FARM LEVEL FINANICAL IMPACTS OF WATER POLICY ON THE SOUTHERN OGALLALA AQUIFER

by

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ABSTRACT

The Texas Southern High Plains relies heavily on irrigation water provided by the Ogallala Aquifer. Throughout history, the agricultural economy and production capabilities in the Texas Panhandle have evolved to become an important supplier of food and fiber around the world. There is no question that this precious resource is finite, as current pumping withdrawals exceed recharge rates in most areas, particularly in the Southern Ogallala. Concerns over future supplies and the sustainability of irrigated agriculture have attracted the attention of policy makers throughout the eight states overlying the Ogallala. Recent legislation in Texas (Senate Bills 1 & 2) has shown a strong commitment towards increasing the efforts of water conservation through water policy implementation.

Due to the increasing likelihood of water management policies being implemented on the Texas High Plains, this study evaluated the response of a representative farm to the implementation of a water policy which restricts the amount of irrigation water availability such that 50% of the current saturated thickness must remain in 50 years, commonly known as the 50/50 water policy. This policy was evaluated over a ten year planning horizon with the primary goals of determining how the farm reacts to the 50/50 policy in terms of enterprise and crop selection and how the farm would be impacted financially both in risk profile and cash positions.

An integrated two step approach was used in the evaluation. First, a non-linear dynamic optimization model was developed to determine farm level response decisions and crop selection, and second a stochastic simulation model was utilized to understand the changes in cash positions of the farm resulting from the policy implementation.

Baseline models were run for four different water availability scenarios (120ft, 100ft, 80ft, and 60ft saturated thickness) representing status quo farming practices. Constrained models were then run under the restriction of the 50/50 water policy to determine the changes from the baseline scenario. Primary results for the optimization models indicate that LEPA irrigated cotton and dryland sorghum are the optimal crops under both baseline and constrained models which maximize net returns per acre. Additionally the policy did affect the producers optimal decisions of crop selection in that total dryland acres increased. Financial viability of the farm decreased under the 50/50 water policy as the probability of negative net cash income and ending cash reserves increased for all scenarios, with the greatest impacts being on the moderate to high saturated thickness levels. The probability of negative net cash income and ending cash reserves was similar for the baseline models and constrained models for the lower saturated thickness scenarios. Finally, significant water savings occurred only on moderate to high levels of initial saturated thickness.

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CHAPTER I

INTRODUCTION

The Development of the Great Plains

The Ogallala Aquifer is one of largest aquifers in the world. It underlies approximately 174,000 square miles of the Great Plains Region of the U.S., and plays a key role in the production of crops such as cotton, wheat, corn, and grain sorghum, Figure 1. The Ogallala Aquifer is particularly important to irrigated agriculture in the High Plains of Texas, Oklahoma, Kansas, Colorado, and Nebraska (Glantz, 1989). The Ogallala Aquifer was named in 1899 by N.H. Darton after the town of Ogallala, Nebraska. The formation of this vast water source began 10 to 12 million years ago during the late Tertiary period. During this time sand, gravel, silt, and other clay eroded from upland areas, specifically the southern Rocky Mountains, which were formed during the Laramide revolution as cretaceous seas retreated (NPGCD, 2008).

The Ogallala Aquifer primarily contains fresh water; however, other minerals such as calcium and bicarbonate are common constituents. Described as being composed of fluvial sediments, water bearing areas of the Ogallala Aquifer are hydraulically connected with the exception of the Canadian River region, which has partially or totally eroded through the formation separating the Northern and Southern Plains. The saturated thickness, or thickness of the aquifer, varies greatly across the Ogallala Aquifer as more northern areas such as Northwest Nebraska exceed 1000 feet while southern regions may be less than 20 feet.

The High Plains region remained a grassland prairie until the later part of the 19th century. As the buffalo herds were pushed out and native people relocated, the

Figure 1. The Ogallala Aquifer Source: HPWD 1

development of the Southern High Plains initially started with the advent of large beef cattle operations. Early livestock operations such as the XIT and LX ranches in the Texas Panhandle grazed thousands of cattle across the lush short grass prairies. Additionally, during this time producers began to break out small parcels of land, initially to sustain the small settlements that were developing across the region. Green (1973) stated that much of the early cropland was devoted to raising hay crops which farmers fed to their own livestock or sold to other ranchers. Early crops included oats, corn, and varieties of grain sorghum.

However the expansion of crop production was limited due to the negative effects of several drought years in the late 1880's and early 1890's. Early attempts at irrigation were generally located near streams or rivers which were rare across much of the region. Additionally, early successes in irrigation were overlooked to a great extent as the drought ended and unusual rainfall was recorded across the High Plains. Perhaps the most important reason early attempts at irrigation failed were the lack of technology to effectively retrieve groundwater or surface water resources (Opie, 1993).

Around the turn of the century, development of cropland and irrigation continued across the West. One of the greatest hindrances in the expansion of cropland was attributed to WWI as early farm machinery increased in price. Additionally, irrigated farming in the Great Plains was a relatively new concept which led to many failures due to inexperience. As more land was brought into cultivation one of the worst natural disasters struck the Great Plains, the Dust Bowl. Beginning in 1932 severe drought hit much of the newly cultivated land throughout the Midwestern and Plains states, covering as much as 75 percent of the country and severely affecting 27 states (PBS, 2008). The severe drought conditions continued to destroy crops and livestock across the Great Plains until the drought ended in approximately 1939. It has been estimated that 5.4 million acres of cropland were detrimentally affected by the severe wind erosion that occurred during this period of drought.

Even though the drought devastated cropland through many parts of the central U.S. it also encouraged the development of new irrigation methods and technology. The attitude towards irrigation, which was previously determined by the climate, was shifting among Great Plains farmers. Through time, less expensive, more efficient and more trouble-free centrifugal pumping plants became prevalent across the region. Chemical fertilizers, combustion engines, and more mechanized farm equipment contributed to the expansion of irrigation and the economic development of the Plains.

The development of irrigation in the Texas High Plains was most rapid from the mid 1940s through the 1950s (Ryder, 1996). The perception that the Ogallala Aquifer was a vast unlimited water source encouraged farmers to expand the number of wells to pump increasing amounts of water on a variety of crops. In 1980, there were 3.9 million irrigated acres in the Texas High Plains and approximately 75,000 irrigation wells (Ryder, 1996).

In 1949, the Texas Legislature authorized the formation of local underground water conservation districts in response to increasing withdrawals of groundwater from aquifers across the state (Brook, 1997). The High Plains Underground Water Conservation District No. 1 (HPUWC #1) was created in 1951 and was the first local district formed under this legislation. From its beginning the HPUWC #1 has encouraged water conservation through education, conservation guidelines, research and some mandatory rules on water use (Brook, 1997). The district's educational efforts have been instrumental in encouraging the adoption of water conservation technologies such as underground tile, tail water return systems, center pivot systems, and drip systems. Another important factor in encouraging water conservation has been cost share programs through the USDA to help producers in investing in water conservation technologies.

The abundant supply of feed grains produced on the High Plains due to the development of irrigation in combination with favorable climatic characteristics led to the establishment of the cattle feeding industry in the region in the early 1960s. The cattle feeding industry has become a vital part of the region's economy. The Texas Cattle Feeders Association (TCFA) reported that Texas, Oklahoma, and Eastern New Mexico marketed 6.7 million head of fed cattle in 2006, representing approximately 30% of the nations fed beef (Texas Cattle Feeders Association, 2007). The Texas cattle feeding industry contributed $7 billion dollars to the economy in 2007 with value added estimates as high as $19 billion. Approximately 8.2 million head of cattle were on feed in Texas, Nebraska, and Kansas in 2007 (NASS, 2008).

The Ogallala Aquifer has permanently changed the Great Plains. The advent of new technology has allowed the production of water thirsty crops providing food and fiber to a growing nation. The pumping of the Ogallala Aquifer is now a vital mechanism that fuels the agriculture industry and contributes greatly to the economy.

However, as producers have come to realize, this vast resource could soon loose its ability to sculpt the Plains.

Irrigation and the Southern Ogallala Aquifer

With rainfall across the Southern region of the High Plains ranging from 15 to 20 inches annually, without the water from the Ogallala Aquifer current crop and livestock production in the region would not be as we see it today. Much of the area being farmed is considered a semi-arid ecosystem which is generally not suitable to produce crops which require large amounts of water. In 2005, approximately 7.96 million acre feet of water were used for irrigation in the Texas High Plains, which represented 93% of total groundwater use in the region (TWB, 2005). In 2006, the Texas High Plains produced 3.6 million bales of irrigated upland cotton on approximately 2 million irrigated acres NASS (2006). Additionally there were 600,000 acres of irrigated corn and nearly 220,000 acres of irrigated grain sorghum planted in 2006. The Texas High Plains produces nearly 65% of the states irrigated corn and approximately 83% of the irrigated cotton. With recent governmental concerns towards sustainability, steps have been made to increase conservation practices to ensure that irrigated agriculture on the Texas High Plains remains productive.

Water Law and Policy

Currently in Texas the law establishing groundwater rights is the Rule of Capture or the English rule, which essentially provides landowners the right to take all the water lying under their land as long as it is not absently wasted or deprives/restricts neighbors of their water pumping capacity (Potter, 2004). Texas adopted the Rule of Capture in 1904 with the *Houston & Texas Railroad Co. vs. East* case and again in 1955 when it was reaffirmed in favor of "reasonable use."

Modifications to the rule of capture occurred in 1997 when Senate Bill 1 was passed designating mandatory water conservation plans through the Texas Water Development Board. Further changes were made in 2001 when Senate Bill 2 was passed giving water conservation districts the authority, through Chapter 36 of the water code, to implement goals and make decisions to promote water conservation.

Over the last several decades state officials have become concerned about the large amounts of water being pumped from the Ogallala Aquifer and more importantly the rapid rate at which the water table is declining. Texas Tech University Geospatial experts estimated that the water in storage within the aquifer over a 41 county area in the Southern Region of the aquifer dropped by nearly 50 million acre feet or approximately 12% over a fifteen year period from 1990-2004. Interest in conserving the Ogallala Aquifer through government regulation stems from federal, state, and local prospectives and while it is not likely that the current Rule of Capture will be modified by the Federal Government there is strong evidence that it will be "amended" by state or local agencies, particularly through the authority given to Underground Water Conservation Districts.

Generally the driving force behind policy intervention in groundwater or irrigation water sources has been to encourage water use efficiency among agricultural producers. Most states overlying the Ogallala Aquifer have given regulation rights to "Management Districts", which work with local and state law makers to help maintain the resource. It is likely that in the future a governmental agency may intervene in the regulation of the Ogallala Aquifer. Previously most water regulations imposed by government agencies have applied only to surface water, particularly that of trans-state rivers or lakes.

Smith (1985) argued that the role of the government in groundwater regulation was likely to increase in the next decade. Debates in the 1970s focused on conserving the Ogallala Aquifer for national and international food security (Peterson et al 2003). In the 2002 farm bill, the focus on how federal policies on water conservation and implementation would affect regional economies became very evident. The 2007 Clean Water and Restoration Act which oversees wetlands may be utilized to intervene in pumping on the Ogallala Aquifer as certain wetland regions may recharge the aquifer, particularly in the northern regions.

On the High Plains, water is so fundamental to the economy that implementing policies to control its use may have detrimental effects on the scope and distribution of economic activities and the use of land and crops planted (Peterson et al 2003). One major step towards conservation through local policy occurred in 1998 when the Panhandle Groundwater Conservation District (PGCD), located in the Northeast corner of the Texas Panhandle, adopted a District Management Plan which through regulation of individual consumers set a standard of saturated thickness and pumping capacity. The 50/50 rule requires that 50% of the aquifer's saturated thickness must remain at the end of fifty years with a maximum annual drawdown of 1.25%. The final version of Rule 15 was adopted by the district in 2004 (PGCD 2008).

Specific Problem

Producers across the Texas High Plains face several escalating issues surrounding the pumping of the aquifer including increased pumping cost due primarily to increasing energy costs, depletion of the aquifer, and most recently, government intervention. While agriculture accounts for the majority of water consumed there are ongoing debates on how to properly conserve water for future generations, not only for agricultural use but also to support population growth. National Population Growth (NPG) estimates that the population of the United States will reach 394 million by the year 2050. The balance between municipal and agricultural water use has drawn much debate in recent years on how to properly manage water resources to allow for future security both in agriculture and alternative uses.

It is this concern for future generations that have Texas governmental agencies such as underground water conservation districts, considering more aggressive regulation of the Ogallala Aquifer. As previously mentioned, Senate Bill 2 has given water districts the authority to impose restrictions on producers in order to reduce the rapid decline of the aquifer. Certain districts such as the Panhandle Groundwater Conservation District are implementing regulation of water used for crop production across the Texas Panhandle while the HPUWCD #1 is in the process of developing a water management plan. These restrictions, while necessary for conservation, could potentially have detrimental effects on producers' economic and financial viability. While previous studies have indicated that any restriction in pumping capacity will have a negative economic impact on the region or county, it is not known exactly how much producers will be affected financially at the farm level. Additionally, while regional crop mixes have been evaluated, the specific alternatives and choices of producers at the farm level have yet to be addressed.

This study evaluates the farm level impacts of local regulation of the Southern Ogallala Aquifer through groundwater conservation district policy implementation. It is assumed that a regulatory policy similar to the 50/50 rule will be imposed in the 16 county HPUWCD#1. It is for this region that farm level impacts were evaluated through optimization and simulation modeling to understand the cropping decisions made by producers and the resulting financial impacts. A representative farm located in Floyd County, approximately 40 miles North-Northeast of Lubbock Texas, was used to evaluate the impact of the 50/50 water policy.

Objectives

The focus and general objective of this study was to analyze and evaluate the farm level financial impacts of a water conservation policy on a representative farm located in Floyd County, Texas. Specific objectives include:

1. Evaluate optimal farm level response to water policy restrictions.
2. Determine the impacts of water policy restrictions on farm income and financial viability.

Chapter II

LITERATURE REVIEW

The focus of this chapter is to present specific materials and studies which relate to farm financial performance, groundwater management, water policy, and aquifer depletion. Due to the complex nature and integration of these topics, the following reviews are grouped into two categories: 1) water policy studies specific to the Ogallala Aquifer and other groundwater resources, and 2) farm finances and simulation studies.

Groundwater and Ogallala Aquifer Policy

There is an extensive body of literature on water policy, regulation, and options for producers over the Ogallala Aquifer. Osborn (1973) focused his study on the direct, indirect, and induced economic impacts of the depletion of the Ogallala Aquifer in forty-two counties of the Texas High Plains for 1970-2020. An input/output model was developed by assuming Leontief characteristics and that the producer's goal was to maximize profit in any given production period. Economic impacts from irrigation were analyzed based on increased application of irrigation water to dryland. The economic impacts were divided into four categories: direct, indirect, induced, and total. Estimations of income and employment effects were determined based on the declining production of irrigated crops. Osborn concluded that the water source would eventually be exhausted since the goal of producers was to maximize profit. This total depletion would result in major impacts on the regions' agricultural economy and related industries. Osborn recommended the implementation of natural resource management policies to stabilize the economy. However, he warned that any management practices would likely not strike a balance between withdrawals and recharge, and that the Ogallala Aquifer would inevitably be exhausted.

Lansford et al. (1983) evaluated the farm level impacts of various water conservation measures in the High Plains of New Mexico. Utilizing linear programming they analyzed three groundwater management strategies compared to a baseline scenario. The options for management strategies included voluntary water conservation, mandatory irrigation supply reduction, and supply augmentation (water importation). Simulations were conducted for five individual years over a forty-three year period and results were reported in terms of net returns and changes in acreage by various crops. Under the baseline scenario net returns in the Northern High Plains were projected to increase significantly along with water diversions, but with only minor increases in irrigated acreage. The Southern High Plains was expected to have the greatest reduction in net returns, irrigated acres, and irrigation diversions under the baseline scenario. The voluntary policy would give greater increases in net returns and irrigated acres while the mandatory policy would decrease net returns and irrigated acres. The importation policy would give the highest level of net returns if producers could afford the irrigation water which was estimated to cost between $500 and $800 per acre foot.

Feinerman and Knapp (1983) investigated the effect that alternative groundwater management policies were likely to have on producers in Kern County, California. This study used a hypothetical application of taxes and quotas to understand the effects of these policies on local agriculture. The research concluded that groundwater users would be better off under quotas than with taxes. The two most significant factors affecting the magnitude of the impacts were energy costs and the discount rate used for the analysis. They concluded that as energy costs continue to rise, the benefits obtained from groundwater management would also increase.

Keplinger (1998) utilized stochastic programming to analyze a proposed water conservation policy on the Edwards Aquifer in Texas. The proposed plan would pay agricultural users to divert irrigation pumping during periods of drought to give additional spring flow for nonagricultural use. Applying a stochastic programming with recourse (SPR) model in conjunction with a water dynamics model (EPIC), results were obtained for cost of conservation and acre feet conserved. Conclusions suggest that large reductions in agricultural water use could be obtained for a relatively small cost per acre-foot. Projected costs of increasing spring flow were calculated to be $1.7 million which amounts to $20 per acre-foot of reduced pumping or $49 per acre-foot of additional spring flow.

Terrell (1998) used optimization models that were an expansion of Feng (1992) to focus on the economic impacts to the Texas High Plains as the Ogallala Aquifer declines based on current policy which had no restrictions on water use. Dynamic linear programming was used in conjunction with an input/output model, IMPLAN, to forecast groundwater depletion, cropping patterns and economic impacts over a thirty-year planning horizon in nineteen counties of the Texas High Plains. Terrell noted that in the original model, assuming that current cropping patterns were not optimal, cropping patterns switched to cotton almost immediately in all nineteen counties. However, this outcome was not agronomically feasible, thus a constraint limiting the amount of acres that could be converted to cotton annually was included. The study concluded that as the water supply decreases, producers would transition from irrigated crops to dryland cotton and that the net revenue of the surrounding communities would decline.

Johnson (2003) expanded on Terrell (1998) by investigating the effects of different policy alternatives on nineteen counties in the Texas High Plains. Specifically Johnson looked at the economic effects to the regional economy and changes in saturated thickness of the Ogallala Aquifer based on a response to three policy alternatives. These potential policies were compared to a baseline scenario in which no changes to policy were implemented and included: 1) a $1 production fee per acre foot extracted; 2) an annual quota restriction of 75% of the ten year average water usage; and 3) a water drawdown restriction of 50% of the initial saturated thickness. Utilizing non linear dynamic modeling, the results indicated that the baseline scenario resulted in the most rapid depletion of the aquifer while also having the greatest decrease in net income for the economy over a fifty year time horizon. The production fee on water extracted showed little change from the baseline partially due to a $1 per acre-foot cap on production fees mandated by legislation. This scenario indicated that a 17% savings in water could occur over the fifty year time horizon compared to the baseline.

The annual water quota restriction gave an immediate decrease in the amount of water used and crop revenue with a stabilization occurring around year twenty-eight. Results also indicated that there could be water savings of 30% compared to the baseline; however, net income per acre was lower than the baseline by approximately 15%. The final policy which restricts drawdown to 50% of the initial saturated thickness resulted in similar water savings compared to the 75% annual quota restriction scenario, but resulted in slight gains to net present value of returns with incomes only 6% less than the baseline.

Johnson concluded that the 50% drawdown policy would be ideal among the considered policies as it minimized the detrimental economic impacts to the region while at the same time conserving water.

Das (2004) developed an integrated regional water policy model by linking a spatially disaggregated hydrology model with a dynamic optimization model for 19 Texas High Plains' counties. Baseline scenarios were compared with two conservation policies; a groundwater extraction tax and a quota restriction on pumping. The results indicated that neither of the examined polices significantly inhibited the agricultural producers use of groundwater over a fifty year planning horizon. Additionally, both policy's conserved similar amounts of water; however, the social costs of the extraction tax was 8.56 times higher than that of the quota restriction.

Wheeler (2005) utilized a non-linear dynamic optimization model based on Johnson (2003) which evaluated the county level impacts of various water policy scenarios on the Ogallala Aquifer for the Southern High Plains region of Texas. Three policy scenarios were considered: 1) compensating producers for decreasing water usage to 0% drawdown relative to the total amount that would have been consumed if a Conservation Reserve Program (CRP) type policy was implemented on the aquifer; 2) 50% drawdown limit in saturated thickness; and 3) limiting water usage to 75% of the current total annual pumpage. All three of these scenarios were evaluated on a sixty year time horizon for 25 counties in the Southern Texas Panhandle and Eastern New Mexico. Optimization results indicated that blanket policies over large geographic regions were likely to be inefficient due to significant hydrologic differences and characteristics and that in counties with low water usage, the cost per acre foot conserved would be high.

Results varied widely and indicated that only certain areas/counties warrant policy intervention and in many cases, especially in areas of marginal water availability, policy implementation costs would be high. Reduction in NPV was linked directly to current and projected water consumption which varied from a loss of 7% in high water usage counties to less than 2% in low water usage counties.

Wheeler (2008) expanded upon her previous 2005 model to consider additional water conservation policies for nine counties over the Southern Ogallala Aquifer. In this study, two water buyout policies were considered over ten and twenty year periods. These policies are very similar to the CRP for erosive lands and soil conservation, but with water conservation as a primary goal. Each policy required that 25% of a county's irrigated acreage be transitioned into dryland production for the respective term of the buyout. Once the buyout expired acres could be brought back into irrigated production. Discount rates of 3%, 6%, and 9% were evaluated and a technology advancement parameter was included in the model. Results indicated that the twenty year water rights buyout saved more water at lower costs per acre foot than the ten year buyout. Additionally, there was little variation in aquifer drawdown based on the discount rate selected with drawdown rate differences less than one foot between the 3% and 9% discount rate. Net present value of net returns was primarily affected by the discount rate with NPV estimates approximately 60% less for the 9% discount rate compared to 3%. However, neither policy alternative provided enough restriction to achieve significant conservation in counties with high water depletion. Wheeler concluded that the buyouts and reserve programs would have to be county specific based on available funding and the specific conservation needs of that county.

Farm Finances and Simulation

The studies discussed in this section represent farm level simulations which have been conducted in related production areas and with similar constraints and inputs. The reviews in this section indicate the similarities in analysis procedures, primarily using simulation and crop modeling programs, to analyze the impacts of changes in input structure, yield, and output price. Much of the agricultural policy projections have been conducted by the Food and Agriculture Policy Research Institute which is a joint effort between the University of Missouri Columbia and Iowa State University. Most studies on farm level impacts of policy and other production aspects have been conducted through the Agricultural and Food Policy Center (AFPC) at Texas A&M University. In the January 2008 outlook projections issued by the AFPC, the representative cotton farms (TXSP2239 and TXSP3745) located in the Southern Texas Plains were predicted to be under severe financial strain through 2013. The probability of negative ending cash reserves was 99% for the entire five year planning horizon analyzed (Richardson et al., 2008).

Richardson (1984) utilized a Monte Carlo simulation model to evaluate the 1980-1982 income tax provisions on a representative rice farm on the Texas Gulf Coast. In an effort to understand the effects of the Economic Recovery Tax Act (ERTA) of 1981 and the Tax Equity and Fiscal Responsibility (TEFRA) Act of 1982 on farm operators' income, the Farm-Level Income and Policy Simulation (FLIPSIM) model was used to predict how the tax law affected rice producers over a ten year time horizon. Conclusions indicated that the ERTA increased producer's net present value of after tax income by only 6.9% and when the TEFRA was introduced it decreased the net present value of after tax income by 1.6%. General results indicate that both acts improved cash flow positions of farmers and that overall tax provisions were more favorable than pre ERTA.

Zhang (2001) estimated the farm financial impacts of the implementation of five Best Management Practices (BMPs) designed to reduce the phosphorus loading in Lake Champlain. Deterministic and stochastic financial indicators were used in a FLIPSIM model, which used a recursive process to simulate the annual production, farm policy, marketing, financial management, growth, and income tax aspects of a farm over a multiple-year (ten year) planning horizon. The study consisted of three representative Vermont dairy farms (60, 150, and 350 cows). The objectives included quantifying the implementation, operating and maintenance costs of selected field related BMPs on different size dairy farms along with calculating the financial impacts of these BMPs on farm performance over time using deterministic and stochastic outcomes. Nutrient management, residual management, conservation cropping, row crop field buffer, and other field buffers were among the considered BMPs. Results indicated that the residual management and conservation cropping BMPs had the largest financial costs while the nutrient management BMP had the least costs to all farms. There was concluding evidence that indicated that none of the BMPs would have substantial detrimental effects on medium and large farms; however, the baseline and predicted outlook scenarios for small dairy farms indicated difficulty maintaining positive cash flows over the ten year horizon.

Byrd (2006) conducted an analysis which investigated the farm level impacts of alternative herbicide and fumigant systems on Georgia pepper farmers. An optimization-simulation linear programming model (LP) was utilized to analytically predict the decision maker's problem and corresponding optimal choices by developing a set of algebraic expressions and relationships. Assuming risk neutrality the researchers developed a representative farm based on characteristics of fifty registered farms with the Georgia Farm Business Management Association. Taking into consideration that the traditional usage of the fumigant Methyl bromide (MeBr) was scheduled to be eliminated due to environmental concerns; the alternatives include three substitute chemicals (C35 + KPAM, Telone II + chloropicrin, and C35 + Chloropicrin). Simulation results indicated that the C35 + KPAM was the preferred alternative among producers resulting in the highest yield of 36.33 lbs per plot and producing the highest gross revenues of $14,821 per acre. The research concluded that C35 + KPAM outperformed the other alternatives in yield (traditional varieties) as well as gross and net returns.

Sartwelle (2006) conducted a study on the sensitivity of net cash farm income on U.S. beef cattle operations resulting from changes in key production variables. Output price and input costs were varied to determine how changes in these inputs affected cow calf producers across several geographical regions. Using sensitivity elasticity's (SEs), ranch level production risk was modeled stochastically with 100 iterations per year for a seven year time horizon. Using Monte Carlo simulation in conjunction with FLIPSIM, parameters for multivariate empirical distributions were simulated on a macro level using the December 2005 FAPRI baseline. Results indicated that a 1.0% change in cattle price could change net cash farm income from a low of 1.39% to a high of 8.69%. While all producers would benefit from higher cattle prices they would also suffer from higher replacement costs. The SEs for all cost changes were negative as expected but with smaller magnitudes than expected. One-percent changes in fuel, labor, various inputs, and interest cost resulted in a decrease of net cash farm income from -0.04% to -6.29%. Overall results indicate that macro cost factors across the U.S. have a relatively smaller effect on net cash farm income than regional production variability and marketing.

Higgens (2007) conducted a study of farm level impacts of revenue based support policy in the 2007 Farm Bill. The objective of the study was to show how a revenue based farm program proposed by the National Corn Growers Association would impact the economic viability of different types of farms across the U.S. over the next five years compared with the baseline of the 2002 farm bill. The analysis was conducted on twelve representative farms across the U.S. Using detailed farm level production and financial information along with FAPRI projections, a stochastic farm financial simulation model of alternative policy scenarios was developed and simulated for a five year period. Utilizing the base scenario information from the 2002 farm bill, various stochastic government payments were calculated and incorporated into the model along with historic prices, yields, and trends. Results of 500 model iterations indicated that the policy would have varying effects on different farms depending on micro characteristics and region. Results indicated that the proposed counter cyclical payment (CCR) would expand payments received by producers. Specific results indicated that rice and cotton farms would receive higher levels of payment in comparison to other crops analyzed.

The Texas A&M Agriculture and Food Policy Center (AFPC) conducts economic outlook projections for 98 representative farms in 28 states across the U.S. Crop, dairy, and livestock operations are analyzed for financial viability by region and commodity using FLIPSIM. In February 2008, AFPC released a forecast for 2008 through 2013 utilizing projected prices, policy variables, and input rates from the 2008 FAPRI baseline.

The report predicts results in a risk context using selected probabilities of historical risk and ranges in annual net cash farm income. Projections include results for net farm income, net worth, asset acquisition, gross receipts, and debt/asset ratio. While generalizations are made regarding the overall performance, key indicators include ending cash balances, equity standings, and changes in real net worth. The baseline outlook for each farm, region, and crop is published annually by the AFPC (Richardson et al., 2008).

CHAPTER III

CONCEPTUAL FRAMEWORK

Economics of Irrigation and Groundwater Use

With respect to agricultural irrigation and its optimal use, water allocation and pricing policies must address a complex set of variables, economic influences, and temporal distributions of water. These temporal and spatial dimensions create a unique scenario which allows a complex set of theories and applications to be applied which can jointly determine quantity, quality, and costs of groundwater conservation and efficiency.

In order to properly determine the decisions made by irrigators it is imperative to understand various optimization and production theories. Several factors affect the decision path of producers resulting in their irrigation schedule, demand for water, and profitability. Crop price, irrigation costs, price of other inputs, risk, expected yield, and water availability all play important roles in determining how and when a producer uses water resources. The social optimum also impacts producers as public policy continues to evolve and strengthen its grip on private rights in irrigation.

This chapter consists of three sections. The first section discusses the role of water policy in irrigation. The second section addresses how optimization modeling and dynamic programming interact with profit and water quantity utilized. The final section reviews concepts tied to economics in production and the producers' optimal choices.

Water Policy Scenarios

As previously mentioned, Texas Water Law is dictated by the Rule of Capture doctrine. This private right to irrigation has led to the mining of groundwater, as producers currently have no incentive to conserve water due to social competition. That is if a producer chooses to conserve water on a voluntary basis this water may eventually be consumed by a neighboring and competing user. These scenarios can lead to the rapid exhaustion of finite resources such as the water in the Ogallala Aquifer. Since there is no voluntary private incentive to conserve water, the only option for policy makers to efficiently conserve water is to implement governmental policies regarding water rights.

Unfortunately policies that restrict water use will have negative effects on crop yield, as there is a direct relationship between quantity of irrigation water applied and yield produced. Regardless if the policy is structured as a subsidy, essentially compensating producers for lost revenue due to decreased yield, or as a direct pumping restriction or quota system, the producer will incur reduced crop yields and associated revenue. Consider a scenario in which a farmer is maximizing profit and producing where marginal factor costs (MFC) intersects the value of marginal productivity (VMP), represented by point X in Figure 3.1, where water input w* results in production level y*. A reduction in water input to w_q due to a quota would result in a direct reduction in yield from y* to y_q . This shift in production will have direct negative impacts on total revenue for the producer. However, the exact impact of these restrictions will vary by producer mainly due to the marginal extraction costs or costs to pump an additional unit of water. Thus, no two producers may be affected the same unless they have identical hydrologic characteristics such as well yield, pump lift, and other mechanical pump characteristics.

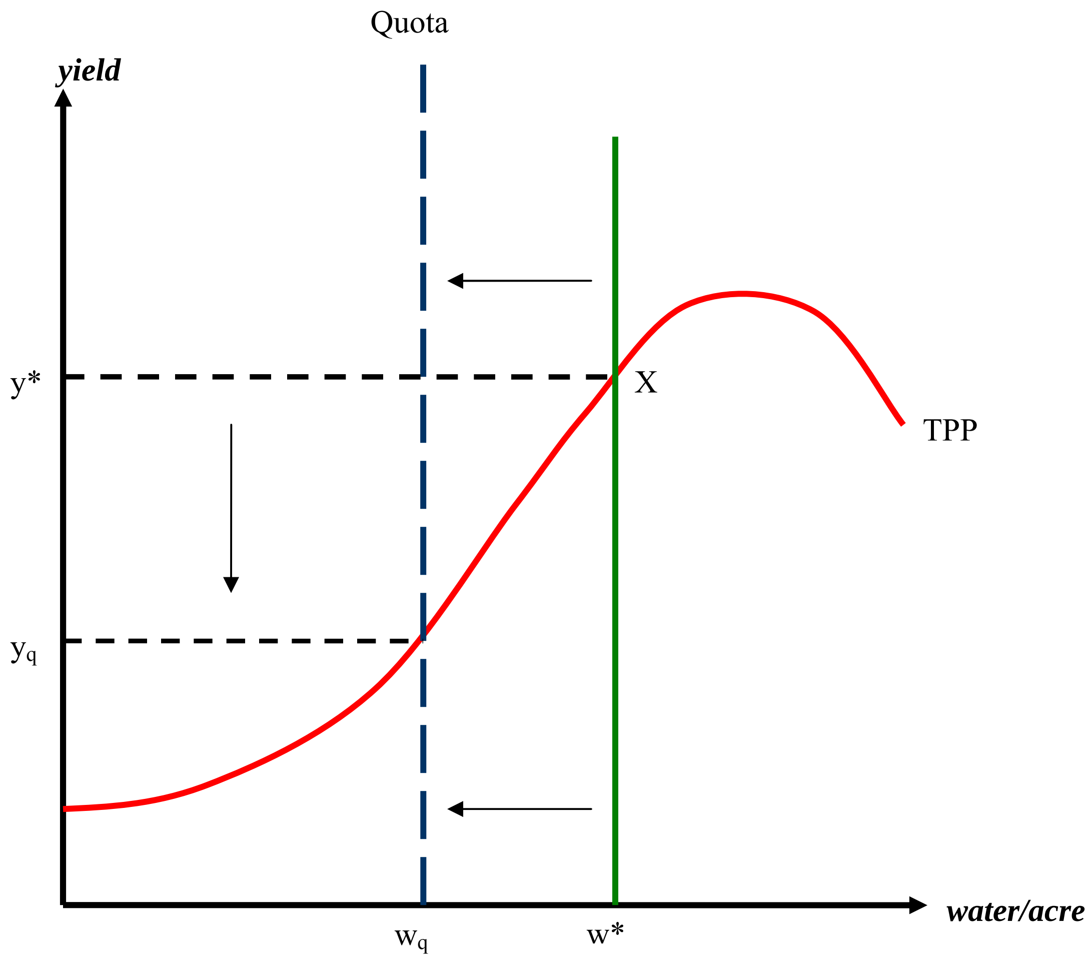

Figure 3.1. Results of the Impositions of a Water Quota.

