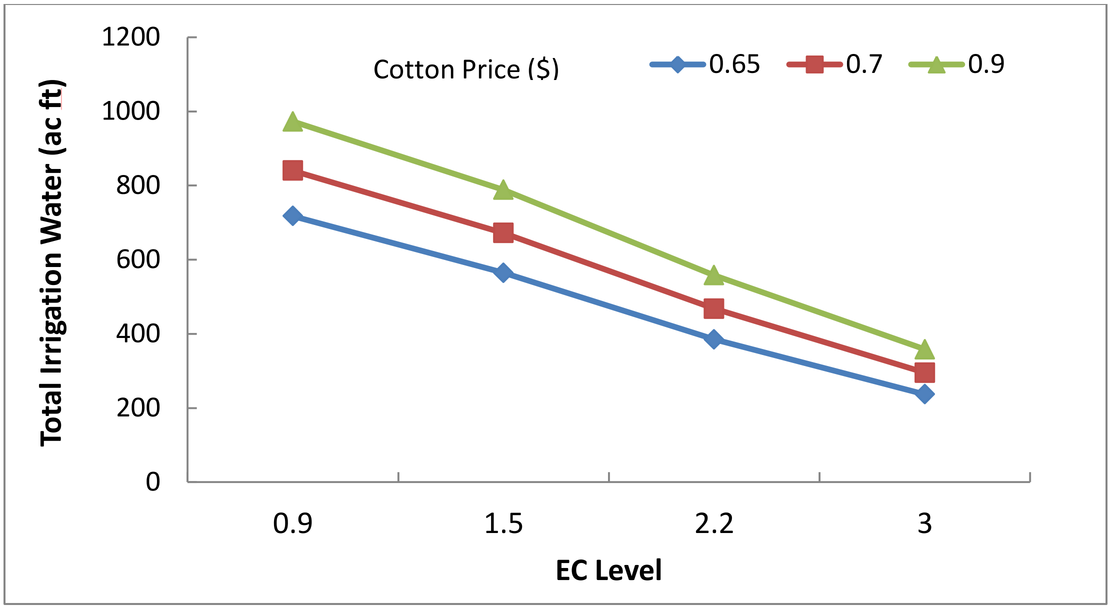

Fig. 20. Total irrigation water per 125.6 acre foot for different EC levels and cotton prices for Design 3 irrigation system.

The aggregate NPVs per acre (above dryland returns) for the scheduled irrigation system at the cotton prices of 65, 75, and 90 cents were $527 (Table 28), $2958 (Table 29), and $6,784 (Table 30), respectively at 1.5 mmhos cm^{-1} EC level. At EC of 1.5 mmhos cm^{-1}, the total NPVs for 68,000 acres of land at the cotton prices of 65, 75, and 90 cents were approximately $35 million (Table 28), $201 million (Table 29), and 463 million (Table 30), respectively. The total water per 125.6 acre ranged from 237 to 718 acre-feet for a cotton price of 65 cents (Table 28), 295 to 840 acre-feet for cotton price of 75 cents (Table 29), and 385 to 973 acre-feet for cotton price of 90 cents (Table 30).

At cotton price of 65 cents, when the EC level was decreased from 1.5 to 0.9 mmhos cm^{-1}, the NPV increased by 112 percent and the average optimum quantity of irrigation water increased by 22 percent. The NPV increased by 29 percent and average optimum quantity of irrigation water per acre increased by 25 percent at a cotton price of

75 cents. At the same increase in EC level, and cotton price of 90 cents, both the NPV per acre and the average optimal quantity of irrigation water per acre increased by 20 percent. Increasing the EC level to 3 from 1.5 mmhos cm^{-1} decreased the NPV by 195 percent (for 65-cent cotton), 55 percent (for 75-cent cotton), and 38 percent (for 90-cent cotton). In the same way, the average optimum quantity of irrigation water per acre decreased by approximately 54 percent for cotton prices of 75 and 90 cents per pound. The total irrigation water per 125.6 acre also decreased by 57 percent (65 cents cotton), 59 percent (75 cents cotton) and 54 percent (90 cents cotton) when EC level was increased to 3 from 1.5 mmhos cm^{-1}. The NPV for Design 3 irrigation system was negative at an EC level of 3 mmhos cm^{-1} and a cotton price of 65 cents per pound. It indicated that the Design 3 irrigation system was unfeasible at higher EC (2.2 or more) level and lower cotton prices (less than 65 cents).

Table 28. Aggregate NPV of irrigated cotton for Design 3 at cotton price of $0.65 per pound for different levels of EC.

EC Level (mmhos cm^{-1})	**0.9**	**1.5**	**2.2**	**3**
Total NPV	$75,327,627	$35,827,977	$(3,993,223)	$(34,052,596)
Average NPV/125.6 Acre	$138,725	$65,982	$(7,354)	$(62,712)
Average irrigation water (ft/ acre)	1.3	1.0	0.7	0.4
Total irrigation water (ft/ 125.6 acre)	718	564	385	237
NPV/Acre above dryland returns	$1,115	$527	($64)	($504)

Table 29. Aggregate NPV of irrigated cotton for Design 3 at cotton price $0.75 per pound for different levels of EC.

EC (mmhos cm^{-1})	**0.9**	**1.5**	**2.2**	**3**
Total NPV	$259,850,367	$201,911,965	$140,963,134	$93,314,077
Average NPV/125.6 acre	$478,546	$371,845	$259,601	$171,849
Average irrigation water (ft/acre)	1.55	1.24	0.86	0.54
Total irrigation water (ft/ 125.6 acre)	840	672	468	295
NPV/Acre above dryland returns	$3,820	$2,958	$2,051	$1,343

Table 30. Aggregate NPV of irrigated cotton for Design 3 at a cotton price $0.9 per pound for different EC levels.

EC (mmhos cm^{-1})	**0.9**	**1.5**	**2.2**	**3**
Total NPV	$550,210,680	$463,049,407	$367,823,753	$291,094,555
Average NPV/125.6 acre	$1,013,279	$852,761	$677,392	$536,086
Average Irrigation Water (ft/acre)	1.79	1.45	1.03	0.66
Total irrigation water (ft/125.6 acre)	973	788	558	358
NPV/Acre above dryland returns	$8,081	$6,784	$5,367	$4,226

Partial Pivot Circles:

There were 30 partial pivot circles ranging from 43 acres to 116 acres in each irrigation system design. The cost of pivot irrigation system would be higher for the partial pivot circles as it irrigates a smaller portion of land but pays for total pivot irrigation system. The costs of pivot irrigation system for the partial pivot circles were higher by \$1 to \$95 per acre than that of full pivot circles. The partial pivots were profitable at higher cotton price and lower EC values for all four designs. For designs 1B, 2, and 3 partial pivots were feasible for 90 cent and 75 cent of cotton prices and more at all EC levels (0.9, 1.5, 2.2, and 3 mmhos cm^{-1}). However, partial pivots and most of the full pivots in Design 1A were not feasible at 75 cent cotton price and EC level higher than 2.2 mmhos cm^{-1}. Likewise, most of the partial and full pivots in Designs 1B and 2 were not profitable at the 70 cents of cotton price at EC level higher than 2.2 mmhos cm^{-1}. Partial pivots in Design 3 were feasible at all EC levels for cotton price of 70 cents and more. However, most of the partial and full pivots were not feasible for 65 cents of cotton price for Design 3 at EC level 2.2 mmhos cm^{-1} and more.

Non Feasible Pivots:

For Design 1A at EC level of 3 mmhos cm^{-1}, 108 pivots were not feasible. Removing these pivots increased per acre cost to \$490 from \$400 at the four percent discount rate. Most of the remaining feasible pivots also became non feasible at that cost. Removal of those non feasible pivots again increased the cost of the system due to decreased total acreages. At the increased cost of the system, the remaining feasible pivots also became non feasible. Ultimately, the process made all of the pivots of the system unfeasible when there were more non feasible pivots in irrigation system. For Design 1A, only three pivots were not feasible for 75 cents of cotton price at 2.2 mmhos cm^{-1} EC level which decreased the acreage of the system to 67,623 acres and increased cost by \$3 per acre. Likewise, three pivots in Designs 1B and two pivots in Design 2 were not feasible at 2.2 mmhos cm^{-1} EC level for 70 cents of cotton price. The acres irrigated for Design 1B and 2 were 67,690 and 67,748 respectively acres. This increased the cost of Design 1B and 2 systems by $2 and $1, respectively. Removing few non feasible pivots in the irrigation system did not significantly increase the fixed cost of the irrigation system and decrease the NPV.

CHAPTER V

CONCLUSIONS

A GIS program was used to identify potential irrigable areas in TTA of Tillman County and southwestern parts of Kiowa County. Total irrigable areas, including identified irrigable soils, and non-irrigable soils that are currently under irrigation, were approximately 73,000 acres. Most of the selected irrigation areas were covered by 543 full and partial pivot circles. Total annual pipeline cost including pipe cost and cost of earth work ranged from \$0.7 (6-inch) to \$102 (120-inch) per linear foot. The cost of pipelines increased with increasing size of pipes. The sizing of pipeline involves tradeoff between annual energy cost and cost of pipeline. Total cost of the pipe increased but the energy required for pumping water through the pipe decreased with increasing pipe diameter. Iteratively increasing or decreasing the pipe size to determine the irrigation system with optimum cost resulted in four different designs for the irrigation system.

Design 1A was the irrigation system without scheduling. The total cost (fixed cost + variable cost) of the irrigation system was approximately \$950 per acre (Fig. 21). At this cost, NPV per acre for partial and full pivots were feasible for the cotton lint price above 75 cents per pound for the EC levels of 0.9, 1.5, 2.2, and 3 mmhos cm^{-1}.

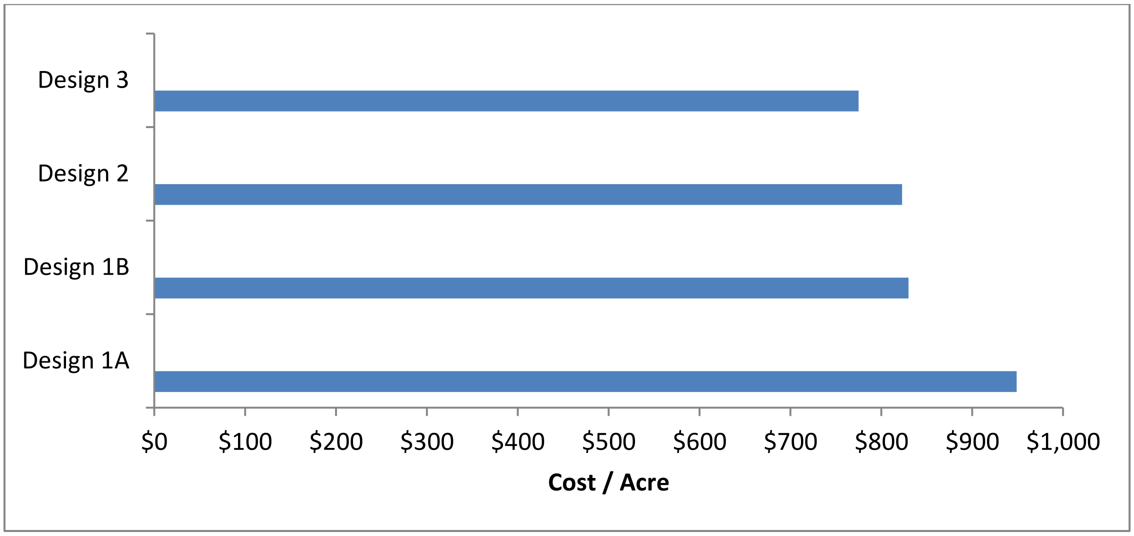

Fig. 21. Comparative representation of total annual costs of four different designs of irrigation system.

At a cotton price of 75 cents all full and partial pivots were feasible at an EC level of 2.2 mmhos cm^{-1} and less. Design 1B was designed to schedule the irrigation alternately to the north and south of the laterals of the Design 1A irrigation system. Design 2 was the scheduled irrigation system with two areas of irrigated lands in which irrigation was scheduled for one area at a time. Both Designs 1B and 2 were feasible above cotton price 70 cent for 0.9, 1.5, 2.2, and 3 mmhos cm^{-1} EC levels. At cotton price of 70 cents the full and partial pivots in Design 1B and 2 were feasible till the EC level of 2.2 mmhos cm^{-1}. Design 3 was another scheduled irrigation system in which irrigable land was divided into four areas and irrigation was scheduled for one area at a time. The total cost of the Design 3 irrigation system was approximately $ 775 per acre (Fig. 21). The NPV per acre was feasible at a cotton lint price of 65 cents per pound at this cost and EC level of 0.9 and 1.5 mmhos cm^{-1}. However, the NPV for 2.2 and 3 mmhos cm^{-1} EC levels were feasible at prices higher than 65 cents for Design 3. The sensitivity analysis for different EC levels and different cotton prices showed that the NPV, average and total optimum irrigation increased with increasing cotton price and decreased with increasing EC levels in a linear pattern (Table 26).

Table 26. NPVs per acre at 4 percent discount rate and cotton price of 75 cents per pound at different EC levels for four different designs.

EC Level (mmhos cm^{-1})	**0.9**	**1.5**	**2.2**	**3**
Design 1A (NPV/Acre)	$578	$446	$364	$320
Design 1B (NPV/Acre)	$2,417	$1,839	$1,273	$857
Design 2 (NPV/Acre)	$2,399	$1,931	$1,337	$898
Design 3 (NPV/Acre)	$3,864	$3,002	$2,095	$1,387

The energy cost per acre foot of water flowing through a pipe decreases as the diameter of pipe increases. Design 1A had larger pipelines but scheduling water as in Design 1B, Designs 2 and 3 allow for a more efficient use of smaller more cost effective pipes which ultimately reduces the irrigation cost. It indicated that most economical irrigation system can be obtained through a combination of pipe sizing and by increased cooperation in the utilization of a pipeline.

The feasibility of pressurized irrigation was evaluated in this study. However, feasibility using canal irrigation can also be assessed for a comparison in further studies. Several designs can be obtained by changing the pipe size, pump location, and scheduling of irrigation. Thus, other designs can be evaluated in future studies.

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APPENDICES

Appendix 1. Coefficient estimates of crop yield response function for different soil types.

Soil Types	Intercept	Total Water Applied	Total Salinity	Non-Growing Season Precipitation	(Total Water Applied)^2	(Total Salinity)^2	(Total Salinity / Total Water Applied)
Tipton	-524.38	940.09	1.60	112.39	-101.98	-1.43	7.37
Madge	-506.50	934.13	-1.53	98.86	-102.05	-1.54	13.68
Spur clay	-593.76	982.90	-0.09	113.44	-109.05	-1.31	11.49
Tillman clay loam	625.82	333.04	-15.13	74.39	-30.40	-0.53	4.56
Hardeman	-172.27	733.06	0.59	62.93	-80.73	-2.65	6.04
Westill	540.69	352.40	-5.64	68.97	-34.24	-0.75	3.97
Abilene	-701.52	1052.92	-5.72	107.77	-119.45	-0.91	21.24
Burford	-574.03	965.56	-12.13	127.51	-104.57	-0.73	17.42
Carey silt	-593.59	938.83	-6.86	144.36	-96.02	-1.25	5.28
Tipton sandy Loam	-744.73	1049.98	-12.29	122.35	-115.86	-1.36	27.93

Source: Choi (2011)

Appendix 2. Coefficients for soil salinity response function at harvest for different soil types