In essence a water quota will have a greater effect on a producer who exhibits a relatively low marginal extraction cost and is pumping higher amounts of water and vise versa.

Dynamic Optimization of Groundwater

Several considerations must be made to investigate how a producer's optimal decisions may change with regard to crop mix as a hypothetical policy restriction of water/irrigation is imposed. Traditional policy analysis, as indicated in the previous chapter, typically forecasts policy effects over a lengthy period of time, in some cases as long as fifty years. It is not realistic to assume that producers make decisions on a fifty year time frame; however, the long run impacts of a policy are intuitive and thus a dynamic model is ideal to the understanding of how a natural resource is allocated over time.

Using a framework originally presented by Howe (1979), Wheeler (2004) developed a dynamic optimization model to analyze economic and hydrologic impacts of alternative policies on the Southern Ogallala Aquifer. The general form of the model can be expressed as follows:

$$\text{Max } Z = \int_0^{\infty} \int_0^{Rt} \{D(R_t)dR + A(S_t) - WR_t\} e^{-rt}\, dt \qquad (3.1)$$

$$\text{S.T.} \qquad S_t^{*} = -R_t \qquad (3.2)$$

$$S_t > 0,\ R_t \geq 0, \qquad (3.3)$$

where *Z* indicates the net present value of net returns; *R* is the rate of groundwater extraction; R_t is the rate of extraction at time *t*; S_t is the water remaining at time *t*; S_t^* is the rate of change of S_t over the planning horizon ; $D(R_t)$ is the derived demand function for groundwater, and the area under the demand function represents the social benefits received from the utilization of R_t; $A(S_t)$ is the value of the unused groundwater stock; W is the per unit cost of extraction; r represents the discount rate; and e^{-rt} is the continuous time discount factor chosen. Equation 3.2 suggests that the rate of change for remaining water is equal to the extraction rate while Equation 3.3 imposes positive stock and extraction values.

This set of equations is typically solved by applying the Hamiltonian function to derive the net social benefit at time t and accounting for the shadow price changes q_t and their affects on the groundwater stock. The Hamiltonian function is defined as follows:

$$H = [\int_0^{Rt} D(R_t)dR + A(S_t) - WR_t]\, e^{-rt} - q_tR_t \, . \tag{3.4}$$

Solving the first order conditions of the Hamiltonian equation yields the two basic conditions for dynamic efficiency.

Stock Condition:

$$P_te^{-rt} = - \partial A/\partial R_t\, e^{-rt} + We^{-rt} + q_t, \tag{3.5}$$

Flow Condition:

$$q_t^* + [p_t-q_t]\, (\partial R_t/\partial S_t) +(\partial A/\partial S_t) = r \cdot q_t, \tag{3.7}$$

where q_t* represents the rate of change of the shadow price, q_t, over time, and P_t represents the price of output. The stock condition, or the generalized efficiency condition, yields the optimal rate of resource utilization over time. At time *t*, resource utilization will be extended to the rate at which the present value of the marginal social value of groundwater, $P_t e^{-rt}$, is exactly equal to the sum of the present value of the unused groundwater stock, the marginal user cost, and the value of marginal extraction cost. The optimal condition is achieved where marginal benefits equal marginal costs. It is assumed that the marginal cost referred to is equal to a marginal social cost including production, amenity, and marginal user costs.

The flow condition yields the optimal path of the stock of the resource through time, which indicates that the amount of the stock (groundwater) remaining in the aquifer is optimal when the sum of the increase in the shadow price, q_t , the increase in future marginal profit of production, $[p_t - q_t]\ (\partial R_t / \partial S_t)$, and the marginal value of environmental services, $\partial A / \partial S_t$, equals the social discount rate, r, times the shadow price, q_t. An optimal time path requires that all points along the optimal path must be optimal at each point in time t (Wheeler, 2008). The flow condition is very similar to the generalization of the classic theorem first derived by Hotelling (1931); however, his social optimum failed to include the stock and environmental effects.

Production and Crop Mix

As the water available for irrigation on the Southern High Plains becomes limited either through decreasing supplies or government intervention it is likely that producers will change their crop mix to accommodate water shortages. For this reason it is imperative to understand the theory of multiproduct production and the sustainability of the farm. Beattie and Taylor (1985) state that the multiproduct production model can be appropriately viewed as the production of several single stage products but with the products being linked through resource constraints, nonallocable factors of production, and jointness in production.

In respect to the research questions asked in this paper, it is logical to consider the primary production factor to be irrigation water which is the factor allocated among several alternatives to maximize profit and derive an optimal path of production through various crop mixes. In its most basic sense, Doll (1992) derived the production function for a two product model with a single allocable factor (irrigation water) in the following implicit form:

$$F(y1,y2,x1)=0, \tag{3.8}$$

where $y1$ and $y2$ are product outputs and $x1$ is the total amount of the single allocable factor used to produce the two products. However, in the above case the allocation of this single factor is not explicitly or mathematically designated to each product. For the case of input $x1$, the amount applied to $y1$ and $y2$ is defined explicitly as $x11$ and $x12$, respectively. In order to take this allocation into consideration the following mathematical representation must be utilized such that:

$$F1(y1,y2,x11)=0 \tag{3.9}$$

$$F2(y1,y2,x12)=0, \tag{3.10}$$

for simplicity these equations are typically rewritten as

$$y1=f1(y2,x11) \tag{3.11}$$

$$y2=f2(y1,x12). \tag{3.12}$$

It is important to note that we have explicitly assumed that the output products *y1* and *y2* are recognized as joint products in production.

The product transformation curve, more commonly known as the production possibilities curve is represented in Figure 3.2 where each curve represents the combination of potential output with a given total input level. In essence this represents the production function in a two dimensional space, similar to the notion of the iso-quant, and is defined by a locus of output production combinations that can be obtained from a given amount of input applied. The combination of output chosen can be defined by the Marginal Rate of Product Substitution (MRPS), or the slope of the product transformation curve. MRPS is traditionally defined as follows,

$$MRPS \text{ of } Y_1 \text{ for } Y_2 = \frac{\Delta Y_2}{\Delta Y_1}. \tag{3.13}$$

The exact MRPS can be determined at any point on the production possibility curve by drawing a tangent at the point in question and measuring the slope of this tangent. The point of tangency for maximum revenue is where the isorevenue line is tangent to the production possibility curve. This point is defined as follows:

$$\frac{\Delta Y_2}{\Delta Y_1} = -\frac{Py_2}{Py_1}, \tag{3.14}$$

where, the left side of equation 3.14 represents the slope of the production possibility curve while the right side is the slope of the iso-revenue line

When the slope of the production possibilities curve is negative it is said that the products in question are competitive, where an increase in one product necessitates a decrease in another product while a positive relationship in outputs exists when the

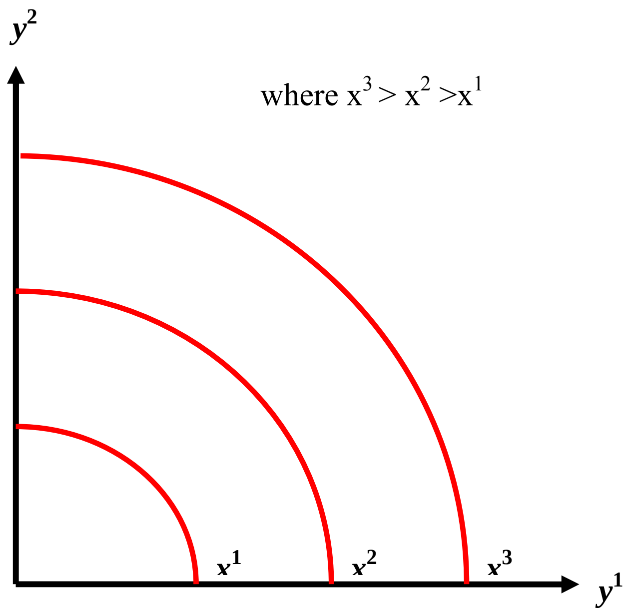

Figure 3.2. Production Possibilities Curves.

products are complimentary. If the slope is equal to zero the products are said to be supplementary such that an increase in one product does not change or affect the output of the other product.

In the case of dynamic optimization of a natural resource, the inherent question generally focuses on the allocation of a finite input to several output products. In the case of water allocation, the decision path focuses on how a producer can maximize irrigation water over several enterprise selections to achieve maximum profitability. These concepts are graphically illustrated in Figure 3.3. One important aspect is the expansion path, which is defined as a locus of points *(y1,y2)* that maximizes revenue subject to a chosen amount of the variable factor. In other words, the expansion path is a special isocline that connects the least cost combinations of inputs for all yield levels of two products. It meets the necessary condition of economic efficiency while additionally meeting the sufficient conditions. The expansion path is derived by maximizing revenue subject to a given amount of the allocable factor. In order to derive these economic factors we must first assume that the market is perfectly competitive, and then establish a constrained Lagrangean revenue function. The following example illustrates the process of deriving the maximum revenue attainable through the combination of two outputs and a fixed amount of input. The Lagrangean of Total Revenue (LTR) function is represented as follows:

$$LTR = p_1 y_1 + p_2 y_2 + \lambda[x^0 - w(y_1, y_2)], \qquad (3.15)$$

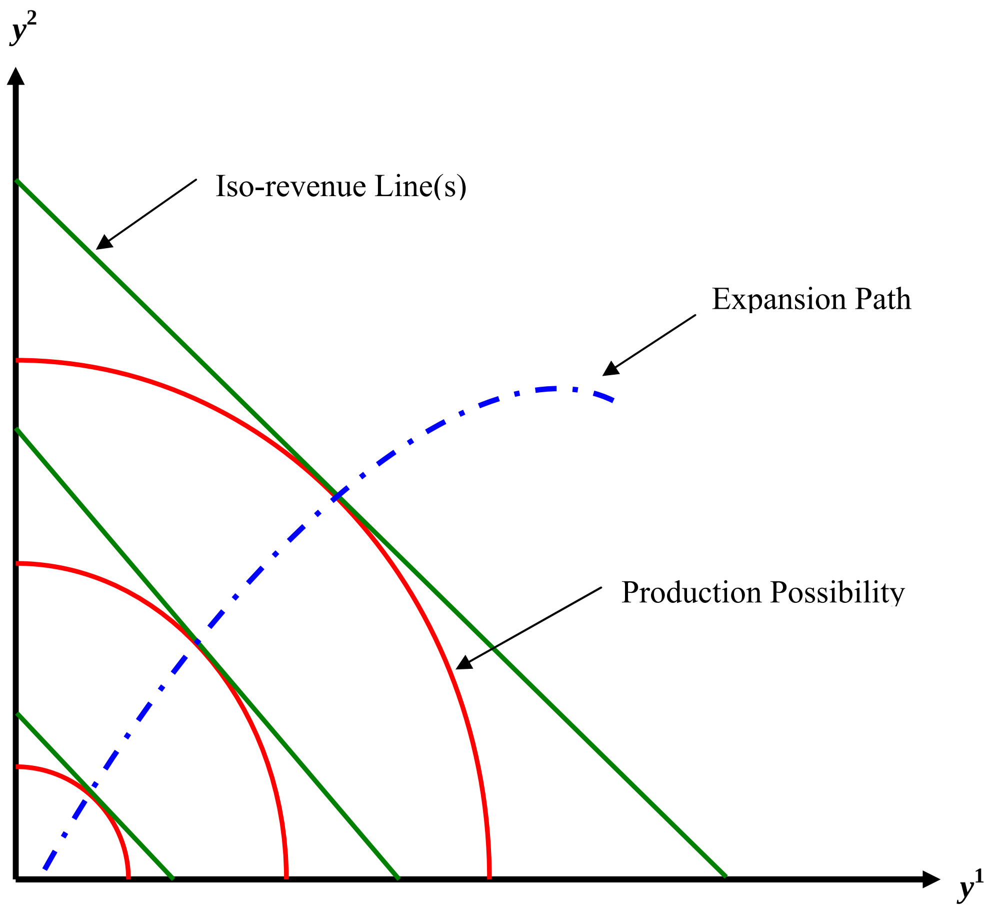

Figure 3.3. Maximum Revenue Combinations for Various Production Possibilities using Iso-revenue Lines.

where the first order conditions for revenue maximization are as follows:

$$\frac{\partial LTR}{\partial y_1} = p_1 - \lambda w_1 = 0 \qquad (3.16)$$

$$\frac{\partial LTR}{\partial y_2} = p_2 - \lambda w_2 = 0 \qquad (3.17)$$

$$\frac{\partial LTR}{\partial \lambda} = x^0 - w(y_1, y_2) = 0\,. \qquad (3.18)$$

Note that the constraint illustrated in the Lagrangean function 3.15 is expressed as a production function in that x^0 represents the amount of the allocable factor being utilized as a function of the quantities of each product produced. Utilizing equations 3.16 and 3.17 we can eliminate λ yielding the marginal condition or the output expansion path,

$$\frac{p_1}{p_2} = \frac{w_1}{w_2} = \frac{MPP_{12}}{MPP_{11}}\,. \qquad (3.19)$$

From equation 3.19 we see that the marginal condition states that there are several equalities to sustain the expansion path; where the price ratio (p_1/p_2) of the outputs equals the input quantity ratio (w_1/w_2) which in turn equals the marginal physical product of each output. If equations 3.16 and 3.17 are solved simultaneously along with the Lagrangean multiplier function, equation 3.18, we obtain the conditional product supply functions. These functions are dependent upon the quantity of input, in this case x, which is a fixed quantity. The conditional product supply functions are represented by,

$$y_j^c = y_j^c(p_1, p_2, x) \qquad \text{for j = 1,2} \tag{3.20}$$
$$\lambda^c = \lambda^c(p_1, p_2, x)$$

Summary

The previous concepts define the nature of the problem through theoretical equations and conceptualization. At the core, the problem defined within the objectives relates to resource management and production economic decisions for individual producers facing finite input quantities. The actual procedures, mathematical constraints, and equation development used to evaluate the objectives will fall under the methods and procedures chapter to follow. While these theories relate to the overall issues regarding production agriculture and resource management, the dynamic nature, model linkage, and specific formulations will be expanded upon in the Chapter IV.

CHAPTER IV

METHODS AND PROCEDURES

General Approach

The analysis of farm level impacts resulting from implementation of a 50/50 water policy scenario was achieved through a combination of dynamic optimization modeling and financial simulation programming. A representative farm consisting of irrigated and dryland crops and livestock enterprise was developed to represent a typical farm on the Southern Texas High Plains. The representative farm was used in the optimization and simulation process to estimate enterprise acres, water use and allocation, costs of production, net revenues, and changes in net worth.

The farm level response to water policy intervention was estimated using the General Algebraic Modeling System (GAMS), a dynamic optimization model, the results of which indicated the optimal path for enterprise decisions under the specified conditions. GAMS is a computer software program designed to analyze dynamic optimization problems, which in this specific case was used to maximize the net present value of returns through a ten year time horizon, utilizing economic, agronomic, and hydrologic constraints and variables. A constraint for irrigation water availability under to a 50/50 water conservation policy was incorporated into the model to estimate the optimal acres of alternative enterprises based on the objective to maximize the net present value of returns over a ten year time horizon.

To estimate the financial impacts on the representative farm, a farm financial simulation model was developed and estimated using Simetar© (<u>Sim</u>ulation and 38

Econometrics to Analyze Risk). Simetar© is an Excel Add-In which allows for the analysis of stochastic simulation models to analyze risk. The simulation model included enterprise costs of production, government program provisions, crop insurance and initial farm financial conditions. In general, the enterprise levels estimated in the dynamic optimization model were the input for the financial risk analysis. In the simulation model the variability of yield and price was incorporated to estimate the financial performance and risk associated with the optimal enterprise combinations estimated by the optimization model. The simulation was conducted over a ten year time horizon and resulted in probabilities associated with net farm income and ending cash reserves.

The specific water conservation policy analyzed was the 50/50 restriction where 50% of the saturated thickness must remain in fifty years. However, in this particular analysis a ten year time horizon was used. A ten year time frame is more realistic for producers to respond to water availability restrictions. Producers do not make planning decisions fifty years into the future and primarily make planting decisions from year to year reflecting market trends in prices; therefore, the ten year time horizon represents a more realistic planning period.

Representative Farm

The specific study area is a representative farm located in Floyd County, Texas, illustrated in Figure 4.1. This region of the Texas High Plains, located approximately forty miles NNE of Lubbock Texas, is an intensive agricultural area that is similar to other counties in the region. The diversity of Floyd County allows the various

Figure 4.1. Location of Floyd County.

land, hydrological, and enterprise characteristics to be represented in a model farm to analyze production options. Specific characteristics incorporated into the farm represent detailed hydrologic and production aspects and practices which predominately occur in the western portion of the county.

The representative farm, detailed in Table 4.1, is comprised of a variety of enterprises including cotton, corn, wheat, grain sorghum, improved pasture, and cattle. The representative farm was developed based on a survey of seven typical producers in Floyd County. The survey provided information such as owned and leased acres, percentage of crops and enterprises, irrigation and well characteristics, and other financial information which is given in Appendix L. The region chosen for the representative farm is near study sites that are part of the Texas Alliance for Water Conservation (TAWC) project. The producers interviewed were all members of the TAWC. The group of producers interviewed was not a random sampling but rather a representation of typical commercial operations in Floyd and the neighboring Hale Counties which covered a broad range of operations including both dryland and irrigated farms. Additional input from the TAWC management team and producer board aided in the development of the representative farm.

Specific Data

Several sources were used to provide data for prices, productions costs, yields, and hydrologic characteristics. While some of the information collected was used directly as inputs or constraints within the optimization model, much of the data collected was used to project distributions and stochastic aspects utilized in the simulation portion of the analysis. Crop information including county yields and prices were obtained from

Table 4.1. General Characteristics of Representative Farm.

Representative Farm, Floyd County Texas			
Initial Enterprises by Acreage and Irrigation Technology			
	LEPA	**Furrow**	**Dryland**
Cotton	650	350	50
Corn	300	0	0
Sorghum	140	0	0
Wheat	270	0	50
Livestock	0	0	0
Total Farm Acreage			1810
Total Irrigated Acres			1710
Total Dryland Acres			100
Initial Pump Lift (Feet)			315
Initial Well Yield (gpm)			336
Initial Acres Served per Well			70

NASS and additional farm level information was obtained from producer records collected through the TAWC project.

Price Projections

The optimization model used expected values for commodity prices and production costs, while the simulation model utilized stochastic values based on estimated distributions. Within the optimization model, projected output prices for the ten year time horizon were obtained from the FAPRI 2008 U.S. and World Agricultural Outlook (2008), and then localized to the Southern High Plains Region. The prices utilized the dynamic optimization model are illustrated in Appendix I. Price distributions utilized in the simulation were based on historical price distributions for each commodity.

Production Costs

Enterprise costs of production were obtained from two main sources: Texas crop and livestock budgets produced by the Texas Agrilife Extension Service for Districts 1 & 2, and enterprise budgets developed by the TAWC for specific producers in the region. The extension budgets provided baseline projections for production costs; however, several modifications were made to reflect specific attributes and production practices of the western portion of Floyd County. The enterprise budgets used in the models were adjusted for each year of the ten year time horizon based on FAPRI predictions of changes in input costs. These budgets and costs projections are given in Appendices G and J.

Crop sharing (commonly referred to as 75-25 crop share lease) is the prevalent method for leasing agricultural land on the Texas High Plains. In most cases the owner of the land receives 25% of the revenue and pays for 25% of fertilizer, chemical, harvest and ginning expenses. For simplicity a cash rent value was derived from the 75-25 scenario for both irrigated and dryland properties. The net rent value under the 75-25 crop share lease was obtained for the typical irrigated and dryland scenario. It was assumed that the cash rent value would be 75% of the estimated crop share lease to account for the additional risk the tenant assumes when under a cash rent agreement. The estimated cash rent was calculated to be $130 per acre for irrigated crop land and $25 per acre for dryland.

One primary driver factor in the NPV analysis is the discount rate. While there is much discussion about what an appropriate rate should be it is generally accepted that the social discount rate is less than private or producer level discount rates. Social discount rates typically range from 1% to 3.5%; while private discount rates can be as high as 9%. In this study a discount rate of 5% was chosen because it represents a balance between a social and private discount rate.

Yields and Production Functions

The yield data utilized within the modeling process was determined through simulations conducted in CROPMAN, a software program used to estimate crop characteristics based on regional climatic and environmental characteristics such as rainfall, ambient temperatures, and soil profiles. The simulations from CROPMAN were based on variations in irrigation water applied with soil type and other production inputs held constant. The results from CROPMAN were then used to estimate crop yield production functions relative to irrigation levels using OLS regression procedures. Irrigated crop yields were calculated as the difference between the estimated CROPMAN yields less the actual county dryland yields from the National Agricultural Statistics Service (NASS). The production functions relative to irrigation water applied were estimated setting the intercept at zero, then the dryland yield was set as the intercept. This procedure allows the production function to show the relationship of irrigation water applied and its effects on yield with the intercept value being the dryland yield. This shows the benefits of irrigation water only, thus if no irrigation water is applied then the production function reflects the dryland yield.

The livestock component of the model was a dryland grazing system on mixed improved pasture, 50% WW-B-Dahl and native grasses. Contract grazing revenues were derived from gains per acre determined from Gillen (1999) and the SARE research project at New Deal, Texas. It was assumed that the only livestock costs were the amortized costs of establishment, which include land preparation, seed, herbicide, and permanent infrastructure such as fencing and water. All variable costs associated with the livestock system are assumed to be incurred by the contracted tenant.

Hydrologic Characteristics

The data utilized to categorize the irrigation components and aquifer characteristics was obtained from the Texas Water Development Board, the High Plains Underground Water Conservation District No. 1, and the Texas Tech Center for Geospatial Technology. Specific characteristics such as well yield, pump lift, and acres per well were based on survey data collected from the producer panel. Since the models evaluated several scenarios of varying saturated thickness levels, the initial well yields for each saturated thickness level were estimated using an equation developed by Lacewell (1973), which is given in Appendix N. While the exact recharge of the Ogallala Aquifer is not certain, estimated values for recharge were based on work originally developed by Stovall (2001).

Dynamic Model Specification

The dynamic optimization model is presented in equations 4.1 through 4.11. The objective function of the model (equation 4.1) is to maximize the net present value of net revenues over a ten year time horizon, subject to a set of constraints (equations 4.2 through 4.11). Expanding upon the models developed in prior studies, the general objective function can be represented as follows:

$$\text{Max NPV} = \sum NR_t \ (1 + r)_, \qquad (4.1)$$

where NPV represents the net present value of net returns; *r* represents the discount rate; and NR_t denotes net revenue at time *t*. NR_t is defined as follows:

$$NR_t = \sum_i \sum_k \Theta_{ikt} \{ P_i Y_{ikt} [WA_{ikt\,,}(WP_{ikt})] - C_{ik} (WP_{ikt}, X_t, ST_t)\}, \qquad (4.2)$$

where *i* represents crop grown; *k* represents irrigation technologies used; Θ_{ikt} represents the percentage of crop *i* produced using irrigation technology *k* in time *t*, P_i represents the price of crop *i*, WA_{ikt} and WP_{ikt} represent irrigation water applied and water pumped per acre respectively. $Y_{ikt}[\cdot]$ represents the per acre yield production function, C_{ikt} represents the production costs per acre, X_t represents pump lift at time *t*, ST_t represents the saturated thickness of the aquifer at time *t*.

Due to the complexity of the analysis and the difficulties associated with predicting variables within the model several additional constraints are utilized to allow the model to perform correctly. While there are many detailed and necessary constraints in the model the basic constraints of the model are:

$$ST_{t+1} = ST_t - [(\sum_i \sum_k \Theta_{ikt} * WP_{ikt}) - R]A/s, \tag{4.3}$$

$$X_{t+1} = X_t + [(\sum_i \sum_k \Theta_{ikt} * WP_{ikt}) - R] A/s, \tag{4.4}$$

$$GPC_t = (ST_t/IST)^2 * (4.42*WY/AW), \tag{4.5}$$

$$WT_t = \sum_i \sum_k \Theta_{ikt} * WP_{ikt}, \tag{4.6}$$

$$WT_t \leq GPC_t \tag{4.7}$$

$$PC_{ikt} = \{[EF(X_t + 2.31*PSI)EP]/EFF\}*WP_{ikt}, \tag{4.8}$$

$$C_{ikt} = VC_{ik} + PC_{ikt} + HC_{ikt} + MC_k + DP_k + LC_k \tag{4.9}$$

$$\sum_i \sum_k \Theta_{ikt} \leq 1 \text{ for all t}, \tag{4.10}$$

$$\Theta_{ikt} \geq 0. \tag{4.11}$$

Equations 4.3 and 4.4 denote the two equations of motion which update the two state variables, saturated thickness ST_t and pumping lift X_t. *R* is the annual recharge rate in acre feet, *A* denotes the percentage of irrigated acres expressed as the initial number of irrigated acres on the farm, and s represents the specific yield of the aquifer. Equations

4.5, 4.6 and 4.7 represent various pump and irrigation characteristics. In equation 4.5, *GPC* is gross pumping capacity, *IST* is the initial saturated thickness, and *WY* is the average initial well yield for the farm. In equation 4.6, WT_t represents the total amount of water pumped per acre for each crop. Equation 4.7 requires that the total amount of water pumped cannot exceed the gross pumping capacity. Equations 4.8 and 4.9 are the costs constraints representing various production costs within the farming operation. PC_{cit} is the cost of pumping, *EF* is the energy use factor for electricity, *EP* is the price of energy, *EFF* indicates pump efficiency, and 2.31 feet is the height of a column of water that will exert a pressure of 1 pound per square inch to convert irrigation system pressure to feet of lift.

In equation 4.9, the cost of production C_{ikt} is a function of variable cost of production per acre, VC_{ik}; harvest cost per acre, HC_{ikt}; the irrigation system maintenance cost per acre, MC_k; the per acre depreciation of the irrigation system per year, DP_k; and the cost of labor per acre for the irrigation system, LC_k. In equation 4.10, the sum of the proportion of crops *i* produced by irrigation systems *k* for time period t must be less than or equal to 1. A non-negativity constraint assures all decision variables in the model take on positive values in equation 4.11.

Simulation Modeling

The simulation model used was developed for the representative farm based on a whole-farm situation. The simulation model estimated farm level financial impacts over a ten year time horizon. Enterprise revenues were based on the levels of each enterprise selected in the optimization model for each year of the time horizon. Yield and price distributions were used to generate stochastic revenue estimates for each year of the simulation. Government farm program provisions were included to account for direct commodity payments, counter cyclical payments and marketing loan provisions. Crop insurance provisions were also included with the guaranteed yields and acreages based on average enrollment values obtained from the Floyd County FSA office. Both the crop insurance and farm program payments were based on the stochastic nature of yield and price. The overall enrollment acres and yields for crop are given in Appendix J.

Production costs for each enterprise were based on initial Texas A&M Agrilife District 2 extension crop budgets for 2008 and adjusted using FARPI cost of production indexes for each year of the planning horizon. Harvest costs and ginning costs were calculated based on the stochastic yield generated in the model. The initial financial condition of the representative farm was specified with regard to the initial debt load and net worth. The results for each year of the simulation updated the financial condition of the farm. The simulation output provided a range of results including: net cash income, net farm income, changes in debt levels and changes in net worth. Probabilities of various financial conditions could be calculated; however, the primary focus was on net cash income and ending cash reserves.

The primary engine of the simulation model is the 500 stochastic iterations of the yield and price distributions for each year of the time horizon which were utilized to calculate the financial positions. Yields and prices were simulated using a Multivariate Empirical Distribution Method. There were 13 enterprise options and 6 commodity prices. Due to program limitations and a low correlation between farm prices and yield, the price and yield distributions were generated separately.

Due to a lack of data available for farm level historical yields, particularly with grain crops, a survey was developed to estimate the representative farm yield distributions for each of the primary crops. Utilizing thirty-five years of Floyd County historical average yield data, estimations of yield distributions were presented to a group of producers to solicit their opinion of the most likely farm level range in yields. The yield distribution estimates were based on county level yield data that was de-trended, with residuals obtained through OLS regression. The residuals were then expanded by six different coefficients ranging from 1.25 to 2.5 in increments of 0.25. These expanded residuals were then applied to the mean yields projected by the optimization model for each crop in each scenario. A survey was then developed and provided to a group Floyd County producers and agricultural leaders to solicit their opinion as to the most likely farm level range in yields. An example survey is presented in Appendix L. National historical prices were obtained from NASS and localized to Texas prices.

Farm revenues in the simulation model were calculated using the enterprise acreage for each year from the optimization model and the stochastic prices and yields from the commodity price and yield distributions. The enterprise costs of production were adjusted for each year of the simulation based on estimates of changes in input cost from FAPRI. Income taxes were calculated using corporate tax schedules. Additionally dividends for family living expenses were calculated using a base withdrawal of $65,000 annually which was derived from observations from 1,232 farm families enrolled in the Illinois Farm Business Farm Management Association. The base annual withdrawal of $65,000 was assumed for each year of the simulation; however, in years where cash available for withdrawal exceed the base level additional withdrawals were made based on a Marginal Propensity to Consume (MPC) of $0.132 per dollar of cash income over the base withdrawal level. The MPC used was obtained from a study conducted on Illinois Farms by Langemeier (1990). Sample income statements, cash flow statements, and balance sheets can be seen in Appendix M.

Validation within the models was done to verify the process for completeness, accuracy, and forecasting ability. The process of verification was done by hand to ensure that variables predicted and calculated within the model were arithmetically accurate and linkage between models or cells was properly calculating. Validation was used to insure that the random variables being simulated were correct and demonstrated characteristics of the parent distribution. In the case of the simulation model, the variables being simulated were that of stochastic yield and price. While the financial position of the farm was the end goal, all prior calculations are based on the yield and price draws within the model. Thus validation of yield and price was achieved in two phases. First, visual inspection of the simulated and historical prices and yields was evaluated in a Cumulative Distribution Function format to ensure that the model was associating proper odds to the draw of a particular stochastic variable. Second, using a Hotelling T2 test, the two matrixes of simulated and historical yield and price were evaluated to ensure that the mean vectors and covariance matrices were statistically equivalent. The visual inspection was subjectively affirmed and the entire Hotelling T2 test failed to reject the null hypothesis of equality.

CHAPTER V

RESULTS

The general objective of this research was to evaluate the response of a representative farm in Floyd County, Texas to a water policy that restricts the availability of irrigation water such that the drawdown in the saturated thickness of the aquifer is restricted to 50% of the current level over a fifty year time horizon (50/50 water policy scenario). The specific objectives include:

1. Evaluate optimal farm level response to water policy restrictions.
2. Determine the impacts of water policy restrictions on farm income and financial viability.

The results of this study are reported in two main sections, each following a specific objective. The first section presents results from the dynamic optimization model, where the farm level response to water policy intervention was evaluated. The second section presents findings from the financial simulation model, which estimated the financial viability and variations in farm financial status resulting from the enterprise mixes determined in the optimization model. In each section the results from the models restricting irrigation availability are compared against a baseline scenario. The baseline models were constrained with regard to irrigation availability only by the hydrological characteristics of the aquifer. The constrained models limit irrigation water availability to levels that meet the 50/50 water policy requirements. Models were run for the baseline and 50/50 water policy at beginning saturated thickness levels of 120, 100, 80, and 60 feet.

Dynamic Optimization Model Results

The results of the dynamic optimization model are presented based on a ten year time horizon. While the 50/50 water policy accounts for intervention within a fifty year time horizon, it is unlikely that producers will be able to make decisions in an extended time frame, therefore a ten year time period was chosen. Additionally, this timeframe corresponded to commodity price and input cost forecasts which are projected by FAPRI. During the ten year time period the restrictions in water availability for each year were calibrated to the 50/50 water policy utilizing a rolling average which is represented in tabular format in Appendix N. Since there are multiple scenarios incorporated into the baseline and constrained models, it is important to define the characteristics of each. In this section the results for both the baseline and constrained scenarios are presented for four initial saturated thickness levels: 120, 100, 80 and 60 feet.

Baseline Models: It is important to note the baseline model is itself a constrained model, in that it is representative of current farming practices. Each of the baseline models is constrained in a manner to represent typical production practices, approaches, and patterns within the enterprise selected and irrigation technology utilized. Each baseline model is constrained to allow water application to only decrease through time and for the percentage of irrigated acres to not exceed the initial year one percentage due to the capital investments in irrigation systems. However, there is no restriction on the percentage of dryland acres. Also, enterprise changes are restricted to a maximum of 33% per year to eliminate drastic changes within the enterprise selection from year to year. There is no restriction on the amount of water that can be utilized; however, water usage in each time period cannot be greater than the previous time period and must remain in the bounds of pumping capacity. This restriction was incorporated into the model to prevent the model from saving or banking water until the end of the time horizon and utilizing it to increase the Net Present Values per acre.

Constrained Models: These models are identical to the baseline models with the addition of a constraint that reflects the requirements imposed within the 50/50 water policy. In all the constrained scenarios, irrigation restrictions were based on the amount of drawdown allowed in the saturated thickness of the aquifer using a rolling average method developed by the Panhandle Water Conservation District and illustrated in Appendix N. The irrigation constraints were updated every five years due to the revaluation period noted in the 50/50 water management plan, thus the restrictions in drawdown occur in the fifth and tenth year.

<u>120 Foot Saturated Thickness Baseline Model</u>

The summary results for the 120 foot baseline model shown in Table 5.1 indicate no shifts to dryland crops until year nine of the ten year time horizon when the percentage of dryland crops increases to 9.4%. Irrigated cropland is initially 94.5% of total acres and declined to 90.6% in year ten, with the shift to dryland acres coming out the furrow irrigated acres. The average water applied per irrigated acre over the ten year time period is 17.95 acre inches, ranging from 20.18 acre inches in year one to 15.49 acre inches in year ten. This is the highest pumping rate of any scenario evaluated. The net present value of net returns was $2,070.88 per acre over the planning horizon. Saturated thickness declined to 97.61 feet in the tenth year with an average decline in saturated

Table 5.1. Summary output for the 120 foot baseline model.

Floyd 120ft Baseline

Period	Saturated Thickness Feet	Pump Lift Feet	GPC Acre in.	Nominal Net Return ($/Acre)	Average Water Applied Per Cropland Acre (in.)	Nominal Pumping Cost ($/Acre in.)	% Cropland LEPA Irrigated	% Cropland Furrow Irrigated	% Cropland Total Irrigated	%Cropland Total Dryland	Average Water Applied Per Irrigated Acre (in.)
1	120.00	315.00	21.22	268.53	19.07	7.33	75.14%	19.34%	94.48%	5.52%	20.18
2	117.17	317.83	20.23	288.94	18.82	7.39	75.14%	19.34%	94.48%	5.52%	19.92
3	114.39	320.61	19.28	268.21	18.79	7.45	75.14%	19.34%	94.48%	5.52%	19.88
4	111.61	323.39	18.35	263.12	18.35	7.51	75.14%	19.34%	94.48%	5.52%	19.43
5	108.92	326.08	17.48	255.23	17.48	7.56	75.14%	19.34%	94.48%	5.52%	18.50
6	106.38	328.62	16.67	249.95	16.67	7.61	75.14%	19.34%	94.48%	5.52%	17.65
7	104.00	331.00	15.93	248.95	15.93	7.66	75.14%	19.34%	94.48%	5.52%	16.87
8	101.75	333.25	15.25	240.23	15.25	7.71	75.14%	19.34%	94.48%	5.52%	16.14
9	99.62	335.38	14.62	230.77	14.62	7.75	75.14%	19.34%	94.48%	5.52%	15.48
10	97.61	337.39	14.04	214.22	14.04	7.80	75.14%	15.46%	90.60%	9.40%	15.49
Net Present Value of Net Returns (NPV)/Acre					$2,070.88					AVG	17.95

thickness of 2.24 feet per year. Nominal net returns per acre initially begin at $268.53, increased to a high of $288.94 in year two, and then declined to $214.22 in year ten.

The enterprise percentages over the time horizon are given in Figures 5.1 through 5.3. LEPA irrigated cotton is the dominant enterprise as its initial acreage increased from 36% in year one to 74% in year ten. All other LEPA irrigated crops declined from their initial values to become an insignificant portion of the enterprise mix by year ten. Furrow irrigated cotton remained steady at its initial value of 19% until year four and then declined, while furrow irrigated wheat increased from 0% in years one through three to 17% in year nine. Furrow irrigated sorghum and corn remained at 0% throughout the planning horizon. With respect to the dryland crops, dryland sorghum increased from 0% in year one to 5% in year nine and 9% in year ten, while dryland cotton acres decreased from 2.8% in year one to 0% in year four. The dryland livestock enterprise did not enter the solution at any point of the time horizon.

<u>120 Foot Saturated Thickness Constrained Model</u>

As shown in Table 5.2, the results for the 120 foot constrained model indicate an increased shift to dryland production compared to the 120 foot baseline model, with the percentage of irrigated acres declining from 94.5% to 77.3% of total farm acres. The increased dryland production came from a reduction in furrow irrigated acres. The average water applied per irrigated acre over the ten year time period was 15.15 acre inches, ranging from 14.84 acre inches in year one to 15.52 acre inches in year ten. Saturated thickness decreased to 105.47 feet in the tenth year with an average decline of 1.45 feet per year. This represents a 35% reduction in water consumption over the ten

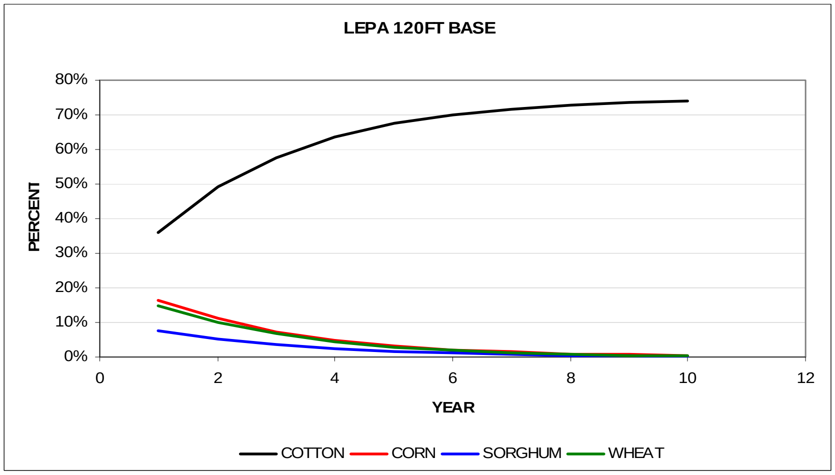

Figure 5.1. Percentage of LEPA irrigated crops through time, 120 foot baseline.

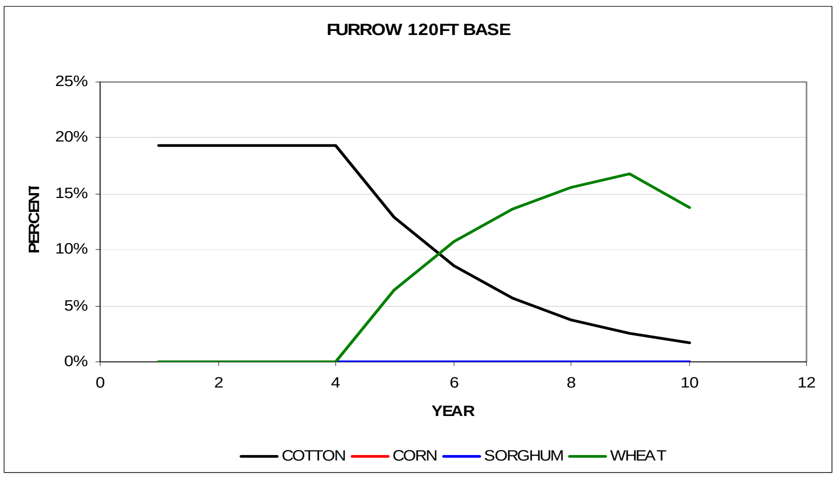

Figure 5.2. Percentage of furrow irrigated crops through time, 120 foot baseline.

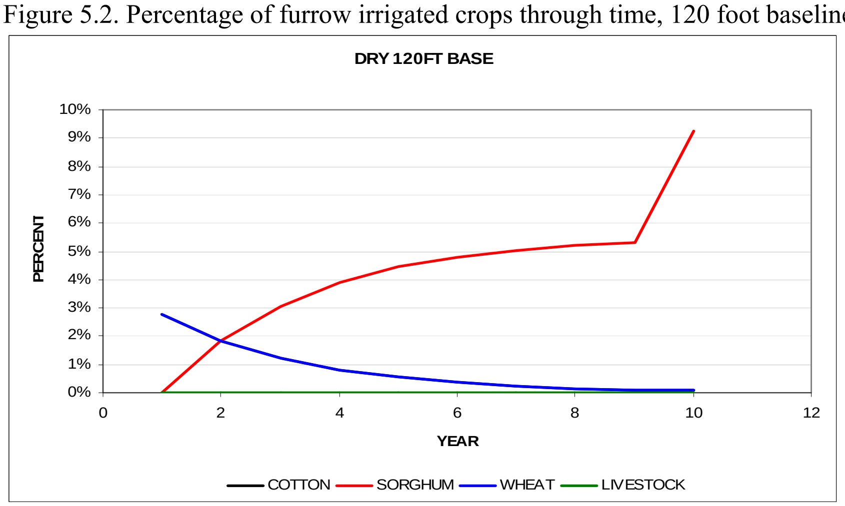

Figure 5.3 Percentage of dryland crops through time, 120 foot baseline.

Table 5.2. Summary output for 120 foot constrained model.

Floyd 120ft Constrained

Period	Saturated Thickness Feet	Pump Lift Feet	GPC Acre in.	Nominal Net Return ($/Acre)	Average Water Applied Per Cropland Acre (in.)	Nominal Pumping Cost ($/Acre in.)	% Cropland LEPA Irrigated	% Cropland Furrow Irrigated	% Cropland Total Irrigated	%Cropland Total Dryland	Average Water Applied Per Irrigated Acre (in.)
1	120.00	315.00	21.22	236.82	14.02	7.33	75.14%	19.34%	94.48%	5.52%	14.84
2	118.10	316.90	20.55	250.00	13.47	7.37	75.14%	16.11%	91.25%	8.75%	14.77
3	116.30	318.70	19.93	222.70	12.75	7.41	75.14%	10.73%	85.87%	14.13%	14.85
4	114.64	320.36	19.36	214.38	12.25	7.44	75.14%	7.15%	82.29%	17.71%	14.88
5	113.07	321.93	18.83	211.18	12.06	7.48	75.14%	4.76%	79.90%	20.10%	15.09
6	111.53	323.47	18.33	209.70	11.95	7.51	75.14%	3.17%	78.31%	21.69%	15.26
7	110.01	324.99	17.83	212.51	11.88	7.54	75.14%	2.11%	77.25%	22.75%	15.38
8	108.51	326.49	17.35	209.72	11.93	7.57	75.14%	2.11%	77.25%	22.75%	15.45
9	106.99	328.01	16.87	205.13	11.97	7.60	75.14%	2.11%	77.25%	22.75%	15.49
10	105.47	329.53	16.39	196.54	11.99	7.63	75.14%	2.11%	77.25%	22.75%	15.52
Net Present Value of Net Returns (NPV)/Acre					$1,773.29					AVG	15.15

year planning horizon compared to the 120 foot baseline. Thus the 50/50 water policy reduced pumping by 2,112 acre feet on the representative farm over the ten year planning horizon. The net present value of net returns was $1,773.29 per acre over the planning horizon. Nominal annual net returns initially begin at $236.82 per acre, increased to a high of $250.00 in year two and then declined to $196.54 in year ten.

The enterprise percentages over the time horizon are given in Figures 5.4 through 5.6. LEPA irrigated cotton increased from 36% in year one to 74% in year ten, while LEPA irrigated corn and sorghum continually decreased throughout the time horizon. Furrow irrigated cotton steadily declines from its initial value of 19% while furrow irrigated wheat increases slightly in year seven and was 2% in year ten. Furrow irrigated sorghum or corn was never a viable option and remained at 0% throughout the planning horizon. With respect to the dryland crops, the projections indicated that dryland sorghum was the primary dryland crop; increasing from 0% in year one to 23% in year ten while dryland cotton acres decrease from 2.8% in year one to 0% in year four. Dryland livestock did not enter the solution.

<u>100 Foot Saturated Thickness Baseline Model</u>

As shown in Table 5.3, the percentage of irrigated acres decreased from 94.5% to 77.5% over the 10 year time period. The decline in irrigated acres came from a shift of furrow irrigated acres to dryland production which reached 22.5% of total acres in year ten. The average water applied per irrigated acre over the ten year time period was 16.27 acre inches, ranging from 18.51 acre inches in year one to 15.17 in year ten, slightly less

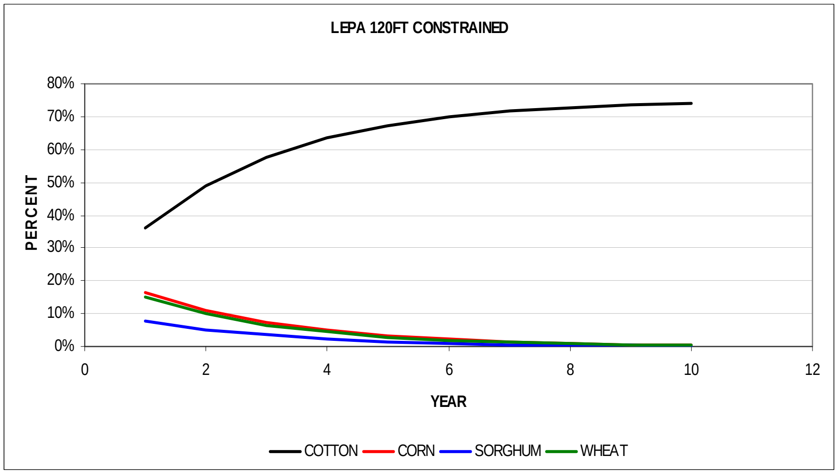

Figure 5.4. Percentage of LEPA irrigated crops through time, 120 foot constrained.

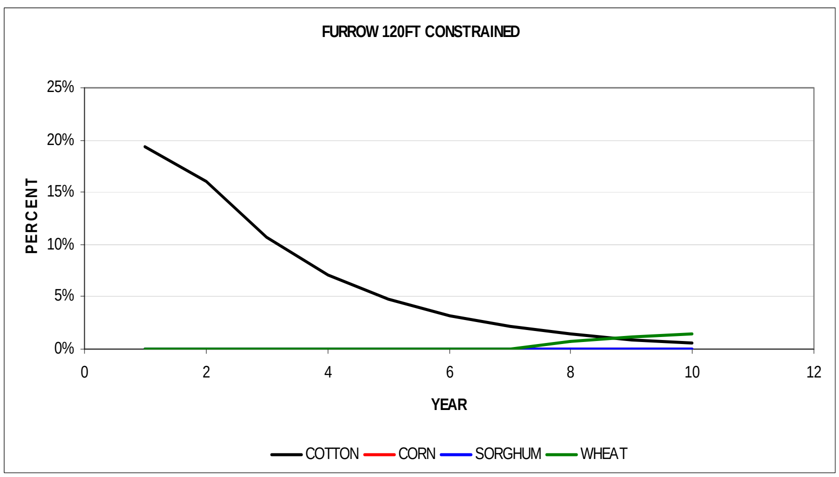

Figure 5.5. Percentage of furrow irrigated crops through time, 120 foot constrained.

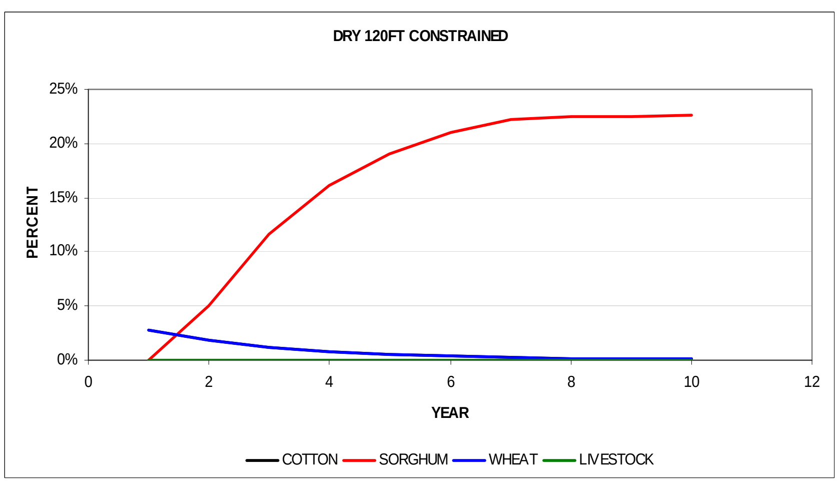

Figure 5.6 Percentage of dryland crops through time, 120 foot constrained

Table 5.3. Summary output for 100 foot baseline model.

Floyd 100ft Baseline

Period	Saturated Thickness Feet	Pump Lift Feet	GPC Acre in.	Nominal Net Return ($/Acre)	Average Water Applied Per Cropland Acre (in.)	Nominal Pumping Cost ($/Acre in.)	% Cropland LEPA Irrigated	% Cropland Furrow Irrigated	% Cropland Total Irrigated	%Cropland Total Dryland	Average Water Applied Per Irrigated Acre (in.)
1	100.00	335.00	17.49	252.66	17.49	7.75	75.14%	19.34%	94.48%	5.52%	18.51
2	97.46	337.54	16.61	269.55	16.61	7.80	75.14%	19.34%	94.48%	5.52%	17.59
3	95.09	339.91	15.81	244.06	15.81	7.85	75.14%	19.34%	94.48%	5.52%	16.74
4	92.86	342.14	15.08	233.64	15.08	7.90	75.14%	19.34%	94.48%	5.52%	15.96
5	90.76	344.24	14.41	225.14	14.41	7.94	75.14%	16.94%	92.08%	7.92%	15.65
6	88.79	346.21	13.79	218.85	13.79	7.98	75.14%	11.74%	86.88%	13.12%	15.87
7	86.94	348.06	13.22	217.11	13.22	8.02	75.14%	7.82%	82.96%	17.04%	15.93
8	85.19	349.81	12.69	208.73	12.69	8.05	75.14%	5.21%	80.35%	19.65%	15.80
9	83.53	351.47	12.20	198.88	12.20	8.09	75.14%	3.47%	78.61%	21.39%	15.52
10	81.97	353.03	11.75	185.19	11.75	8.12	75.14%	2.31%	77.45%	22.55%	15.17

Net Present Value of Net Returns (NPV)/Acre	$1,853.61	AVG	16.27

than the 120 foot baseline due to a decrease in water availability. Saturated thickness decreased to 81.97 feet in the tenth year with an average decline of 1.8 feet per year. The net present value of net returns was $1,853.61 per acre over the planning horizon. Nominal net returns initially were $252.66 per acre, increased to a high of $269.55 in year two, and then continued to decline to $185.19 in year ten.

The enterprise percentages over the time horizon are given in Figures 5.7 through 5.9. LEPA irrigated cotton acreage increased from 36% in year one to 74% in year ten, while LEPA irrigated corn and sorghum acres continually declined from their initial values. Furrow irrigated cotton steadily declined from its initial value of 19%, while furrow irrigated wheat increased from 0% to 8% in year five followed by a decline to 1% in year ten as furrow irrigated acres shifted to dryland production. Furrow irrigated sorghum and corn remained at 0% throughout the planning horizon. With respect to the dryland crops, dryland sorghum increased from 0% in year one to 22% in year ten while dryland cotton acreage decreased from 2.8% in year one to 0% in year four. The dryland livestock enterprise did not enter the solution.

<u>100 Foot Saturated Thickness Constrained Model</u>

As shown in Table 5.4, dryland production started to increase in year two and reached 26.9% of total acres in year five. The percentage of irrigated acres decreased from 94.5% to 73.1% over the 10 year time period, with the decline in irrigated acres coming from an almost total shift of furrow irrigated acres and a 2.5% shift from LEPA acres to dryland production. The percentage of irrigated acres under the 50/50 water policy was only slightly less than the 100 foot baseline; however, the shift to dryland

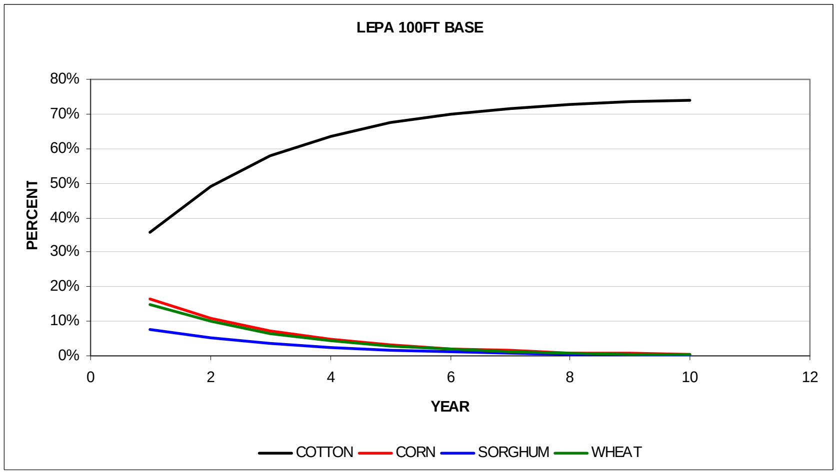

Figure 5.7. Percentage of LEPA irrigated crops through time, 100 foot baseline.

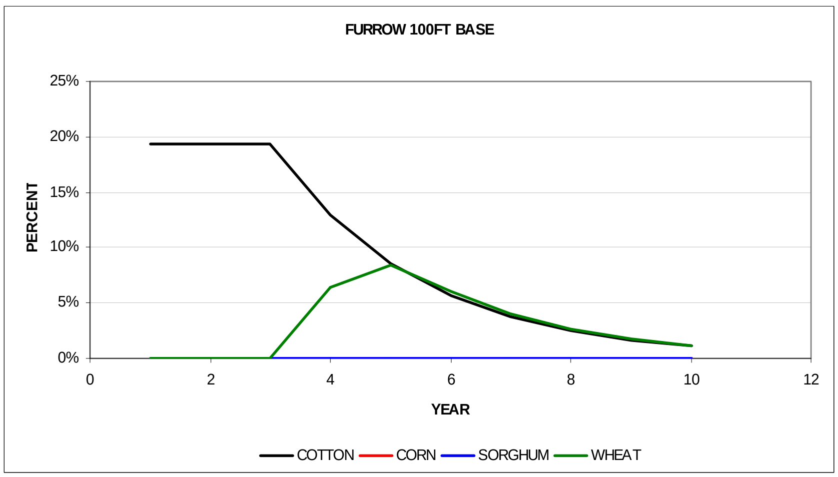

Figure 5.8. Percentage of furrow irrigated crops through time, 100 foot baseline.

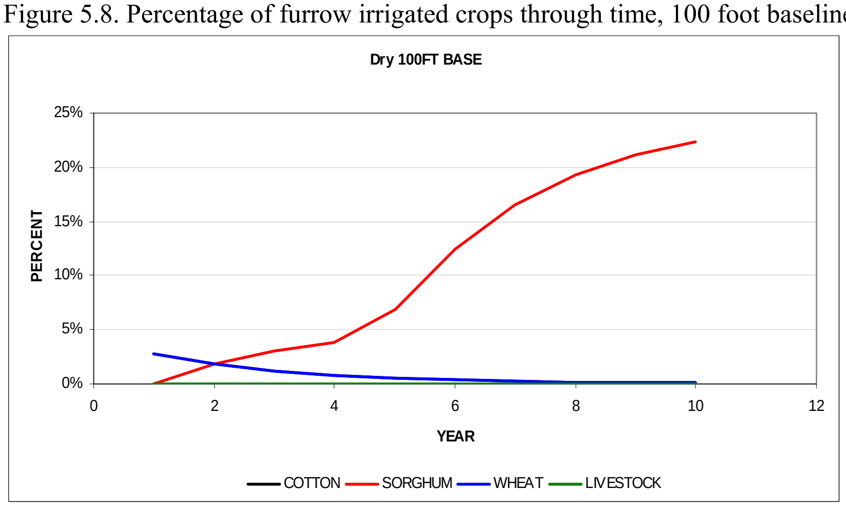

Figure 5.9 Percentage of dryland crops through time, 100 foot baseline.

Table 5.4. Summary output for 100 foot constrained model.

Floyd 100ft Constrained

Period	Saturated Thickness Feet	Pump Lift Feet	GPC Acre in.	Nominal Net Return ($/Acre)	Average Water Applied Per Cropland Acre (in.)	Nominal Pumping Cost ($/Acre in.)	% Cropland LEPA Irrigated	% Cropland Furrow Irrigated	% Cropland Total Irrigated	%Cropland Total Dryland	Average Water Applied Per Irrigated Acre (in.)
1	100.00	335.00	17.49	215.12	12.81	7.75	75.14%	19.34%	94.48%	5.52%	13.56
2	98.32	336.68	16.91	224.33	12.04	7.78	75.14%	12.88%	88.02%	11.98%	13.67
3	96.79	338.21	16.39	200.55	11.51	7.81	75.14%	8.58%	83.72%	16.28%	13.75
4	95.35	339.65	15.90	193.23	11.10	7.84	75.14%	5.71%	80.85%	19.15%	13.73
5	93.99	341.01	15.45	178.84	10.15	7.87	69.33%	3.80%	73.14%	26.86%	13.88
6	92.81	342.19	15.06	181.13	10.27	7.90	70.60%	2.53%	73.14%	26.86%	14.05
7	91.60	343.40	14.67	186.16	10.36	7.92	71.45%	1.69%	73.14%	26.86%	14.17
8	90.37	344.63	14.28	184.05	10.42	7.95	72.01%	1.12%	73.14%	26.86%	14.25
9	89.13	345.87	13.90	179.98	10.46	7.97	72.39%	0.75%	73.14%	26.86%	14.30
10	87.89	347.11	13.51	172.14	10.49	8.00	72.64%	0.50%	73.14%	26.86%	14.34

Net Present Value of Net Returns (NPV)/Acre					$1,569.15					AVG	13.97

occurred much earlier in the time period. The average water applied per irrigated acre over the ten year time period was 13.97 acre inches, ranging from 13.56 acre inches in year one to 14.34 acre inches in year ten. Saturated thickness declined to 87.89 feet in the tenth year with an average decline of 1.21 feet per year; representing a 33% reduction in water consumption over the ten year planning horizon compared to the baseline scenario. Thus the 50/50 water policy reduced pumping by 1,607 acre feet on the representative farm over the ten year period. The net present value of net returns was $1,569.15 per acre over the planning horizon. Nominal net returns were initially $215.12 per acre, increased to a high of $224.33 in year two and declined to $172.14 in year ten.

The enterprise percentages over the time horizon are given in Figures 5.10 through 5.12. LEPA irrigated cotton acres increased from 36% in year one to 71% in year ten, while LEPA irrigated corn and sorghum acres continually declined. Furrow irrigated cotton steadily declined from its initial value of 19% as acres shifted to dryland production. Furrow irrigated sorghum, corn, and wheat did not enter the solution. With respect to the dryland crops, dryland sorghum increased from 0% in year one to 26% in year six, then increased slightly to a maximum of 27% in year ten, while cotton acres decreased from 2.8% in year one to 0% in year four. The dryland livestock enterprise did not enter the solution.

<u>80 Foot Saturated Thickness Baseline Model</u>

The 80 foot baseline results indicated an increased shift to a more dryland intensive production system. As shown in Table 5.5, dryland production increased from

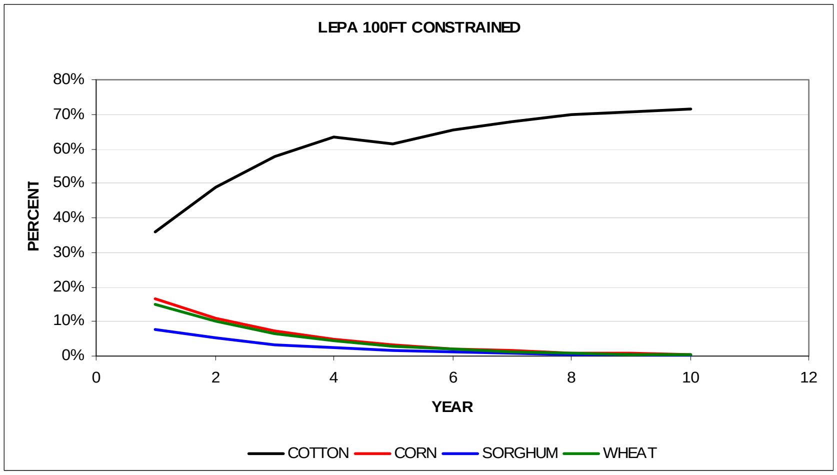

Figure 5.10. Percentage of LEPA irrigated crops through time, 100 foot constrained.

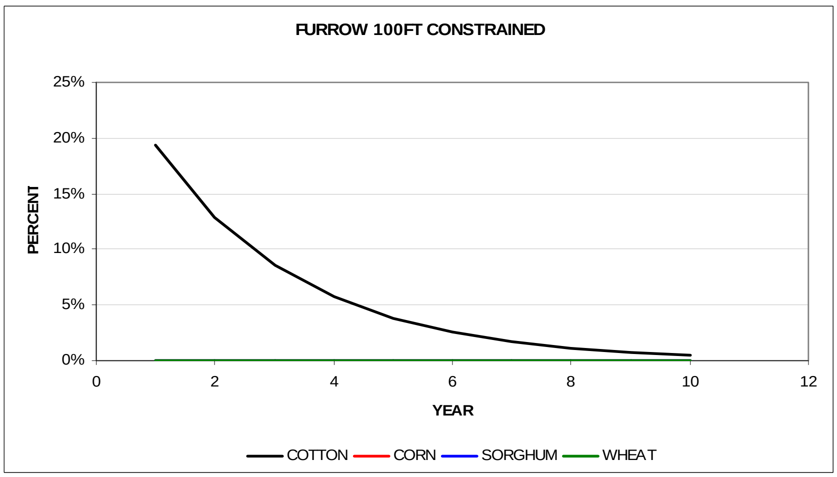

Figure 5.11. Percentage of furrow irrigated crops through time, 100 foot constrained.

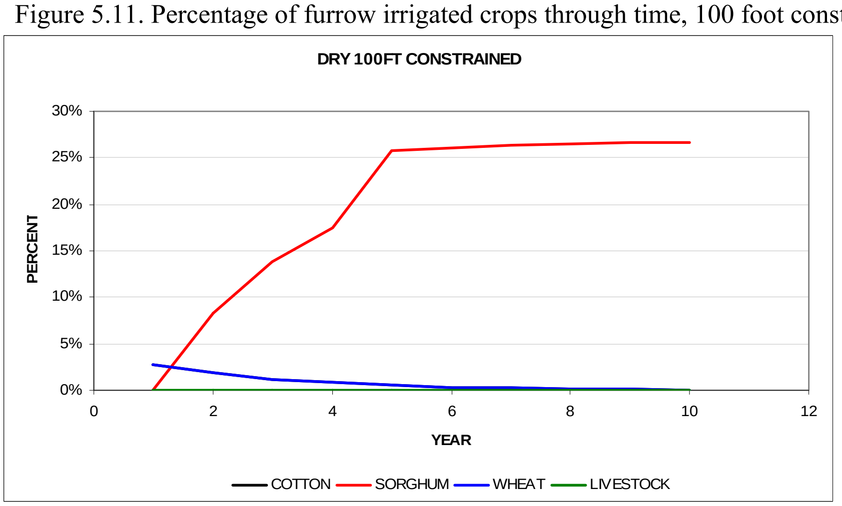

Figure 5.12 Percentage of dryland crops through time, 100 foot constrained.

Table 5.5. Summary output for 80 foot baseline model.

Floyd 80ft Baseline

Period	Saturated Thickness Feet	Pump Lift Feet	GPC Acre in.	Nominal Net Return ($/Acre)	Average Water Applied Per Cropland Acre (in.)	Nominal Pumping Cost ($/Acre in.)	% Cropland LEPA Irrigated	% Cropland Furrow Irrigated	% Cropland Total Irrigated	%Cropland Total Dryland	Average Water Applied Per Irrigated Acre (in.)
1	80.00	355.00	13.70	216.87	13.70	8.16	75.14%	19.34%	94.48%	5.52%	14.50
2	78.16	356.84	13.08	228.72	13.08	8.20	75.14%	13.18%	88.32%	11.68%	14.81
3	76.43	358.57	12.51	205.01	12.51	8.24	75.14%	8.78%	83.92%	16.08%	14.90
4	74.81	360.19	11.98	197.12	11.98	8.27	75.14%	5.85%	80.99%	19.01%	14.80
5	73.29	361.71	11.50	190.88	11.50	8.30	75.14%	3.89%	79.03%	20.97%	14.55
6	71.85	363.15	11.05	185.32	11.05	8.33	75.14%	2.59%	77.73%	22.27%	14.22
7	70.50	364.50	10.64	183.33	10.64	8.36	72.62%	1.73%	74.35%	25.65%	14.31
8	69.22	365.78	10.26	175.27	10.26	8.39	70.21%	1.15%	71.36%	28.64%	14.38
9	68.02	366.98	9.90	166.38	9.90	8.41	67.91%	0.77%	68.68%	31.32%	14.42
10	66.88	368.12	9.58	154.72	9.58	8.43	65.74%	0.51%	66.25%	33.75%	14.45

Net Present Value of Net Returns (NPV)/Acre	$1,566.88	
	AVG	14.54

5.5% in year one to 33.7% in year ten as furrow irrigated acres were shifted to dryland and LEPA irrigated acres decreased from 75.1% to 65.7% of total acres. The average water applied per irrigated acre over the ten year time period was 14.54 acre inches. Saturated thickness decreased to 66.88 feet in the tenth year with an average decline of 1.31 feet per year. The net present value of net returns was $1,566.88 per acre over the planning horizon. Nominal net returns initially were $216.87 per acre, increased to a high of $228.72 in year two, and continued to decline to $154.72 in year ten.