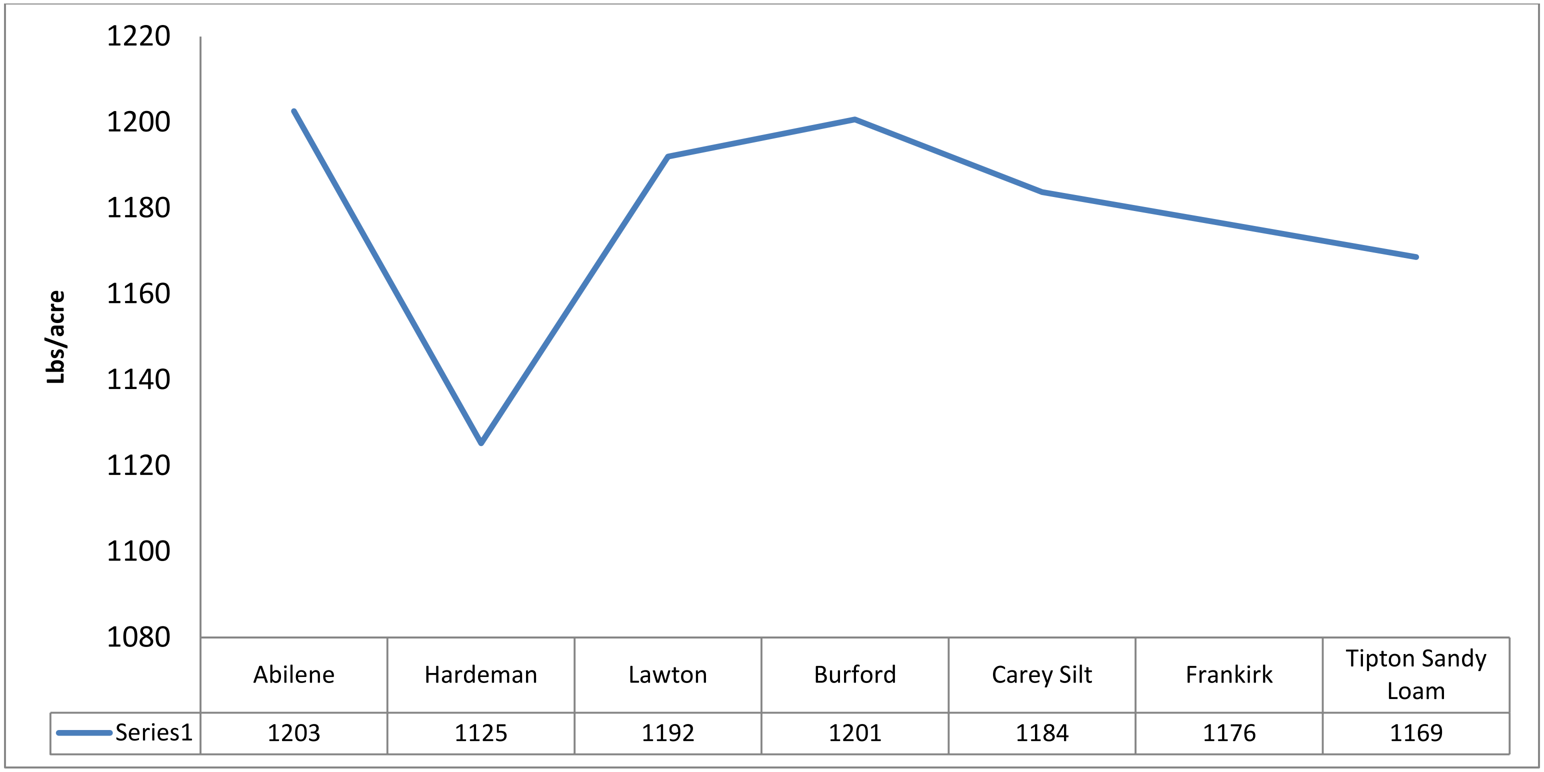
Soil Types	Intercept	Irrigation water	Amount of Salt in Irrigation water	Soil Salinity at Planting Day	Growing Season Rainfall
Tipton	2.6418	-0.4781	0.7049	0.8980	-1.3373
Madge	2.4821	-0.4519	0.7292	0.8899	-1.2609
Spur clay	2.6866	-0.4853	0.7046	0.9018	-1.3533
Tillman clay loam	2.9271	-0.6801	0.6960	0.9311	-1.2572
Hardeman	1.8523	-0.3885	0.7539	0.8515	-0.9316
Westill	2.5408	-0.5276	0.6854	0.9369	-1.1868
Abilene	3.1533	-0.6580	0.6997	0.9182	-1.4716
Buford	3.2036	-0.6683	0.6540	0.9349	-1.4610
Carey silt	2.9288	-0.5360	0.6418	0.9072	-1.4389
Tipton Sandy Loam	2.3090	-0.4691	0.7274	0.9048	-1.1015

Source: Choi (2011)

Appendix 3**.** Coefficients for dynamic soil salinity function at planting for different soil types

Soil Types	Intercept	Soil Salinity at Previous Harvest	Non-Growing Season Precipitation
Tipton	1.2914	0.9149	-1.7457
Madge	1.247	0.9139	-1.7148
Spur clay	1.2706	0.9216	-1.7321
Tillman clay loam	1.3701	0.9494	-1.8865
Hardeman	1.0541	0.8711	-1.4912
Westill	1.2526	0.9499	-1.7693
Abilene	1.4122	0.9378	-1.9137
Burford	1.3692	0.9503	-1.8581
Carey silt	1.2368	0.926	-1.6985
Tipton sandy loam	1.3754	0.9165	-1.8673

Source: Choi (2011)



Appendix 4. Yield for different soil types for Design1A irrigation system at 0.76 acre-ft. of irrigation water with EC of 1.5 mmhos cm^{-1}.

Appendix 5. Soil Types and Land Section for each Pivot Circle and Water Pressure at the Pivot Head

Pivots	**Sections**	**Abilene**	**Carey silt**	**Madge**	**Grandfiled**	**Spur clay**	**Hardemon**	**Lawton**	**Tillman clay loam**	**Burford**	**Frankirk**	**Tipton sandy laom**	**Tipton**	**Grand Total**	**Head (PSI)**
1	28-T2N-R17W	0.0	86.7	22.3	0.0	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	125.6	37.7
2	28-T2N-R17W	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	35.1
3	28-T2N-R17W	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	43.8
4	28-T2N-R17W	0.0	98.3	5.7	0.0	0.0	0.0	0.0	18.6	0.0	0.0	0.0	0.0	125.6	49.4
5	21-T2N-R17W	0.0	103.3	0.0	0.0	0.0	0.0	0.0	22.4	0.0	0.0	0.0	0.0	125.6	47.9
6	34-T2N-R17W	0.0	125.1	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	125.6	45.2
7	34-T2N-R17W	0.0	114.7	10.1	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	125.6	44.5
8	34-T2N-R17W	0.0	122.5	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0	125.6	44.1
9	34-T2N-R17W	0.0	75.6	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0	125.6	43.6
10	35-T2N-R17W	0.0	83.4	0.0	0.0	0.0	0.0	0.0	0.0	42.2	0.0	0.0	0.0	125.6	44.1
11	33-T2N-R17W	0.0	109.9	0.0	0.0	0.0	0.0	0.0	0.0	7.5	0.0	0.0	5.7	123.1	45.6
12	17-T1N-R17W	71.5	0.0	0.0	0.0	0.0	0.0	54.1	0.0	0.0	0.0	0.0	0.0	125.6	37.4
13	17-T1N-R17W	86.5	0.0	0.0	0.0	0.0	0.9	38.2	0.0	0.0	0.0	0.0	0.0	125.6	38.6
14	17-T1N-R17W	52.0	0.0	0.0	0.0	0.0	35.6	0.0	0.0	5.7	0.0	0.0	26.2	119.5	38.0
15	17-T1N-R17W	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	39.5
16	20-T1N-R17W	59.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.8	0.0	125.6	36.7
17	18-T1N-R17W	48.4	46.2	0.0	0.0	0.0	0.6	0.0	0.0	0.0	30.4	0.0	0.0	125.6	35.7
18	20-T1N-R17W	80.6	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.0	0.0	22.8	19.6	125.6	30.5

Appendix 5. Continued

19	26-T1N-R18W	0.0	96.8	0.0	28.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	36.9
20	26-T1N-R18W	0.0	81.0	0.0	44.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	36.0
21	26-T1N-R18W	0.0	113.9	6.9	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	34.7
22	25-T1N-R18W	0.0	116.6	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	36.3
23	36-T1N-R18W	0.0	18.7	0.0	106.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	59.8
24	36-T1N-R18W	19.3	0.0	0.0	106.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	36.2
25	34-T1N-R18W	55.1	0.0	0.0	70.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	35.7
26	34-T1N-R18W	36.2	0.0	0.0	89.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	49.4
27	34-T1N-R18W	26.1	0.0	0.0	93.8	0.0	0.0	0.0	0.0	5.7	0.0	0.0	0.0	125.6	50.3
28	33-T1N-R18W	0.0	0.0	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	48.6
29	28-T1N-R18W	4.5	57.3	0.0	63.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	48.1
30	28-T1N-R18W	0.0	96.5	0.0	29.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	50.9
31	27-T1N-R18W	0.0	6.9	0.0	118.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	47.6
32	27-T1N-R18W	0.0	0.0	0.0	99.2	0.0	0.0	0.0	0.0	26.4	0.0	0.0	0.0	125.6	48.8
33	27-T1N-R18W	0.0	0.0	0.0	117.9	0.0	0.0	0.0	0.0	7.7	0.0	0.0	0.0	125.6	50.6
34	27-T1N-R18W	0.6	2.2	0.0	122.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	58.2
35	21-T1N-R18W	14.7	40.5	0.0	70.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	47.5
36	21-T1N-R18W	0.0	96.2	0.0	29.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	52.6
37	21-T1N-R18W	0.0	81.7	0.0	43.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	49.3
38	21-T1N-R18W	0.0	90.1	0.0	29.4	0.0	0.0	0.0	0.0	0.0	0.0	6.1	0.0	125.6	52.4
39	16-T1N-R18W	5.3	21.1	0.0	0.0	0.0	55.8	0.0	0.0	0.0	0.0	43.4	0.0	125.6	52.6
40	15-T1N-R18W	0.0	66.8	0.0	0.0	0.0	0.8	0.0	0.0	0.1	58.0	0.0	0.0	125.6	50.1
41	20-T1N-R18W	0.0	102.8	0.0	22.6	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	125.6	52.4
42	29-T1N-R18W	0.0	82.8	0.0	37.9	0.0	4.9	0.0	0.0	0.0	0.0	0.0	0.0	125.6	44.8
43	30-T1N-R18W	0.0	62.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.7	0.0	0.0	125.6	35.7
44	29-T1N-R18W	0.0	64.4	0.0	14.2	0.0	47.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	43.3

Appendix 5. Continued

45	29-T1N-R18W	0.0	57.0	0.0	0.0	0.0	68.7	0.0	0.0	0.0	0.0	0.0	0.0	125.6	57.9
46	30-T1N-R18W	0.0	69.7	0.0	0.0	0.0	52.4	0.0	0.0	0.0	3.5	0.0	0.0	125.6	38.0
47	30-T1N-R18W	0.0	90.8	0.0	0.0	0.0	32.2	0.0	0.0	0.0	0.0	2.6	0.0	125.6	44.5
48	25-T1N-R19W	0.0	59.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.7	22.8	0.0	125.6	34.3
49	25-T1N-R19W	0.0	94.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.0	0.0	0.0	125.6	44.9
50	25-T1N-R19W	0.0	4.7	0.0	76.8	0.0	0.0	0.0	0.0	0.0	44.2	0.0	0.0	125.6	34.0
51	24-T1N-R19W	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	119.0	0.0	0.0	125.6	46.1
52	24-T1N-R19W	22.7	18.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	84.6	0.0	0.0	125.6	42.0
53	19-T1N-R18W	0.0	86.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.8	0.0	0.0	125.6	51.3
54	19-T1N-R18W	31.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	94.1	0.0	0.0	125.6	46.4
55	20-T1N-R18W	0.0	3.5	0.0	53.2	0.0	0.0	0.0	0.0	0.0	68.9	0.0	0.0	125.6	54.0
56	17-T1N-R18W	69.7	11.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.4	0.0	0.0	125.6	55.0
57	19-T1N-R18W	0.0	12.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	112.7	0.0	0.0	125.6	53.7
58	24-T1N-R19W	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	122.6	0.0	0.0	125.6	55.7
59	25-T1N-R19W	0.0	109.3	0.0	16.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	55.9
60	26-T1N-R19W	0.0	103.7	0.0	21.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	39.6
61	36-T1N-R19W	0.0	32.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.4	35.5	0.0	125.6	40.0
62	36-T1N-R19W	0.0	77.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.7	0.0	125.6	44.9
63	35-T1N-R19W	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	43.1
64	31-T1N-R18W	0.0	40.0	0.0	0.0	0.0	7.4	0.0	0.0	0.0	21.1	57.1	0.0	125.6	38.5
65	31-T1N-R18W	0.0	63.6	0.0	0.0	0.0	62.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	42.0
66	32-T1N-R18W	11.9	36.0	0.0	0.0	0.0	77.8	0.0	0.0	0.0	0.0	0.0	0.0	125.6	38.4
67	31-T1N-R18W	0.0	78.7	0.0	23.5	0.0	23.4	0.0	0.0	0.0	0.0	0.0	0.0	125.6	57.2
68	36-T1N-R19W	0.0	38.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.3	67.0	0.0	125.6	43.4
69	36-T1N-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53.7	71.9	0.0	125.6	44.3
70	2-T1S-R19W	0.0	28.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	97.2	0.0	125.6	49.7

Appendix 5. Continued

71	2-T1S-R19W	0.0	60.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.1	0.0	125.6	48.2
72	2-T1S-R19W	0.0	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	111.6	0.0	125.6	45.8
73	2-T1S-R19W	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	109.2	0.0	113.2	47.9
74	1-T1S-R19W	0.0	49.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	73.9	0.0	125.6	44.1
75	12-T1S-R19W	0.0	52.8	0.0	6.9	0.0	0.0	0.0	0.0	0.0	0.0	28.1	0.0	87.8	43.5
76	11-T1S-R19W	0.0	32.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.3	0.0	89.2	35.1
77	11-T1S-R19W	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	123.1	0.0	125.6	40.8
78	11-T1S-R19W	0.0	95.8	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	28.2	0.0	125.6	52.5
79	11-T1S-R19W	0.0	56.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69.6	0.0	125.6	49.4
80	12-T1S-R19W	0.0	3.1	0.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0	62.7	0.0	83.9	40.3
81	14-T1S-R19W	0.0	103.6	0.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	47.1
82	14-T1S-R19W	0.0	48.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	56.5	0.0	104.7	42.6
83	13-T1S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	77.0	0.0	77.0	44.4
84	13-T1S-R19W	0.0	0.0	0.0	13.9	0.0	46.9	0.0	0.0	0.0	0.0	64.8	0.0	125.6	38.0
85	3-T1S-R19W	0.0	93.9	0.0	8.5	0.0	18.5	0.0	0.0	0.0	4.7	0.0	0.0	125.6	38.6
86	3-T1S-R19W	0.0	107.9	0.0	13.7	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	125.6	40.4
87	10-T1S-R19W	0.0	68.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	56.9	0.0	125.6	38.7
88	10-T1S-R19W	0.0	106.4	0.0	19.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	41.8
89	10-T1S-R19W	0.0	56.6	0.0	0.0	0.0	23.8	0.0	0.0	0.0	45.2	0.0	0.0	125.6	49.7
90	10-T1S-R19W	0.0	115.3	0.0	3.3	0.0	0.0	0.0	0.0	0.0	7.1	0.0	0.0	125.6	43.1
91	15-T1S-R19W	0.0	63.5	0.0	62.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	43.2
92	15-T1S-R19W	0.0	114.4	0.0	11.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	43.1
93	16-T1S-R19W	0.0	0.0	62.4	0.3	0.0	57.9	0.0	0.0	0.0	5.0	0.0	0.0	125.6	35.1
94	16-T1S-R19W	0.0	0.0	72.1	0.1	0.0	11.3	0.0	0.0	0.0	37.4	4.8	0.0	125.6	39.0
95	15-T1S-R19W	0.0	113.3	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.0	125.6	36.9
96	15-T1S-R19W	0.0	51.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	74.4	0.0	125.6	37.6

Appendix 5. Continued

97	14-T1S-R19W	0.0	66.0	0.0	0.0	0.0	17.9	0.0	0.0	0.0	0.0	32.1	0.0	116.1	36.3
98	14-T1S-R19W	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	41.2	0.0	43.3	37.9
99	13-T1S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	98.1	0.0	98.1	36.2
100	13-T1S-R19W	0.0	43.0	0.0	0.0	0.0	9.4	0.0	0.0	0.0	0.0	73.3	0.0	125.6	49.3
101	22-T1S-R19W	0.0	87.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.9	13.6	0.0	125.6	37.3
102	22-T1S-R19W	0.0	6.9	2.8	0.0	0.0	0.0	0.0	0.0	0.0	29.9	86.0	0.0	125.6	47.7
103	27-T1S-R19W	0.0	70.7	0.0	9.5	0.0	21.1	0.0	0.0	0.0	0.0	24.3	0.0	125.6	49.2
104	27-T1S-R19W	0.0	68.5	0.0	15.9	0.0	0.0	0.0	0.0	0.0	0.0	41.2	0.0	125.6	45.5
105	34-T1S-R19W	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.4	0.0	125.6	40.3
106	34-T1S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	43.4
107	34-T1S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	44.0
108	27-T1S-R19W	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	121.4	0.0	125.6	45.9
109	27-T1S-R19W	23.2	54.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.4	0.0	125.6	42.4
110	34-T1S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	43.4
111	35-T1S-R19W	0.0	18.3	0.0	0.0	0.0	60.9	0.0	0.0	0.0	0.0	46.4	0.0	125.6	51.4
112	26-T1S-R19W	3.3	0.0	0.0	0.0	0.0	12.0	0.0	0.0	0.0	0.0	110.3	0.0	125.6	40.6
113	26-T1S-R19W	0.0	49.4	0.0	0.0	0.0	13.2	0.0	0.0	0.0	0.0	63.1	0.0	125.6	41.4
114	26-T1S-R19W	0.0	18.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.9	91.2	0.0	125.6	39.2
115	26-T1S-R19W	0.0	49.2	0.0	0.0	0.0	47.0	0.0	0.0	0.0	0.0	29.4	0.0	125.6	40.0
116	35-T1S-R19W	0.0	86.6	0.0	0.0	0.0	6.6	0.0	0.0	0.0	24.0	8.4	0.0	125.6	34.9
117	35-T1S-R19W	0.0	83.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.7	33.9	0.0	125.6	37.9
118	35-T1S-R19W	0.0	26.2	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	94.8	0.0	125.6	53.9
119	2-T2S-R19W	0.0	100.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	24.7	0.0	125.6	53.0
120	2-T2S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	54.6
121	3-T2S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	37.4
122	3-T2S-R19W	0.0	27.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	98.0	0.0	125.6	49.0