The enterprise percentages over the time horizon are given in Figures 5.13 through 5.15. Results indicated that LEPA irrigated cotton acres increased from 36% in year one to a maximum of 70% in year six followed by a slight decline to 65% in year ten. LEPA irrigated corn, wheat, and sorghum continually declined throughout the period. Furrow irrigated cotton steadily declined from an initial value of 19% as furrow irrigated acres were converted to dryland production. Furrow irrigated sorghum, wheat, and corn did not enter the solution. With respect to the dryland crops, dryland sorghum increased from 0% in year one to 34% by year ten, while dryland cotton acres decreased from 2.8% in year one to 0% in year four. The dryland livestock enterprise did not enter the solution.

<u>80 Foot Saturated Thickness Constrained Model</u>

The 80 foot constrained results show a shift to dryland production much earlier in the time horizon compared to the baseline model. As seen in Table 5.6, the percentage of dryland acres increased to 36.3% in year four and remained at that level through year ten.

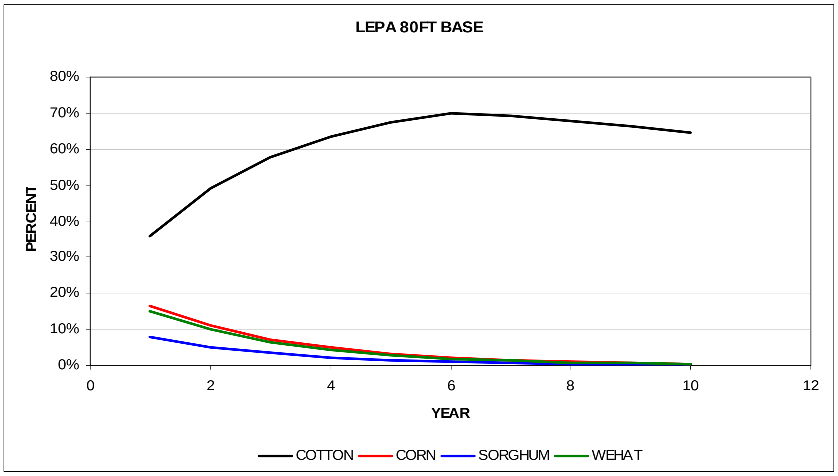

Figure 5.13. Percentage of LEPA irrigated crops through time, 80 foot baseline.

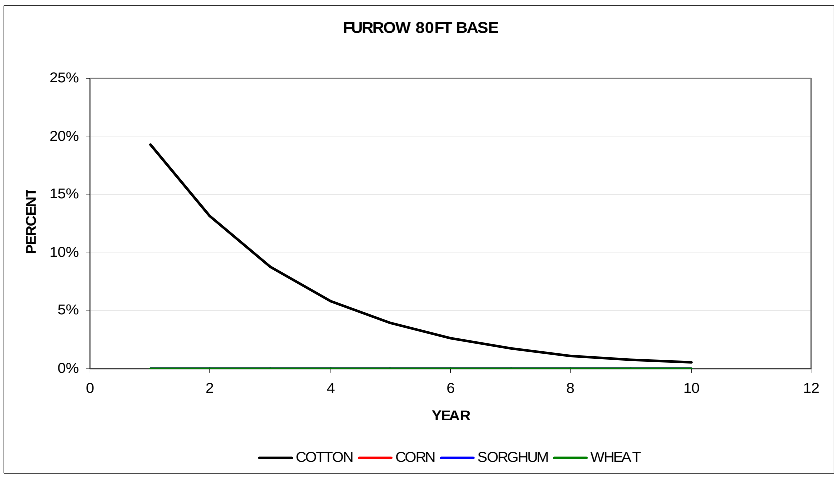

Figure 5.14. Percentage of furrow irrigated crops through time, 80 foot baseline.

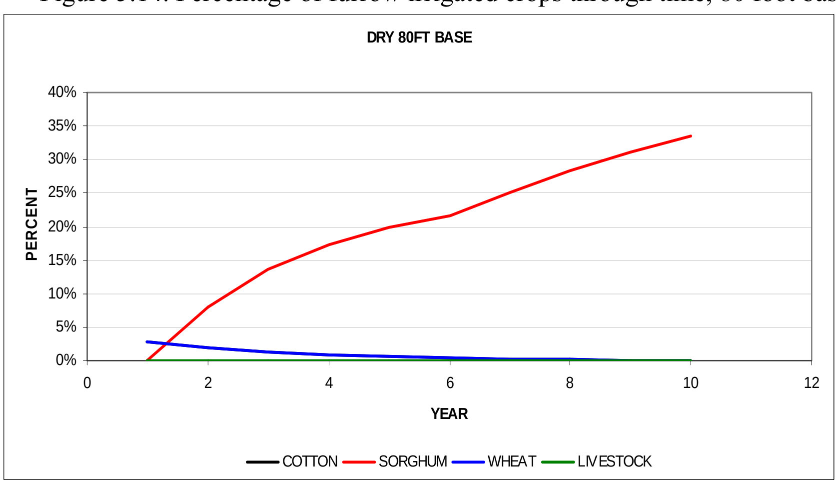

Figure 5.15 Percentage of dryland crops through time, 80 foot baseline.

Table 5.6. Summary output for 80 foot constrained model.

Floyd 80ft Constrained

Period	Saturated Thickness Feet	Pump Lift Feet	GPC Acre in.	Nominal Net Return ($/Acre)	Average Water Applied Per Cropland Acre (in.)	Nominal Pumping Cost ($/Acre in.)	% Cropland LEPA Irrigated	% Cropland Furrow Irrigated	% Cropland Total Irrigated	%Cropland Total Dryland	Average Water Applied Per Irrigated Acre (in.)
1	80.00	355.00	13.70	196.61	11.98	8.16	75.14%	19.34%	94.48%	5.52%	12.68
2	78.48	356.52	13.19	205.62	11.21	8.19	75.14%	12.88%	88.02%	11.98%	12.73
3	77.10	357.90	12.73	176.85	10.39	8.22	71.19%	8.58%	79.77%	20.23%	13.02
4	75.87	359.13	12.32	145.51	8.41	8.25	57.93%	5.71%	63.65%	36.35%	13.21
5	75.00	360.00	12.04	151.11	8.61	8.27	59.84%	3.80%	63.65%	36.35%	13.52
6	74.10	360.90	11.75	154.09	8.74	8.28	61.11%	2.53%	63.65%	36.35%	13.73
7	73.17	361.83	11.46	159.46	8.83	8.30	61.96%	1.69%	63.65%	36.35%	13.87
8	72.23	362.77	11.17	157.84	8.89	8.32	62.52%	1.12%	63.65%	36.35%	13.96
9	71.27	363.73	10.88	154.71	8.93	8.34	62.90%	0.75%	63.65%	36.35%	14.03
10	70.31	364.69	10.58	147.88	8.95	8.36	63.15%	0.50%	63.65%	36.35%	14.07
Net Present Value of Net Returns (NPV)/Acre					$1,354.80					AVG	13.48

Furrower irrigated acres steadily declined throughout the time period. The average water applied per irrigated acre over the ten year time period is 13.48 acre inches. Saturated thickness decreased to 70.31 feet in the tenth year with an average decline in saturated thickness of 0.97 feet per year. This represented a 23% reduction in water consumption over the ten year planning horizon compared to the baseline model. Thus the 50/50 water policy reduced pumping by 932 acre feet on the representative farm over the ten year period. The net present value of net returns was $1,354.80 per acre over the planning horizon. Nominal net returns were initially $196.61 per acre, increased to a high of $205.62 in year two, then decline to a value of $147.88 in year ten.

The enterprise percentages over the time horizon are given in Figures 5.16 through 5.18. LEPA irrigated cotton acres increased from 36% in year one to 54% in year two, slightly decreased in years five and six, and then increased to 62% in year ten. The percentage of LEPA irrigated corn, wheat, and sorghum continually declined from their initial values. Furrow irrigated cotton steadily declined from an initial value of 19% to 0.5% in year ten. Furrow irrigated sorghum, wheat, and corn did not enter the solution. Dryland sorghum became the primary dryland enterprise as dryland acres increased, while dryland cotton acres declined to 0% in year four. The dryland livestock enterprise did not enter the solution.

<u>60 foot Saturated Thickness Baseline Model</u>

The 60 foot baseline results indicated an increased shift to dryland production. As shown in Table 5.7, the percentage of dryland acres continually increased throughout the time period to 37.6% in year ten. Furrower irrigated acres steadily declined

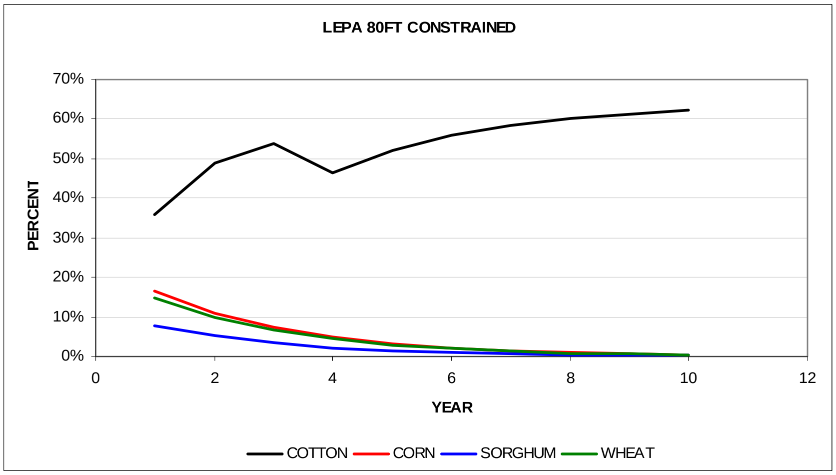

Figure 5.16. Percentage of LEPA irrigated crops through time, 80 foot constrained.

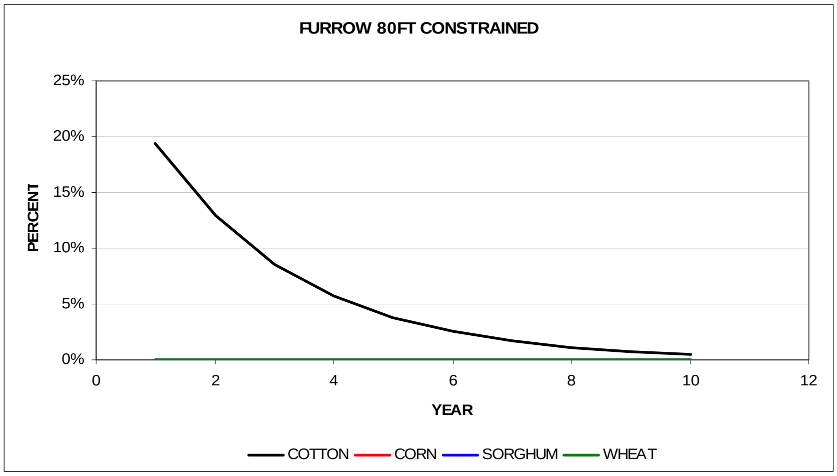

Figure 5.17. Percentage of furrow irrigated crops through time, 80 foot constrained.

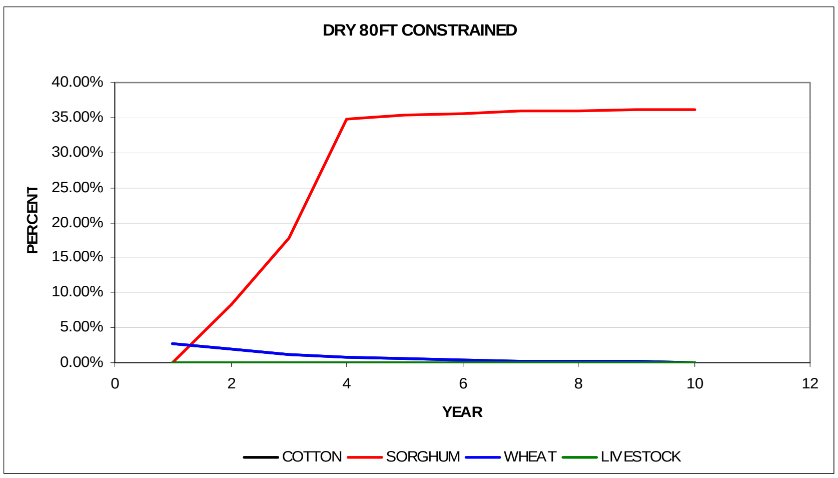

Figure 5.18 Percentage of dryland crops through time, 80 foot constrained.

Table 5.7. Summary output for 60 foot baseline model.

Floyd 60ft Baseline

Period	Saturated Thickness Feet	Pump Lift Feet	GPC Acre in.	Nominal Net Return ($/Acre)	Average Water Applied Per Cropland Acre (in.)	Nominal Pumping Cost ($/Acre in.)	% Cropland LEPA Irrigated	% Cropland Furrow Irrigated	% Cropland Total Irrigated	%Cropland Total Dryland	Average Water Applied Per Irrigated Acre (in.)
1	60.00	375.00	9.98	152.01	9.98	8.58	75.14%	19.34%	94.48%	5.52%	10.56
2	58.85	376.15	9.60	171.58	9.60	8.60	74.78%	12.88%	87.65%	12.35%	10.95
3	57.76	377.24	9.25	151.57	9.25	8.62	73.72%	8.58%	82.30%	17.70%	11.23
4	56.74	378.26	8.92	146.42	8.92	8.64	72.26%	5.71%	77.97%	22.03%	11.44
5	55.78	379.22	8.62	143.12	8.62	8.66	70.58%	3.80%	74.39%	25.61%	11.59
6	54.87	380.13	8.34	140.12	8.34	8.68	68.81%	2.53%	71.35%	28.65%	11.70
7	54.02	380.98	8.09	140.44	8.09	8.70	67.02%	1.69%	68.71%	31.29%	11.77
8	53.21	381.79	7.85	134.87	7.85	8.72	65.26%	1.12%	66.38%	33.62%	11.82
9	52.45	382.55	7.62	128.50	7.62	8.73	63.55%	0.75%	64.30%	35.70%	11.86
10	51.73	383.27	7.42	119.32	7.42	8.75	61.91%	0.50%	62.41%	37.59%	11.88

Net Present Value of Net Returns (NPV)/Acre	$1,171.44		AVG	11.48

throughout the time period to near 0%, while LEPA irrigated acres declined from 75.1% in year one to 69.1% in year ten. Total irrigated acres declined to 62.4% of total acres in year ten. The average water applied per irrigated acre over the ten year time period was 11.48 acre inches. Saturated thickness decreased to a value of 51.73 feet in the tenth year with an average decline in saturated thickness of 0.83 feet per year. The net present value of net returns was $1,171.44 per acre over the planning horizon. Nominal net returns were initially $152.01 per acre, increased to a high of $171.58 in year two, and then declined to $119.32 in year ten.

The enterprise percentages over the time horizon are given in Figures 5.19 through 5.21. LEPA irrigated cotton acres increased from 36% in year one to 64% in year six, followed by a decrease to 61% in year ten. Furrow irrigated cotton steadily declined from its initial value of 19%, with furrow irrigated sorghum, wheat, and corn not entering the solution. With respect to the dryland crops, dryland sorghum increased from 0% in year one to 37% by year ten while dryland cotton acreage decreased from 2.8% in year one to 0% in year four. The dryland livestock enterprise did not enter the solution.

<u>60 foot Saturated Thickness Constrained Model</u>

The 60 foot constrained summary results were similar to the 60 foot baseline model. The shift to dryland production occurred earlier in the time period under the water constrained model; however, the percentage of dryland acres in year ten is slightly less than the baseline. As shown in Table 5.8, average water applied per irrigated acre over the ten year time period was 11.47 acre inches. Saturated thickness decreased to

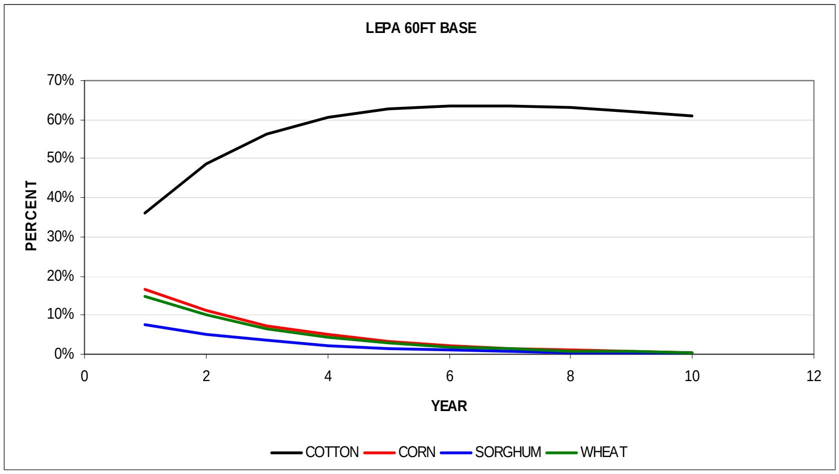

Figure 5.19. Percentage of LEPA irrigated crops through time, 60 foot baseline.

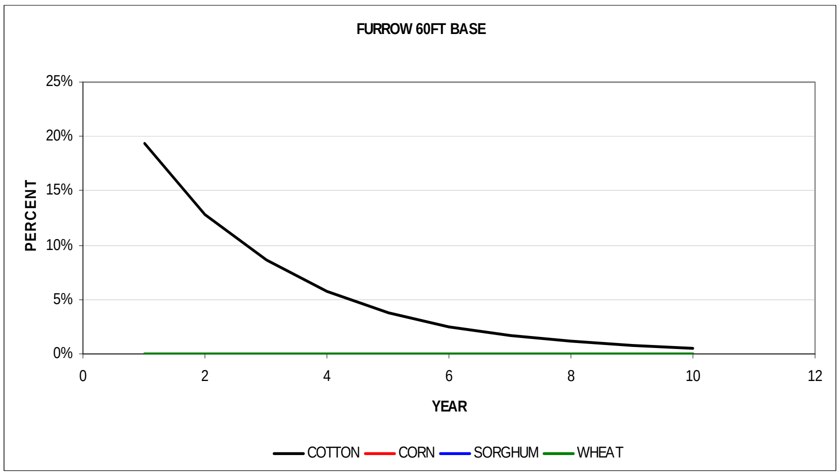

Figure 5.20. Percentage of furrow irrigated crops through time, 60 foot baseline.

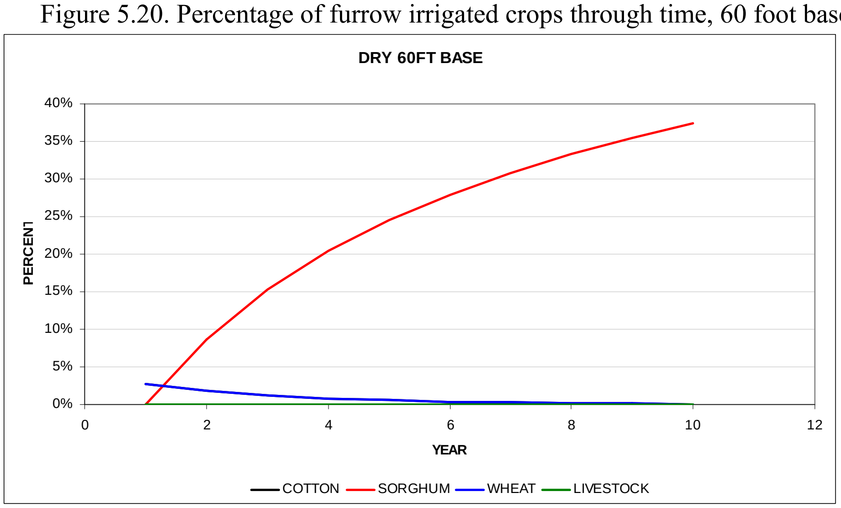

Figure 5.21 Percentage of dryland crops through time, 60 foot baseline.

Table 5.8. Summary output for 60 foot constrained model.

Floyd 60ft Constrained

Period	Saturated Thickness Feet	Pump Lift Feet	GPC Acre in.	Nominal Net Return ($/Acre)	Average Water Applied Per Cropland Acre (in.)	Nominal Pumping Cost ($/Acre in.)	% Cropland LEPA Irrigated	% Cropland Furrow Irrigated	% Cropland Total Irrigated	%Cropland Total Dryland	Average Water Applied Per Irrigated Acre (in.)
1	60.00	375.00	9.98	152.01	9.98	8.58	75.14%	19.34%	94.48%	5.52%	10.56
2	58.85	376.15	9.60	171.58	9.60	8.60	74.78%	12.88%	87.65%	12.35%	10.95
3	57.76	377.24	9.25	137.67	8.33	8.62	66.08%	8.58%	74.66%	25.34%	11.16
4	56.91	378.09	8.97	122.37	7.28	8.64	58.47%	5.71%	64.18%	35.82%	11.34
5	56.25	378.75	8.77	126.98	7.40	8.66	60.38%	3.80%	64.18%	35.82%	11.54
6	55.57	379.43	8.56	129.27	7.49	8.67	61.65%	2.53%	64.18%	35.82%	11.67
7	54.87	380.13	8.34	133.85	7.55	8.68	62.49%	1.69%	64.18%	35.82%	11.76
8	54.16	380.84	8.13	131.89	7.58	8.70	63.06%	1.12%	64.18%	35.82%	11.82
9	53.45	381.55	7.92	128.57	7.61	8.71	63.43%	0.75%	64.18%	35.82%	11.86
10	52.73	382.27	7.71	121.84	7.71	8.73	62.15%	2.03%	64.18%	35.82%	12.01

Net Present Value of Net Returns (NPV)/Acre					$1,110.92					AVG	11.47

52.73 feet in the tenth year with an average decline in saturated thickness of 0.73 feet per year. This represented a 1.9% reduction in water consumption over the ten year planning horizon. Thus the 50/50 water policy reduced pumping by 276.9 acre feet on the representative farm over the ten year planning horizon. The net present value of net returns was $1,110.92 per acre over the planning horizon. Nominal net returns were $152.71 per acre, increased to a high of $171.58 in year two, and then declined to $121.84 in year ten.

The enterprise percentages over the time horizon are given in Figures 5.22 through 5.24. LEPA irrigated cotton acres increased from 36% in year one to 48% in year three, then increased to 61% by year ten. LEPA irrigated corn, wheat, and sorghum continually declined from their initial values. Furrow irrigated cotton steadily declined from its initial value of 19% as these acres were shifted to dryland production. Furrow irrigated sorghum and corn did not enter the solution, while furrow irrigated wheat did enter the solution at 1.5% in year ten. Dryland sorghum increased from 0% in year one to 35% in year six then stabilized for the remainder of the time period, while dryland cotton acres decreased from 2.8% in year one to 0% in year four. The dryland livestock enterprise did not enter the solution.

Table 5.9 presents the summary output of farm level financial positions based on the dynamic optimization model solutions using mean values for yields and price. The results for net cash income and ending cash reserve were calculated using mean values with on stochastic simulation. As seen under the 60ft scenario, mean net cash income and ending cash reserves are mostly negative when all cost of production are included. However, when water availability is not a binding constraint as is the case of the 120 foot

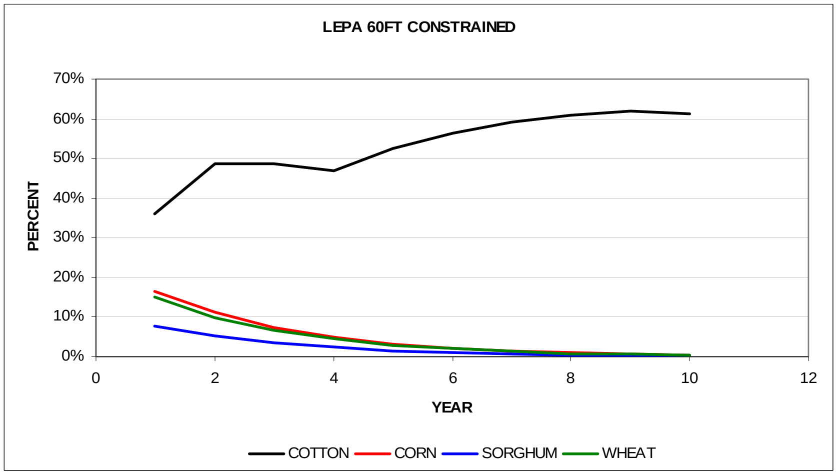

Figure 5.22. Percentage of LEPA irrigated crops through time, 60 foot constrained.

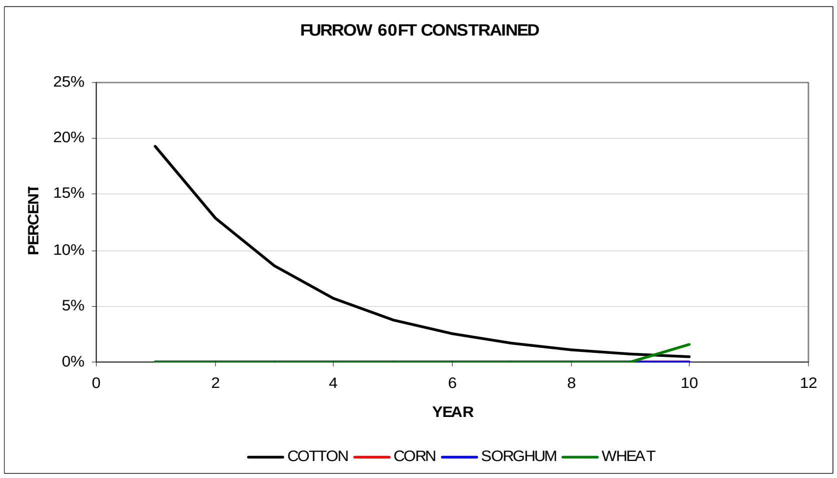

Figure 5.23. Percentage of furrow irrigated crops through time, 60 foot constrained.

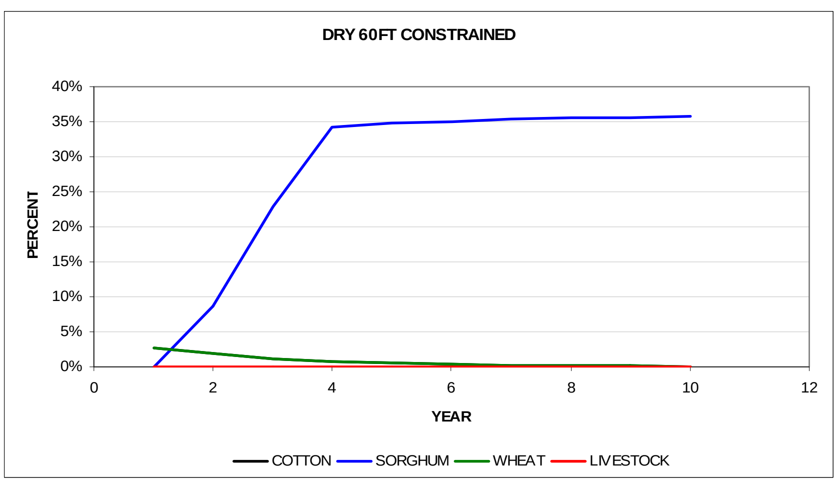

Figure 5.24 Percentage of dryland crops through time, 60 foot constrained.

Table 5.9. Mean Financial Summary of Dynamic Optimization Models.

	Initial Saturated Thickness Level							
	120ft		100ft		80ft		60ft	
	Base	Con	Base	Con	Base	Con	Base	Con
Mean Financial Results								
Mean Net Cash Income ($1000)								
2008	266.9	221.1	240.8	185.9	184.5	156.5	84.1	84.1
2009	258.2	202.2	225.6	164.6	169.1	132.6	76.3	76.3
2010	164.1	116.8	126.8	85.6	88.7	56.1	10.1	5.9
2011	159.5	113.9	121.4	82.4	85.1	43.6	6.2	-1.6
2012	146.4	106.0	107.3	69.5	72.3	46.1	-5.8	-8.8
2013	131.4	95.7	94.0	62.6	55.8	40.9	-22.6	-23.7
2014	120.1	89.3	84.2	58.3	48.4	33.1	-38.5	-38.6
2015	100.3	76.8	66.6	46.4	35.2	16.1	-63.2	-63.5
2016	95.7	77.0	61.8	46.3	34.4	10.2	-77.1	-78.2
2017	72.9	62.4	41.5	32.6	18.6	-8.8	-103.9	-103.9
Mean Ending Cash Reserve ($1000)								
2008	162.8	132.1	146.2	105.3	104.0	79.8	16.9	16.9
2009	303.6	232.6	264.2	173.0	175.6	118.7	4.3	4.3
2010	376.2	261.2	302.7	172.1	177.4	88.7	-76.3	-80.5
2011	444.5	285.1	335.0	165.1	173.0	41.8	-164.3	-176.2
2012	500.6	299.7	352.6	143.0	153.7	-8.2	-267.9	-282.9
2013	541.8	301.7	355.3	109.5	113.9	-69.3	-392.4	-408.4
2014	570.3	293.6	345.1	65.8	60.5	-142.6	-537.4	-553.5
2015	609.5	301.0	345.8	35.1	18.3	-206.4	-680.5	-696.9
2016	644.4	307.0	340.0	1.0	-28.3	-278.0	-839.4	-856.8
2017	658.9	298.2	311.6	-50.2	-93.5	-370.6	-1027.1	-1044.6

model, profitable margins at the mean are possible. Particularly under the 120 foot baseline scenario, ending cash reserves actually increase through time from an initial $162,800 in year one to a high of $658,900 in year ten. This trend continues for both the 120 foot constrained model and the 100 foot baseline model, as both indicate increasing cash positions over the planning horizon.

The results of the dynamic optimization model support several intuitive conclusions. First, it appears from the various scenarios of saturated thickness that the greatest savings in water from the implementation of the 50/50 water policy were achieved when the available saturated thickness is higher. These savings can be gained with little detrimental effect on the producer as indicated in the 120 foot and 100 foot scenarios. While net present value of net returns declined upon the intervention of the 50/50 water policy, changes in cropping patterns did not substantially shift towards dryland enterprises. Conversely, the water savings on the more marginal saturated thickness were insignificant and only increased the burden placed on the irrigation enterprises.

Additionally, the results indicated that LEPA irrigated cotton was the most profitable crop in terms of returns to irrigation water applied. Dryland cropping patterns appeared to incorporate grain sorghum over cotton; however these projections excluded any farm program support. This pattern was apparent regardless of the saturated thickness level analyzed. While there has been much interest in livestock operations to reduce water usage, the results indicated that livestock on dryland pasture was not a viable option. Livestock gains per acre would need to triple in order to become competitive with dryland sorghum based on current projected yields. It is also important to note that the shifts from irrigated crops to dryland crops, even under the lower water availability scenarios, did not occur suddenly, but rather over the time period. This is a crucial part of the overall results, as it is important to realize not just what the changes in enterprises may be, but how to manage the transition in enterprises through time.

In conclusion, the results indicated that the 50\50 water policy is more restrictive in areas where saturated thickness is the greatest. At the lowest level of saturated thickness evaluated (60 feet), the constrained scenario was marginally more restrictive than the baseline scenario. The results of the baseline models for lower saturated thicknesses indicated that dryland enterprises were already a crucial part of the farm and that the implementation of the policy only extended and magnified those trends. If saturated thickness levels are above 100 feet, the impacts of the 50/50 policy is minimal to the typical producer on the High Plains whose production characteristics are similar to those represented in the representative farm.

Farm Level Financial Viability

This section presents the results generated from the farm level financial simulation models, in accordance with the second objective of the analysis to determine how the 50/50 water policy affects the financial sustainability and viability of the typical producer in Floyd County. Changes in farm level financial positions are compared between the baseline model and the constrained model for each scenario to estimate the financial impacts of the 50/50 water policy.

The output from the optimization models was utilized as input into the financial simulation model which incorporated stochastic yield and price risk over a ten year planning horizon. While the dynamic optimization models objective was to maximize net returns, it did not include stochastic yields and prices to incorporate risk. Three variables were transferred from the optimization model to the simulation model: first the optimal cropping percentages were used to compare scenarios and the effects of the constrained policy models, second the mean predicted yields were used to construct scenario specific yield distributions, and third the predicted variable costs excluding harvest and ginning costs were used as the basis for costs per acre.

While each of the eight scenarios was analyzed individually in the simulation model the summaries are presented in this section. All individual and scenario specific distributions of risk are given in Appendices A and B. It is imperative to note that the results presented in this section account for a broad and diverse risk profile and apply to the average management practices of the typical producer in Floyd County. Best management practices or exceptional risk management were not considered in these simulation scenarios. The two primary output variables from the simulation model were net cash income and ending cash reserves. Each of these is discussed in the following section.

Net Cash Income

This section presents the results of the financial aspects of the representative farm, specifically net cash income. Net cash income was calculated as the total stochastic production receipts combined with farm program payments and insurance indemnities, less total production costs including harvest, ginning, interest expenses on land and equipment notes, and cash rent on leased land. In this calculation net cash income is not cumulative but rather illustrates the probabilities associated with net cash income in an average year during the planning horizon. The stoplight chart illustrated in Figure 5.25 presents the risk profiles of each of the eight scenarios analyzed in this study. The Cumulative Distribution Function (CDF) graph in Figure 5.26 shows how the various scenarios compare to each other in terms of the overall variability of net cash income, however due to the difficulty associated with presenting individual results from the CDF, the probabilities presented in the Figure 5.26 will be the primary focus.

The stoplight chart shows the probabilities of having an average net cash income relative to the range of $0 and $200,000. Green represents the probability of a net cash income greater than $200,000; yellow represents the probability of a net cash income between 0$ than $200,000; and red represents the probability of a negative net cash income. The X axis identifies each of the eight scenarios analyzed with the label B indicating the baseline or status quo models while the label C represents the constrained models in which the 50/50 water policy was implemented. It is apparent from the results that the risk profile of the representative farm increases as the amount of irrigation water available decreases either from policy implementation or from lower initial saturated thickness of the aquifer. Additionally, the chart indicates that with higher levels of water availability producers can lower their risk profiles with irrigation. The 120 foot baseline model has the lowest probability of negative cash income at 7%. However there is a slight increase in the probability of negative cash flows to 13% when the 120 foot model

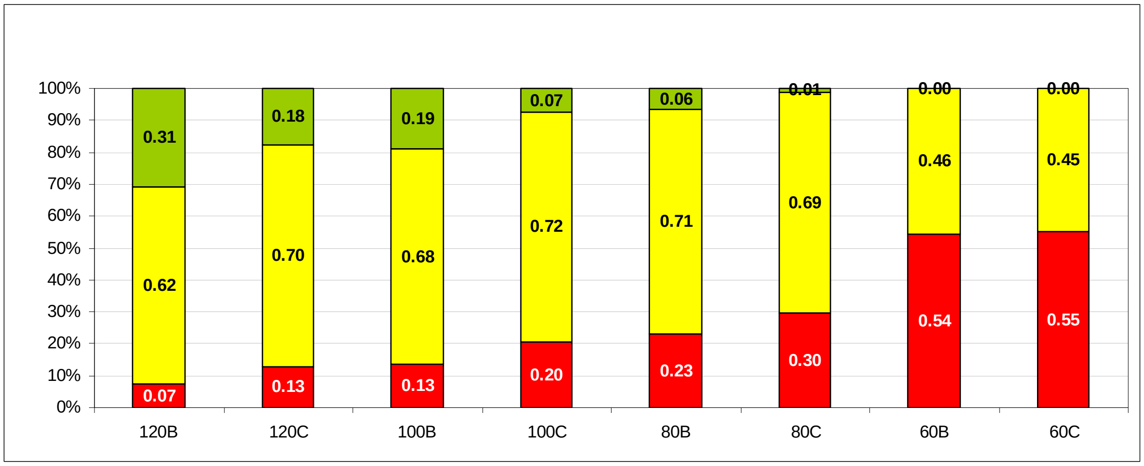

Figure 5.25. Average probability profiles of net cash income, baseline (B) and constrained (C) by saturated thickness level.

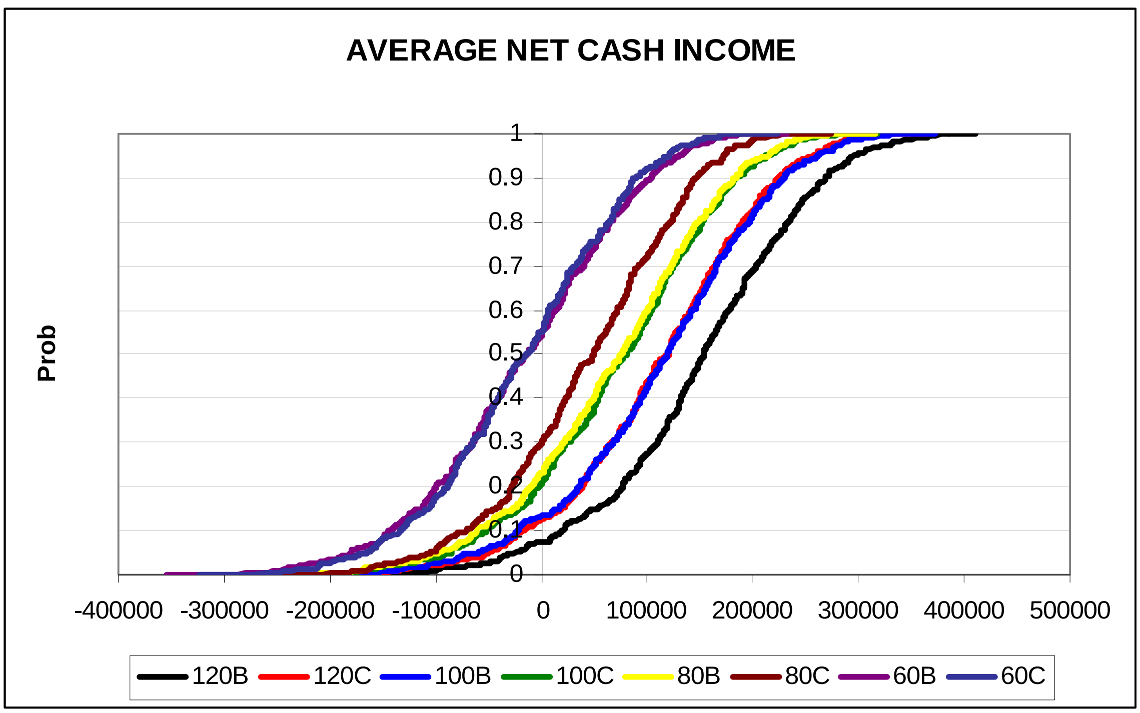

Figure 5.26. Cumulative Distribution Function of average net cash income.

is constrained to the 50/50 water policy. This trend continues throughout the scenarios with the greatest impact of the policy being seen in the 100 and 80 foot models as the probability of negative net cash income increases on average by 7% for the constrained model versus the baseline model. In terms of the low water availability scenario, the 60 foot models showed similar results in probability of negative net cash income as the baseline and constrained models are very similar in terms of water availability, thus the water policy does not impact the lower water level scenario to the degree it does higher water availability situations.

Ending Cash Reserves

While net cash income is a key indicator of analyzing the financial sustainability and viability of a farm, it does not take into account all the expenses that a producer incurs in their farming operation. Expenses such as dividends for family living and principal payments on debt are accounted for in the ending cash reserves as well as adding back any additional cash that remained from the previous year and the interest earned on that cash. While it is possible for ending cash reserves to be higher than net cash income in any given year, the risk associated with ending cash reserves is traditionally higher than with net cash income. The values represented for ending cash reserves are cumulative in that they include the previous year's cash positions including rollover cash debt or ending cash revenue. This is illustrated in the stoplight chart shown in Figure 5.27 and in the CDF chart in Figure 5.28. Again the results will focus on the probabilities associated with cumulative ending cash reserves in Figure 5.27.

The 120 foot baseline model indicated a 35% probability of negative ending cash reserves, which increased by 14% to 49% under the constrained model. The 100 foot scenario appears to be the most affected by the implementation of the 50/50 water policy as the probability of negative ending cash reserves increased from 49% for the base line model to 66%, for the constrained model, an increase of 17%. The 80 foot scenario's probability of negative ending cash reserves also increased ten percentage points from 68% to 78%. The probability of negative ending cash reserves for the 60 foot scenario was relatively unchanged by the implementation of the water policy but remains in a high risk environment with odds similar for the baseline and constrained models, with both exceeding 90%. This high level of risk shown in the models for the representative farm is similar to predictions made in the FAPRI/AFPC baseline outlook for the Texas Southern Plains cotton farms in February 2008. Additionally, it can be inferred that the 50/50 water policy had little affect on the 60 foot scenario.

The summary of mean net returns for the simulation model is presented in Table 5.10. The results of the simulation model for net cash income, ending cash reserves, and government support programs are categorized by scenario. Also it is important to note that while changes through the time horizon are important for intuition the focus of this research was to determine how the 50/50 policy could impact final cash positions over the planning horizon.

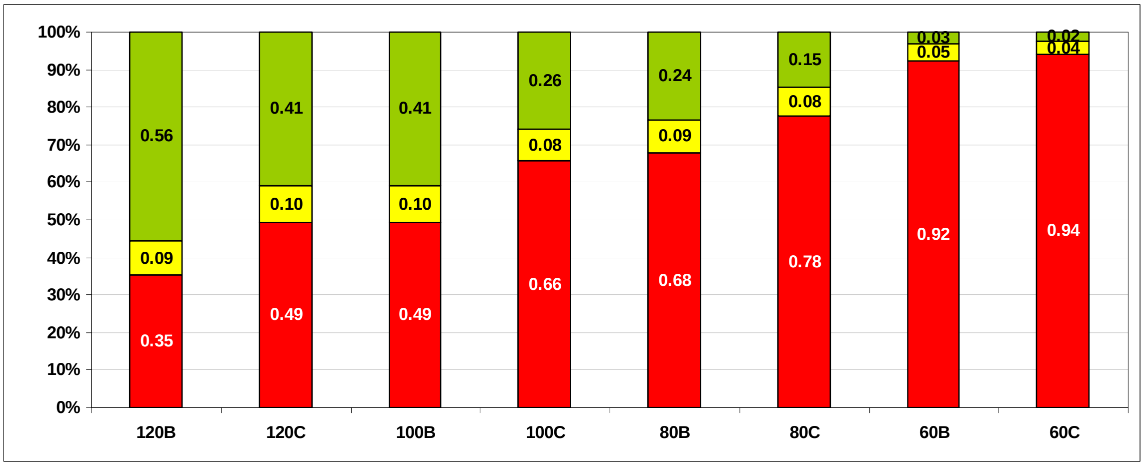

Figure 5.27. Risk profiles of ending cash reserves, baseline (B) and constrained (C) by saturated thickness level, cumulative for 10th year.

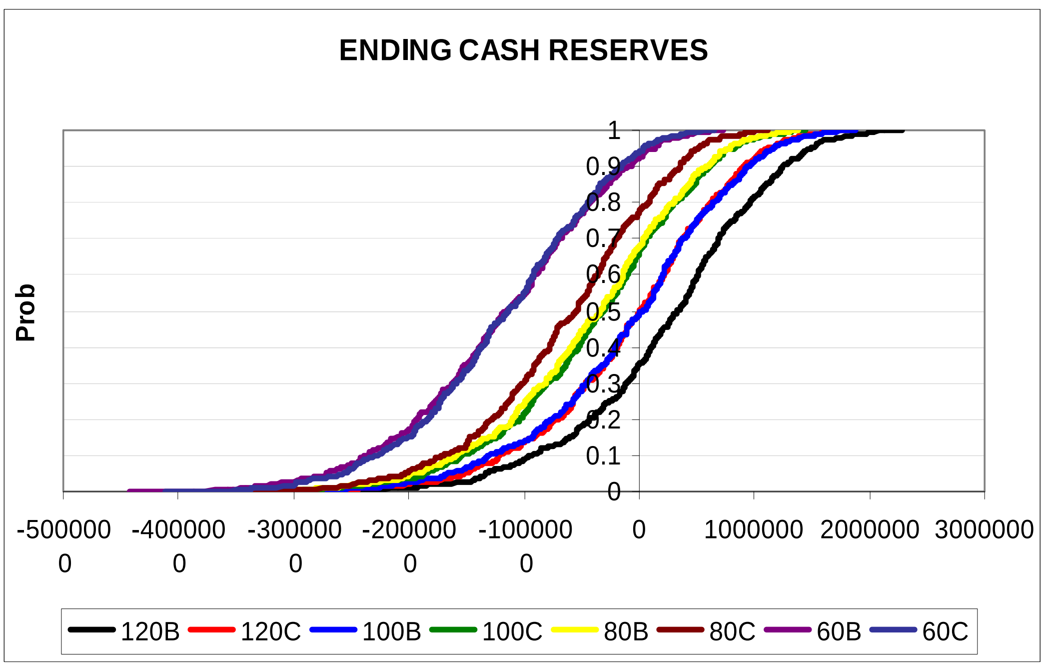

Figure 5.28. Cumulative Distribution Function for 10th year for ending cash reserves.

Table 5.10. Mean Financial Summary of Simulation Models

	Initial Saturated Thickness Level							
	120ft		100ft		80ft		60ft	
	Base	Con	Base	Con	Base	Con	Base	Con
Stochastic Financial Simulation Results								
Mean Net Cash Income ($1000)								
2008	278.9	236.1	253.5	201.9	199.6	173.4	106.3	106.3
2009	259.7	202.9	226.7	164.8	169.1	187.8	74.9	74.9
2010	165.8	116.5	127.8	84.2	87.1	30.8	3.6	-1.1
2011	165.1	116.6	124.4	82.9	85.6	38.4	3.4	-5.1
2012	147.5	104.0	105.3	63.1	66.2	21.3	-12.3	-14.4
2013	130.7	91.8	90.1	52.8	46.0	17.0	-29.5	-29.0
2014	115.9	80.6	75.7	41.8	31.1	9.9	-47.0	-45.0
2015	92.5	63.2	53.0	22.9	9.9	-7.3	-73.1	-70.7
2016	87.9	61.7	46.1	18.3	3.5	-12.6	-86.1	-84.1
2017	59.0	39.5	17.7	-5.8	-20.6	-36.2	-116.4	-113.1
Mean Ending Cash Reserve ($1000)								
2008	150.4	124.3	133.6	100.2	97.8	79.4	26.1	26.1
2009	255.9	191.6	215.7	139.4	139.2	132.3	-8.1	-8.1
2010	290.1	191.1	220.6	111.9	113.1	62.6	-106.8	-108.0
2011	316.1	183.3	216.6	75.5	77.9	-7.8	-212.7	-215.4
2012	328.1	161.9	195.4	21.8	23.3	-92.5	-336.5	-337.3
2013	325.8	127.1	158.8	-45.8	-52.2	-187.5	-480.1	-477.9
2014	307.7	77.3	105.1	-129.2	-145.3	-295.7	-644.7	-639.2
2015	297.4	37.5	57.4	-205.4	-231.7	-395.9	-808.5	-800.1
2016	282.0	-5.8	2.1	-288.1	-324.9	-503.6	-985.5	-975.4
2017	242.9	-69.3	-78.9	-394.3	-441.3	-635.4	-1193.1	-1180.1

Average Farm Program Support ($1000)	**Total Direct and Counter Cyclical Payment, not Scenario Specific**
2008	88.0
2009	45.1
2010	50.8
2011	51.0
2012	54.0
2013	56.3
2014	55.8
2015	53.8
2016	53.6
2017	52.6
Average	56.1

As expected, the mean net cash income was the highest in the 120 foot baseline model which ended the planning horizon with $59,000. However when the 120 foot baseline is constrained with the implementation of the 50/50 policy the mean net cash income was reduced on by $19,500 to $39,500 in the tenth year. As previously indicated the cumulative effect that occurs in the final year of the planning horizon allows for interpretation of how the various scenarios compare to each other through time. The 100 foot scenario again was the most impacted by policy in that the ending mean net cash income decreased by $23,500 to present the first negative net cash income of ($5,000) for the 100 foot constrained model.

With respect to ending cash reserves the overall impacts become more dramatic as the farm is faced with additional expenses such as dividends for family withdrawals and principle payments on land and equipment. This continues to burden the financial situation of the farm. The 120 foot baseline model is the only scenario in which ending cash reserves are greater than ending net cash income. This is due to the profitable nature of this scenario and given the calculation of ending cash reserves takes into account the previous years ending cash position. Thus if the farm is able to make profits for several years in a row the farm can actually increase its ending cash reserves through time. This was the only model were the previous years net cash incomes were high enough to overcome sustained losses.

However the 120 foot baseline is not immune to the effects and restrictions of the water policy. Ending cash reserves were reduced dramatically at the end of the planning horizon by $312,200 with the 50/50 policy implemented. The likelihood of a negative ending position was first predicted in the 100 foot constrained model with a predicted cumulative ending cash reserve of ($69,300). The 100 foot constrained scenario again showed to be the most vulnerable to the policy's impacts by reducing the ending cash position by $315,900.

Finally it is important to understand how farm program payments are affecting the producer's cash flow and viability. The final portion of Table 5.9 represents the average farm program support by year. These values are the sum of both direct and countercyclical payments received for the farm. The characteristics of farm program enrollment including base acres, enrollment yield, and pay rates are presented in Appendix J. Since the government payments are assumed to be decoupled there are no direct ties to the current or future enterprise selection made by the farmer. Also, loan deficiency payments are not included in farm program calculations as the projected prices utilized in all modeling processes were higher than the national loan rates. Thus the odds of receiving a government payment are solely based on enrollment characteristics and market price. Within the simulation model the values associated with each payment were calculated from stochastic pay rates and prices. As seen in Table 5.9 the average farm program payment over the ten year planning horizon is approximately $56,100. The highest farm program support $88,000 was observed in 2008 primarily due to lower initial prices, however when projected prices increased farm program support decreased and stabilized ranging from $45,100 in 2009 to approximately $52,600 in 2017. It appears from this analysis that farm program payments only contribute a minor amount to the overall cash position of the farm, specifically on a cotton intensive farm. Additionally, due to nature of the forecasted prices, cotton was the only crop to receive any substantial amount of farm program support. At best, these farm program payments reduce the losses incurred by producers but should not be considered a profitable addition to the cash characteristics of the model farm analyzed.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The Texas Southern High Plains relies heavily on irrigation water provided by the Ogallala Aquifer. Throughout history, the agricultural economy and production capabilities in the Texas Panhandle has evolved to become an important supplier of food and fiber around the world. There is no question that this precious resource is finite, as current pumping withdrawals exceed recharge rates in most areas, particularly in the Southern Ogallala. Concerns over future supplies and the sustainability of irrigated agriculture have attracted the attention of policy makers throughout the eight states overlying the Ogallala. Recent legislation in Texas (Senate Bills 1 & 2) has shown a strong commitment towards increasing the efforts of water conservation through water policy implementation.

Additionally several Texas Panhandle water conservation districts have or are considering implementing district wide water conservation programs. The Panhandle Groundwater Conservation District in the northeastern portion of the Texas panhandle has been on the forefront of policy implementation and has taken the first crucial steps towards implementing a water conservation program. Due to the likelihood that other panhandle water districts such as the High Plains Underground Water Conservation District No. 1 (HPUWCD #1) will take similar measures, it was imperative to know how a policy could affect the producers within this region.

While several water policy analysis and impact studies have been conducted for this region, most have focused on the long term regional or county level economic impacts. This study differs from previous studies in that it specifically looks at the farm level impacts of water policy both in terms of enterprise selection and financial sustainability. The 50/50 water policy which was implemented by the Panhandle Groundwater Conservation District in 2005 was used as the water policy analyzed in this study. This policy states that 50% of the current saturated thickness in a given area must remain in 50 years. While this policy may not be chosen by the HPUWCD #1, it is assumed to be an option. Thus a model farm was developed in a representative area of the district, Floyd County, to measure the effects of this policy at the farm level. Once this farm was developed, responses to the 50/50 water policy were analyzed utilizing a combination of methods both through a non-linear dynamic program and financial simulation. These methods were applied to a range of scenarios or differing levels of saturated thickness such that farm response could be seen in a variety of water availability situations. Four levels of saturated thickness were evaluated 120 foot, 100 foot, 80 foot, and 60 foot.

The non-linear dynamic program was developed specifically to evaluate the optimal enterprise selection which maximized the net present value of net returns on the representative farm over a ten year planning horizon. Hydrologic parameters, crop-water production functions, and various production inputs and costs were specified in the model and obtained from values associated with the representative farm. The main objective of this model was to evaluate the optimal farm level response to water policy or the ideal choice of enterprises and their corresponding irrigation quantities under both a baseline model and a constrained model which imposed the 50/50 water policy.

The purpose of the financial simulation model was to determine the sustainability and viability of the farm's decisions based on the optimal cropping pattern and predicted yield chosen in the dynamic optimization model. In essence, the output from the non-linear programming model became an input into the financial simulation model. Stochastic price and yield distributions were estimated and additional costs were applied to the farm's financial situation. Through this analysis the risk associated with the change in farming practices as a result of the 50/50 water policy was evaluated in terms of traditional financial measure such as net cash income and ending cash positions under risk.

Each of the four saturated thickness scenarios was run under two conditions resulting in eight unique model outputs. A baseline or status quo condition represented the currently practiced characteristics observed by the farm with no restrictions imposed on the farm in terms of the amount of water that could be pumped. The constrained models were identical to the baseline models with the exception that they had a restriction on water utilized which is dictated by the 50/50 water policy.

Overall the results indicated several key components. First, in terms of water savings the 50/50 water policy saved as much as 2,112 acre feet over the ten year planning horizon for the 120 foot scenario. However, as the saturated thickness availability decreases so did the amount of potential water savings. This implies that less water will be saved in the areas of the county or region which overly marginal quantities of irrigation water as seen in the 60 foot scenario were the water savings are only 276.7 acre feet over the planning horizon.

While detailed results of the optimal enterprise selection are presented in Chapter V, there are several overall aspects that should be considered. It is apparent that there are two primary crops that optimized the farm's net returns through time. Regardless of the water available and whether a baseline or constrained model was evaluated, LEPA irrigated cotton was the primary irrigated crop. This crop presented the greatest returns to irrigation while providing the highest net returns per acre. The 120 foot scenario utilized nearly 75% of the LEPA irrigated acres to grow cotton, while some furrow irrigated cotton was also utilized. This trend of LEPA irrigated cotton continued throughout the analysis.

Additionally, in terms of dryland crop selection it appears that dryland sorghum was the dominant crop. Even in a scenario with high water availability, such as the 120 foot saturated thickness, the dryland crop which maximizes net returns was sorghum. As the water availability decreased and fewer acres were devoted to irrigation, dryland sorghum became a viable and considerable portion of the enterprise selection. While only 9% of the crop mix was devoted to dryland sorghum in the 120 foot constrained model, nearly 35% of the farm's acres were devoted to dryland sorghum in the 60 foot constrained model. Several crops did not enter the farm's enterprise selection in any model such as furrow irrigated corn and sorghum. LEPA irrigated corn and sorghum never increased beyond their initial acreages nor does dryland livestock become a consistently viable option.

The financial simulation model presented expected results. The risk profile increased as a result of the policy implementation, as the farm was faced with a lack of ability to ensure yields through irrigation. Average net cash incomes and cumulative ending cash reserves were presented in detail in the previous chapter. In general, based on forecasted prices and production costs overall revenues declined through time. Additionally, the highest average net cash income at the end of the planning horizon was seen on the 120 foot model. The probability of negative net cash incomes increased for all scenarios between the baseline and constrained models. Cumulative ending cash reserves, which include the previous year's cash flow, increased the risk profile of the farm. Ending cash reserves includes additional farm costs such as dividends for family living and principal payments on loans. Again the cumulative affects on risk can be seen as the water policy implementation increased the probability of negative ending cash reserves, increasing by 14 percentage points on the 120 foot model and 17 percentage points on the 100 foot scenario, indicating the overall risk of the farm had increased as a result of the water policy. Again the 60 foot model showed little response the policy in terms of its risk in ending cash reserves.

Conclusions

As the social and political concerns about water resources gain momentum, the future of the Ogallala Aquifer will certainly be among the top priorities. This vast freshwater resource has created a rich agricultural environment on the Texas High Plains developing an entire economy from its fruits. However, as water levels drop local water agencies, producers, and municipalities have all expressed interest in conservation policies. This study showed how a representative farm in the Southern High Plains might react to water policy implementation specifically that of a 50/50 water policy. In terms of water savings the benefits of this policy will only be realized in areas with high saturated thickness levels, whereas marginal areas will not see much benefit. Enterprise selection will vary by producer, but will typically employ two primary crops. If land can be irrigated under a LEPA sprinkler, cotton would be the optimal choice. Under dryland production, sorghum appears to be the crop of choice.

The changes in crop selection as a result of the 50/50 water policy did affect the producers risk profile. In all saturated thickness scenarios analyzed, except the lowest 60 foot level, the probability of having negative net cash income and ending cash reserves increased as the farm was forced to either reduce irrigation quantities applied or select more dryland enterprise acres. In certain cases risk of negative cash positions increased by one third making the policy makers decisions more difficult. Regardless of the policy analyzed if producers are forced to reduce irrigation levels, thus increasing their risk, then they will be adversely affected. Through the various scenarios analyzed in this study the results indicate that the downside effects of the 50/50 water policy will be greatest in the areas where saturated thickness levels are high, conversely impacts will be low in areas of low saturated thickness.

Limitations & Recommendations

As with any analysis there are limitations based on the assumptions made in the modeling process. One limitation of the non-linear programming model was that it did not include the fixed costs associated with farm operation such as interest expenses, lone principal payments, and dividends for family living. These costs could change the optimal allocation and choice of enterprises. Additionally, the production functions utilized to calculate the crop yield response to irrigation were developed utilizing CROPMAN, which uses average county values for weather and soil type which can vary greatly by farm, thus affecting the overall production levels. Currently there is no method employed to evaluate the returns to livestock gains from additional irrigation water. If livestock production functions could be developed for various grazing systems the model could be expanded to consider other alternative livestock systems. The optimization model's objective was to maximum the net present value of net returns regardless of the extent of marginal gain from a shift in enterprises. Therefore, the model did not take into account the management decision that would make a producer change from one crop to another as there is most certainly a threshold of profitability that must be breached before a producer will select a different enterprise. One option could be to consider an objective of maximizing efficiency of water in terms of dollars generated per acre inch applied.

The simulation model utilized an expansion of the yield distributions derived from the variation in average county yields. While this may present the broadest and most robust yield distribution, it assumes that the variation in farm level yields is always greater than the full range in variation in county level yields. Producers may be able to manage some of their yield risk through management practices which reflect a higher level than was employed in the simulation model. If the simulation model were utilized for a specific producer, yield distribution functions could be modified to reflect individual tendencies and outcomes. Also the simulation model does not take into account the risk associated with weather patterns. Variation in yield was originally derived at the mean from the non linear program and then expanded based on county values, however weather does play a role in how an individual producer manages irrigation practices. Ideally the decision to irrigate a crop would not solely be based on the availability of groundwater, but a combination of weather patterns, rainfall, and available water.

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APPENDIX A.

SIMULATION CDF CHARTS FOR NET CASH INCOME

This appendix presents the Cumulative Distribution Functions (CDF) of net cash income generated in the simulation model. Each page consists of a baseline and constrained CDF and is represented for each of the four saturated thickness scenarios 120ft, 100ft, 80ft, and 60ft. The Y axis indicates the probabilities or odds against the X axis which indicates the associated annual net cash income. Each graph is a total representation of the net cash income probabilities for each of the ten years simulated. The legend is formatted such that NC 1 is the CDF of net cash income for the first year of simulation while NC 2 is the CDF for net cash income in year two. This pattern continues throughout graphical analysis with NC 10 representing the CDF for the final year of the analysis, 2017. It is important to note that the odds of negative net cash income increase with decreases in saturated thickness and resulting policy or constrained model implementation.

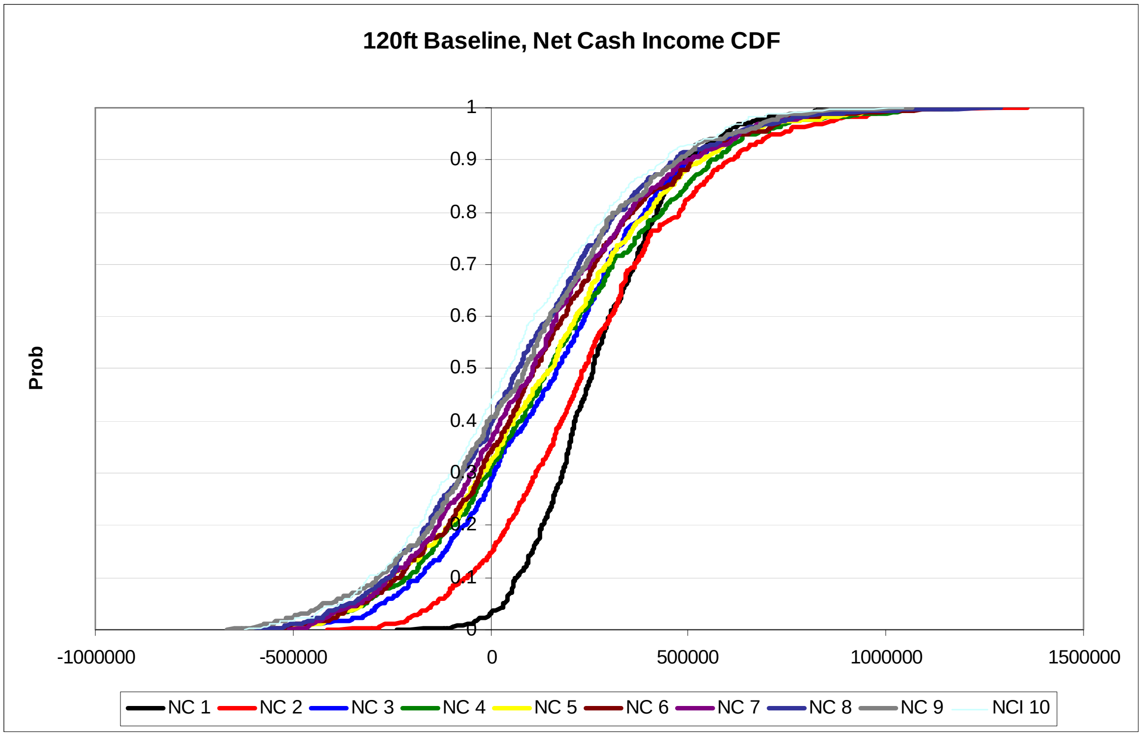


Figure A.1. Net Cash Income CDF, 120ft Baseline

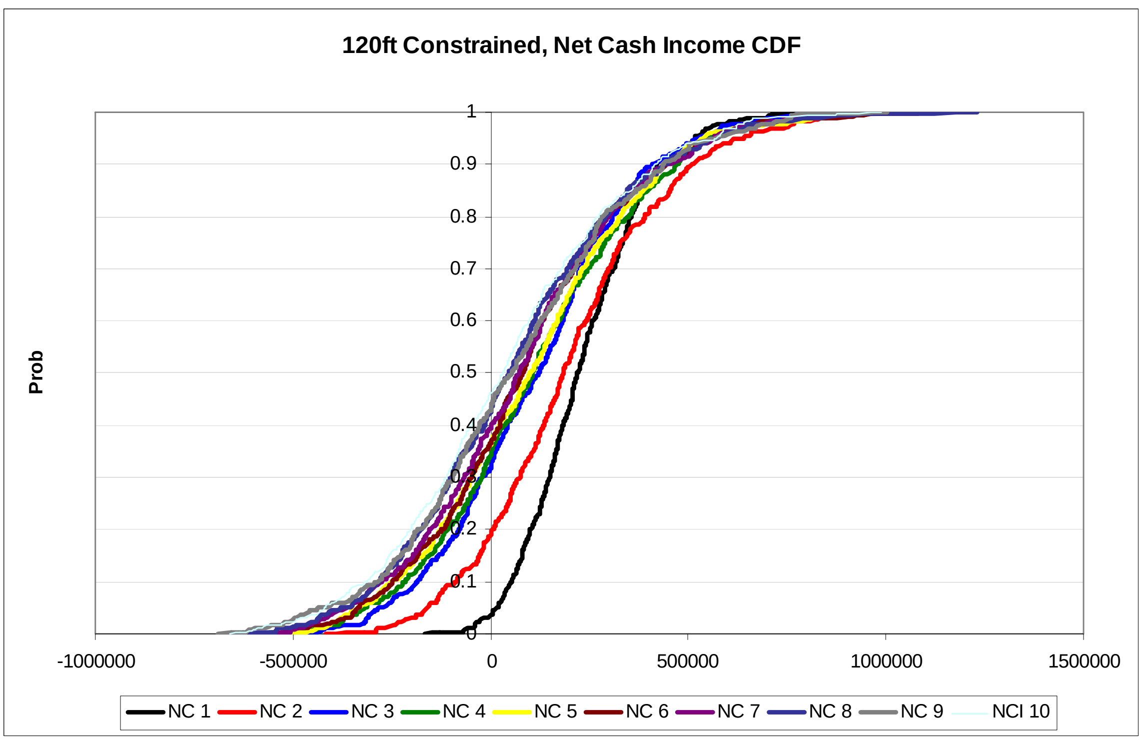


Figure A.2. Net Cash Income CDF, 120ft Constrained

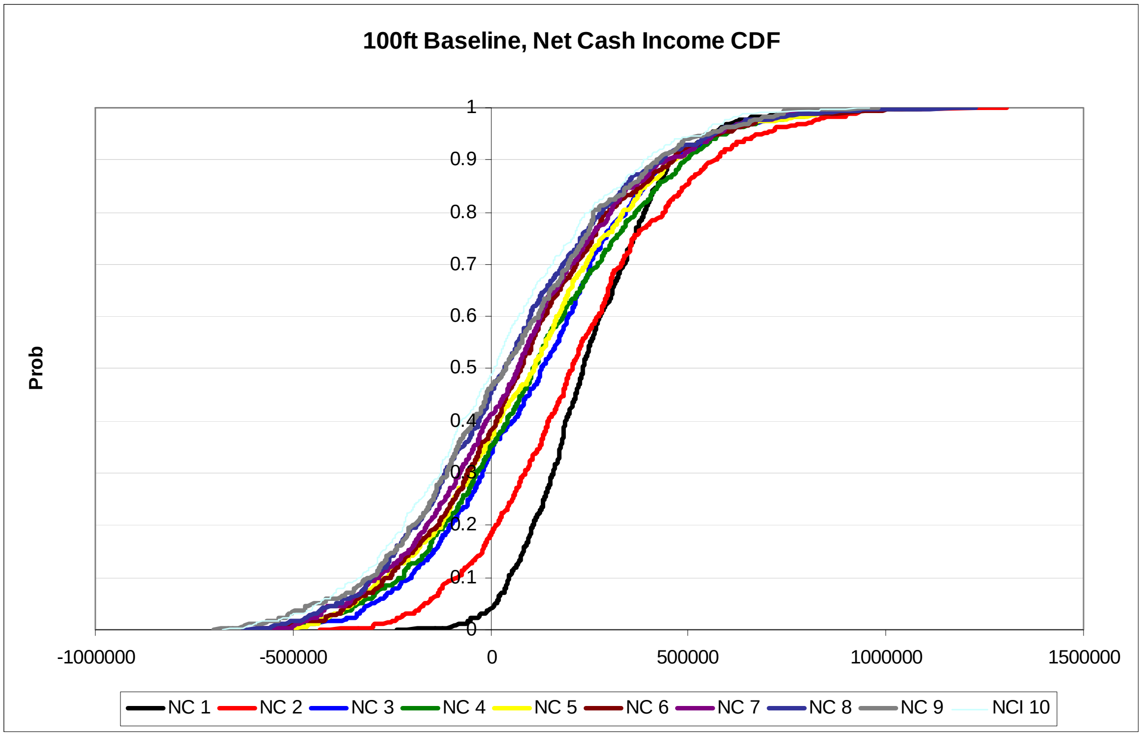


Figure A.3. Net Cash Income CDF, 100ft Baseline.