Appendix 5. Continued

123	3-T2S-R19W	0.0	55.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.5	0.0	95.8	38.2
124	4-T2S-R19W	0.3	20.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	62.3	0.0	82.9	40.3
125	3-T2S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	40.4
126	2-T2S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.8	115.8	0.0	125.6	40.7
127	2-T2S-R19W	0.0	47.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	77.8	0.0	0.0	125.6	40.0
128	36-T1S-R19W	0.0	37.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.1	42.5	0.0	107.4	36.7
129	36-T1S-R19W	0.0	6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	118.7	0.0	125.6	38.3
130	1-T2S-R19W	0.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.5	48.4	0.0	125.6	35.5
131	1-T2S-R19W	0.0	51.9	0.0	0.0	0.0	65.6	0.0	0.0	0.0	8.1	0.0	0.0	125.6	42.8
132	12-T2S-R19W	0.0	29.6	0.0	0.0	0.0	88.4	0.0	0.0	0.0	0.0	7.7	0.0	125.6	36.0
133	12-T2S-R19W	0.0	8.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	117.1	0.0	125.6	53.3
134	11-T2S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	38.6
135	11-T2S-R19W	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	122.0	0.0	123.1	48.2
136	10-T2S-R19W	0.0	0.0	0.0	0.0	0.0	28.9	0.0	0.0	0.0	0.0	26.4	0.0	55.3	48.6
137	10-T2S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	49.0
138	10-T2S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	49.4
139	10-T2S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	37.9
140	9-T2S-R19W	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	124.2	0.0	125.6	40.1
141	9-T2S-R19W	0.0	0.0	0.0	0.0	0.0	10.3	0.0	0.0	0.0	0.0	115.3	0.0	125.6	35.7
142	16-T2S-R19W	0.0	8.9	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	113.9	0.0	125.6	35.2
143	15-T2S-R19W	0.0	1.5	0.0	0.0	0.0	17.2	0.0	0.0	0.0	0.0	106.9	0.0	125.6	37.5
144	14-T2S-R19W	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	125.2	0.0	125.6	50.8
145	14-T2S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	36.8
146	13-T2S-R19W	0.0	49.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.1	0.0	125.6	35.7
147	12-T2S-R19W	0.0	31.6	0.0	0.0	0.0	78.7	0.0	0.0	0.0	0.0	15.4	0.0	125.6	36.3
148	12-T2S-R19W	0.0	13.3	0.0	0.0	0.0	20.5	0.0	0.0	0.0	0.0	91.8	0.0	125.6	38.4

Appendix 5. Continued

149	13-T2S-R19W	0.0	80.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.2	0.0	125.6	37.5
150	14-T2S-R19W	0.0	0.0	0.0	0.0	0.0	36.0	0.0	0.0	0.0	0.0	36.2	0.0	72.2	43.4
151	15-T2S-R19W	0.0	0.0	0.0	0.0	0.0	8.7	0.0	0.0	0.0	0.0	2.8	0.0	11.5	43.5
152	15-T2S-R19W	0.0	0.0	0.0	0.0	0.0	17.2	0.0	0.0	0.0	0.0	108.4	0.0	125.6	46.8
153	16-T2S-R19W	0.0	0.0	0.0	0.0	0.0	73.0	0.0	0.0	0.0	0.0	52.7	0.0	125.6	46.8
154	14-T2S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	47.8
155	13-T2S-R19W	0.0	22.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	102.8	0.0	125.6	47.2
156	13-T2S-R19W	0.0	81.3	0.0	0.0	0.0	10.5	0.0	0.0	0.0	0.0	33.9	0.0	125.6	47.6
157	22-T2S-R19W	0.0	0.0	0.0	0.0	0.0	17.5	0.0	0.0	0.0	0.0	108.1	0.0	125.6	43.8
158	23-T2S-R19W	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.0	0.0	82.5	47.1
159	23-T2S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	40.9
160	24-T2S-R19W	0.0	36.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	89.7	0.0	125.6	45.5
161	24-T2S-R19W	0.0	72.9	0.0	0.0	0.0	9.9	0.0	0.0	0.0	0.0	42.8	0.0	125.6	37.9
162	22-T2S-R19W	0.0	0.0	0.0	0.0	0.0	10.3	0.0	0.0	0.0	0.0	115.3	0.0	125.6	41.4
163	23-T2S-R19W	0.0	38.0	0.0	0.0	0.0	47.9	0.0	0.0	0.0	0.0	39.7	0.0	125.6	45.0
164	23-T2S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	53.4
165	23-T2S-R19W	0.0	25.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.8	0.0	125.6	57.0
166	24-T2S-R19W	0.0	100.9	0.0	0.0	0.0	18.0	0.0	0.0	0.0	6.7	0.0	0.0	125.6	47.7
167	26-T2S-R19W	0.0	86.5	0.0	0.0	0.0	39.1	0.0	0.0	0.0	0.0	0.0	0.0	125.6	56.1
168	26-T2S-R19W	0.0	19.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	106.1	0.0	125.6	56.1
169	25-T2S-R19W	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.9	102.4	0.0	125.6	43.9
170	25-T2S-R19W	0.0	51.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61.0	13.4	0.0	125.6	42.6
171	19-T2S-R18W	0.0	90.7	0.0	0.0	0.0	20.1	0.0	0.0	0.0	0.0	14.8	0.0	125.6	48.3
172	30-T2S-R18W	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.3	101.3	0.0	125.6	42.1
173	19-T2S-R18W	0.0	3.4	0.0	0.0	0.0	90.8	0.0	0.0	0.0	31.2	0.3	0.0	125.6	48.0
174	30-T2S-R18W	0.0	41.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64.4	20.0	0.0	125.6	41.4

Appendix 5. Continued

175	30-T2S-R18W	0.0	93.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.3	0.3	0.0	125.6	45.5
176	30-T2S-R18W	0.0	52.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49.9	23.6	0.0	125.6	36.8
177	25-T2S-R19W	0.0	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71.5	48.8	0.0	125.6	51.3
178	25-T2S-R19W	0.0	70.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.4	39.0	0.0	125.6	35.3
179	26-T2S-R19W	0.0	28.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1	88.2	0.0	125.6	35.5
180	26-T2S-R19W	0.0	82.0	0.0	0.0	0.0	43.7	0.0	0.0	0.0	0.0	0.0	0.0	125.6	40.6
181	27-T2S-R19W	0.0	0.0	0.0	0.0	0.0	51.4	0.0	0.0	0.0	0.0	74.2	0.0	125.6	33.1
182	27-T2S-R19W	0.0	0.0	0.0	0.0	0.0	74.0	0.0	0.0	0.0	0.0	51.6	0.0	125.6	36.4
183	27-T2S-R19W	0.0	0.0	0.0	0.0	0.0	64.6	0.0	0.0	0.0	0.0	61.0	0.0	125.6	33.8
184	27-T2S-R19W	0.0	0.0	0.0	0.0	0.0	58.2	0.0	0.0	0.0	0.0	67.4	0.0	125.6	37.7
185	34-T2S-R19W	0.0	0.0	0.0	0.0	0.0	28.9	0.0	0.0	0.3	0.0	96.5	0.0	125.6	34.6
186	34-T2S-R19W	0.0	31.7	0.0	0.0	0.0	17.2	0.0	0.0	0.0	43.1	33.7	0.0	125.6	38.7
187	35-T2S-R19W	0.0	26.6	0.0	0.0	0.0	20.9	0.0	0.0	0.0	78.1	0.0	0.0	125.6	41.2
188	35-T2S-R19W	0.0	113.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.9	0.0	0.0	125.6	51.1
189	36-T2S-R19W	0.0	38.9	0.0	0.0	0.0	30.5	0.0	0.0	0.0	56.2	0.0	0.0	125.6	42.5
190	36-T2S-R19W	0.0	82.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.5	0.0	0.0	125.6	46.0
191	24-T1S-R19W	0.0	0.0	0.0	0.0	0.0	11.8	0.0	0.0	0.0	0.0	113.8	0.0	125.6	50.7
192	24-T1S-R19W	0.0	0.0	0.0	0.0	0.0	37.5	0.0	0.0	0.0	6.8	81.3	0.0	125.6	44.3
193	24-T1S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	49.8
194	25-T1S-R19W	0.0	3.4	0.0	0.0	0.0	62.7	0.0	0.0	0.0	15.8	43.8	0.0	125.6	45.2
195	25-T1S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	45.1
196	25-T1S-R19W	0.0	7.1	0.0	0.0	0.0	49.4	0.0	0.0	0.0	12.4	48.5	0.0	117.4	42.2
197	25-T1S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	107.2	0.0	107.2	53.9
198	36-T1S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	52.3
199	36-T1S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	50.5
200	1-T2S-R19W	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	122.7	0.0	125.6	48.8

Appendix 5. Continued

201	1-T2S-R19W	0.0	68.8	0.0	0.0	0.0	21.1	0.0	0.0	0.0	0.0	35.7	0.0	125.6	46.8
202	6-T2S-R18W	0.0	6.4	0.0	0.0	0.0	4.7	0.0	0.0	0.0	0.0	114.6	0.0	125.6	44.7
203	6-T2S-R18W	0.0	0.0	0.0	0.0	15.0	65.1	0.0	0.0	0.0	0.0	45.6	0.0	125.6	47.6
204	31-T1S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	50.5
205	31-T1S-R18W	0.0	0.0	0.0	0.0	0.0	23.8	0.0	0.0	0.0	0.0	101.8	0.0	125.6	53.3
206	31-T1S-R18W	0.0	0.0	0.0	0.0	0.0	13.8	0.0	0.0	0.0	0.0	111.8	0.0	125.6	36.0
207	31-T1S-R18W	0.0	0.0	0.0	0.0	0.0	8.7	0.0	0.0	0.0	0.0	116.9	0.0	125.6	32.4
208	6-T2S-R18W	0.0	37.8	0.0	0.0	0.0	16.7	0.0	0.0	0.0	0.0	71.1	0.0	125.6	31.1
209	32-T1S-R18W	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	123.2	0.0	125.6	27.8
210	32-T1S-R18W	0.0	0.0	0.0	0.0	0.0	58.6	0.0	0.0	0.0	0.0	67.0	0.0	125.6	52.7
211	5-T2S-R18W	0.0	2.0	0.0	0.0	0.0	5.4	0.0	0.0	0.0	0.0	118.2	0.0	125.6	32.5
212	6-T2S-R18W	0.0	91.5	0.0	0.0	0.0	34.2	0.0	0.0	0.0	0.0	0.0	0.0	125.6	48.2
213	5-T2S-R18W	0.0	66.7	0.0	0.0	0.0	43.2	0.0	0.0	0.0	0.0	15.8	0.0	125.6	33.6
214	7-T2S-R18W	0.0	56.0	0.0	30.0	0.0	39.6	0.0	0.0	0.0	0.0	0.0	0.0	125.6	51.2
215	5-T2S-R18W	0.0	49.6	0.0	0.0	0.0	26.9	0.0	0.0	0.0	0.0	49.1	0.0	125.6	27.5
216	32-T1S-R18W	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	123.5	0.0	125.6	52.6
217	32-T1S-R18W	0.0	0.0	0.0	0.0	0.0	45.8	0.0	0.0	0.0	16.3	63.5	0.0	125.6	45.5
218	29-T1S-R18W	0.0	9.6	0.0	0.0	0.0	15.4	0.0	0.0	0.0	18.1	82.6	0.0	125.6	38.9
219	29-T1S-R18W	0.0	9.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	115.9	0.0	125.6	55.7
220	30-T1S-R18W	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	123.3	0.0	125.6	35.5
221	5-T2S-R18W	0.0	48.5	0.0	0.0	0.0	77.1	0.0	0.0	0.0	0.0	0.0	0.0	125.6	38.8
222	7-T2S-R18W	0.0	73.4	0.0	0.0	0.0	52.2	0.0	0.0	0.0	0.0	0.0	0.0	125.6	49.7
223	8-T2S-R18W	0.0	102.7	0.0	0.0	0.0	7.1	0.0	0.0	0.0	0.0	15.7	0.0	125.6	48.8
224	8-T2S-R18W	0.0	67.0	0.0	0.0	0.0	58.6	0.0	0.0	0.0	0.0	0.0	0.0	125.6	45.3
225	17-T2S-R18W	0.0	49.8	0.0	0.0	0.0	75.8	0.0	0.0	0.0	0.0	0.0	0.0	125.6	38.2
226	8-T2S-R18W	0.0	65.7	0.0	0.0	0.0	59.9	0.0	0.0	0.0	0.0	0.0	0.0	125.6	36.1

Appendix 5. Continued

227	17-T2S-R18W	0.0	99.1	0.0	0.0	0.0	26.5	0.0	0.0	0.0	0.0	0.0	0.0	125.6	37.5
228	17-T2S-R18W	0.0	51.9	0.0	0.0	0.0	73.7	0.0	0.0	0.0	0.0	0.0	0.0	125.6	35.7
229	17-T2S-R18W	0.0	64.7	0.0	0.0	0.0	61.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	37.8
230	16-T2S-R18W	0.0	107.8	0.0	2.9	0.0	14.9	0.0	0.0	0.0	0.0	0.0	0.0	125.6	35.4
231	20-T2S-R18W	0.0	63.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61.8	0.0	125.6	51.2
232	16-T2S-R18W	0.0	37.4	0.0	45.9	0.0	42.3	0.0	0.0	0.0	0.0	0.0	0.0	125.6	39.8
233	21-T2S-R18W	0.0	72.0	0.0	7.0	0.0	0.0	0.0	0.0	0.0	43.3	3.3	0.0	125.6	32.8
234	21-T2S-R18W	0.0	54.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.1	4.7	0.0	125.6	49.7
235	29-T2S-R18W	0.0	28.8	0.0	0.0	0.0	30.0	0.0	0.0	0.0	34.2	32.6	0.0	125.6	36.0
236	20-T2S-R18W	0.0	51.1	0.0	0.0	0.0	72.0	0.0	0.0	0.0	2.5	0.0	0.0	125.6	51.2
237	20-T2S-R18W	0.0	47.6	0.0	0.0	0.0	45.7	0.0	0.0	0.0	3.6	28.7	0.0	125.6	33.5
238	29-T2S-R18W	0.0	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.9	81.4	0.0	125.6	40.2
239	29-T2S-R18W	0.0	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.3	92.2	0.0	125.6	50.3
240	29-T2S-R18W	17.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.5	0.0	125.6	51.5
241	32-T2S-R18W	44.0	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.4	0.0	125.6	50.3
242	32-T2S-R18W	0.0	87.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.1	0.0	125.6	45.5
243	31-T2S-R18W	0.0	81.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.1	0.0	0.0	125.6	44.5
244	31-T2S-R18W	0.0	66.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59.4	0.0	0.0	125.6	42.8
245	36-T2S-R19W	0.0	98.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.2	0.0	0.0	125.6	46.4
246	36-T2S-R19W	0.0	99.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.0	0.0	0.0	125.6	42.6
247	35-T2S-R19W	0.0	71.0	0.0	0.0	0.0	25.2	0.0	0.0	0.0	29.4	0.0	0.0	125.6	48.1
248	31-T2S-R18W	0.0	0.0	0.0	0.0	0.0	57.3	0.0	0.0	0.0	68.3	0.0	0.0	125.6	60.4
249	31-T2S-R18W	0.0	95.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.3	10.0	0.0	125.6	54.2
250	32-T2S-R18W	48.0	73.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	125.6	48.6
251	32-T2S-R18W	102.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.4	0.0	125.6	62.0
252	9-T2S-R18W	0.0	69.6	0.0	0.0	0.0	56.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	60.5

Appendix 5. Continued

253	8-T2S-R18W	0.0	27.3	0.0	0.0	0.0	98.3	0.0	0.0	0.0	0.0	0.0	0.0	125.6	55.8
254	9-T2S-R18W	0.0	39.1	0.0	0.0	0.0	86.5	0.0	0.0	0.0	0.0	0.0	0.0	125.6	51.1
255	16-T2S-R18W	0.0	68.8	0.0	0.0	0.0	53.2	0.0	0.0	0.0	0.0	3.7	0.0	125.6	51.3
256	9-T2S-R18W	0.0	59.5	0.0	0.0	0.0	35.2	0.0	0.0	0.0	0.0	31.0	0.0	125.6	50.0
257	9-T2S-R18W	0.0	57.9	0.0	0.0	0.0	66.0	0.0	0.0	0.0	0.0	1.7	0.0	125.6	47.5
258	16-T2S-R18W	0.0	78.1	0.0	47.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	51.8
259	21-T2S-R18W	0.0	83.1	0.0	27.7	0.0	0.0	0.0	0.0	0.0	14.8	0.0	0.0	125.6	52.9
260	21-T2S-R18W	0.0	84.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.5	0.0	0.0	125.6	52.1
261	28-T2S-R18W	0.0	6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.9	79.7	0.0	125.6	49.9
262	28-T2S-R18W	0.0	46.3	0.0	0.0	0.0	33.0	0.0	0.0	0.0	38.0	8.3	0.0	125.6	41.3
263	28-T2S-R18W	0.0	26.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.6	74.4	0.0	125.6	40.5
264	28-T2S-R18W	0.0	57.9	0.0	0.0	0.0	67.7	0.0	0.0	0.0	0.0	0.0	0.0	125.6	42.0
265	15-T2S-R18W	0.0	28.5	0.0	15.3	0.0	81.8	0.0	0.0	0.0	0.0	0.0	0.0	125.6	41.8
266	15-T2S-R18W	0.0	108.7	0.0	0.7	0.0	16.2	0.0	0.0	0.0	0.0	0.0	0.0	125.6	40.7
267	10-T2S-R18W	0.0	52.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	73.1	0.0	125.6	41.2
268	10-T2S-R18W	0.0	82.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.9	0.0	125.6	56.7
269	22-T2S-R18W	0.0	81.9	0.0	0.0	0.0	43.7	0.0	0.0	0.0	0.0	0.0	0.0	125.6	40.7
270	34-T2S-R19W	0.0	9.6	0.0	0.0	0.0	1.6	0.0	0.0	12.7	0.0	101.8	0.0	125.6	41.8
271	34-T2S-R19W	0.0	65.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53.9	5.8	0.0	125.6	45.2
272	35-T2S-R19W	0.0	15.9	0.0	0.0	0.0	40.1	0.0	0.0	0.0	69.6	0.0	0.0	125.6	39.2
273	3-T3S-R19W	0.0	72.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.7	0.0	125.6	42.5
274	3-T3S-R19W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.2	0.0	116.4	0.0	125.6	40.0
275	3-T3S-R19W	13.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	2.6	107.1	0.0	125.6	44.6
276	3-T3S-R19W	0.0	10.8	0.0	0.0	0.0	38.2	0.0	0.0	0.0	0.0	76.6	0.0	125.6	44.2
277	2-T3S-R19W	0.0	73.6	0.0	0.0	0.0	45.7	0.0	0.0	0.0	5.2	1.1	0.0	125.6	55.3
278	2-T3S-R19W	0.0	63.7	0.0	0.0	0.0	2.6	0.0	0.0	0.0	1.4	58.0	0.0	125.6	67.5

Appendix 5. Continued

279	2-T3S-R19W	0.0	55.0	0.0	0.0	0.0	43.7	0.0	0.0	0.5	26.5	0.0	0.0	125.6	64.7
280	1-T3S-R19W	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	40.6
281	1-T3S-R19W	0.0	88.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.9	0.0	0.0	125.6	51.9
282	6-T3S-R18W	0.0	23.6	0.0	0.0	0.0	39.4	0.0	0.0	0.0	62.6	0.0	0.0	125.6	50.4
283	6-T3S-R18W	0.0	24.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	101.4	0.0	125.6	44.0
284	5-T3S-R18W	92.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.0	0.0	125.6	40.9
285	5-T3S-R18W	72.4	11.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.0	0.0	125.6	44.7
286	6-T3S-R18W	0.0	92.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2	26.7	0.0	125.6	41.2
287	1-T3S-R19W	0.0	35.1	0.0	0.0	0.0	32.3	0.0	0.0	0.0	58.2	0.0	0.0	125.6	39.7
288	1-T3S-R19W	0.0	51.2	0.0	30.6	0.0	43.4	0.0	0.0	0.0	0.5	0.0	0.0	125.6	38.6
289	11-T3S-R19W	0.0	33.2	0.0	0.0	0.0	21.7	0.0	0.0	0.0	0.0	70.7	0.0	125.6	40.4
290	11-T3S-R19W	0.0	0.5	0.0	0.0	0.0	41.4	0.0	0.0	0.0	0.0	83.7	0.0	125.6	31.1
291	14-T3S-R19W	0.0	34.0	0.0	0.0	0.0	35.4	0.0	0.0	0.0	0.0	56.3	0.0	125.6	33.0
292	14-T3S-R19W	0.0	0.0	0.0	0.0	0.0	52.7	0.0	0.0	0.0	0.0	72.9	0.0	125.6	29.8
293	6-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	30.1
294	7-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	49.9
295	7-T3S-R18W	0.0	65.8	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	59.0	0.0	125.6	51.2
296	7-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	53.7
297	7-T3S-R18W	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	123.6	0.0	125.6	43.1
298	18-T3S-R18W	0.0	0.8	0.0	0.0	0.0	37.5	0.0	0.0	0.0	0.0	87.4	0.0	125.6	44.6
299	18-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	122.4	0.0	125.6	40.3
300	18-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.7	0.0	104.9	0.0	125.6	43.3
301	18-T3S-R18W	0.0	63.9	0.0	0.0	0.0	28.4	0.0	0.0	0.0	0.0	33.4	0.0	125.6	38.5
302	19-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	40.3
303	19-T3S-R18W	0.0	10.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.4	69.5	0.0	125.6	32.3
304	30-T3S-R18W	0.0	66.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58.1	1.5	0.0	125.6	36.0

Appendix 5. Continued

305	30-T3S-R18W	0.0	78.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.1	0.0	0.0	125.6	30.3
306	30-T3S-R18W	0.0	79.9	0.0	0.0	0.0	26.5	0.0	0.0	0.0	19.2	0.0	0.0	125.6	33.2
307	31-T3S-R18W	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	43.7
308	36-T3S-R19W	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	36.7
309	36-T3S-R19W	0.0	71.7	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	53.0	0.0	125.6	50.2
310	35-T3S-R19W	0.0	42.2	0.0	0.0	0.0	22.2	0.0	0.2	0.0	53.9	7.1	0.0	125.6	45.1
311	35-T3S-R19W	0.0	0.1	0.0	0.0	0.0	98.3	14.9	12.3	0.0	0.0	0.0	0.0	125.6	41.3
312	25-T3S-R19W	0.0	105.9	0.0	0.0	0.0	19.8	0.0	0.0	0.0	0.0	0.0	0.0	125.6	43.5
313	25-T3S-R19W	0.0	96.7	0.0	0.0	0.0	28.9	0.0	0.0	0.0	0.0	0.0	0.0	125.6	38.7
314	24-T3S-R19W	0.0	97.7	0.0	0.0	0.0	27.9	0.0	0.0	0.0	0.0	0.0	0.0	125.6	37.9
315	24-T3S-R19W	0.0	119.3	0.0	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0	0.0	125.6	35.8
316	23-T3S-R19W	0.0	71.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54.5	0.0	125.6	37.2
317	26-T3S-R19W	0.0	53.5	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	70.4	0.0	125.6	34.6
318	36-T3S-R19W	0.0	9.4	0.0	0.0	0.0	115.9	0.0	0.3	0.0	0.0	0.0	0.0	125.6	34.8
319	36-T3S-R19W	0.0	5.0	0.0	0.0	0.0	120.6	0.0	0.0	0.0	0.0	0.0	0.0	125.6	30.3
320	1-T4S-R19W	7.5	0.0	0.0	0.0	0.0	112.1	0.0	6.1	0.0	0.0	0.0	0.0	125.6	42.8
321	31-T3S-R18W	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	36.9
322	32-T3S-R18W	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	50.7
323	29-T3S-R18W	0.0	110.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.1	0.0	0.0	125.6	52.5
324	29-T3S-R18W	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49.8	72.6	0.0	125.6	45.3
325	20-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	46.2
326	20-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	41.8
327	5-T3S-R18W	56.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69.7	0.0	125.6	43.5
328	8-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	37.8
329	8-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	36.2
330	17-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	38.0

Appendix 5. Continued

331	17-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	35.0
332	20-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	36.2
333	17-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	29.7
334	17-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	33.4
335	20-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	29.9
336	8-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	35.8
337	8-T3S-R18W	0.0	54.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.4	58.3	0.0	125.6	34.1
338	5-T3S-R18W	0.7	66.6	0.0	0.0	0.0	15.4	0.0	0.0	0.0	0.0	43.0	0.0	125.6	35.2
339	4-T3S-R18W	0.0	45.5	0.0	0.0	0.0	76.4	0.0	0.0	0.0	0.0	3.7	0.0	125.6	39.2
340	4-T3S-R18W	0.0	23.6	0.0	0.0	0.0	44.3	0.0	0.0	0.0	57.7	0.0	0.0	125.6	38.9
341	9-T3S-R18W	0.0	1.7	0.0	0.0	51.5	0.0	0.0	0.0	0.0	65.4	7.0	0.0	125.6	42.4
342	9-T3S-R18W	0.0	0.0	0.0	0.0	2.1	28.0	0.0	0.0	0.0	62.7	32.9	0.0	125.6	42.4
343	16-T3S-R18W	0.0	0.0	0.0	0.0	0.0	51.7	0.0	0.0	0.0	53.9	20.1	0.0	125.6	35.4
344	16-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.4	109.3	0.0	125.6	38.6
345	9-T3S-R18W	0.0	17.9	0.0	0.0	29.0	7.0	0.0	0.0	0.0	71.5	0.2	0.0	125.6	33.3
346	9-T3S-R18W	0.0	26.1	0.0	0.0	0.0	47.8	0.0	0.0	0.0	24.4	27.4	0.0	125.6	38.3
347	16-T3S-R18W	9.1	0.0	0.0	0.0	0.0	6.5	0.0	0.0	0.0	54.2	55.8	0.0	125.6	36.9
348	16-T3S-R18W	72.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.6	42.3	0.0	125.6	33.6
349	21-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	42.4
350	21-T3S-R18W	64.8	0.0	0.0	0.0	0.0	27.5	0.0	0.0	0.0	0.0	33.3	0.0	125.6	32.3
351	21-T3S-R18W	17.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	107.8	0.0	125.6	11.8
352	21-T3S-R18W	83.1	0.0	0.0	0.0	7.2	24.9	0.0	0.0	0.0	0.0	3.5	0.0	118.7	11.0
353	28-T3S-R18W	111.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.6	0.0	125.6	47.2
354	29-T3S-R18W	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.2	112.6	0.0	125.6	49.3
355	28-T3S-R18W	63.8	0.0	0.0	0.0	1.1	10.9	0.0	0.0	0.0	24.0	1.5	0.0	101.3	41.5
356	28-T3S-R18W	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	37.7

Appendix 5. Continued

357	29-T3S-R18W	2.0	60.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63.0	0.0	125.6	38.0
358	28-T3S-R18W	88.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.8	0.0	125.6	35.0
359	27-T3S-R18W	0.0	0.0	0.0	0.0	1.3	24.0	0.0	0.0	0.0	36.1	64.2	0.0	125.6	39.4
360	27-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.4	124.6	0.0	125.6	16.1
361	27-T3S-R18W	21.9	0.0	0.0	0.0	0.0	0.0	7.1	0.0	0.0	0.0	96.6	0.0	125.6	32.3
362	27-T3S-R18W	0.0	0.0	0.0	0.0	0.0	13.6	0.0	0.0	0.0	0.0	112.1	0.0	125.6	37.2
363	26-T3S-R18W	88.0	0.0	0.0	0.0	0.0	24.6	13.1	0.0	0.0	0.0	0.0	0.0	125.6	32.0
364	15-T3S-R18W	45.6	7.7	0.0	0.0	0.0	72.2	0.0	0.0	0.0	0.0	0.0	0.0	125.6	33.5
365	15-T3S-R18W	15.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	110.5	0.0	125.6	19.9
366	10-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	36.3
367	10-T3S-R18W	0.0	0.0	0.0	0.0	0.0	3.9	0.0	0.0	0.0	14.9	106.8	0.0	125.6	40.7
368	3-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	119.5	0.0	119.5	34.8
369	4-T3S-R18W	0.0	10.2	0.0	0.0	42.7	0.0	0.0	0.0	0.0	60.1	12.6	0.0	125.6	39.2
370	4-T3S-R18W	0.0	51.1	0.0	0.0	17.8	5.0	0.0	0.0	0.0	51.7	0.0	0.0	125.6	31.3
371	3-T3S-R18W	0.0	0.0	0.0	0.0	18.6	0.0	0.0	0.0	0.0	37.3	63.5	0.0	119.4	42.3
372	3-T3S-R18W	0.0	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.2	0.0	67.3	52.1
373	2-T3S-R18W	59.6	1.2	0.0	0.0	0.0	0.0	20.5	0.0	0.0	0.0	44.3	0.0	125.6	52.8
374	3-T3S-R18W	29.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.4	0.0	119.5	40.0
375	10-T3S-R18W	25.3	11.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	89.0	0.0	125.6	54.6
376	10-T3S-R18W	0.0	56.3	0.0	0.0	0.0	32.3	0.0	0.0	0.0	0.0	37.0	0.0	125.6	46.4
377	15-T3S-R18W	25.1	30.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.1	0.0	125.6	38.3
378	22-T3S-R18W	30.5	71.7	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	22.7	0.0	125.6	47.6
379	23-T3S-R18W	74.7	49.1	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	125.6	39.7
380	23-T3S-R18W	122.4	2.9	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	125.6	34.4
381	26-T3S-R18W	108.0	0.0	0.0	0.0	0.0	0.0	17.7	0.0	0.0	0.0	0.0	0.0	125.6	34.5
382	26-T3S-R18W	120.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	0.0	125.6	37.9

Appendix 5. Continued

383	26-T3S-R18W	26.6	0.0	0.0	0.0	0.0	6.5	71.3	0.0	0.0	0.0	21.2	0.0	125.6	44.6
384	34-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	38.4	86.4	0.0	125.6	51.2
385	34-T3S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	123.9	0.0	125.6	49.3
386	33-T3S-R18W	17.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.1	98.5	0.0	125.6	54.8
387	33-T3S-R18W	9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	116.3	0.0	125.6	48.9
388	32-T3S-R18W	0.0	96.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.0	0.0	125.6	42.9
389	32-T3S-R18W	0.0	0.7	0.0	0.0	0.0	50.7	0.0	0.0	0.0	0.0	74.2	0.0	125.6	44.4
390	32-T3S-R18W	0.0	22.5	0.0	0.0	0.0	11.1	0.0	0.0	0.0	0.0	92.0	0.0	125.6	38.1
391	33-T3S-R18W	0.0	0.0	0.0	0.0	0.0	8.7	0.0	0.0	0.0	0.0	116.9	0.0	125.6	39.5
392	5-T4S-R18W	0.0	0.0	0.0	0.0	0.0	101.2	0.0	0.0	0.0	0.0	24.5	0.0	125.6	33.0
393	5-T4S-R18W	0.0	0.0	0.0	0.0	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	125.6	33.7
394	31-T3S-R18W	0.0	32.7	0.0	0.0	0.0	91.4	0.0	0.0	0.0	0.0	1.5	0.0	125.6	35.5
395	31-T3S-R18W	0.0	19.2	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	98.4	0.0	125.6	32.5
396	3-T4S-R18W	0.0	0.0	0.0	0.0	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	125.6	30.6
397	3-T4S-R18W	0.0	0.0	0.0	0.0	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	125.6	41.1
398	4-T4S-R18W	0.0	0.0	0.0	0.0	0.0	123.4	0.0	0.0	0.0	0.0	2.2	0.0	125.6	50.2
399	35-T3S-R18W	39.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	75.6	0.0	125.6	40.4
400	25-T3S-R18W	101.2	0.0	0.0	0.0	0.0	24.4	0.0	0.0	0.0	0.0	0.0	0.0	125.6	41.4
401	36-T3S-R18W	37.3	11.4	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	73.3	0.0	125.6	33.1
402	25-T3S-R18W	47.5	0.0	0.0	0.0	0.0	33.1	0.0	0.0	39.2	5.1	0.7	0.0	125.6	33.5
403	36-T3S-R18W	0.0	82.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.9	0.0	125.6	23.8
404	35-T3S-R18W	0.0	0.0	0.0	0.0	0.0	38.7	0.0	0.0	0.0	0.0	86.9	0.0	125.6	30.7
405	36-T3S-R18W	0.0	13.8	0.0	0.0	0.0	34.2	0.0	0.0	0.0	8.8	68.9	0.0	125.6	36.0
406	30-T3S-R17W	121.3	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0	1.2	0.0	125.6	35.4
407	25-T3S-R18W	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	39.9
408	25-T3S-R18W	44.0	0.0	0.0	0.0	0.0	26.9	0.0	0.0	0.0	13.3	41.4	0.0	125.6	47.4

Appendix 5. Continued

409	30-T3S-R17W	57.0	0.0	0.0	0.0	0.0	25.7	0.0	0.0	0.0	19.8	23.0	0.0	125.6	45.7
410	30-T3S-R17W	0.0	10.9	0.0	0.0	0.0	28.1	0.0	0.0	7.6	0.0	77.3	1.8	125.6	50.7
411	30-T3S-R17W	0.0	1.0	0.0	0.0	0.0	31.9	0.0	0.0	5.4	0.0	87.4	0.0	125.6	47.3
412	2-T4S-R18W	0.0	0.0	0.0	0.0	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	125.6	51.5
413	11-T3S-R18W	14.4	93.6	0.0	0.0	0.0	17.6	0.0	0.0	0.0	0.0	0.0	0.0	125.6	36.4
414	2-T3S-R18W	117.6	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	37.4
415	14-T3S-R18W	0.0	120.8	0.0	0.0	0.0	4.9	0.0	0.0	0.0	0.0	0.0	0.0	125.6	35.5
416	13-T3S-R18W	50.4	47.4	0.0	0.0	0.0	27.8	0.0	0.0	0.0	0.0	0.0	0.0	125.6	36.6
417	13-T3S-R18W	112.0	12.6	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	35.9
418	24-T3S-R18W	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	35.8
419	24-T3S-R18W	95.5	0.0	0.0	0.0	0.0	0.0	22.7	0.0	0.0	0.0	0.0	7.5	125.6	29.8
420	24-T3S-R18W	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	36.6
421	24-T3S-R18W	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	41.6
422	34-T2S-R18W	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	27.4	97.7	0.0	125.6	45.0
423	34-T2S-R18W	0.0	1.1	0.0	0.0	19.7	0.0	0.0	0.0	0.0	104.0	0.8	0.0	125.6	41.4
424	27-T2S-R18W	0.0	12.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.9	37.1	0.0	125.6	43.9
425	27-T2S-R18W	0.0	22.1	0.0	0.0	0.0	73.8	0.0	0.0	0.0	29.7	0.0	0.0	125.6	39.2
426	34-T2S-R18W	10.5	47.9	0.0	0.0	2.5	43.6	0.0	0.0	0.0	21.1	0.0	0.0	125.6	36.0
427	27-T2S-R18W	0.0	0.0	0.0	0.0	36.1	0.0	0.0	0.0	0.0	76.3	13.2	0.0	125.6	35.2
428	23-T2S-R18W	0.0	46.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.3	3.3	0.0	125.6	38.4
429	26-T2S-R18W	15.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.5	62.2	0.0	105.5	35.6
430	26-T2S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72.0	0.0	72.0	37.7
431	23-T2S-R18W	88.8	0.0	0.0	0.0	0.0	17.6	0.0	0.0	0.0	12.2	7.0	0.0	125.6	35.4
432	26-T2S-R18W	104.2	0.0	0.0	0.0	0.0	0.0	6.3	0.0	0.0	0.0	0.4	0.0	110.9	30.5
433	24-T1S-R19W	0.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	121.2	0.0	125.6	36.0
434	19-T1S-R18W	0.0	72.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53.3	0.0	125.6	35.8