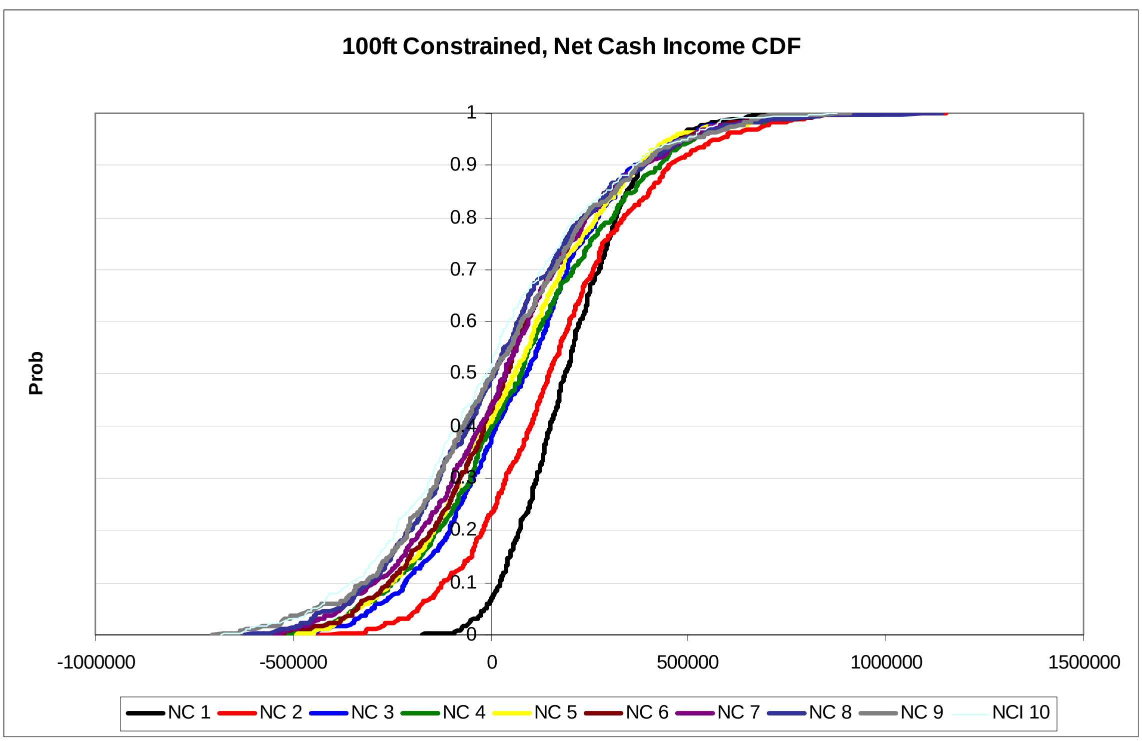


Figure A.4. Net Cash Income CDF, 100ft Constrained.

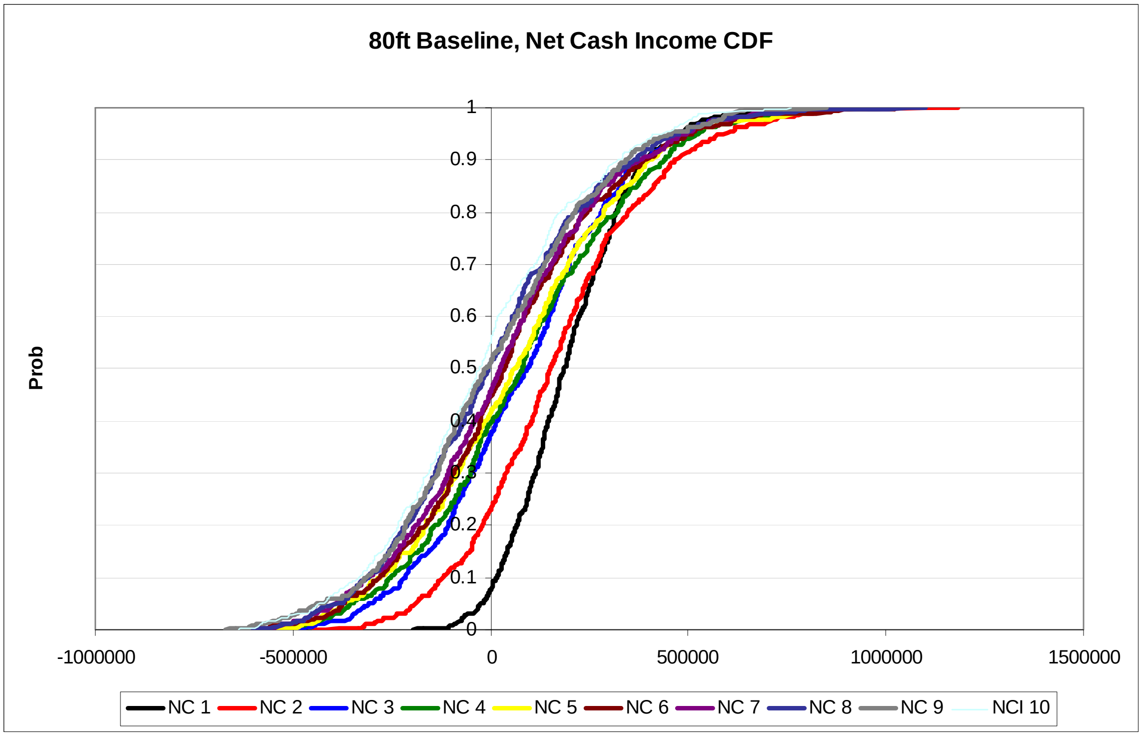


Figure A.5. Net Cash Income CDF, 80ft Baseline.

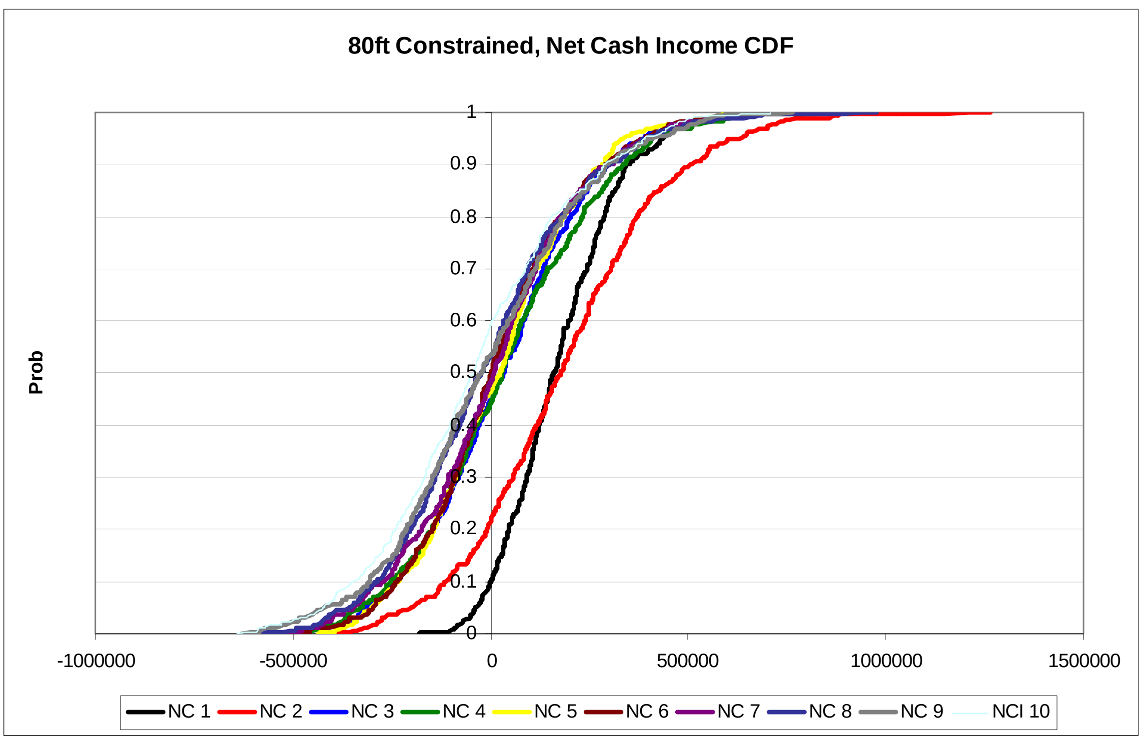


Figure A.6. Net Cash Income CDF, 80ft Constrained.

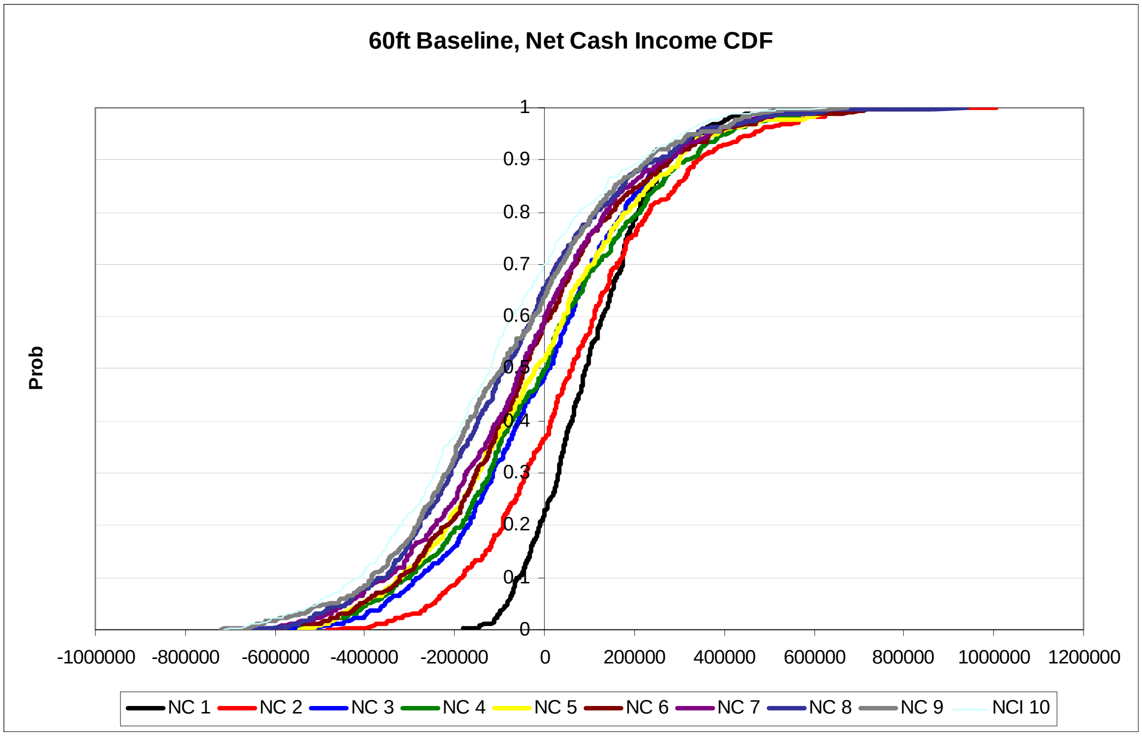


Figure A.7. Net Cash Income CDF, 60ft Baseline.

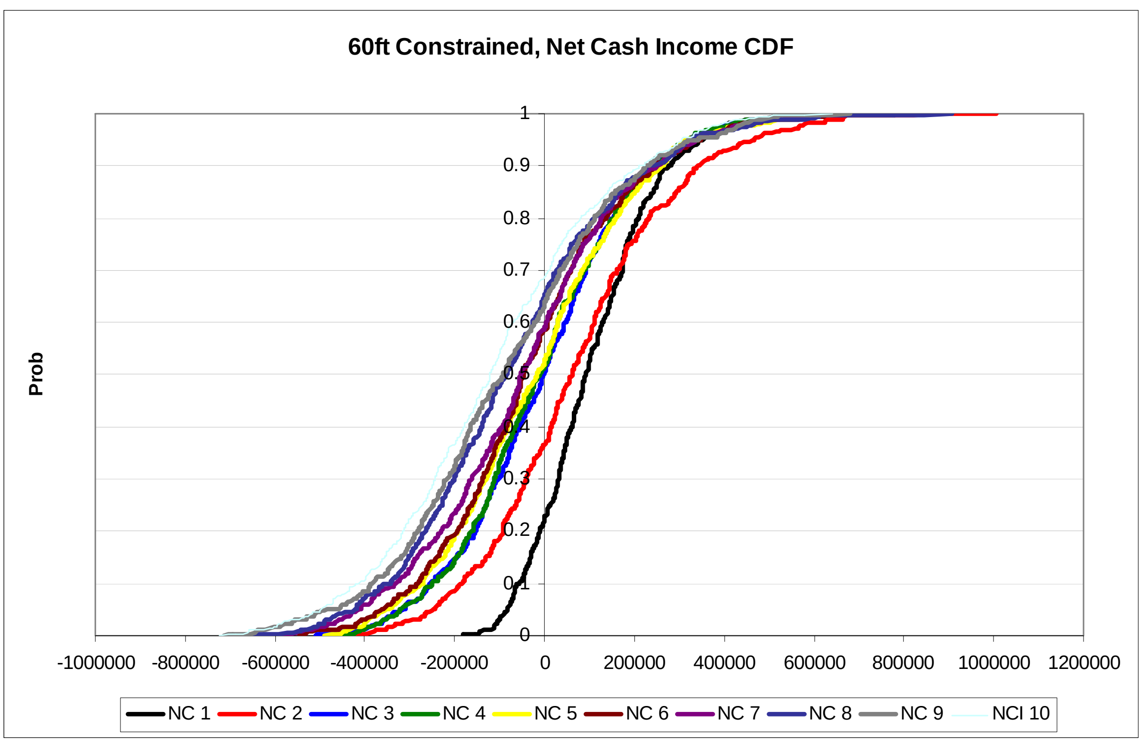
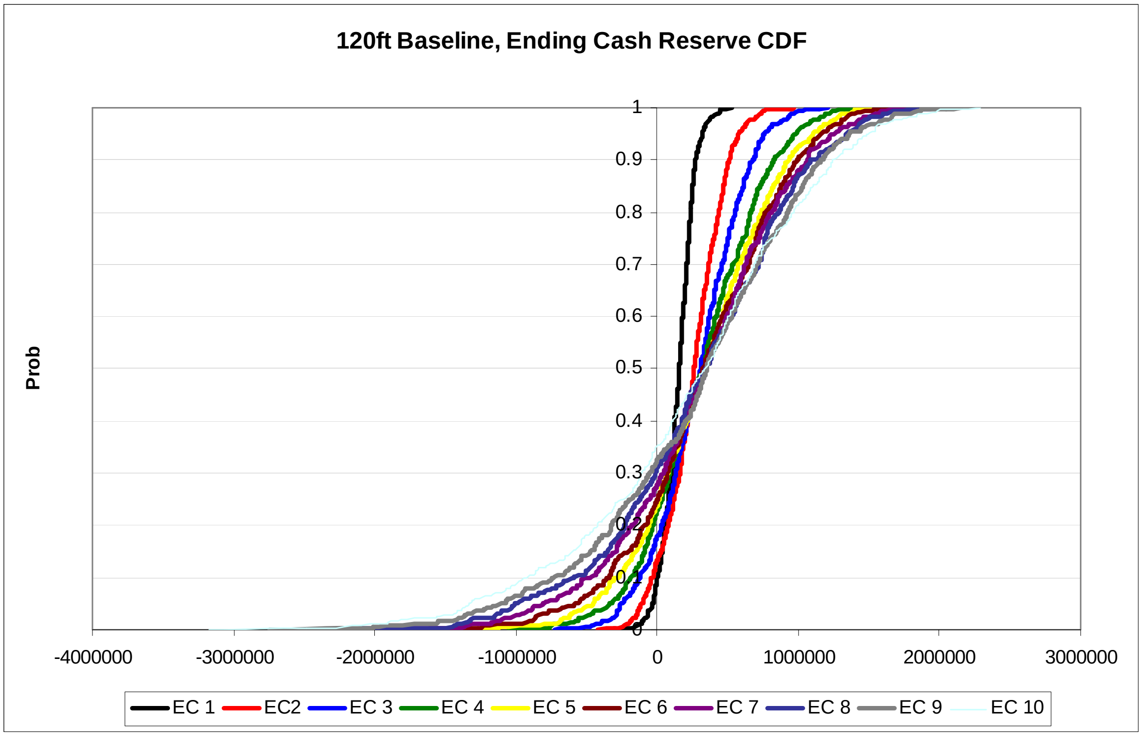


Figure A.8. Net Cash Income CDF, 60ft Constrained.

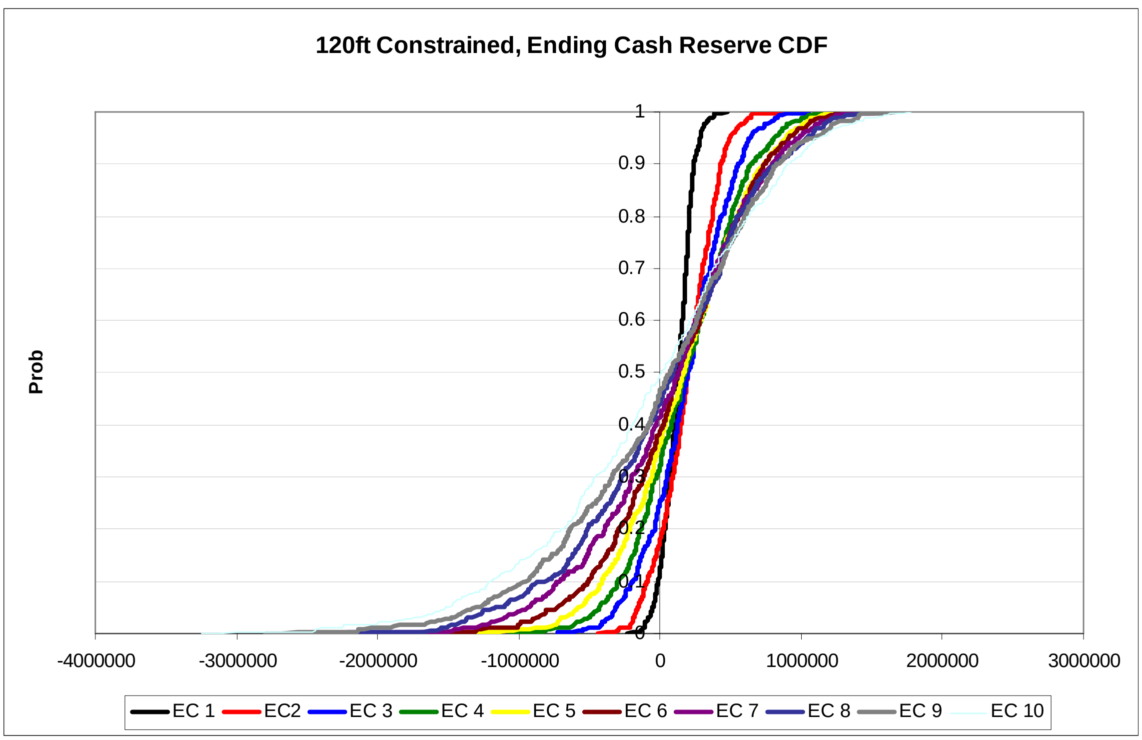
APPENDIX B

SIMULATION CDF CHARTS FOR ENDING CASH RESERVES BY SCENARIO AND SATURATED THICKNESS

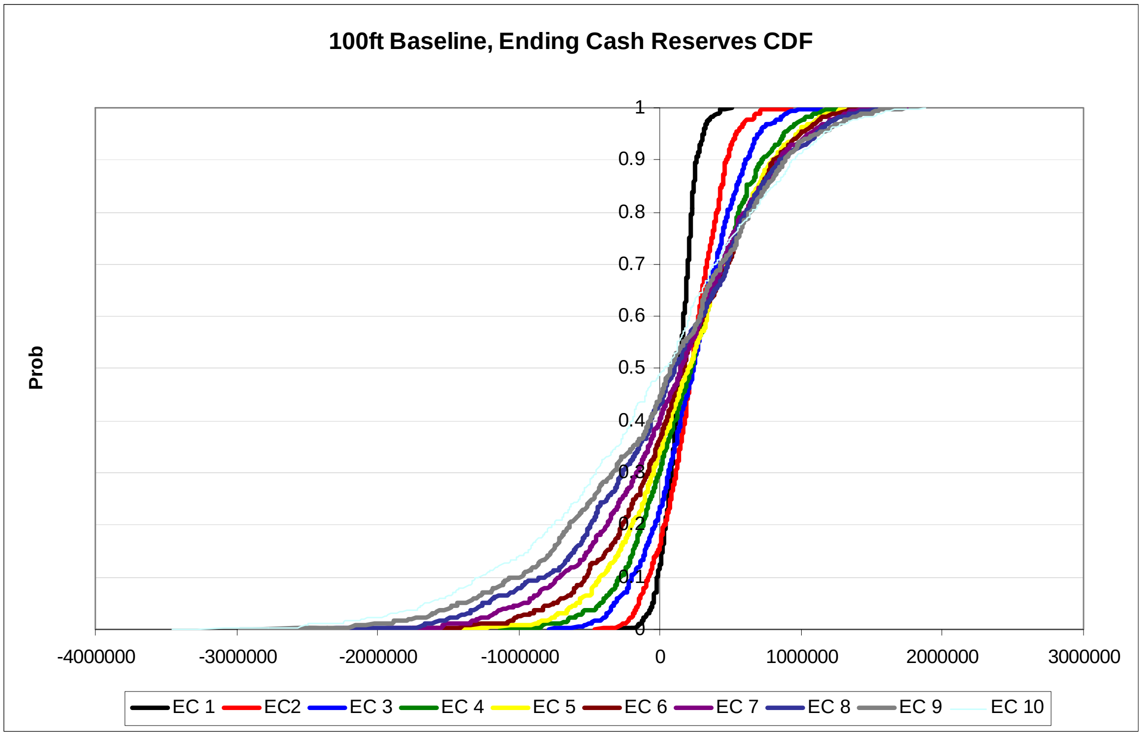
This appendix provides the Cumulative Distribution Functions (CDF) of ending cash reserves generated in the simulation model. Each page consists of a baseline and constrained CDF and is represented for each of the four saturated thickness scenarios 120ft, 100ft, 80ft, and 60ft. The Y axis indicates the probabilities or odds against the X axis which indicates the associated annual ending cash reserves. The legend is formatted such that EC 1 is the CDF of ending cash reserves for the first year of simulation while EC 2 is the CDF for ending cash reserves in year two. This pattern continues throughout graphical analysis with EC 10 representing the CDF for ending cash reserves in the final year of the analysis, 2017. It is important to note that the odds of negative ending cash reserves increase with decreases in saturated thickness and resulting policy or constrained model implementation. Also ending cash reserves is a cumulative analysis in that each year has a beginning cash income or previous years positive ending cash, the interest earned on cash, and additional loan deficit for negative ending cash reserves in previous crop years. Thus in the CDF of ending cash reserves there is a cumulative affect that is dependent on the previous year. EC 10 is the cumulative affect of ending cash reserves for the entire planning horizon and is the final cash position of the farm in year ten or 2017.



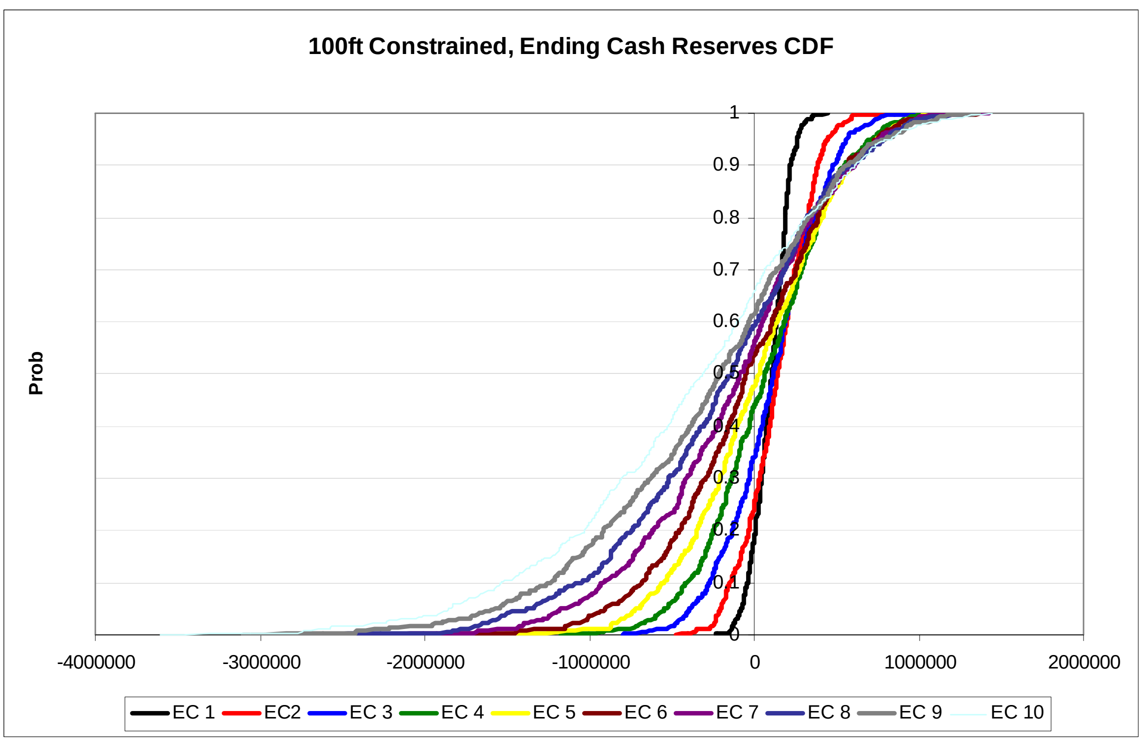
B.1. Ending Cash Reserves CDF, 120ft Baseline.



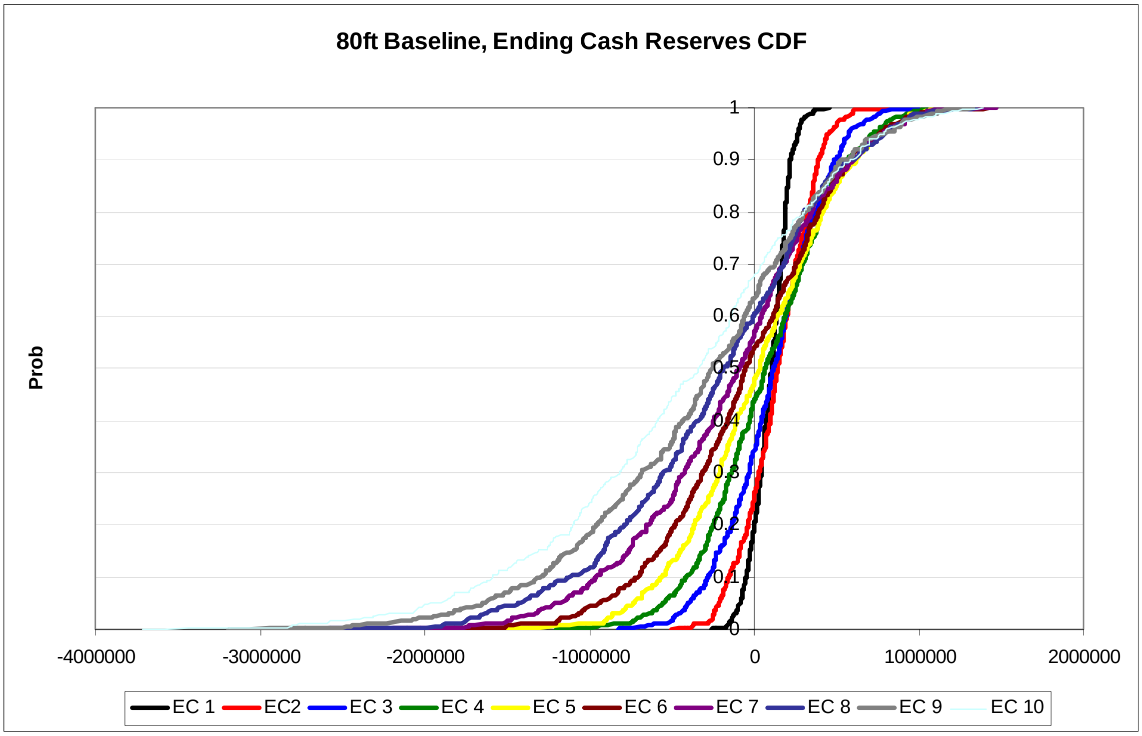
B.2. Ending Cash Reserves CDF, 120ft Constrained.



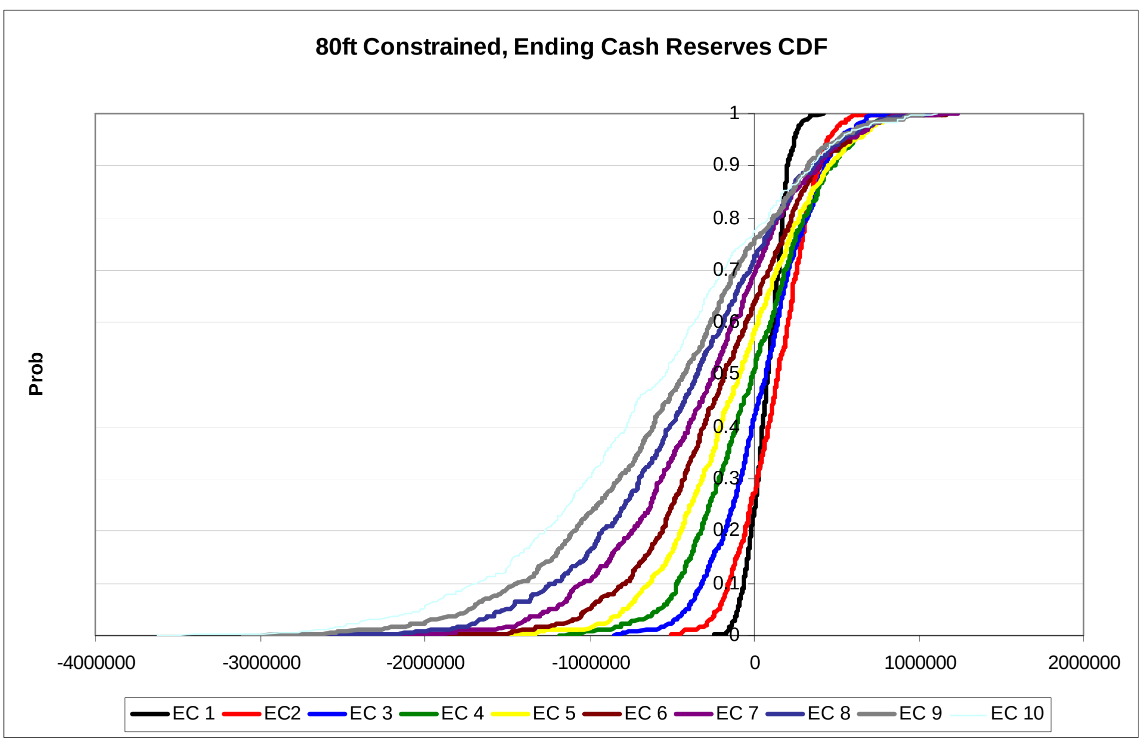
B.4. Ending Cash Reserves CDF, 100ft Baseline.



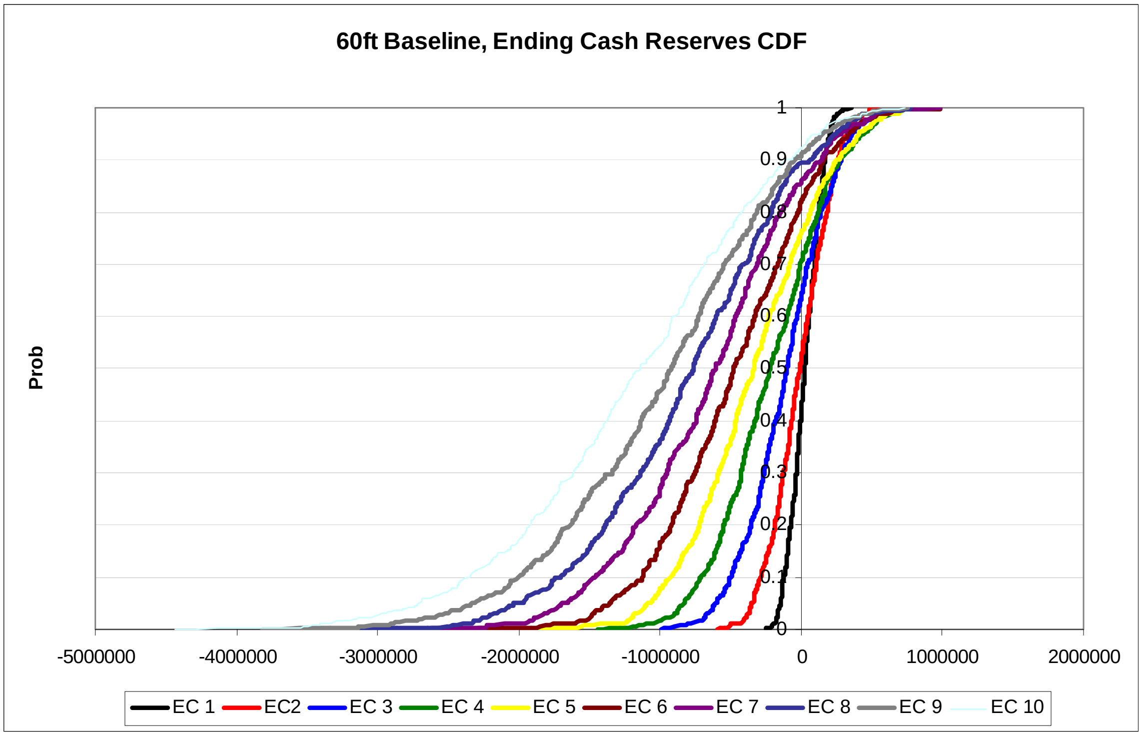
B.4. Ending Cash Reserves CDF, 100ft Constrained.



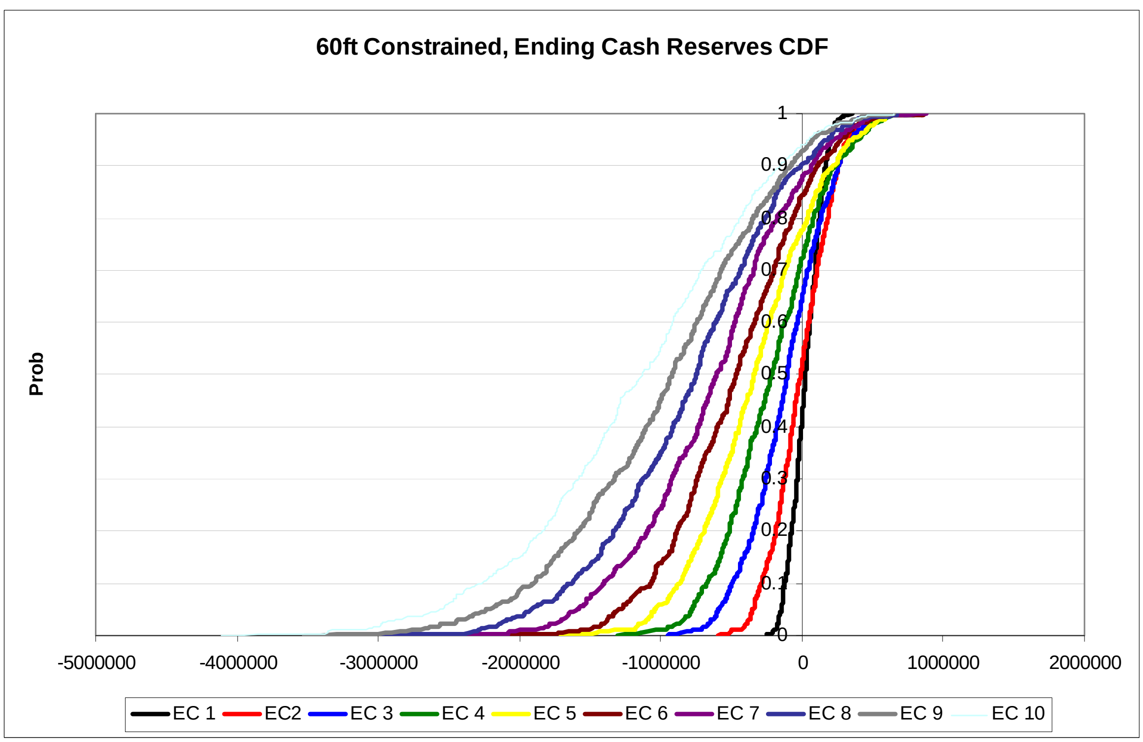
B.5. Ending Cash Reserves CDF, 80ft Baseline.



B.6. Ending Cash Reserves CDF, 80ft Constrained.



B.7. Ending Cash Reserves CDF, 60ft Baseline.



B.8. Ending Cash Reserves CDF, 60ft Constrained.

APPENDIX C

OPTIMAL CROP PERCENTAGES BY SCENARIO

Each of the following tables represents the optimal percentages of enterprises selected in the dynamic optimization model. The years of the planning horizon are represented such that 1 is the first year and 10 is the final year of the modeling process. Within a given crop option there is an associated technology which could be selected either LEPA irrigated, Furrow irrigated, or Dryland technology. Each of the four scenarios is presented for both the baseline and constrained model: 120ft, 100ft, 80ft, and 60ft. These data points were crucial in understanding how the farm reacted to the implementation of a 50/50 policy and provided the foundation input into the financial analysis. As indicated in Chapter V, not all crops are selected and several crops and technologies are not chosen during the planning horizon. The model selected those crops which maximized the net present value of returns under the given assumptions and resource constraints.

Table C.1 120ft Baseline Crop Percentage

Sum of CROPPERC		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.166	0.110	0.074	0.049	0.033	0.022	0.014	0.010	0.006	0.004
COTTON	DRY	0.028	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001
	IRRFURROW	0.193	0.193	0.193	0.193	0.129	0.086	0.057	0.038	0.025	0.017
	IRRLEPA	0.359	0.490	0.577	0.636	0.674	0.700	0.717	0.729	0.736	0.741
SORGHUM	DRY	0.000	0.018	0.031	0.039	0.044	0.048	0.050	0.052	0.053	0.093
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.077	0.052	0.034	0.023	0.015	0.010	0.007	0.004	0.003	0.002
WHEAT	DRY	0.028	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001
	IRRFURROW	0.000	0.000	0.000	0.000	0.065	0.108	0.136	0.155	0.168	0.138
	IRRLEPA	0.149	0.099	0.066	0.044	0.029	0.020	0.013	0.009	0.006	0.004
LIVESTOCK	DRY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C.2 120ft Constrained Crop Percentage.

Sum of CROPPERC		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.166	0.110	0.074	0.049	0.033	0.022	0.014	0.010	0.006	0.004
COTTON	DRY	0.028	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001
	IRRFURROW	0.193	0.161	0.107	0.071	0.048	0.032	0.021	0.014	0.009	0.006
	IRRLEPA	0.359	0.490	0.577	0.636	0.674	0.700	0.717	0.729	0.736	0.741
SORGHUM	DRY	0.000	0.051	0.117	0.161	0.190	0.210	0.223	0.224	0.225	0.226
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.077	0.052	0.034	0.023	0.015	0.010	0.007	0.004	0.003	0.002
WHEAT	DRY	0.028	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.012	0.015
	IRRLEPA	0.149	0.099	0.066	0.044	0.029	0.020	0.013	0.009	0.006	0.004
LIVESTOCK	DRY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C.3 100ft Baseline Crop Percentage

Sum of CROPPERC		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.166	0.110	0.074	0.049	0.033	0.022	0.014	0.010	0.006	0.004
COTTON	DRY	0.028	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001
	IRRFURROW	0.193	0.193	0.193	0.129	0.086	0.057	0.038	0.025	0.017	0.011
	IRRLEPA	0.359	0.490	0.577	0.636	0.674	0.700	0.717	0.729	0.736	0.741
SORGHUM	DRY	0.000	0.018	0.031	0.039	0.068	0.124	0.166	0.193	0.212	0.224
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.077	0.052	0.034	0.023	0.015	0.010	0.007	0.004	0.003	0.002
WHEAT	DRY	0.028	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001
	IRRFURROW	0.000	0.000	0.000	0.065	0.084	0.060	0.040	0.027	0.018	0.012
	IRRLEPA	0.149	0.099	0.066	0.044	0.029	0.020	0.013	0.009	0.006	0.004
LIVESTOCK	DRY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C.4 100ft Constrained Crop Percentage

Sum of CROPPERC		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.166	0.110	0.074	0.049	0.033	0.022	0.014	0.010	0.006	0.004
COTTON	DRY	0.028	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001
	IRRFURROW	0.193	0.129	0.086	0.057	0.038	0.025	0.017	0.011	0.007	0.005
	IRRLEPA	0.359	0.490	0.577	0.636	0.616	0.655	0.680	0.697	0.709	0.716
SORGHUM	DRY	0.000	0.083	0.138	0.175	0.258	0.261	0.264	0.265	0.266	0.267
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.077	0.052	0.034	0.023	0.015	0.010	0.007	0.004	0.003	0.002
WHEAT	DRY	0.028	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.149	0.099	0.066	0.044	0.029	0.020	0.013	0.009	0.006	0.004
LIVESTOCK	DRY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C.5 80ft Baseline Crop Percentage

Sum of CROPPERC		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.166	0.110	0.074	0.049	0.033	0.022	0.014	0.010	0.006	0.004
COTTON	DRY	0.028	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001
	IRRFURROW	0.193	0.132	0.088	0.058	0.039	0.026	0.017	0.012	0.008	0.005
	IRRLEPA	0.359	0.490	0.577	0.636	0.674	0.700	0.692	0.679	0.664	0.647
SORGHUM	DRY	0.000	0.080	0.136	0.174	0.199	0.215	0.252	0.283	0.311	0.336
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.077	0.052	0.034	0.023	0.015	0.010	0.007	0.004	0.003	0.002
WHEAT	DRY	0.028	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.149	0.099	0.066	0.044	0.029	0.020	0.013	0.009	0.006	0.004
LIVESTOCK	DRY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C.6 80ft Constrained Crop Percentage

Sum of CROPPERC		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.166	0.110	0.074	0.049	0.033	0.022	0.014	0.010	0.006	0.004
COTTON	DRY	0.028	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001
	IRRFURROW	0.193	0.129	0.086	0.057	0.038	0.025	0.017	0.011	0.007	0.005
	IRRLEPA	0.359	0.490	0.538	0.463	0.521	0.560	0.585	0.602	0.614	0.621
SORGHUM	DRY	0.000	0.083	0.178	0.347	0.353	0.356	0.359	0.360	0.361	0.362
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.077	0.052	0.034	0.023	0.015	0.010	0.007	0.004	0.003	0.002
WHEAT	DRY	0.028	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.149	0.099	0.066	0.044	0.029	0.020	0.013	0.009	0.006	0.004
LIVESTOCK	DRY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C.7 60ft Baseline Crop Percentage

Sum of CROPPERC		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.166	0.110	0.074	0.049	0.033	0.022	0.014	0.010	0.006	0.004
COTTON	DRY	0.028	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001
	IRRFURROW	0.193	0.129	0.086	0.057	0.038	0.025	0.017	0.011	0.007	0.005
	IRRLEPA	0.359	0.487	0.563	0.607	0.629	0.637	0.636	0.630	0.620	0.609
SORGHUM	DRY	0.000	0.087	0.153	0.204	0.245	0.279	0.308	0.333	0.355	0.374
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.077	0.052	0.034	0.023	0.015	0.010	0.007	0.004	0.003	0.002
WHEAT	DRY	0.028	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.149	0.099	0.066	0.044	0.029	0.020	0.013	0.009	0.006	0.004
LIVESTOCK	DRY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C.8 60ft Constrained Crop Percentage

Sum of CROPPERC		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.166	0.110	0.074	0.049	0.033	0.022	0.014	0.010	0.006	0.004
COTTON	DRY	0.028	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001
	IRRFURROW	0.193	0.129	0.086	0.057	0.038	0.025	0.017	0.011	0.007	0.005
	IRRLEPA	0.359	0.487	0.487	0.469	0.527	0.565	0.591	0.608	0.619	0.611
SORGHUM	DRY	0.000	0.087	0.229	0.342	0.347	0.351	0.353	0.355	0.356	0.357
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.077	0.052	0.034	0.023	0.015	0.010	0.007	0.004	0.003	0.002
WHEAT	DRY	0.028	0.018	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.015
	IRRLEPA	0.149	0.099	0.066	0.044	0.029	0.020	0.013	0.009	0.006	0.004
LIVESTOCK	DRY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRFURROW	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	IRRLEPA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

APPENDIX D

OPTIMAL CROP YIELD BY SCENARIO

This appendix indicates the optimal crop yields per acre generated within the dynamic optimization model. These data points are categorized by crop and technology employed, LEPA irrigated, Furrow irrigated, and Dryland. Yields were calculated within the dynamic optimization model based on the production functions indicated in APPENDIX H and the resource constraints within each of the baseline or constrained models. These values were used as the forecasted per acre mean yields which were crucial in the development of the stochastic yields within the multivariate empirical distribution in the simulation model.

Table D.1 120ft Baseline Crop Yield

Sum of YIELD		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00
	IRRFURROW	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44
	IRRLEPA	216.95	215.09	213.48	206.60	198.70	189.50	179.13	166.80	154.75	151.04
COTTON	DRY	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00
	IRRFURROW	1,304.63	1,304.63	1,303.78	1,292.58	1,271.72	1,247.88	1,221.53	1,194.19	1,163.55	1,160.03
	IRRLEPA	1,540.64	1,540.64	1,539.74	1,531.26	1,515.69	1,498.11	1,478.93	1,459.04	1,436.82	1,434.21
SORGHUM	DRY	2,106.00	2,106.00	2,106.00	2,106.00	2,106.00	2,106.00	2,106.00	2,106.00	2,106.00	2,106.00
	IRRFURROW	3,686.00	3,686.00	3,686.00	3,686.00	3,686.00	3,686.00	3,686.00	3,686.00	3,686.00	3,686.00
	IRRLEPA	3,172.24	3,172.24	3,172.24	3,172.24	3,172.24	3,172.24	3,172.24	3,172.24	3,172.24	3,172.24
WHEAT	DRY	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96
	IRRFURROW	111.52	111.52	111.52	111.52	111.52	108.80	105.98	102.91	100.76	99.69
	IRRLEPA	122.32	118.81	118.22	116.94	115.10	112.84	110.53	108.01	106.29	105.38
LIVESTOCK	DRY	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	IRRFURROW	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	IRRLEPA	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00

Corn (bu/acre), Cotton (lbs/acre), Sorghum (lbs/acre), Wheat (bu/acre), Livestock (lbs gain/acre)

Table D.2 120ft Constrained Crop Yield

Sum of YIELD		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00
	IRRFURROW	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44
	IRRLEPA	159.91	151.54	148.34	148.34	148.34	148.34	148.34	148.34	148.34	148.34
COTTON	DRY	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00
	IRRFURROW	1163.41	1163.41	1149.39	1131.69	1114.03	1107.91	1107.91	1107.91	1107.91	1107.91
	IRRLEPA	1437.55	1437.55	1426.77	1415.90	1415.90	1415.90	1415.90	1415.90	1415.90	1415.90
SORGHUM	DRY	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00
	IRRFURROW	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00
	IRRLEPA	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24
WHEAT	DRY	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96
	IRRFURROW	104.38	104.38	104.38	104.38	104.38	104.38	104.38	104.38	104.38	104.38
	IRRLEPA	113.87	103.43	100.87	98.93	98.79	98.79	98.79	98.79	98.79	98.79
LIVESTOCK	DRY	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	IRRFURROW	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	IRRLEPA	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00

Corn (bu/acre), Cotton (lbs/acre), Sorghum (lbs/acre), Wheat (bu/acre), Livestock (lbs gain/acre)

Table D.3 100ft Baseline Crop Yield

Sum of YIELD		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00
	IRRFURROW	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44
	IRRLEPA	202.83	189.45	174.88	160.29	156.40	156.40	156.40	150.86	148.34	148.34
COTTON	DRY	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00
	IRRFURROW	1267.40	1251.38	1219.47	1194.81	1175.82	1175.82	1169.75	1157.31	1138.93	1117.77
	IRRLEPA	1512.42	1501.14	1477.61	1459.49	1445.74	1445.74	1441.28	1432.31	1419.02	1403.70
SORGHUM	DRY	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00
	IRRFURROW	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00
	IRRLEPA	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24
WHEAT	DRY	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96
	IRRFURROW	100.54	100.54	100.54	100.54	99.43	99.43	99.43	98.44	97.95	94.75
	IRRLEPA	120.23	112.61	108.68	105.93	105.06	105.06	105.06	104.32	103.99	101.32
LIVESTOCK	DRY	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	IRRFURROW	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	IRRLEPA	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00

Corn (bu/acre), Cotton (lbs/acre), Sorghum (lbs/acre), Wheat (bu/acre), Livestock (lbs gain/acre)

Table D.4 100ft Constrained Crop Yield

Sum of YIELD		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00
	IRRFURROW	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44
	IRRLEPA	148.34	148.34	148.34	148.34	148.34	148.34	148.34	148.34	148.34	148.34
COTTON	DRY	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00
	IRRFURROW	1105.28	1105.28	1086.68	1063.17	1039.44	1031.01	1031.01	1031.01	1031.01	1031.01
	IRRLEPA	1396.08	1396.08	1381.62	1367.98	1367.98	1367.98	1367.98	1367.98	1367.98	1367.98
SORGHUM	DRY	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00
	IRRFURROW	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00
	IRRLEPA	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24
WHEAT	DRY	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96
	IRRFURROW	94.42	94.42	94.42	94.42	94.42	94.42	94.42	94.42	94.42	94.42
	IRRLEPA	110.47	97.26	93.93	91.37	91.03	91.03	91.03	91.03	91.03	91.03
LIVESTOCK	DRY	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	IRRFURROW	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	IRRLEPA	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00

Corn (bu/acre), Cotton (lbs/acre), Sorghum (lbs/acre), Wheat (bu/acre), Livestock (lbs gain/acre)

Table D.5 80ft Baseline Crop Yield

Sum of YIELD		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00
	IRRFURROW	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44
	IRRLEPA	153.32	153.32	148.34	148.34	148.34	148.34	148.34	148.34	148.34	148.34
COTTON	DRY	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00
	IRRFURROW	1155.04	1155.04	1151.97	1128.64	1102.23	1069.32	1069.32	1069.32	1069.32	1069.32
	IRRLEPA	1437.41	1437.41	1428.64	1411.60	1392.43	1372.71	1372.71	1372.71	1372.71	1372.71
SORGHUM	DRY	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00
	IRRFURROW	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00
	IRRLEPA	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24
WHEAT	DRY	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96
	IRRFURROW	77.96	77.96	77.96	77.96	77.96	77.96	77.96	77.96	77.96	77.96
	IRRLEPA	112.29	105.43	101.15	98.59	97.02	95.24	95.24	95.24	95.24	95.24
LIVESTOCK	DRY	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	IRRFURROW	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	IRRLEPA	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00

Corn (bu/acre), Cotton (lbs/acre), Sorghum (lbs/acre), Wheat (bu/acre), Livestock (lbs gain/acre)

Table D.6 80ft Constrained Crop Yield

Sum of YIELD		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00
	IRRFURROW	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44
	IRRLEPA	148.34	148.34	148.34	148.34	148.34	148.34	148.34	148.34	148.34	148.34
COTTON	DRY	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00
	IRRFURROW	1036.03	1036.03	1016.50	1016.50	1016.50	1016.50	1016.50	1016.50	1016.50	1016.50
	IRRLEPA	1357.13	1357.13	1357.13	1357.13	1357.13	1357.13	1357.13	1357.13	1357.13	1357.13
SORGHUM	DRY	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00
	IRRFURROW	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00
	IRRLEPA	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24
WHEAT	DRY	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96
	IRRFURROW	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00
	IRRLEPA	106.41	89.88	87.41	87.41	87.41	87.41	87.41	87.41	87.41	87.41
LIVESTOCK	DRY	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	IRRFURROW	60	60	60	60	60	60	60	60	60	60
	IRRLEPA	60	60	60	60	60	60	60	60	60	60

Corn (bu/acre), Cotton (lbs/acre), Sorghum (lbs/acre), Wheat (bu/acre), Livestock (lbs gain/acre)

Table D.7 60Ft Baseline Crop Yield

Sum of YIELD		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00
	IRRFURROW	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44
	IRRLEPA	148.34	148.34	148.34	148.34	148.34	148.34	148.34	148.34	148.34	148.34
COTTON	DRY	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00
	IRRFURROW	969.60	969.60	969.60	969.60	969.60	969.60	969.60	969.60	969.60	969.60
	IRRLEPA	1254.27	1254.27	1254.27	1254.27	1254.27	1254.27	1254.27	1254.27	1254.27	1254.27
SORGHUM	DRY	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00
	IRRFURROW	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00
	IRRLEPA	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24
WHEAT	DRY	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96
	IRRFURROW	102.19	102.19	102.19	102.19	102.19	102.19	102.19	102.19	102.19	102.19
	IRRLEPA	71.26	71.26	71.26	71.26	71.26	71.26	71.26	71.26	71.26	71.26
LIVESTOCK	DRY	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	IRRFURROW	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	IRRLEPA	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00

Corn (bu/acre), Cotton (lbs/acre), Sorghum (lbs/acre), Wheat (bu/acre), Livestock (lbs gain/acre)

Table D.8 60ft Constrained Crop Yield

Sum of YIELD		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00	53.00
	IRRFURROW	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44	153.44
	IRRLEPA	148.34	148.34	148.34	148.34	148.34	148.34	148.34	148.34	148.34	148.34
COTTON	DRY	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00
	IRRFURROW	969.60	969.60	969.60	969.60	969.60	969.60	969.60	969.60	969.60	969.60
	IRRLEPA	1254.27	1254.27	1254.27	1254.27	1254.27	1254.27	1254.27	1254.27	1254.27	1254.27
SORGHUM	DRY	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00	2106.00
	IRRFURROW	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00	3686.00
	IRRLEPA	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24	3172.24
WHEAT	DRY	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96	19.96
	IRRFURROW	115.95	115.95	115.95	115.95	115.95	115.95	115.95	115.95	115.95	115.95
	IRRLEPA	71.26	71.26	71.26	71.26	71.26	71.26	71.26	71.26	71.26	71.26
LIVESTOCK	DRY	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	IRRFURROW	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
	IRRLEPA	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00

Corn (bu/acre), Cotton (lbs/acre), Sorghum (lbs/acre), Wheat (bu/acre), Livestock (lbs gain/acre)

APPENDIX E

VARIABLE COSTS BY SCENARIO

This appendix provides the variable costs which were utilized in both the dynamic optimization and simulation models. Each variable costs is categorized by crop and technology adopted for the ten year planning horizon. Year 1 represents 2008 while year ten is the end of the planning horizon, 2017. The costs utilized in this analysis are based from Texas Agrilife and Extension 2008 Budgets which are inflated according to FAPRI's baseline projections of increases in production costs. Additionally costs reflected in the following tables are calculated based on the production characteristics chosen in the optimization model. Livestock enterprises exclude variable costs and only account for an amortized establishment costs.

Table E.1 120ft Baseline Variable Costs

Sum of VCOSTS		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	IRRFURROW	514.30	517.59	550.58	557.87	565.12	571.77	580.57	589.39	598.62	607.94
	IRRLEPA	634.38	632.46	656.37	642.90	627.99	610.58	593.62	573.98	556.96	557.60
COTTON	DRY	188.32	188.70	207.38	210.29	213.23	215.79	219.67	223.63	227.88	232.20
	IRRFURROW	524.16	527.63	559.13	560.93	558.72	555.56	554.29	553.39	552.44	560.19
	IRRLEPA	576.77	580.15	612.11	615.17	615.30	614.51	615.69	617.23	618.87	627.15
SORGHUM	DRY	69.83	69.97	76.89	77.97	79.06	80.01	81.45	82.92	84.49	86.10
	IRRFURROW	287.25	289.56	306.86	311.15	315.38	319.37	324.48	329.58	334.88	340.24
	IRRLEPA	285.83	287.79	303.79	307.63	311.53	315.14	319.74	324.43	329.35	334.38
WHEAT	DRY	48.67	48.77	53.59	54.34	55.10	55.77	56.77	57.79	58.89	60.01
	IRRFURROW	294.18	296.87	310.12	314.17	318.14	313.68	310.24	306.63	305.76	307.66
	IRRLEPA	354.02	341.51	352.33	351.62	349.34	345.92	343.48	340.92	340.91	343.09
LIVESTOCK	DRY	4.23	4.24	4.66	4.73	4.79	4.85	4.94	5.03	5.12	5.22
	IRRFURROW	38.07	39.22	40.37	41.44	42.45	43.58	44.78	45.96	47.14	48.34
	IRRLEPA	66.23	67.31	68.25	69.25	70.30	71.39	72.47	73.62	74.81	76.05

All costs are in $/acre.

Table E.2 120ft Constrained Variable Costs

Sum of VARCOST		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	IRRFURROW	514.30	517.09	549.54	556.23	562.88	568.99	577.32	585.73	594.63	603.69
	IRRLEPA	494.65	481.02	502.42	508.12	513.89	519.14	526.21	533.44	541.11	548.95
COTTON	DRY	188.32	188.70	207.38	210.29	213.23	215.79	219.67	223.63	227.88	232.20
	IRRFURROW	472.62	475.21	502.22	503.62	505.11	509.24	517.09	525.03	533.43	541.97
	IRRLEPA	537.46	540.07	568.43	571.67	578.15	584.04	592.03	600.20	608.88	617.74
SORGHUM	DRY	69.83	69.97	76.89	77.97	79.06	80.01	81.45	82.92	84.49	86.10
	IRRFURROW	287.25	289.28	306.29	310.24	314.13	317.82	322.67	327.55	332.67	337.87
	IRRLEPA	285.83	287.60	303.39	307.00	310.66	314.06	318.47	323.01	327.80	332.73
WHEAT	DRY	48.67	48.77	53.59	54.34	55.10	55.77	56.77	57.79	58.89	60.01
	IRRFURROW	274.68	276.82	289.50	292.92	296.27	299.51	303.57	307.65	311.90	316.23
	IRRLEPA	322.31	297.37	304.04	303.13	306.08	309.14	312.94	316.86	320.98	325.21
LIVESTOCK	DRY	4.23	4.24	4.66	4.73	4.79	4.85	4.94	5.03	5.12	5.22
	IRRFURROW	38.07	39.22	40.37	41.44	42.45	43.58	44.78	45.96	47.14	48.34
	IRRLEPA	66.23	67.31	68.25	69.25	70.30	71.39	72.47	73.62	74.81	76.05

All costs are in $/acre.

Table E.3 100ft Baseline Variable Costs

Sum of VCOSTS		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	IRRFURROW	525.13	528.26	561.03	568.02	574.95	581.29	589.81	598.35	607.33	616.41
	IRRLEPA	607.80	575.04	567.86	541.83	539.75	545.28	552.57	548.41	550.99	558.85
COTTON	DRY	188.32	188.70	207.38	210.29	213.23	215.79	219.67	223.63	227.88	232.20
	IRRFURROW	518.75	515.23	534.51	532.58	532.85	538.88	545.00	549.16	551.98	554.26
	IRRLEPA	575.10	573.35	596.06	596.25	598.29	604.43	611.12	616.44	620.90	624.98
SORGHUM	DRY	69.83	69.97	76.89	77.97	79.06	80.01	81.45	82.92	84.49	86.10
	IRRFURROW	293.26	295.48	312.67	316.79	320.84	324.66	329.61	334.56	339.72	344.94
	IRRLEPA	290.04	291.94	307.85	311.58	315.35	318.85	323.33	327.91	332.73	337.67
WHEAT	DRY	48.67	48.77	53.59	54.34	55.10	55.77	56.77	57.79	58.89	60.01
	IRRFURROW	273.14	275.47	288.31	291.90	292.69	296.04	300.16	301.86	304.92	301.68
	IRRLEPA	354.20	329.12	330.46	326.70	327.98	331.25	335.23	337.42	340.80	338.54
LIVESTOCK	DRY	4.23	4.24	4.66	4.73	4.79	4.85	4.94	5.03	5.12	5.22
	IRRFURROW	38.07	39.22	40.37	41.44	42.45	43.58	44.78	45.96	47.14	48.34
	IRRLEPA	66.23	67.31	68.25	69.25	70.30	71.39	72.47	73.62	74.81	76.05

All costs are in $/acre.

Table E.4 100ft Constrained Variable Costs

Sum of CROPPERC		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	IRRFURROW	525.13	527.79	560.10	566.67	573.20	579.12	587.29	595.55	604.30	613.20
	IRRLEPA	481.04	483.34	510.64	516.24	521.92	527.02	533.96	541.07	548.63	556.35
COTTON	DRY	188.32	188.70	207.38	210.29	213.23	215.79	219.67	223.63	227.88	232.20
	IRRFURROW	464.89	467.30	493.13	493.15	493.25	496.71	504.36	512.12	520.34	528.69
	IRRLEPA	534.65	537.09	564.42	566.93	573.26	578.94	586.75	594.74	603.24	611.92
SORGHUM	DRY	69.83	69.97	76.89	77.97	79.06	80.01	81.45	82.92	84.49	86.10
	IRRFURROW	293.26	295.22	312.15	316.04	319.86	323.45	328.21	333.00	338.04	343.16
	IRRLEPA	290.04	291.76	307.49	311.05	314.67	318.00	322.35	326.82	331.55	336.43
WHEAT	DRY	48.67	48.77	53.59	54.34	55.10	55.77	56.77	57.79	58.89	60.01
	IRRFURROW	259.23	261.16	273.63	276.86	280.03	283.04	286.89	290.77	294.82	298.95
	IRRLEPA	320.51	290.27	295.54	293.51	295.97	298.88	302.53	306.30	310.29	314.37
LIVESTOCK	DRY	4.23	4.24	4.66	4.73	4.79	4.85	4.94	5.03	5.12	5.22
	IRRFURROW	38.07	39.22	40.37	41.44	42.45	43.58	44.78	45.96	47.14	48.34
	IRRLEPA	66.23	67.31	68.25	69.25	70.30	71.39	72.47	73.62	74.81	76.05

All costs are in $/acre.

Table E.5 80ft Baseline Variable Costs

Sum of CROPPERC		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	IRRFURROW	535.95	538.71	571.12	577.79	584.40	590.46	598.70	606.99	615.73	624.57
	IRRLEPA	499.83	502.25	519.21	524.89	530.63	535.84	542.84	549.97	557.52	565.20
COTTON	DRY	188.32	188.70	207.38	210.29	213.23	215.79	219.67	223.63	227.88	232.20
	IRRFURROW	487.89	490.45	520.45	519.47	517.80	514.15	521.89	529.71	537.95	546.30
	IRRLEPA	556.95	559.53	588.16	589.01	589.47	589.39	597.27	605.28	613.78	622.42
SORGHUM	DRY	69.83	69.97	76.89	77.97	79.06	80.01	81.45	82.92	84.49	86.10
	IRRFURROW	299.27	301.28	318.27	322.21	326.09	329.75	334.55	339.36	344.38	349.48
	IRRLEPA	294.25	296.00	311.78	315.38	319.03	322.41	326.79	331.27	336.00	340.85
WHEAT	DRY	48.67	48.77	53.59	54.34	55.10	55.77	56.77	57.79	58.89	60.01
	IRRFURROW	232.43	234.25	246.61	249.75	252.83	255.79	259.56	263.34	267.27	271.25
	IRRLEPA	333.96	316.24	317.80	314.93	314.56	313.59	317.31	321.13	325.14	329.22
LIVESTOCK	DRY	4.23	4.24	4.66	4.73	4.79	4.85	4.94	5.03	5.12	5.22
	IRRFURROW	38.07	39.22	40.37	41.44	42.45	43.58	44.78	45.96	47.14	48.34
	IRRLEPA	66.23	67.31	68.25	69.25	70.30	71.39	72.47	73.62	74.81	76.05

All costs are in $/acre.