Appendix 5. Continued

435	19-T1S-R18W	0.0	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.0	96.6	0.0	125.6	40.3
436	19-T1S-R18W	0.0	101.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.0	0.0	0.0	125.6	35.2
437	30-T1S-R18W	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	121.3	0.0	125.6	38.8
438	30-T1S-R18W	0.0	105.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	16.1	0.0	125.6	37.9
439	29-T1S-R18W	0.0	125.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	125.6	40.1
440	29-T1S-R18W	0.0	45.7	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.0	76.1	0.0	125.6	40.8
441	22-T1S-R18W	0.0	0.0	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	46.7
442	28-T1S-R18W	0.0	20.1	0.0	0.0	0.0	12.6	0.0	0.0	0.0	56.6	36.3	0.0	125.6	44.5
443	28-T1S-R18W	0.0	14.2	0.0	0.0	0.0	13.1	0.0	0.0	0.0	9.5	88.8	0.0	125.6	48.3
444	28-T1S-R18W	0.0	0.0	0.0	0.0	0.0	70.7	0.0	0.0	0.0	0.0	54.9	0.0	125.6	41.6
445	28-T1S-R18W	0.0	48.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.8	0.0	125.6	44.6
446	33-T1S-R18W	0.0	0.0	0.0	0.0	0.0	22.3	0.0	0.0	0.0	0.0	103.3	0.0	125.6	40.9
447	33-T1S-R18W	0.0	62.9	0.0	0.0	0.0	11.1	0.0	0.0	0.0	0.0	51.6	0.0	125.6	42.6
448	33-T1S-R18W	10.3	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	112.3	0.0	125.6	42.2
449	4-T2S-R18W	0.0	0.0	0.0	0.0	0.0	12.8	0.0	0.0	0.0	0.0	112.8	0.0	125.6	44.6
450	4-T2S-R18W	0.0	64.1	0.0	0.0	0.0	61.1	0.0	0.0	0.0	0.0	0.5	0.0	125.6	43.8
451	4-T2S-R18W	0.0	35.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	89.9	0.0	125.6	36.7
452	4-T2S-R18W	0.0	33.4	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	90.2	0.0	125.6	40.2
453	3-T2S-R18W	0.0	41.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	83.9	0.0	125.6	35.6
454	3-T2S-R18W	0.0	41.5	0.0	0.0	0.0	8.4	0.0	0.0	0.0	0.0	75.8	0.0	125.6	39.7
455	20-T1S-R18W	0.0	41.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	84.2	0.0	125.6	48.7
456	20-T1S-R18W	0.0	96.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.5	0.0	0.0	125.6	49.7
457	21-T1S-R18W	0.0	92.1	0.0	24.3	0.0	0.0	0.0	0.0	0.0	0.0	9.2	0.0	125.6	50.6
458	22-T1S-R18W	0.0	47.9	0.0	77.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	51.7
459	16-T1S-R18W	29.4	11.8	0.0	84.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	50.9
460	10-T1S-R18W	0.0	0.0	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	53.6

Appendix 5. Continued

461	10-T1S-R18W	0.0	0.0	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	52.5
462	16-T1S-R18W	0.0	23.5	0.0	102.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	54.0
463	15-T1S-R18W	0.0	0.0	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	50.5
464	15-T1S-R18W	16.5	0.0	0.0	109.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	55.0
465	10-T1S-R18W	1.5	0.0	0.0	124.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	40.2
466	15-T1S-R18W	0.0	0.0	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	52.2
467	14-T1S-R18W	0.0	17.8	0.0	107.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	56.1
468	14-T1S-R18W	0.0	51.8	0.0	73.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	47.2
469	14-T1S-R18W	0.0	96.6	0.0	29.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	52.5
470	14-T1S-R18W	13.5	9.4	0.0	102.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	44.7
471	11-T1S-R18W	4.6	0.0	0.0	121.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	46.3
472	11-T1S-R18W	7.4	0.0	0.0	118.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	42.4
473	10-T1S-R18W	2.2	0.0	0.0	123.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	45.3
474	9-T1S-R18W	0.0	0.0	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	41.6
475	9-T1S-R18W	0.0	0.0	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	45.2
476	16-T1S-R18W	0.0	16.3	0.0	109.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	35.6
477	21-T1S-R18W	0.0	61.8	0.0	63.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	43.1
478	22-T1S-R18W	11.6	0.0	0.0	114.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	39.0
479	22-T1S-R18W	0.0	0.5	0.0	125.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	44.2
480	23-T1S-R18W	0.0	58.7	0.0	66.5	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	125.6	40.5
481	27-T1S-R18W	0.0	72.9	0.0	19.5	0.0	33.2	0.0	0.0	0.0	0.0	0.0	0.0	125.6	41.4
482	23-T1S-R18W	0.0	71.6	0.0	0.0	0.0	54.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	51.8
483	26-T1S-R18W	0.0	115.5	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	8.8	0.0	125.6	56.0
484	26-T1S-R18W	0.0	46.8	0.0	0.0	0.0	14.8	0.0	0.0	0.0	0.0	64.0	0.0	125.6	54.9
485	27-T1S-R18W	0.0	103.9	0.0	0.0	0.0	21.7	0.0	0.0	0.0	0.0	0.0	0.0	125.6	55.1
486	13-T1S-R18W	0.0	19.1	0.0	50.7	0.0	54.1	0.0	0.0	0.2	0.0	0.0	0.0	125.6	52.5

Appendix 5. Continued

487	13-T1S-R18W	0.0	0.4	0.0	45.0	12.5	49.7	0.0	0.0	4.9	0.0	0.0	0.0	125.6	50.7
488	24-T1S-R18W	0.0	54.7	0.0	16.4	0.0	54.6	0.0	0.0	0.0	0.0	0.0	0.0	125.6	36.9
489	23-T1S-R18W	0.0	33.7	0.0	91.8	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	125.6	50.9
490	23-T1S-R18W	0.0	65.3	0.0	8.8	0.0	44.0	0.0	0.0	0.0	0.0	7.6	0.0	125.6	47.7
491	24-T1S-R18W	0.0	69.1	0.0	32.7	0.0	23.8	0.0	0.0	0.0	0.0	0.0	0.0	125.6	48.2
492	13-T1S-R18W	0.0	125.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	45.9
493	13-T1S-R18W	0.0	84.1	0.0	9.4	0.0	32.1	0.0	0.0	0.0	0.0	0.0	0.0	125.6	44.7
494	11-T2S-R18W	0.0	15.2	0.0	0.0	0.0	17.1	0.0	0.0	0.0	0.0	93.3	0.0	125.6	43.0
495	10-T2S-R18W	0.0	2.0	0.0	0.1	0.0	65.8	0.0	0.0	0.0	0.0	57.6	0.0	125.6	52.8
496	3-T2S-R18W	0.0	0.0	0.0	0.0	0.0	31.1	0.0	0.0	0.0	0.0	94.5	0.0	125.6	56.1
497	3-T2S-R18W	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	124.7	0.0	125.6	40.2
498	34-T1S-R18W	0.0	52.1	0.0	0.0	0.0	9.7	0.0	0.0	0.0	0.0	63.9	0.0	125.6	39.6
499	34-T1S-R18W	21.0	7.1	0.0	0.0	0.0	28.1	0.0	0.0	0.0	0.0	69.4	0.0	125.6	42.9
500	34-T1S-R18W	0.5	116.2	0.0	0.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	45.1
501	27-T1S-R18W	0.0	96.3	0.0	0.0	0.0	9.9	0.0	0.0	0.0	0.0	19.5	0.0	125.6	48.0
502	34-T1S-R18W	0.0	98.2	0.0	0.0	0.0	27.4	0.0	0.0	0.0	0.0	0.0	0.0	125.6	52.0
503	35-T1S-R18W	0.0	79.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.3	0.0	125.6	51.4
504	35-T1S-R18W	34.7	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	89.1	0.0	125.6	50.2
505	26-T1S-R18W	1.7	31.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.7	0.0	125.6	36.7
506	26-T1S-R18W	0.0	57.0	0.0	0.0	0.0	12.0	0.0	0.0	0.0	0.0	56.6	0.0	125.6	50.1
507	25-T1S-R18W	0.0	83.0	0.0	0.0	0.0	17.6	0.0	0.0	0.0	0.0	25.0	0.0	125.6	48.0
508	25-T1S-R18W	32.4	69.6	0.0	0.0	0.0	23.6	0.0	0.0	0.0	0.0	0.0	0.0	125.6	52.5
509	36-T1S-R18W	66.4	54.7	0.0	3.9	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	125.6	55.7
510	36-T1S-R18W	67.2	41.3	0.0	9.6	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0	125.6	72.0
511	35-T1S-R18W	60.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64.8	0.0	125.6	54.3
512	2-T2S-R18W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	125.6	65.7

Appendix 5. Continued

513	2-T2S-R18W	5.9	36.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	83.3	0.0	125.6	40.0
514	2-T2S-R18W	35.1	3.4	0.0	0.0	0.0	23.9	0.0	0.0	0.0	32.2	31.1	0.0	125.6	35.1
515	1-T2S-R18W	27.4	14.6	0.0	0.0	0.0	11.3	3.6	0.0	0.0	14.2	44.9	0.0	125.6	38.5
516	36-T1S-R18W	34.0	21.7	0.0	0.0	0.0	20.3	0.0	0.0	0.0	0.0	49.6	0.0	125.6	29.9
517	36-T1S-R18W	71.0	43.6	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	44.9
518	25-T1S-R18W	107.9	0.0	0.0	0.0	0.0	17.7	0.0	0.0	0.0	0.0	0.0	0.0	125.6	33.1
519	11-T1S-R18W	0.0	39.9	0.0	85.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	33.1
520	12-T1S-R18W	17.1	0.0	0.0	108.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	51.0
521	12-T1S-R18W	31.3	0.0	0.0	94.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	50.9
522	12-T1S-R18W	0.0	25.0	0.0	89.6	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	54.2
523	12-T1S-R18W	19.9	55.5	0.0	50.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	56.4
524	20-T1S-R18W	0.0	50.0	0.0	64.8	0.0	0.0	0.0	0.0	0.0	10.9	0.0	0.0	125.6	51.1
525	20-T1S-R18W	0.0	93.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.3	0.0	125.6	50.6
526	21-T1S-R18W	0.0	77.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.8	15.0	0.0	125.6	45.0
527	21-T1S-R18W	0.0	41.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54.6	30.0	0.0	125.6	45.8
528	21-T2N-R17W	0.0	69.3	0.0	0.0	0.0	0.0	0.0	56.3	0.0	0.0	0.0	0.0	125.6	41.7
529	22-T2N-R17W	0.0	48.7	0.0	0.0	0.0	0.0	0.0	40.0	36.9	0.0	0.0	0.0	125.6	44.5
530	9-T2N-R17W	0.0	96.9	0.0	0.0	0.0	0.0	0.0	28.7	0.0	0.0	0.0	0.0	125.6	42.5
531	10-T2N-R17W	0.7	105.0	0.0	0.0	0.0	0.0	0.0	8.5	11.4	0.0	0.0	0.0	125.6	45.7
532	10-T2N-R17W	27.2	13.6	0.0	0.0	0.0	0.0	0.0	13.0	71.8	0.0	0.0	0.0	125.6	35.1
533	2-T2N-R17W	36.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	86.0	0.0	0.0	0.0	125.6	40.6
534	2-T2N-R17W	0.0	42.4	0.0	0.0	0.0	0.0	0.0	0.0	83.2	0.0	0.0	0.0	125.6	39.0
535	2-T2N-R17W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.6	0.0	0.0	0.0	125.6	38.1
536	35-T3N-R17W	28.4	18.0	0.0	0.0	0.0	0.0	0.0	25.7	53.6	0.0	0.0	0.0	125.6	35.4
537	19-T1N-R18W	0.0	125.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	125.6	45.3
538	33-T2S-R18W	0.0	34.9	0.0	0.0	0.0	53.8	0.0	0.0	0.0	0.0	36.9	0.0	125.6	35.1

Appendix 5. Continued

539	33-T2S-R18W	0.0	58.1	0.0	0.0	0.0	3.5	0.0	0.0	0.0	11.4	52.7	0.0	125.6	37.1
540	33-T2S-R18W	0.0	39.8	0.0	0.0	0.0	17.6	0.0	0.0	0.0	68.3	0.0	0.0	125.6	38.2
541	33-T2S-R18W	0.0	44.8	0.0	0.0	0.0	70.5	0.0	0.0	0.0	10.3	0.0	0.0	125.6	36.7
542	2-T3S-R19W	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	72.5	47.2	0.0	0.0	125.6	40.6
543	33-T2N-R17W	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	53.9	0.0	0.0	0.3	58.4	42.9

Appendix 6. Annual pipeline cost per linear foot for different pipe sizes.

GPM	600	1200	1800	2400	3000	3600	4200	4800	5400	6000	6600	7200	7800	8400	9000	9600	10200	10800	11400
Diameter (in)					**Annual Cost of Pipeline (in hundred dollars)**														
6	$1.5	$3.2	$5.9	$9.5	$14.0	$19.2	$25.3	$32.2	$39.8	$48.3	$57.4	$67.3	$77.9	$89.3	$101.3	$114.1	$127.6	$141.7	$156.6
8	$1.0	$1.4	$2.1	$3.0	$4.1	$5.4	$6.9	$8.5	$10.4	$12.5	$14.8	$17.2	$19.8	$22.6	$25.6	$28.7	$32.0	$35.5	$39.2
10	$0.9	$1.0	$1.2	$1.5	$1.9	$2.3	$2.8	$3.4	$4.1	$4.8	$5.5	$6.3	$7.2	$8.2	$9.2	$10.2	$11.3	$12.5	$13.8
12	$0.8	$0.9	$1.0	$1.1	$1.3	$1.4	$1.7	$1.9	$2.1	$2.4	$2.7	$3.1	$3.5	$3.8	$4.3	$4.7	$5.1	$5.6	$6.1
14	$0.8	$0.9	$0.9	$1.0	$1.0	$1.1	$1.2	$1.3	$1.4	$1.6	$1.7	$1.9	$2.1	$2.2	$2.4	$2.6	$2.9	$3.1	$3.3
16	$0.8	$0.8	$0.9	$0.9	$0.9	$1.0	$1.0	$1.1	$1.1	$1.2	$1.3	$1.4	$1.5	$1.6	$1.7	$1.8	$1.9	$2.0	$2.1
18	$0.8	$0.8	$0.8	$0.9	$0.9	$0.9	$0.9	$1.0	$1.0	$1.0	$1.1	$1.1	$1.2	$1.2	$1.3	$1.4	$1.4	$1.5	$1.6
20	$0.8	$0.8	$0.8	$0.8	$0.9	$0.9	$0.9	$0.9	$0.9	$0.9	$1.0	$1.0	$1.0	$1.1	$1.1	$1.1	$1.2	$1.2	$1.3
24	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.9	$0.9	$0.9	$0.9	$0.9	$0.9	$0.9	$0.9	$0.9	$1.0	$1.0	$1.0
30	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.9	$0.9	$0.9	$0.9	$0.9
36	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8

Appendix 7. Annual pumping cost (calculated using EGC formula 3) for different diameters of pipe at different water demand.

GPM	**600**	**1200**	**1800**	**2400**	**3000**	**3600**	**4200**	**4800**	**5400**	**6000**	**6600**	**7200**	**7800**	**8400**	**9000**	**9600**	**10200**	**10800**	**11400**
Diameter (in)	**Annual Cost per acre (in thousand dollars)**																		
6	$4.1	$18.0	$50	$106	$195	$323	$496	$721	$1,003	$1,350	$1,767	$2,260	$2,835	$3,497	$4,253	$5,108	$6,067	$7,137	$8,322
8	$2.7	$7.8	$17	$33	$57	$90	$134	$191	$262	$350	$454	$577	$720	$885	$1,073	$1,286	$1,524	$1,789	$2,083
10	$2.4	$5.6	$10	$17	$27	$39	$56	$76	$102	$133	$170	$213	$263	$320	$385	$458	$539	$630	$731
12	$2.3	$5.0	$8	$12	$18	$24	$32	$42	$54	$68	$84	$103	$125	$150	$178	$210	$245	$283	$326
14	$2.3	$4.7	$7	$11	$14	$19	$24	$29	$36	$44	$53	$63	$75	$88	$102	$118	$136	$155	$177
16	$2.3	$4.6	$7	$10	$13	$16	$20	$24	$29	$34	$40	$46	$53	$61	$69	$79	$89	$100	$113
18	$2.3	$4.6	$7	$10	$12	$15	$18	$21	$25	$29	$33	$38	$43	$48	$54	$60	$67	$74	$82
20	$2.3	$4.6	$7	$9	$12	$14	$17	$20	$23	$26	$30	$33	$37	$42	$46	$51	$56	$61	$67
24	$2.3	$4.5	$7	$9	$12	$14	$16	$19	$22	$24	$27	$30	$33	$36	$39	$42	$46	$49	$53
30	$2.3	$4.5	$7	$9	$11	$14	$16	$18	$21	$23	$26	$28	$31	$33	$36	$38	$41	$44	$46
36	$2.3	$4.5	$7	$9	$11	$14	$16	$18	$21	$23	$25	$28	$30	$32	$35	$37	$39	$42	$44

Appendix 8. Sum of pipe cost and pumping cost per linear foot for different pipe diameters and gallons of water per minute.

	GPM																		
Dia (in)	**600**	**1200**	**1800**	**2400**	**3000**	**3600**	**4200**	**4800**	**5400**	**6000**	**6600**	**7200**	**7800**	**8400**	**9000**	**9600**	**10200**	**10800**	**11400**
	Total cost per linear foot (in thousand dollars)																		
6	$4.5	$18.4	$50	$107	$196	$323	$496	$721	$1,004	$1,350	$1,767	$2,260	$2,835	$3,497	$4,253	$5,108	$6,068	$7,137	$8,323
8	$3.3	$8.5	$18	$34	$57	$90	$135	$192	$263	$350	$455	$578	$721	$886	$1,074	$1,286	$1,524	$1,789	$2,083
10	$3.6	$6.8	$12	$18	$28	$40	$57	$78	$103	$134	$171	$214	$264	$321	$386	$459	$541	$632	$732
12	$3.8	$6.5	$10	$14	$19	$26	$34	$44	$55	$70	$86	$105	$127	$152	$180	$211	$246	$285	$328
14	$3.8	$6.3	$9	$12	$16	$20	$25	$31	$38	$46	$55	$65	$76	$89	$104	$120	$137	$157	$178
16	$4.5	$6.9	$9	$12	$15	$18	$22	$26	$31	$36	$42	$48	$55	$63	$72	$81	$91	$103	$115
18	$5.0	$7.3	$10	$12	$15	$18	$21	$24	$28	$32	$36	$40	$45	$51	$57	$63	$70	$77	$85
20	$11.8	$14.1	$16	$19	$21	$24	$27	$30	$33	$36	$39	$43	$47	$51	$55	$60	$65	$70	$76
24	$12.6	$14.9	$17	$19	$22	$24	$27	$29	$32	$34	$37	$40	$43	$46	$49	$52	$56	$59	$63
30	$15.3	$17.6	$20	$22	$24	$27	$29	$31	$34	$36	$39	$41	$44	$46	$49	$51	$54	$57	$59
36	$19.8	$22.0	$24	$27	$29	$31	$33	$36	$38	$40	$43	$45	$47	$50	$52	$55	$57	$59	$62
Min Cost	$3	$6	$9	$12	$15	$18	$21	$24	$28	$32	$36	$40	$43	$46	$49	$51	$54	$57	$59
Dia (in)	8	14	14	16	18	18	18	18	18	18	18	24	24	24	30	30	30	30	30

Appendix 9. An input file for EPANET for Design 3 irrigation system

```
[TITLE]
MAIN                LEFT      RIGHT

[JUNCTIONS]
;ID                 Elev      Demand   Pattern
 C1                     1222         0            ;
 C11                    1350         0            ;
 C14                    1341         0            ;
 C155                   1349         0            ;
 C156                   1332         0            ;
 C157                   1320         0            ;
 C158                   1320         0            ;
 C159                   1303         0            ;
 C160                   1275         0            ;
 C161                   1244         0            ;
 C162                   1289         0            ;
 C163                   1276         0            ;
 C164                   1264         0            ;
 C165                   1250         0            ;
 C166                   1230         0            ;
 C167                   1225         0            ;
 C168                   1283         0            ;
 C169                   1274         0            ;
 C170                   1271         0            ;
 C171                   1221         0            ;
 C172                   1270         0            ;
 C173                   1267         0            ;
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 C175                   1268         0            ;
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 C177                   1217         0            ;
 C178                   1291         0            ;
 C179                   1275         0            ;
 C180                   1266         0            ;
 C181                   1257         0            ;
 C182                   1250         0            ;
```

Appendix 9. Continued

C183	**1209**	**0**	**;**
C184	**1268**	**0**	**;**
C185	**1259**	**0**	**;**
C186	**1250**	**0**	**;**
C187	**1233**	**0**	**;**
C188	**1218**	**0**	**;**
C189	**1210**	**0**	**;**
C190	**1276**	**0**	**;**
C191	**1272**	**0**	**;**
C192	**1290**	**0**	**;**
C193	**1264**	**0**	**;**
C194	**1249**	**0**	**;**
C195	**1213**	**0**	**;**
C196	**1222**	**0**	**;**
C197	**1255**	**0**	**;**
C198	**1225**	**0**	**;**
C199	**1215**	**0**	**;**
C200	**1209**	**0**	**;**
C201	**1202**	**0**	**;**
C202	**1201**	**0**	**;**
C203	**1193**	**0**	**;**
C204	**1187**	**0**	**;**
C205	**1178**	**0**	**;**
C206	**1183**	**0**	**;**
C29	**1225**	**0**	**;**
C30	**1228**	**0**	**;**
C307	**1358**	**0**	**;**
C308	**1322**	**0**	**;**
C309	**1327**	**0**	**;**
C31	**1225**	**0**	**;**
C310	**1322**	**0**	**;**
C311	**1370**	**0**	**;**
C312	**1363**	**0**	**;**
C313	**1361**	**0**	**;**
C314	**1297**	**0**	**;**
C315	**1296**	**0**	**;**

Appendix 9. Continued

C316	**1287**	**0**	**;**
C317	**1291**	**0**	**;**
C319	**1286**	**0**	**;**
C32	**1265**	**0**	**;**
C320	**1281**	**0**	**;**
C321	**1278**	**0**	**;**
C322	**1263**	**0**	**;**
C323	**1274**	**0**	**;**
C324	**1252**	**0**	**;**
C325	**1205**	**0**	**;**
C326	**1204**	**0**	**;**
C327	**1200**	**0**	**;**
C328	**1345**	**0**	**;**
C329	**1356**	**0**	**;**
C33	**1277**	**0**	**;**
C333	**1346**	**0**	**;**
C336	**1347**	**0**	**;**
C337	**1349**	**0**	**;**
C34	**1289**	**0**	**;**
C341	**1342**	**0**	**;**
C342	**1350**	**0**	**;**
C345	**1347**	**0**	**;**
C346	**1345**	**0**	**;**
C347	**1346**	**0**	**;**
C35	**1215**	**0**	**;**
C350	**1346**	**0**	**;**
C352	**1323**	**0**	**;**
C354	**1326**	**0**	**;**
C355	**1314**	**0**	**;**
C356	**1346**	**0**	**;**
C358	**1350**	**0**	**;**
C359	**1345**	**0**	**;**
C36	**1252**	**0**	**;**
C360	**1348**	**0**	**;**
C361	**1348**	**0**	**;**
C362	**1346**	**0**	**;**

Appendix 9. Continued

C37	**1217**	**0**	**;**
C38	**1225**	**0**	**;**
C39	**1253**	**0**	**;**
C4	**1184**	**0**	**;**
C40	**1226**	**0**	**;**
C41	**1220**	**0**	**;**
C42	**1232**	**0**	**;**
C43	**1223**	**0**	**;**
C44	**1216**	**0**	**;**
C45	**1198**	**0**	**;**
C46	**1203**	**0**	**;**
C63	**1336**	**0**	**;**
C7	**1284**	**0**	**;**
C8	**1296**	**0**	**;**
C81	**1189**	**0**	**;**
C82	**1185**	**0**	**;**
C83	**1305**	**0**	**;**
C84	**1337**	**0**	**;**
C85	**1352**	**0**	**;**
COO1	**1377**	**0**	**;**
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J394	**1347**	**800**	**;**
J395	**1329**	**800**	**;**
J397	**1318**	**800**	**;**
J400	**1329**	**800**	**;**
J401	**1311**	**800**	**;**
J404	**1320**	**800**	**;**
J405	**1282**	**800**	**;**
J409	**1245**	**800**	**;**
J412	**1248**	**800**	**;**
J413	**1229**	**800**	**;**
J416	**1225**	**800**	**;**
J420	**1227**	**800**	**;**
J421	**1339**	**800**	**;**
J423	**1313**	**800**	**;**
J426	**1293**	**800**	**;**

Appendix 9. Continued

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J430	**1284**	**800**	**;**
J431	**1285**	**800**	**;**
J434	**1280**	**800**	**;**
J435	**1269**	**800**	**;**
J438	**1267**	**800**	**;**
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J447	**1225**	**800**	**;**
J450	**1224**	**800**	**;**
J454	**1281**	**800**	**;**
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J466	**1268**	**800**	**;**
J467	**1228**	**800**	**;**
J470	**1226**	**800**	**;**
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J481	**1273**	**800**	**;**
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J488	**1265**	**800**	**;**
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J492	**1263**	**800**	**;**
J493	**1272**	**800**	**;**
J496	**1266**	**800**	**;**
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J499	**1218**	**800**	**;**

Appendix 9. Continued

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J503	**1290**	**800**	**;**
J506	**1288**	**800**	**;**
J507	**1277**	**800**	**;**
J510	**1276**	**800**	**;**
J511	**1262**	**800**	**;**
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J523	**1257**	**800**	**;**
J527	**1215**	**800**	**;**
J531	**1210**	**800**	**;**
J535	**1286**	**800**	**;**
J538	**1281**	**800**	**;**
J539	**1287**	**800**	**;**
J542	**1290**	**800**	**;**
J543	**1266**	**800**	**;**
J546	**1269**	**800**	**;**
J547	**1260**	**800**	**;**
J550	**1260**	**800**	**;**
J554	**1250**	**800**	**;**
J558	**1231**	**800**	**;**
J562	**1216**	**800**	**;**
J563	**1209**	**800**	**;**
J566	**1210**	**800**	**;**
J567	**1278**	**800**	**;**
J570	**1271**	**800**	**;**
J571	**1277**	**800**	**;**
J574	**1267**	**800**	**;**
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J581	**1228**	**800**	**;**
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J589	**1231**	**800**	**;**

Appendix 9. Continued

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J594	**1221**	**800**	**;**
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J615	**1218**	**800**	**;**
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J627	**1207**	**800**	**;**
J630	**1195**	**800**	**;**
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J1695	**1341**	**800**	**;**
J1704	**1331**	**800**	**;**

Appendix 9. Continued

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 J1660              1358      800          ;
 J1663              1361      800          ;
 J1682              1349      800          ;
 J1725              1354      800          ;
 J1688              1356      800          ;
 J1683              1341      800          ;
 J1708              1333      800          ;
 J1685              1342      800          ;
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 C3                 1189      800          ;
 C343               1360      800          ;
 C344               1362      800          ;
 C348               1343      800          ;
 C349               1344      800          ;
 C353               1330      800          ;

[RESERVOIRS]
;ID                Head      Pattern
 Resv1              1415              ;

[TANKS]
;ID                Elevation InitLevel MinLevel MaxLevel Diameter MinVol    VolCurve

[PIPES]
;ID                Node1     Node2     Length   Diameter Roughness Minor    Status
                                                                   Loss
 M0                C1        C2          2656       48      140        0  Open     ;
 M04               C323      C322        2917       48      140        0  Open     ;
 M05               C326      C327        2618       36      140        0  Open     ;
 M06               C327      C3          2476       36      140        0  Open     ;
 M35               C317      C316        2656       60      140        0  Open     ;
 M36               C316      C319        2708       60      140        0  Open     ;
 M37               C319      C320        2487       60      140        0  Open     ;
 M38               C320      C321        2813       60      140        0  Open     ;
 M39               C321      C323        2240       60      140        0  Open     ;
```

Appendix 9. Continued

M41	**C322**	**C324**	**2734**	**48**	**140**	**0**	**Open**	**;**
M42	**C324**	**C1**	**2643**	**48**	**140**	**0**	**Open**	**;**
M43	**C2**	**C325**	**2630**	**48**	**140**	**0**	**Open**	**;**
M44	**C325**	**C326**	**2604**	**36**	**140**	**0**	**Open**	**;**
M45	**C3**	**C4**	**2713**	**36**	**140**	**0**	**Open**	**;**
M07	**C308**	**C309**	**5432**	**96**	**140**	**0**	**Open**	**;**
MainP1	**COO1**	**C307**	**36953**	**96**	**140**	**0**	**Open**	**;**
M08	**C307**	**C308**	**14740**	**96**	**140**	**0**	**Open**	**;**
M09	**C309**	**C310**	**5527**	**96**	**140**	**0**	**Open**	**;**
M11	**C85**	**C311**	**4074**	**84**	**140**	**0**	**Open**	**;**
M12	**C311**	**C14**	**7118**	**84**	**140**	**0**	**Open**	**;**
M14	**C312**	**C313**	**629**	**96**	**140**	**0**	**Open**	**;**
M15	**C313**	**C11**	**7992**	**96**	**140**	**0**	**Open**	**;**
M16	**C11**	**C328**	**5404**	**96**	**140**	**0**	**Open**	**;**
M18	**C358**	**C329**	**4903**	**84**	**140**	**0**	**Open**	**;**
M19	**C329**	**C359**	**2376**	**84**	**140**	**0**	**Open**	**;**
M20	**C359**	**C360**	**3502**	**84**	**140**	**0**	**Open**	**;**
M21	**C360**	**C361**	**2312**	**84**	**140**	**0**	**Open**	**;**
M22	**C361**	**C333**	**2331**	**84**	**140**	**0**	**Open**	**;**
M23	**C333**	**C337**	**2798**	**84**	**140**	**0**	**Open**	**;**
M24	**C337**	**C336**	**2353**	**84**	**140**	**0**	**Open**	**;**
M25	**C336**	**C362**	**3097**	**84**	**140**	**0**	**Open**	**;**
M26	**C362**	**C341**	**2526**	**84**	**140**	**0**	**Open**	**;**
M27	**C341**	**C346**	**2740**	**84**	**140**	**0**	**Open**	**;**
M28	**C346**	**C345**	**2469**	**84**	**140**	**0**	**Open**	**;**
M29	**C345**	**C356**	**2800**	**84**	**140**	**0**	**Open**	**;**
M30	**C356**	**C350**	**3726**	**84**	**140**	**0**	**Open**	**;**
M31	**C350**	**C63**	**2563**	**84**	**140**	**0**	**Open**	**;**
M32	**C63**	**C354**	**2799**	**84**	**140**	**0**	**Open**	**;**
M33	**C354**	**C355**	**3154**	**84**	**140**	**0**	**Open**	**;**
M333	**C314**	**C315**	**2513**	**84**	**140**	**0**	**Open**	**;**
M334	**C315**	**C317**	**2643**	**84**	**140**	**0**	**Open**	**;**
M34	**C355**	**C314**	**4546**	**84**	**140**	**0**	**Open**	**;**
L17.1	**C155**	**C342**	**2525**	**30**	**140**	**0**	**Open**	**;**
L17.2	**C156**	**C155**	**2747**	**30**	**140**	**0**	**Open**	**;**
L17.3	**C157**	**C156**	**2760**	**24**	**150**	**0**	**Open**	**;**

Appendix 9. Continued

L17.4	**C158**	**C157**	**2526**	**18**	**150**	**0**	**Open**	**;**
L17.5	**C159**	**C158**	**2474**	**18**	**150**	**0**	**Open**	**;**
L17.6	**C160**	**C159**	**2539**	**18**	**150**	**0**	**Open**	**;**
L17.7	**C161**	**C160**	**2734**	**18**	**150**	**0**	**Open**	**;**
L17.8	**C30**	**C161**	**2591**	**16**	**150**	**0**	**Open**	**;**
L17.9	**C29**	**C30**	**2730**	**10**	**150**	**0**	**Open**	**;**
L18.1	**C84**	**C347**	**2517**	**30**	**150**	**0**	**Open**	**;**
L18.2	**C83**	**C84**	**5339**	**30**	**150**	**0**	**Open**	**;**
L18.3	**C162**	**C83**	**2617**	**30**	**150**	**0**	**Open**	**;**
L18.4	**C163**	**C162**	**2734**	**24**	**150**	**0**	**Open**	**;**
L18.5	**C164**	**C163**	**2474**	**18**	**150**	**0**	**Open**	**;**
L18.6	**C165**	**C164**	**2552**	**18**	**150**	**0**	**Open**	**;**
L18.7	**C166**	**C165**	**2604**	**18**	**150**	**0**	**Open**	**;**
L18.8	**C167**	**C166**	**2608**	**14**	**150**	**0**	**Open**	**;**
L19.1	**C168**	**C352**	**7785**	**24**	**150**	**0**	**Open**	**;**
L19.2	**C169**	**C168**	**2812**	**24**	**150**	**0**	**Open**	**;**
L19.3	**C170**	**C169**	**2669**	**18**	**150**	**0**	**Open**	**;**
L19.4	**C32**	**C170**	**2461**	**18**	**150**	**0**	**Open**	**;**
L19.5	**C31**	**C32**	**5169**	**16**	**150**	**0**	**Open**	**;**
L19.6	**C171**	**C31**	**2585**	**10**	**150**	**0**	**Open**	**;**
L20.2	**C33**	**C34**	**2813**	**30**	**150**	**0**	**Open**	**;**
L20.3	**C172**	**C33**	**2331**	**30**	**150**	**0**	**Open**	**;**
L20.4	**C173**	**C172**	**2852**	**24**	**150**	**0**	**Open**	**;**
L20.5	**C174**	**C173**	**2552**	**18**	**150**	**0**	**Open**	**;**
L20.6	**C175**	**C174**	**2539**	**18**	**150**	**0**	**Open**	**;**
L20.7	**C176**	**C175**	**2956**	**16**	**150**	**0**	**Open**	**;**
L20.8	**C177**	**C176**	**2253**	**14**	**150**	**0**	**Open**	**;**
L21.2	**C179**	**C178**	**2721**	**18**	**150**	**0**	**Open**	**;**
L21.3	**C180**	**C179**	**2669**	**18**	**150**	**0**	**Open**	**;**
L21.4	**C181**	**C180**	**2539**	**18**	**150**	**0**	**Open**	**;**
L21.5	**C182**	**C181**	**2747**	**18**	**150**	**0**	**Open**	**;**
L21.6	**C36**	**C182**	**2708**	**16**	**150**	**0**	**Open**	**;**
L21.7	**C35**	**C36**	**2656**	**14**	**150**	**0**	**Open**	**;**
L21.8	**C183**	**C35**	**2381**	**10**	**150**	**0**	**Open**	**;**
L22.2	**C7**	**C8**	**2617**	**30**	**150**	**0**	**Open**	**;**
L22.3	**C8**	**C184**	**2604**	**24**	**150**	**0**	**Open**	**;**

Appendix 9. Continued

L22.4	C184	C185	2734	18	150	0	Open	;
L22.5	C185	C186	2604	18	150	0	Open	;
L22.6	C186	C187	2604	18	150	0	Open	;
L22.7	C187	C188	2695	16	150	0	Open	;
L22.8	C188	C189	2617	14	150	0	Open	;
L23.2	C191	C190	2552	24	150	0	Open	;
L23.3	C192	C191	2682	18	150	0	Open	;
L23.4	C193	C192	2604	18	150	0	Open	;
L23.5	C194	C193	2630	18	150	0	Open	;
L23.6	C38	C194	2643	18	150	0	Open	;
L23.7	C37	C38	2630	14	150	0	Open	;
L23.8	C195	C37	2305	10	150	0	Open	;
L24.2	C197	C39	2552	18	150	0	Open	;
L24.3	C39	C40	8086	16	150	0	Open	;
L24.4	C40	C196	2565	10	150	0	Open	;
L25.2	C42	C198	2591	14	150	0	Open	;
L25.3	C41	C42	7123	10	150	0	Open	;
L26.2	C43	C44	5443	18	150	0	Open	;
L26.3	C199	C43	2617	18	150	0	Open	;
L26.4	C200	C199	2396	14	150	0	Open	;
L27.2	C202	C201	2683	18	150	0	Open	;
L27.3	C46	C202	2709	16	150	0	Open	;
L27.4	C45	C46	2631	14	150	0	Open	;
L27.5	C203	C45	2357	10	150	0	Open	;
L28.2	C81	C82	2734	18	150	0	Open	;
L17.003	C342	C343	2345	30	150	0	Open	;
L17.002	C343	C344	2951	30	150	0	Open	;
L18.03	C347	C348	2519	30	150	0	Open	;
L18.02	C348	C349	2474	30	150	0	Open	;
L19.11	C352	C353	2605	30	150	0	Open	;
L28.3	C204	C81	2813	18	150	0	Open	;
L28.4	C205	C204	2513	16	150	0	Open	;
L28.5	C206	C205	2123	10	150	0	Open	;
F153	J391	C155	1499	8	150	0	Open	;
F154	C155	J394	1304	8	150	0	Open	;
F155	J395	C156	1492	8	150	0	Open	;

Appendix 9. Continued

F156	**J397**	**C157**	**1543**	**8**	**150**	**0**	**Open**	**;**
F157	**C157**	**J400**	**1434**	**8**	**150**	**0**	**Open**	**;**
F158	**J401**	**C158**	**1434**	**8**	**150**	**0**	**Open**	**;**
F159	**C158**	**J404**	**1304**	**8**	**150**	**0**	**Open**	**;**
F160	**J405**	**C159**	**1434**	**8**	**150**	**0**	**Open**	**;**
F162	**J409**	**C161**	**1564**	**8**	**150**	**0**	**Open**	**;**
F163	**C161**	**J412**	**1695**	**8**	**150**	**0**	**Open**	**;**
F164	**J413**	**C30**	**1451**	**8**	**150**	**0**	**Open**	**;**
F165	**C30**	**J416**	**1261**	**8**	**150**	**0**	**Open**	**;**
F167	**C29**	**J420**	**1434**	**8**	**150**	**0**	**Open**	**;**
F168	**J421**	**C84**	**1510**	**8**	**150**	**0**	**Open**	**;**
F169	**J423**	**C83**	**1499**	**8**	**150**	**0**	**Open**	**;**
F170	**C83**	**J426**	**1499**	**8**	**150**	**0**	**Open**	**;**
F171	**J427**	**C162**	**1434**	**8**	**150**	**0**	**Open**	**;**
F172	**C162**	**J430**	**1564**	**8**	**150**	**0**	**Open**	**;**
F173	**J431**	**C163**	**1238**	**8**	**150**	**0**	**Open**	**;**
F174	**C163**	**J434**	**1434**	**8**	**150**	**0**	**Open**	**;**
F175	**J435**	**C164**	**1434**	**8**	**150**	**0**	**Open**	**;**
F176	**C164**	**J438**	**1564**	**8**	**150**	**0**	**Open**	**;**
F177	**J439**	**C165**	**1392**	**8**	**150**	**0**	**Open**	**;**
F178	**C165**	**J442**	**1345**	**8**	**150**	**0**	**Open**	**;**
F179	**J443**	**C166**	**1457**	**8**	**150**	**0**	**Open**	**;**
F180	**C166**	**J446**	**1228**	**8**	**150**	**0**	**Open**	**;**
F181	**J447**	**C167**	**1238**	**8**	**150**	**0**	**Open**	**;**
F182	**C167**	**J450**	**1564**	**8**	**150**	**0**	**Open**	**;**
F184	**C168**	**J454**	**1434**	**8**	**150**	**0**	**Open**	**;**
F185	**J455**	**C169**	**1406**	**8**	**150**	**0**	**Open**	**;**
F186	**C169**	**J458**	**1499**	**8**	**150**	**0**	**Open**	**;**
F187	**J459**	**C170**	**1435**	**8**	**150**	**0**	**Open**	**;**
F188	**C170**	**J462**	**1501**	**8**	**150**	**0**	**Open**	**;**
F189	**J463**	**C32**	**1310**	**8**	**150**	**0**	**Open**	**;**
F190	**C32**	**J466**	**1464**	**8**	**150**	**0**	**Open**	**;**
F191	**J467**	**C31**	**1536**	**8**	**150**	**0**	**Open**	**;**
F192	**C31**	**J470**	**1173**	**8**	**150**	**0**	**Open**	**;**
F193	**J471**	**C171**	**1583**	**8**	**150**	**0**	**Open**	**;**
F194	**J473**	**C34**	**1434**	**8**	**150**	**0**	**Open**	**;**

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F195	**C34**	**J476**	**1442**	**8**	**150**	**0**	**Open**	**;**
F196	**J477**	**C33**	**1304**	**8**	**150**	**0**	**Open**	**;**
F197	**C33**	**J480**	**1499**	**8**	**150**	**0**	**Open**	**;**
F198	**J481**	**C172**	**1304**	**8**	**150**	**0**	**Open**	**;**
F199	**C172**	**J484**	**1434**	**8**	**150**	**0**	**Open**	**;**
F200	**J485**	**C173**	**1304**	**8**	**150**	**0**	**Open**	**;**
F201	**C173**	**J488**	**1564**	**8**	**150**	**0**	**Open**	**;**
F202	**J489**	**C174**	**1564**	**8**	**150**	**0**	**Open**	**;**
F203	**C174**	**J492**	**1629**	**8**	**150**	**0**	**Open**	**;**
F204	**J493**	**C175**	**1629**	**8**	**150**	**0**	**Open**	**;**
F205	**C175**	**J496**	**1369**	**8**	**150**	**0**	**Open**	**;**
F206	**C176**	**J498**	**1455**	**8**	**150**	**0**	**Open**	**;**
F207	**J499**	**C177**	**1631**	**8**	**150**	**0**	**Open**	**;**
F208	**C177**	**J502**	**1496**	**8**	**150**	**0**	**Open**	**;**
F209	**J503**	**C178**	**1499**	**8**	**150**	**0**	**Open**	**;**
F210	**C178**	**J506**	**1527**	**8**	**150**	**0**	**Open**	**;**
F211	**J507**	**C179**	**1434**	**8**	**150**	**0**	**Open**	**;**
F212	**C179**	**J510**	**1629**	**8**	**150**	**0**	**Open**	**;**
F213	**J511**	**C180**	**1305**	**8**	**150**	**0**	**Open**	**;**
F215	**J515**	**C181**	**1369**	**8**	**150**	**0**	**Open**	**;**
F217	**J519**	**C182**	**1329**	**8**	**150**	**0**	**Open**	**;**
F219	**J523**	**C36**	**1173**	**10**	**150**	**0**	**Open**	**;**
F221	**J527**	**C35**	**1524**	**8**	**150**	**0**	**Open**	**;**
F223	**J531**	**C183**	**1515**	**8**	**150**	**0**	**Open**	**;**
F225	**J535**	**C7**	**1434**	**8**	**150**	**0**	**Open**	**;**
F226	**C7**	**J538**	**1435**	**8**	**150**	**0**	**Open**	**;**
F227	**J539**	**C8**	**1401**	**8**	**150**	**0**	**Open**	**;**
F228	**C8**	**J542**	**959**	**8**	**150**	**0**	**Open**	**;**
F229	**J543**	**C184**	**1505**	**8**	**150**	**0**	**Open**	**;**
F230	**C184**	**J546**	**1173**	**8**	**150**	**0**	**Open**	**;**
F231	**J547**	**C185**	**1370**	**8**	**150**	**0**	**Open**	**;**
F232	**C185**	**J550**	**1045**	**8**	**150**	**0**	**Open**	**;**
F234	**C186**	**J554**	**1183**	**8**	**150**	**0**	**Open**	**;**
F236	**C187**	**J558**	**1499**	**8**	**150**	**0**	**Open**	**;**
F238	**C188**	**J562**	**1399**	**8**	**150**	**0**	**Open**	**;**
F239	**J563**	**C189**	**1620**	**8**	**150**	**0**	**Open**	**;**

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F240	**C189**	**J566**	**1494**	**8**	**150**	**0**	**Open**	**;**
F241	**J567**	**C190**	**1494**	**8**	**150**	**0**	**Open**	**;**
F242	**C190**	**J570**	**1371**	**8**	**150**	**0**	**Open**	**;**
F243	**J571**	**C191**	**1369**	**10**	**150**	**0**	**Open**	**;**
F244	**C191**	**J574**	**1246**	**8**	**150**	**0**	**Open**	**;**
F245	**J575**	**C192**	**1539**	**10**	**150**	**0**	**Open**	**;**
F246	**J577**	**C193**	**1800**	**10**	**150**	**0**	**Open**	**;**
F247	**J579**	**C194**	**1515**	**8**	**150**	**0**	**Open**	**;**
F248	**J581**	**C38**	**1494**	**8**	**150**	**0**	**Open**	**;**
F249	**J583**	**C37**	**1479**	**8**	**150**	**0**	**Open**	**;**
F250	**J585**	**C195**	**1506**	**8**	**150**	**0**	**Open**	**;**
F251	**C38**	**J588**	**1183**	**8**	**150**	**0**	**Open**	**;**
F252	**J589**	**C40**	**1427**	**8**	**150**	**0**	**Open**	**;**
F253	**J591**	**C196**	**1681**	**8**	**150**	**0**	**Open**	**;**
F254	**C40**	**J594**	**1352**	**8**	**150**	**0**	**Open**	**;**
F255	**J595**	**C39**	**1538**	**8**	**150**	**0**	**Open**	**;**
F256	**C39**	**J598**	**1369**	**8**	**150**	**0**	**Open**	**;**
F257	**J599**	**C197**	**1614**	**10**	**150**	**0**	**Open**	**;**
F258	**C197**	**J602**	**1495**	**8**	**150**	**0**	**Open**	**;**
F259	**J603**	**C41**	**1422**	**8**	**150**	**0**	**Open**	**;**
F260	**J605**	**C42**	**1576**	**8**	**150**	**0**	**Open**	**;**
F261	**J607**	**C198**	**1477**	**8**	**150**	**0**	**Open**	**;**
F262	**C198**	**J610**	**1288**	**8**	**150**	**0**	**Open**	**;**
F263	**J611**	**C43**	**1433**	**8**	**150**	**0**	**Open**	**;**
F264	**C43**	**J614**	**1245**	**8**	**150**	**0**	**Open**	**;**
F265	**J615**	**C199**	**1369**	**8**	**150**	**0**	**Open**	**;**
F266	**C199**	**J618**	**1369**	**8**	**150**	**0**	**Open**	**;**
F267	**J619**	**C200**	**1561**	**8**	**150**	**0**	**Open**	**;**
F268	**C200**	**J622**	**1432**	**8**	**150**	**0**	**Open**	**;**
F269	**J623**	**C44**	**1309**	**8**	**150**	**0**	**Open**	**;**
F270	**C44**	**J626**	**1307**	**8**	**150**	**0**	**Open**	**;**
F271	**J627**	**C201**	**1058**	**8**	**150**	**0**	**Open**	**;**
F272	**C201**	**J630**	**1371**	**8**	**150**	**0**	**Open**	**;**
F273	**J631**	**C202**	**1058**	**8**	**150**	**0**	**Open**	**;**
F274	**C202**	**J634**	**1432**	**8**	**150**	**0**	**Open**	**;**
F275	**C46**	**J636**	**1245**	**8**	**150**	**0**	**Open**	**;**

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F276	**C45**	**J638**	**1403**	**8**	**150**	**0**	**Open**	**;**
F277	**C203**	**J640**	**1532**	**8**	**150**	**0**	**Open**	**;**
F278	**J641**	**C82**	**1557**	**8**	**150**	**0**	**Open**	**;**
F279	**J643**	**C81**	**1272**	**8**	**150**	**0**	**Open**	**;**
F280	**J645**	**C204**	**1534**	**8**	**150**	**0**	**Open**	**;**
F281	**J647**	**C205**	**1499**	**8**	**150**	**0**	**Open**	**;**
F282	**J649**	**C206**	**1411**	**8**	**150**	**0**	**Open**	**;**
F283	**C205**	**J652**	**1528**	**8**	**150**	**0**	**Open**	**;**
F348	**C342**	**J1654**	**1429**	**8**	**150**	**0**	**Open**	**;**
F367	**J1655**	**C342**	**1365**	**8**	**150**	**0**	**Open**	**;**
F368	**C347**	**J1694**	**1327**	**8**	**150**	**0**	**Open**	**;**
F379	**J1695**	**C347**	**1218**	**8**	**150**	**0**	**Open**	**;**
F380	**C352**	**J1704**	**1138**	**6**	**150**	**0**	**Open**	**;**
F389	**J1705**	**C352**	**1042**	**6**	**150**	**0**	**Open**	**;**
F364	**C344**	**J1714**	**977**	**6**	**150**	**0**	**Open**	**;**
F366	**C343**	**J1660**	**1093**	**8**	**150**	**0**	**Open**	**;**
F369	**J1663**	**C343**	**1128**	**8**	**150**	**0**	**Open**	**;**
F370	**C348**	**J1682**	**1532**	**8**	**150**	**0**	**Open**	**;**
F371	**J1725**	**C344**	**994**	**6**	**150**	**0**	**Open**	**;**
F372	**C349**	**J1688**	**1606**	**8**	**150**	**0**	**Open**	**;**
F381	**J1683**	**C348**	**979**	**8**	**150**	**0**	**Open**	**;**
F382	**C353**	**J1708**	**1175**	**6**	**150**	**0**	**Open**	**;**
F383	**J1685**	**C349**	**1035**	**6**	**150**	**0**	**Open**	**;**
MP1	**C14**	**C312**	**7996**	**96**	**140**	**0**	**Open**	**;**
Main	**C328**	**C358**	**3214**	**96**	**140**	**0**	**Open**	**;**
MAINPIPE	**C310**	**C85**	**23456**	**96**	**140**	**0**	**Open**	**;**

[PUMPS]

;ID	**Node1**	**Node2**	**Parameters**	
MainP	**Resv1**	**COO1**	**HEAD MC**	**;**
LP1	**C345**	**C344**	**HEAD LP1**	**;**
LP2	**C350**	**C349**	**HEAD LP2**	**;**
LP3	**C354**	**C353**	**HEAD LP3**	**;**
LP4	**C314**	**C34**	**HEAD LP4**	**;**

Appendix 9. Continued

```
 LP5                C317      C178      HEAD      ;
                                        CR5
 LP6                C319      C7        HEAD      ;
                                        CR6
 LP7                C321      C190      HEAD      ;
                                        CR7
 LP8                C322      C197      HEAD      ;
                                        CR8
 LP10               C325      C44       HEAD      ;
                                        CR10
 LP9                C1        C198      HEAD      ;
                                        CR9
 LP11               C327      C201      HEAD      ;
                                        CR11
 LP12               C4        C82       HEAD      ;
                                        CR12

[VALVES]
;ID                 Node1     Node2     Diameter  Type      Setting   MinorLoss

[TAGS]

[DEMANDS]
;Junction           Demand    Pattern   Category

[STATUS]
;ID                 Status/Setting

[PATTERNS]
;ID                 Multipliers

[CURVES]
;ID                 X-Value   Y-Value
;PUMP: PUMP:        PUMP:     PUMP:
PUMP:
 MC                    116800       210
;PUMP: PUMP:
 LP1                    15200       100
;PUMP: PUMP:
 LP2                    16800       100
;PUMP: PUMP:
 LP3                    10400       100
```

Appendix 9. Continued

```
;PUMP: PUMP:
 LP4                    12000        50
;PUMP:
 CR5                     8000        60
;PUMP:
 CR6                    10400        30
;PUMP:
 CR7                     8800        70
;PUMP:
 CR8                     5600        30
;PUMP:
 CR9                     3200        10
;PUMP:
 CR10                    6400        20
;PUMP:
 CR11                    5600     0.001
;PUMP:
 CR12                    4200     0.001

[CONTROLS]

[RULES]

[ENERGY]
 Global Efficiency         75
 Global Price               0
 Demand Charge              0

[EMITTERS]
;Junction            Coefficient

[QUALITY]
;Node                InitQual

[SOURCES]
;Node                Type        Quality     Pattern
```

Appendix 9. Continued

```
[REACTIONS]
;Type                Pipe/Tank   Coefficient



[REACTIONS]
 Order Bulk                  1
 Order Tank                  1
 Order Wall                  1
 Global Bulk                 0
 Global Wall                 0
 Limiting Potential          0
 Roughness                   0
Correlation

[MIXING]
;Tank                Model

[TIMES]
 Duration                 0:00
 Hydraulic Timestep       1:00
 Quality Timestep         0:05
 Pattern Timestep         1:00
 Pattern Start            0:00
 Report Timestep          1:00
 Report Start             0:00
 Start ClockTime      12:00 AM
 Statistic           NONE

[REPORT]
 Status              Full
 Summary             No
 Page                        0

[OPTIONS]
 Units               GPM
 Headloss            H-W
 Specific Gravity            1
```

Appendix 9. Continued

Viscosity	**1**
Trials	**40**
Accuracy	**0.001**
CHECKFREQ	**2**
MAXCHECK	**10**
DAMPLIMIT	**0**
Unbalanced	**Continue 10**
Pattern	**1**
Demand Multiplier	**1**
Emitter Exponent	**0.5**
Quality	**None mg/L**
Diffusivity	**1**
Tolerance	**0.01**

[COORDINATES]

;Node	**X-Coord**	**Y-Coord**
C1	**489413.5**	**3794390**
C11	**489697**	**3818432**
C14	**493442.3**	**3821681**
C155	**489031.9**	**3807277**
C156	**488195.3**	**3807289**
C157	**487358.5**	**3807289**
C158	**486585.8**	**3807292**
C159	**485831.5**	**3807288**
C160	**485057.3**	**3807288**
C161	**484223**	**3807297**
C162	**486585.8**	**3805686**
C163	**485751.8**	**3805698**
C164	**484997.3**	**3805709**
C165	**484220.6**	**3805666**
C166	**483426.8**	**3805668**
C167	**482632**	**3805713**
C168	**487459.4**	**3804074**
C169	**486601.3**	**3804056**
C170	**485789.6**	**3804049**
C171	**482677.8**	**3804067**

Appendix 9. Continued

C172	**487439.5**	**3802448**
C173	**486567.9**	**3802473**
C174	**485791.6**	**3802462**
C175	**485017.2**	**3802441**
C176	**484119.4**	**3802468**
C177	**483428.1**	**3802453**
C178	**489057.6**	**3800847**
C179	**488233.7**	**3800860**
C180	**487419.7**	**3800840**
C181	**486645.3**	**3800845**
C182	**485808.3**	**3800848**
C183	**483454.8**	**3800853**
C184	**487420.5**	**3799229**
C185	**486585.8**	**3799229**
C186	**485792.5**	**3799234**
C187	**484997.2**	**3799239**
C188	**484180.8**	**3799244**
C189	**483381.8**	**3799243**
C190	**488979.6**	**3797604**
C191	**488201.8**	**3797612**
C192	**487389**	**3797593**
C193	**486591.3**	**3797590**
C194	**485788.3**	**3797585**
C195	**483478.2**	**3797592**
C196	**485014.6**	**3796032**
C197	**489039.2**	**3796038**
C198	**489031.7**	**3794393**
C199	**486548.9**	**3792817**
C200	**485813.1**	**3792796**
C201	**489016.4**	**3791204**
C202	**488199.8**	**3791197**
C203	**485849.8**	**3791244**
C204	**487328.2**	**3789589**
C205	**486566.1**	**3789580**
C206	**485913.3**	**3789575**
C29	**482594.1**	**3807288**

Appendix 9. Continued

C30	**483432.8**	**3807292**
C307	**501523.8**	**3836504**
C308	**500486**	**3832143**
C309	**500099.1**	**3830526**
C31	**483464**	**3804063**
C310	**499710.4**	**3828889**
C311	**494961.2**	**3823232**
C312	**491685.9**	**3820130**
C313	**491535.6**	**3820013**
C314	**489413.8**	**3802414**
C315	**489422.4**	**3801656**
C316	**489420.8**	**3800039**
C317	**489417.4**	**3800849**
C319	**489422.9**	**3799217**
C32	**485037.1**	**3804057**
C320	**489421.2**	**3798459**
C321	**489420.6**	**3797600**
C322	**489417**	**3796030**
C323	**489417.6**	**3796919**
C324	**489416.9**	**3795195**
C325	**489415.1**	**3792782**
C326	**489416**	**3791983**
C327	**489409.7**	**3791182**
C328	**489624.9**	**3816921**
C329	**491382.6**	**3815284**
C33	**488152.3**	**3802435**
C333	**491941.7**	**3812123**
C336	**491954.6**	**3810530**
C337	**491941.7**	**3811281**
C34	**489009**	**3802416**
C341	**492230.6**	**3808865**
C342	**489817.6**	**3807306**
C345	**492484**	**3807300**
C346	**492357.4**	**3808051**
C347	**489794.4**	**3805622**
C35	**484170.5**	**3800847**

Appendix 9. Continued

C350	**491743.5**	**3805538**
C352	**489834.1**	**3804127**
C354	**490937.7**	**3804111**
C355	**490479**	**3803290**
C356	**492290.5**	**3806498**
C358	**490244.4**	**3816123**
C359	**491561.8**	**3814565**
C36	**484982.5**	**3800844**
C360	**491788.4**	**3813704**
C361	**491938.8**	**3812838**
C362	**492102.1**	**3809633**
C37	**484182.3**	**3797578**
C38	**484979.7**	**3797591**
C39	**488259.4**	**3796039**
C4	**489467.7**	**3789606**
C40	**485798.2**	**3796031**
C41	**486077.5**	**3794418**
C42	**488246.3**	**3794398**
C43	**487346.2**	**3792800**
C44	**489000**	**3792789**
C45	**486571.3**	**3791227**
C46	**487370.3**	**3791214**
C63	**491345.6**	**3804845**
C7	**489010.1**	**3799224**
C8	**488211.2**	**3799225**
C81	**488185.4**	**3789595**
C82	**489020.2**	**3789602**
C83	**487381.9**	**3805675**
C84	**489010.3**	**3805651**
C85	**495835**	**3824119**
COO1	**490566.7**	**3839440**
J391	**489029.1**	**3807722**
J394	**489029.1**	**3806868**
J395	**488214.6**	**3807742**
J397	**487380.2**	**3807762**
J400	**487360.3**	**3806848**

Appendix 9. Continued

J401	**486585.5**	**3807722**
J404	**486585.5**	**3806907**
J405	**485830.6**	**3807722**
J409	**484221.4**	**3807762**
J412	**484221.4**	**3806808**
J413	**483446.6**	**3807742**
J416	**483426.7**	**3806907**
J420	**482592.3**	**3806848**
J421	**489009.2**	**3806113**
J423	**487380.2**	**3806152**
J426	**487380.2**	**3805239**
J427	**486585.5**	**3806152**
J430	**486585.5**	**3805239**
J431	**485751.1**	**3806113**
J434	**485751.1**	**3805298**
J435	**484996.2**	**3806172**
J438	**484996.2**	**3805298**
J439	**484221.4**	**3806093**
J442	**484221.4**	**3805258**
J443	**483426.7**	**3806113**
J446	**483426.7**	**3805298**
J447	**482632**	**3806093**
J450	**482632**	**3805278**
J454	**487459.6**	**3803655**
J455	**486605.4**	**3804490**
J458	**486605.4**	**3803596**
J459	**485771**	**3804470**
J462	**485810.7**	**3803596**
J463	**484996.2**	**3804450**
J466	**485055.8**	**3803615**
J467	**483466.4**	**3804529**
J470	**483466.4**	**3803715**
J471	**482632**	**3804549**
J473	**489009.2**	**3802841**
J476	**489009.2**	**3801986**
J477	**488155**	**3802841**

Appendix 9. Continued

J480	**488155**	**3801986**
J481	**487439.8**	**3802861**
J484	**487439.8**	**3802026**
J485	**486565.6**	**3802900**
J488	**486565.6**	**3802026**
J489	**485790.8**	**3802940**
J492	**485790.8**	**3801986**
J493	**485016**	**3802920**
J496	**485016**	**3802006**
J498	**484122**	**3802026**
J499	**483446.6**	**3802920**
J502	**483406.8**	**3802006**
J503	**489049**	**3801311**
J506	**489068.8**	**3800377**
J507	**488234.4**	**3801311**
J510	**488234.4**	**3800377**
J511	**487400**	**3801231**
J515	**486645.1**	**3801251**
J519	**485810.7**	**3801251**
J523	**484976.3**	**3801192**
J527	**484161.8**	**3801311**
J531	**483426.7**	**3801311**
J535	**489009.2**	**3799670**
J538	**489029.1**	**3798776**
J539	**488214.6**	**3799650**
J542	**488214.6**	**3798935**
J543	**487419.9**	**3799690**
J546	**487419.9**	**3798875**
J547	**486605.4**	**3799650**
J550	**486605.4**	**3798915**
J554	**485792.7**	**3798881**
J558	**484957.9**	**3798805**
J562	**484180**	**3798805**
J563	**483364.2**	**3799716**
J566	**483383.2**	**3798824**
J567	**488980.1**	**3798065**

Appendix 9. Continued

J570	**488999.1**	**3797192**
J571	**488202.2**	**3798046**
J574	**488221.2**	**3797249**
J575	**487386.4**	**3798065**
J577	**486589.5**	**3798141**
J579	**485792.7**	**3798046**
J581	**484976.9**	**3798065**
J583	**484180**	**3798027**
J585	**483421.1**	**3798046**
J588	**484976.9**	**3797230**
J589	**485792.7**	**3796471**
J591	**485014.8**	**3796547**
J594	**485830.6**	**3795617**
J595	**488259.1**	**3796509**
J598	**488259.1**	**3795636**
J599	**489037**	**3796528**
J602	**489056**	**3795599**
J603	**485906.5**	**3794821**
J605	**488240.2**	**3794878**
J607	**489018**	**3794840**
J610	**489018**	**3794005**
J611	**487329.5**	**3793246**
J614	**487348.4**	**3792411**
J615	**486551.6**	**3793246**
J618	**486551.6**	**3792411**
J619	**485773.7**	**3793265**
J622	**485811.7**	**3792354**
J623	**488999.1**	**3793189**
J626	**488999.1**	**3792392**
J627	**489018**	**3791538**
J630	**488999.1**	**3790817**
J631	**488202.2**	**3791519**
J634	**488202.2**	**3790760**
J636	**487367.4**	**3790836**
J638	**486570.6**	**3790798**
J640	**485830.6**	**3790779**

Appendix 9. Continued

J641	**489018**	**3790077**
J643	**488183.2**	**3789983**
J645	**487329.5**	**3790058**
J647	**486589.5**	**3790040**
J649	**485773.7**	**3789983**
J652	**486551.6**	**3789110**
J1654	**489829.2**	**3807734**
J1655	**489826.6**	**3806909**
J1694	**489777.9**	**3806036**
J1695	**489777.9**	**3805242**
J1704	**489811.3**	**3804477**
J1705	**489830.8**	**3803800**
J1714	**491444.8**	**3807001**
J1660	**490583.9**	**3807632**
J1663	**490576.2**	**3806955**
J1682	**490576.2**	**3806053**
J1725	**491470.6**	**3807635**
J1688	**491338.9**	**3806075**
J1683	**490560.9**	**3805288**
J1708	**490677.5**	**3804501**
J1685	**491341.1**	**3805257**
C2	**489415.6**	**3793578**
C3	**489436.1**	**3790432**
C343	**490571.6**	**3807313**
C344	**491458**	**3807314**
C348	**490568.3**	**3805589**
C349	**491332.3**	**3805589**
C353	**490642.2**	**3804131**
Resv1	**488388.3**	**3839411**

[VERTICES]

;Link	**X-Coord**	**Y-Coord**
MainP1	**494761.9**	**3839162**
M34	**490429.3**	**3803197**
M34	**489407.5**	**3802398**

Appendix 9. Continued

```
[LABELS]
;X-Coord         Y-Coord         Label & Anchor Node

[BACKDROP]
 DIMENSIONS              488804     3787114     502129.5     3841932
 UNITS                   None
 FILE
 OFFSET                        0           0

[END]
```

VITA

Monika Ghimire

Candidate for the Degree of

Master of Science

Thesis: GIS AND HYDROLOGICAL SIMULATION MODEL INTEGRATED FEASIBILITY STUDY OF IRRIGATION DEVELOPMENT UNDER SALINITY

Major Field: Agricultural Economics

Biographical:

Education:

Completed the requirements for the Master of Science in Agricultural Economics at Oklahoma State University, Stillwater, Oklahoma in July, 2012.

Completed the requirements for the Bachelor of Science in Environment Management at Pokhara University, Kathmandu, Nepal in 2008.

Experience:

Graduate Research Assistant, Department of Agricultural Economics, Oklahoma State University, August 2010 to Present.
Environmental Impact Analyst MaxTech Study and Services, September 2008 to May 2010.

Professional Memberships:

Agricultural and Applied Economics Association (AAEA) - Member

Name: Monika Ghimire Date of Degree: July, 2012

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: GIS AND HYDROLOGICAL SIMULATION MODEL INTEGRATED FEASIBILITY STUDY OF IRRIGATION DEVELOPMENT UNDER SALINITY

Pages in Study: 129 Candidate for the Degree of Master of Science

Major Field: Agricultural Economics

Scope and Method of Study: This study estimated net irrigation benefits of irrigation development from the proposed Cable Mountain Reservoir (CMR) on the North Fork of the Red River in Southwestern Oklahoma to Tillman terrace Area (TTA) of Western Tillman County. Part of the benefits from the CMR might come from replacing the largely depleted groundwater in the TTA. The area of irrigation capability lands, and the length and route of pipelines were identified using GIS in TTA. This study also determined the cost of the pipeline and the net returns of irrigation from yield increment with the aid of the EPANET a hydrological simulation model and mathematical optimization model, respectively. The NPVs of the areas for four different designs of irrigation system for pivot irrigation was estimated at different EC levels of irrigation water and cotton prices.

Findings and Conclusions: Total irrigable areas of 68,000 acres within 543 full and partial pivot circles were identified. The length of main, lateral, and final pipelines were 41, 133, and 151 miles, respectively. The size of main pipeline ranged from 48 to 120 inches, lateral pipeline ranged from 12 to 36 inches, and final pipes were 8 to 10 inches. Design 1A allowed all producers to irrigate simultaneously at 600 GPM. The total annual cost of the irrigation system was approximately $950 per acre. At this cost, NPV per acre was feasible for the cotton lint price of 75 cents (at an EC levels less than and equal to 2.2 mmhos cm^{-1}) and more per pound at EC levels of 0.9, 1.5, 2.2 and 3 mmhos cm^{-1}. Design 1B was designed to schedule the irrigation alternately to the north and south of the laterals of Design 1A irrigation system. With an approximate total cost of $830 per acre this irrigation system was feasible for cotton price of 70 cents (at EC levels less than and equal to 2.2 mmhos cm^{-1}) and more for 0.9, 1.5, 2.2, and 3 mmhos cm^{-1} EC levels. Design 2 divided the irrigable acreages into two areas. With total annual cost of $825 per acre, Design 2 system was feasible at the cotton price of 70 cents (at EC levels less than and equal to 2.2 mmhos cm^{-1}) and more for 0.9, 1.5, 2.2, and 3 mmhos cm^{-1} EC levels. Design 3 system divided the irrigable land into four areas to allow producers to irrigate one area at a time with 800 gpm of individual pivot demand. This design was feasible for cotton price of 65 cents (at EC levels less than and equal to 1.5 mmhos cm^{-1}) and more for 0.9, 1.5, 2.2, and 3 mmhos cm^{-1} EC levels. The analysis showed that the NPV and irrigation water increased with increasing cotton price and decreased with increasing EC levels in linear pattern. The study suggests that economies can be obtained through a combination of pipe sizing and by increased cooperation or utilization of the pipeline.

ADVISER’S APPROVAL: Dr. Art Stoecker