Table E.6 80ft Constrained Variable Costs

Sum of CROPPERC		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	IRRFURROW	535.95	538.54	570.76	577.22	583.48	589.25	597.26	605.37	613.96	622.72
	IRRLEPA	489.45	491.70	518.93	524.44	529.91	534.90	541.72	548.71	556.15	563.75
COTTON	DRY	188.32	188.70	207.38	210.29	213.23	215.79	219.67	223.63	227.88	232.20
	IRRFURROW	454.12	456.39	482.11	488.12	493.99	499.41	506.96	514.61	522.72	530.97
	IRRLEPA	532.47	534.80	566.14	572.30	578.41	583.96	591.64	599.50	607.87	616.42
SORGHUM	DRY	69.83	69.97	76.89	77.97	79.06	80.01	81.45	82.92	84.49	86.10
	IRRFURROW	299.27	301.19	318.07	321.89	325.58	329.08	333.75	338.46	343.41	348.45
	IRRLEPA	294.25	295.94	311.64	315.16	318.67	321.94	326.22	330.64	335.31	340.13
WHEAT	DRY	48.67	48.77	53.59	54.34	55.10	55.77	56.77	57.79	58.89	60.01
	IRRFURROW	329.89	332.04	344.70	348.08	351.24	354.33	358.24	362.20	366.33	370.54
	IRRLEPA	316.89	280.71	287.90	290.89	293.86	296.67	300.23	303.91	307.80	311.80
LIVESTOCK	DRY	4.23	4.24	4.66	4.73	4.79	4.85	4.94	5.03	5.12	5.22
	IRRFURROW	38.07	39.22	40.37	41.44	42.45	43.58	44.78	45.96	47.14	48.34
	IRRLEPA	66.23	67.31	68.25	69.25	70.30	71.39	72.47	73.62	74.81	76.05

All costs are in $/acre.

Table E.7 60ft Baseline Variable Costs

Sum of CROPPERC		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	IRRFURROW	546.78	549.16	581.23	587.57	593.88	599.65	607.62	615.66	624.15	632.77
	IRRLEPA	497.87	499.96	527.07	532.50	538.00	542.99	549.78	556.71	564.07	571.58
COTTON	DRY	188.32	188.70	207.38	210.29	213.23	215.79	219.67	223.63	227.88	232.20
	IRRFURROW	443.88	445.96	476.51	482.42	488.28	493.68	501.17	508.76	516.78	524.92
	IRRLEPA	513.70	515.79	546.93	552.94	559.02	564.52	572.10	579.85	588.10	596.49
SORGHUM	DRY	69.83	69.97	76.89	77.97	79.06	80.01	81.45	82.92	84.49	86.10
	IRRFURROW	305.29	307.09	323.89	327.65	331.35	334.86	339.50	344.18	349.07	354.03
	IRRLEPA	298.46	300.07	315.71	319.18	322.71	325.98	330.25	334.64	339.27	344.04
WHEAT	DRY	48.67	48.77	53.59	54.34	55.10	55.77	56.77	57.79	58.89	60.01
	IRRFURROW	292.73	294.55	306.92	310.07	313.15	316.12	319.90	323.68	327.62	331.61
	IRRLEPA	249.11	250.62	262.55	265.42	268.34	271.08	274.56	278.14	281.93	285.81
LIVESTOCK	DRY	4.23	4.24	4.66	4.73	4.79	4.85	4.94	5.03	5.12	5.22
	IRRFURROW	38.07	39.22	40.37	41.44	42.45	43.58	44.78	45.96	47.14	48.34
	IRRLEPA	66.23	67.31	68.25	69.25	70.30	71.39	72.47	73.62	74.81	76.05

All costs are in $/acre.

Table E.8 60ft Constrained Variable Costs

Sum of CROPPERC		YEAR									
CROP	SYSTEM	1	2	3	4	5	6	7	8	9	10
CORN	DRY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	IRRFURROW	546.78	549.16	581.23	587.48	593.62	599.27	607.16	615.14	623.61	632.23
	IRRLEPA	497.87	499.96	527.07	532.42	537.80	542.70	549.42	556.31	563.65	571.15
COTTON	DRY	188.32	188.70	207.38	210.29	213.23	215.79	219.67	223.63	227.88	232.20
	IRRFURROW	443.88	445.96	476.51	482.36	488.14	493.47	500.92	508.47	516.47	524.62
	IRRLEPA	513.70	515.79	546.93	552.88	558.85	564.27	571.80	579.51	587.74	596.13
SORGHUM	DRY	69.83	69.97	76.89	77.97	79.06	80.01	81.45	82.92	84.49	86.10
	IRRFURROW	305.29	307.09	323.89	327.59	331.21	334.65	339.25	343.89	348.76	353.73
	IRRLEPA	298.46	300.07	315.71	319.15	322.61	325.84	330.08	334.44	339.06	343.83
WHEAT	DRY	48.67	48.77	53.59	54.34	55.10	55.77	56.77	57.79	58.89	60.01
	IRRFURROW	339.98	341.94	354.45	357.64	360.69	363.66	367.45	371.29	375.30	379.38
	IRRLEPA	249.11	250.62	262.55	265.39	268.26	270.96	274.40	277.97	281.75	285.63
LIVESTOCK	DRY	4.23	4.24	4.66	4.73	4.79	4.85	4.94	5.03	5.12	5.22
	IRRFURROW	38.07	39.22	40.37	41.44	42.45	43.58	44.78	45.96	47.14	48.34
	IRRLEPA	66.23	67.31	68.25	69.25	70.30	71.39	72.47	73.62	74.81	76.05

All costs are in $/acre.

APPENDIX F

CROP BUDGETS

This appendix contains the 2008 Texas Agrilife Extension projected production budgets by crop. Each of these crop budgets was used to develop the baseline costs per acre of each crop and enterprise option within the modeling process. Several additional costs are not presented on the budgets including harvest, ginning, maintenance and labor on irrigation systems, depreciation expenses, and pumping costs. These costs were calculated separately within the optimization model based on the resource availability and optimal decision path chosen.

Table F.1 Dryland Cotton Budget

DRYLAND COTTON

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
DIRECT EXPENSES				
Seed				
seed-cotton dry	thou	0.88	39.00	34.28
FERTILIZER				
fert. (P)	lb	0.62	20.00	12.41
fert. (N)	lb	0.62	30.00	18.61
CUSTOM				
preplant herb+appl	acre	12.41	1.00	12.41
fert appl	acre	4.65	1.00	4.65
insec+appl	appl	12.41	0.50	6.20
harvaid appl	acre	20.68	0.50	10.34
CROP INSURANCE				
cotton-dryland	acre	12.67	1.00	12.67
BOLL WEEVIL ASESS				
dryland	acre	3.10	1.00	3.10
OPERATOR LABOR				
implements	hour	10.34	1.19	12.33
tractors	hour	10.34	1.16	11.97
HAND LABOR				
implements	hour	10.34	0.15	1.58
DIESEL FUEL				
tractors	gal	2.74	5.13	14.05
GASOLINE				
self propelled equip	gal	3.00	2.01	6.03
REPAIR & MAINTENANCE				
implements	acre	14.24	1.00	14.24
tractors	acre	12.84	1.00	12.84
self propelled equip	acre	0.17	1.00	0.17
TOTAL DIRECT EXPENSES				187.87

Table F.2. Irrigated Cotton Budget

IRRIGATED COTTON

ITEM		UNIT	PRICE	QUANTITY	AMOUNT
DIRECT EXPENSES					
Seed					
	seed-cotton dry	thou	1.00	52.00	52.00
FERTILIZER					
	fert. (P)	lb	0.60	25.00	15.00
	fert. (N)	lb	0.60	100.00	60.00
CUSTOM					
	preplant herb+appl	acre	12.00	1.00	12.00
	fert appl	acre	4.50	1.00	4.50
	post emergent	acre	16.00	1.00	16.00
	insec+appl	appl	12.00	1.00	12.00
	harvaid appl	acre	25.00	1.00	25.00
CROP INSURANCE					
	cotton-irrigated	acre	20.00	1.00	20.00
BOLL WEEVIL ASESS					
	dryland	acre	6.00	1.00	6.00
OPERATOR LABOR					
	implements	hour	10.00	1.06	10.59
	tractors	hour	10.00	1.08	10.85
HAND LABOR					
	implements	hour	10.00	0.20	1.98
DIESEL FUEL					
	tractors	gal	2.65	4.85	12.86
GASOLINE					
	self propelled equip	gal	2.90	3.51	10.18
REPAIR & MAINTENANCE					
	implements	acre	12.45	1.00	12.45
	tractors	acre	11.77	1.00	11.77
	self propelled equip	acre	0.28	1.00	0.28
TOTAL DIRECT EXPENSES					293.46

Table F.3. Dryland Wheat Budget

DRYLAND WHEAT

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
DIRECT EXPENSES				
Seed				
seed-wheat g	bu	12.30	1.00	12.30
FERTILIZER				
fert. (N)	lb	0.60	30.00	18.00
CUSTOM				
fert appl	acre	4.50	1.00	4.50
insec+appl	appl	11.00	0.50	5.50
CROP INSURANCE				
wheat	acre	5.33	1.00	5.33
OPERATOR LABOR				
implements	hour	10.00	0.28	2.76
tractors	hour	10.00	0.44	4.43
HAND LABOR				
implements	hour	10.00	0.21	2.12
DIESEL FUEL				
tractors	gal	2.65	2.22	5.89
GASOLINE				
self propelled equip	gal	2.90	2.01	5.83
REPAIR & MAINTENANCE				
implements	acre	3.80	1.00	3.80
tractors	acre	4.46	1.00	4.46
self propelled equip	acre	0.16	1.00	0.16
TOTAL DIRECT EXPENSES				75.07

Table F.4. Irrigated Wheat Budget

IRRIGATED WHEAT

ITEM		UNIT	PRICE	QUANTITY	AMOUNT
DIRECT EXPENSES					
Seed					
	seed-wheat g	bu	12.30	1.50	18.45
FERTILIZER					
	fert. (P)	lb	0.60	60.00	36.00
	fert. (N)	lb	0.60	50.00	30.00
CUSTOM					
	preplant herb+appl	acre	4.50	1.00	4.50
	insec+appl	appl	11.00	1.00	11.00
CROP INSURANCE					
	wheat	acre	10.00	1.00	10.00
OPERATOR LABOR					
	implements	hour	10.00	0.36	3.64
	tractors	hour	10.00	0.52	5.15
HAND LABOR					
	implements	hour	10.00	0.21	2.12
DIESEL FUEL					
	tractors	gal	2.65	2.46	6.52
GASOLINE					
	self propelled equip	gal	2.90	2.01	5.83
REPAIR & MAINTENANCE					
	implements	acre	4.47	1.00	4.47
	tractors	acre	5.55	1.00	5.55
	self propelled equip	acre	0.16	1.00	0.16
TOTAL DIRECT EXPENSES					143.39

Table F.5. Dryland Sorghum Budget

DRYLAND SORGHUM

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
DIRECT EXPENSES				
Seed				
seed-sorghum	lb	1.25	2.25	2.82
FERTILIZER				
fert. (N)	lb	0.60	40.00	24.00
CUSTOM				
fert appl	acre	4.50	1.00	4.50
insec+appl	appl	13.00	0.33	4.29
herb + appl	acre	10.50	1.00	10.50
CROP INSURANCE				
wheat	acre	6.25	1.00	6.25
OPERATOR LABOR				
implements	hour	10.00	0.54	5.40
tractors	hour	10.00	0.60	6.00
HAND LABOR				
implements	hour	10.00	0.15	1.53
DIESEL FUEL				
tractors	gal	2.65	3.16	8.37
GASOLINE				
self propelled equip	gal	2.90	2.01	5.83
REPAIR & MAINTENANCE				
implements	acre	7.37	1.00	7.37
tractors	acre	7.72	1.00	7.72
self propelled equip	acre	0.16	1.00	0.16
TOTAL DIRECT EXPENSES				94.74

Table F.6. Irrigated Sorghum Budget

IRRIGATED SORGHUM

ITEM		UNIT	PRICE	QUANTITY	AMOUNT
DIRECT EXPENSES					
Seed					
	seed-sorghum	lb	1.25	4.50	5.63
FERTILIZER					
	fert. (P)	lb	0.60	50.00	30.00
	fert. (N)	lb	0.60	60.00	36.00
	fert. (N)	lb	0.60	40.00	24.00
CUSTOM					
	fertlizer	acre	9.00	1.00	9.00
	herb app	acre	21.12	1	21.12
	insec+appl	appl	13.00	0.33	4.29
CROP INSURANCE					
	wheat	acre	15.25	1.00	15.25
OPERATOR LABOR					
	implements	hour	10.00	0.54	5.44
	tractors	hour	10.00	0.61	6.06
HAND LABOR					
	implements	hour	10.00	0.15	1.50
DIESEL FUEL					
	tractors	gal	2.65	3.16	8.37
GASOLINE					
	self propelled equip	gal	2.90	2.01	5.83
REPAIR & MAINTENANCE					
	implements	acre	7.37	1.00	7.37
	tractors	acre	7.72	1.00	7.72
	self propelled equip	acre	0.16	1.00	0.16
TOTAL DIRECT EXPENSES					187.74

Table F.7. Irrigated Corn Budget

IRRIGATED CORN

ITEM		UNIT	PRICE	QUANTITY	AMOUNT
DIRECT EXPENSES					
Seed					
	corn bt	bags	132.00	0.35	46.20
FERTILIZER					
	fert. (P)	lb	0.60	180.00	108.00
	fert. (N)	lb	0.60	50.00	30.00
	herb pre	acre	17.50	1.00	17.50
	herb post	acre	24.85	1.00	24.85
CUSTOM					
	fertlizer	acre	4.50	1.00	4.50
	insec+appl	appl	25.00	1.00	25.00
CROP INSURANCE					
	wheat	acre	15.00	1.00	15.00
OPERATOR LABOR					
	implements	hour	10.00	0.29	2.93
	tractors	hour	10.00	0.40	3.97
HAND LABOR					
	implements	hour	10.00	0.15	1.50
DIESEL FUEL					
	tractors	gal	2.65	2.18	5.78
GASOLINE					
	self propelled equip	gal	2.90	2.01	5.83
REPAIR & MAINTENANCE					
	implements	acre	5.61	1.00	5.61
	tractors	acre	4.80	1.00	4.80
	self propelled equip	acre	0.16	1.00	0.16
TOTAL DIRECT EXPENSES					301.62

APPENDIX G

COUNTY PRODUCTION FUNCTION PARAMETERS

$$YIELD = B0 + B1WATER - B2WATER^2$$

Table G.1. Floyd County Production Parameters.

LEPA Yield Response to Applied Water

CROP	B0*	B1**	B2	R^2
Cotton	386	94.5 (4.43)	-1.86 (.14)	0.994
Corn	53	7.93 (.43)	-.08(.007)	0.988
Sorghum	2106	168 (19.6)	-2.24 (1.2)	0.975
Wheat	20	9.93 (1.4)	-0.23 (.08)	0.968

FURROW Yield Response to Applied Water

	B0*	B1**	B2	R^2
Cotton	386	71.16 (20.8)	-1.28 (.99)	0.952
Corn	53	6.48(.195)	-.05(.003)	0.997
Sorghum	2106	186(6.6)	-2.8(.2)	0.999
Wheat	20	8.2 (.67)	-0.18 (.115)	0.983

**Standard Errors Appear in Parenthesis Next to Coefficients

*B0 = Actual Dryland Yield

APPENDIX H

COUNTY HYDROLOGIC PARAMETERS

Table H.1. Farm Level Hydrologic Parameters

Scenario	Recharge in/ac Primary + Secondary	Pump Lift Feet	Saturated Thickness Feet	Well Yield GPM	Acres Per Well	Specific Yield
120ft Base	3.7007	315	120	336	70	0.154
120ft Con	3.7007	315	120	336	70	0.154
100ft Base	3.7007	335	100	277	70	0.154
100ft Con	3.7007	335	100	277	70	0.154
80ft Base	3.7007	355	80	217	70	0.154
80ft Con	3.7007	355	80	217	70	0.154
60ft Base	3.7007	375	60	158	70	0.154
60ft Con	3.7007	375	60	158	70	0.154

APPENDIX I

PRICES AND COSTS OF PRODUCTION

BY CROP AND SYSTEM

Table I.1 Variable Cost of Dryland

	cotton	corn	sorghum	wheat	livestock
2008	198.77	0.00	99.45	73.74	4.23
2009	199.16	0.00	99.65	73.89	4.24
2010	218.88	0.00	109.52	81.21	4.66
2011	221.95	0.00	111.05	82.34	4.73
2012	225.05	0.00	112.60	83.49	4.79
2013	227.75	0.00	113.96	84.50	4.85
2014	231.85	0.00	116.01	86.02	4.94
2015	236.03	0.00	118.09	87.57	5.03
2016	240.51	0.00	120.34	89.23	5.12
2017	245.08	0.00	122.63	90.93	5.22

All costs are in $/acre

Table I.2 Additional Variable Cost for LEPA Irrigation

	cotton	corn	sorghum	wheat	livestock
2008	112.15	321.63	98.39	72.28	0.00
2009	112.37	322.28	98.59	72.43	0.00
2010	123.50	354.18	108.35	79.60	0.00
2011	125.23	359.14	109.87	80.71	0.00
2012	126.98	364.17	111.41	81.84	0.00
2013	128.50	368.54	112.74	82.82	0.00
2014	130.82	375.17	114.77	84.31	0.00
2015	133.17	381.92	116.84	85.83	0.00
2016	135.70	389.18	119.06	87.46	0.00
2017	138.28	396.57	121.32	89.12	0.00

All costs are in $/acre

Table I.3 Additional Variable Cost for Furrow Irrigation

	cotton	corn	sorghum	wheat	livestock
2008	104.74	333.27	93.10	60.31	0.00
2009	104.95	333.94	93.29	60.43	0.00
2010	115.34	367.00	102.53	66.41	0.00
2011	116.96	372.13	103.96	67.34	0.00
2012	118.59	377.34	105.42	68.28	0.00
2013	120.02	381.87	106.68	69.10	0.00
2014	122.18	388.75	108.60	70.34	0.00
2015	124.38	395.74	110.56	71.61	0.00
2016	126.74	403.26	112.66	72.97	0.00
2017	129.15	410.92	114.80	74.36	0.00

All costs are in $/acre

Table I.4 Harvest Cost:
Cotton($/lb lint),Corn($/bu), Sorghum ($/lb), Wheat ($/bu

	cotton	corn	sorghum	wheat
2008	0.143	0.312	0.006	0.534
2009	0.143	0.313	0.006	0.535
2010	0.157	0.344	0.007	0.588
2011	0.160	0.349	0.007	0.597
2012	0.162	0.354	0.007	0.605
2013	0.164	0.358	0.007	0.612
2014	0.167	0.364	0.008	0.623
2015	0.170	0.371	0.008	0.634
2016	0.173	0.378	0.008	0.647
2017	0.176	0.385	0.008	0.659

Table I.5 Forecasted Prices Utilized

	FORCASTED MEAN PRICES					
	CORN	COTTON	SORGHUM	WHEAT	LIVESTOCK	COTTON SEED
2008	4.250	0.540	0.070	6.570	0.300	183.700
2009	4.170	0.624	0.065	5.160	0.295	170.900
2010	4.140	0.607	0.067	5.090	0.278	173.930
2011	4.030	0.608	0.064	5.050	0.261	174.610
2012	4.080	0.602	0.066	5.120	0.250	177.260
2013	4.130	0.597	0.066	5.170	0.255	179.620
2014	4.200	0.597	0.068	5.280	0.245	182.750
2015	4.200	0.597	0.068	5.330	0.252	184.030
2016	4.230	0.603	0.069	5.490	0.261	186.530
2017	4.180	0.604	0.069	5.420	0.272	187.140

Cotton($/lblint),Corn($/bu),Sorghum($/lb),Wheat($/bu),Livestock($/lb gain), Cottonseed($/ton)

APPENDIX J

INSURANCE AND FARM PROGRAM VALUES

Table J.1
Farm Program Enrollment

	Base Acres	DP Yield	CCP Yield
CORN	300	96	101
COTTON	1,050	386	425
SORGHUM	140	3416	3024
WHEAT	320	19	18

Table J.2
Farm Program Pay Rates (Stochastic)

	Corn	Cotton	Sorghum	Wheat	Peanuts
Loan Rate	1.950	0.520	0.035	2.750	355.000
Target Price	2.600	0.724	0.046	3.920	495.000
DP Rate	0.280	0.067	0.006	0.520	36.000

PAY RATES

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Corn	-1.796	-1.057	-1.686	-2.219	-2.368	-2.514	-2.403	-1.618	-1.806	-1.741
Cotton	0.131	0.268	0.064	0.202	0.071	-0.181	0.143	0.150	-0.097	0.056
Sorghum	-0.029	-0.006	-0.026	-0.029	-0.042	-0.042	-0.028	-0.024	-0.029	-0.028
Wheat	-2.228	-0.156	-1.826	-1.767	-5.373	-2.679	-1.840	-1.124	-1.635	-1.426

Table J.3
Insurance Gaurentee Yield, APH, and Price Election

			Price Election									
	Gaurentee Yield	**APH**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
DCORN	30	46	3.89	3.87	3.76	3.8000	3.8500	3.9300	3.9200	3.9500	3.9000	3.9000
FCORN	107	164	3.89	3.87	3.76	3.8000	3.8500	3.9300	3.9200	3.9500	3.9000	3.9000
LCORN	107	164	3.89	3.87	3.76	3.8000	3.8500	3.9300	3.9200	3.9500	3.9000	3.9000
DCOTTON	254	391	0.648	0.636	0.637	0.6310	0.6260	0.6240	0.6290	0.6320	0.6330	0.6330
FCOTTON	810	1,246	0.648	0.636	0.637	0.6310	0.6260	0.6240	0.6290	0.6320	0.6330	0.6330
LCOTTON	973	1,497	0.648	0.636	0.637	0.6310	0.6260	0.6240	0.6290	0.6320	0.6330	0.6330
DSORGHUM	1,151	1,770	0.063	0.065	0.062	0.0640	0.0640	0.0660	0.0660	0.0670	0.0670	0.0670
FSOGHUM	2,129	3,275	0.063	0.065	0.062	0.0640	0.0640	0.0660	0.0660	0.0670	0.0670	0.0670
LSORGHUM	2,129	3,275	0.063	0.065	0.062	0.0640	0.0640	0.0660	0.0660	0.0670	0.0670	0.0670
DWHEAT	13	20	5.27	5.20	5.16	5.23	5.28	5.39	5.44	5.50	5.53	5.56
FWHEAT	67	103	5.27	5.20	5.16	5.23	5.28	5.39	5.44	5.50	5.53	5.56
LWHEAT	67	103	5.27	5.20	5.16	5.23	5.28	5.39	5.44	5.50	5.53	5.56

APPENDIX K

BASELINE DYNAMIC OPTIMIZATION MODEL

```
*  Floyd County
*  Suppress listing of equations and columns if Limrow=0, Limcol=0
*OPTION LIMCOL = 0;
*OPTION LIMROW = 0;
*Surpress listing of solution in lst file if set solprint=off
*Option solprint = off;

SETS
    C      CROPS / COTTON, CORN,PEANUTS,SORGHUM, WHEAT, LIVESTOCK/
    B      IRRIG CROP PRODUCTION FUNCTION PARAMETERS /B0, B1, B2/
    I      IRRIGATION SYSTEMS / IRRLEPA, IRRFURROW, DRY /
    T      NUMBER TIME PERIODS IN OPTIMIZATION / 1*10/
    SUBT(T) NUMBER TIME PERIODS USED IN NPV CALCULATION /1*10/;

*******************************************************************
*******************************************************************
*  COUNTY SPECIFIC PARAMETERS
*******************************************************************

ACRONYM Floyd;
PARAMETER  CNTYNAME;

CNTYNAME = Floyd;

SCALAR AREA       FARM LAND AREA (acres)  /5466/;

SCALAR AREAAQ     FARM AREA ABOVE OGALLALA AQUIFER (acres) /5029/;

SCALAR RECHARGE   AMOUNT OF RECHARGE IN INCHES PER ACRE /3.7007/;

SCALAR SPECYLD    SPECIFIC YIELD /.154/;

SCALAR ISATTHK    INITIAL SATURATED THICKNESS (feet) /120/;

SCALAR ILIFT      INITIAL LIFT (feet) /315/;

SCALAR IWellYld   INITIAL WELL YIELD (gpm) /336/;

SCALAR IAcPerWell INITIAL ACRES SERVED PER WELL /70/;

TABLE MINWATER(I,C) Minimum water application by crop per irr acre

           COTTON    CORN    PEANUTS  SORGHUM    WHEAT   LIVESTOCK
    IRRLEPA     7       14       8       7          6      0
    IRRFURROW  10       18       0      10          8      0
    DRY         0        0       0       0          0      0;

TABLE IACRESC(C,I)  YEAR 1 ACREAGE (MAJOR IRR AND NONIRR)

           IRRLEPA    IRRFURROW    DRY
   COTTON      650         350       50
   CORN        300           0        0
   PEANUTS       0           0        0
```

```
  SORGHUM     140         0       0
  WHEAT       270         0      50
  LIVESTOCK     0         0       0;

PARAMETER ICI(I) TOTAL YR1 IRR VS DRY (NOT JUST MAJOR)

  /IRRLEPA    1360
   IRRFURROW   350
   DRY   100 /;

PARAMETER MIACRESC YR 1 MAJOR ACREAGE BY SYSTEM(IRR VS DRY);

  MIACRESC(I) = SUM(C, IACRESC(C,I));
  DISPLAY MIACRESC;

PARAMETER TMIACRES YR 1 TOTAL MAJOR ACREAGE (IRR AND DRY);

  TMIACRES = SUM(C, SUM(I, IACRESC(C,I)));
  DISPLAY TMIACRES;

*****

PARAMETER SCALE(I) SCALE FACTOR TO ADJUST FOR OMMITTED CROPS;

  SCALE(I) = ICI(I)/MIACRESC(I);

PARAMETER RIACRES(C,I) ADJUSTED MAJOR YR1 ACREAGES IRR AND DRY;

    RIACRES(C,I) = SCALE(I)*IACRESC(C,I)

PARAMETER RIACRESI(I) ADJUSTED YR1 IRR VS DRY ACREAGE;

    RIACRESI(I) = SUM(C, RIACRES(C,I))
    DISPLAY RIACRESI

PARAMETER SP(I,C,T) PERCENT CROP BY SYSTEM (CROP DISTRIBUTION in T=1);

  SP(I,C,"1") =  RIACRES(C,I)/ICI(I);
  DISPLAY SP;

PARAMETER RTOTACRES CHECKING SCALING EFFECT FOR ACCURACY;

  RTOTACRES = SUM(C, SUM(I, RIACRES(C,I)));
  DISPLAY RTOTACRES;

PARAMETER PIRRACRES YR 1 PERCENT OF ACREAGE THAT IS IRRIGATED;

  PIRRACRES = (RIACRESI("IRRLEPA")+ RIACRESI("IRRFURROW"))/RTOTACRES;
  DISPLAY PIRRACRES;

*****
PARAMETER TOTCACRES TOTAL YR1 COUNTY ACREAGE (NOT JUST MAJOR);

  TOTCACRES = SUM(I, ICI(I));
  DISPLAY TOTCACRES;
```

```
PARAMETER PIPEANUT YR 1 IRRI PEANUT ACRES AS % OF ALL (I&D) ACREAGE;

   PIPEANUT = (RIACRES("PEANUTS","IRRLEPA") + RIACRES("PEANUTS","IRRFURROW"))
          /RTOTACRES;
   DISPLAY PIPEANUT;


***********************************************************************
*  CROP SPECIFIC PARAMETERS
***********************************************************************
*   ESTIMATED DRYLAND YIELD PARAMETERS FROM CROPMAN/EPIC
***********************************************************************
PARAMETER DY(I,C,T) DRYLAND YIELD DATA ;
* Units
* Cotton (lb lint), Corn(bu), Peanuts(lb), Sorghum(lb), Wheat(bu), Livestock (lb gain)

     DY("DRY","COTTON",T) =  386;
     DY("DRY","CORN",T)   =  53;
     DY("DRY","PEANUTS",T)=   0;
     DY("DRY","SORGHUM",T)= 2106;
     DY("DRY","WHEAT",T)  = 19.96;
     DY("DRY","LIVESTOCK",T)=60;
***********************************************************************
*  IRRIGATED CROP PRODUCTION FUNCTION WATER RESPONSE PARAMETERS
***********************************************************************
TABLE PFLEPA(C,B) YIELD RESPONSE TO APPLIED WATER UNDER CP SYSTEM XX% Eff

               B0      B1      B2
    COTTON       386      94.95   -1.86
    CORN         53       7.93    -.08
    PEANUTS       0         0      0
    SORGHUM     2106       168    -2.24
    WHEAT       19.96      9.93   -.23
    LIVESTOCK    60         0      0 ;


TABLE PFFURROW(C,B) YIELD RESPONSE TO APPLIED WATER UNDER CP SYSTEM XX% Eff

               B0      B1      B2
    COTTON       386      71.16   -1.28
    CORN         53       6.48    -.05
    PEANUTS       0         0      0
    SORGHUM     2106       186    -2.8
    WHEAT       19.96      8.69   -.18
    LIVESTOCK    60         0      0 ;

***********************************************************************
*   CROP REVENUE AND COST PARAMETERS
**********************************************************************
TABLE P(C,T) AVERAGE PRICES OF CROPS FAPRI BASLINE PROJECTIONS
*Units
*Cotton($/lb lint),Corn($/bu),Peanuts($/lb),Sorghum($/lb),Wheat($/bu),Livestock($/lb gain)
             1      2      3      4      5      6      7      8      9      10
    COTTON   0.747  0.774  0.778  0.773  0.770  0.771  0.779  0.783  0.786  0.787
    CORN     4.25   4.17   4.14   4.03   4.08   4.13   4.20   4.20   4.23   4.18
    PEANUTS  0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
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    SORGHUM   0.070   0.065   0.067   0.064  0.066  0.066  0.068  0.068  0.069  0.069
    WHEAT     6.57    5.16    5.09    5.05   5.12   5.17   5.28   5.33   5.49   5.42
    LIVESTOCK 0.43    0.37    0.33    0.31   0.31   0.34   0.37   0.42   0.45   0.49 ;


TABLE VCD(I,T,C) variable cost of dryland CROPs exc. harvest ($ per acre)
              COTTON    CORN    PEANUTS  SORGHUM    WHEAT   LIVESTOCK
    IRRLEPA  . 1  188.32   0.00     0.00    69.83     48.67    0.00
    IRRLEPA  . 2  188.70   0.00     0.00    69.97     48.77    0.00
    IRRLEPA  . 3  207.38   0.00     0.00    76.89     53.59    0.00
    IRRLEPA  . 4  210.29   0.00     0.00    77.97     54.34    0.00
    IRRLEPA  . 5  213.23   0.00     0.00    79.06     55.10    0.00
    IRRLEPA  . 6  215.79   0.00     0.00    80.01     55.77    0.00
    IRRLEPA  . 7  219.67   0.00     0.00    81.45     56.77    0.00
    IRRLEPA  . 8  223.63   0.00     0.00    82.92     57.79    0.00
    IRRLEPA  . 9  227.88   0.00     0.00    84.49     58.89    0.00
    IRRLEPA  . 10 232.20   0.00     0.00    86.10     60.01    0.00
    IRRFURROW. 1  188.32   0.00     0.00    69.83     48.67    0.00
    IRRFURROW. 2  188.70   0.00     0.00    69.97     48.77    0.00
    IRRFURROW. 3  207.38   0.00     0.00    76.89     53.59    0.00
    IRRFURROW. 4  210.29   0.00     0.00    77.97     54.34    0.00
    IRRFURROW. 5  213.23   0.00     0.00    79.06     55.10    0.00
    IRRFURROW. 6  215.79   0.00     0.00    80.01     55.77    0.00
    IRRFURROW. 7  219.67   0.00     0.00    81.45     56.77    0.00
    IRRFURROW. 8  223.63   0.00     0.00    82.92     57.79    0.00
    IRRFURROW. 9  227.88   0.00     0.00    84.49     58.89    0.00
    IRRFURROW. 10 232.20   0.00     0.00    86.10     60.01    0.00
    DRY      . 1  188.32   0.00     0.00    69.83     48.67    4.23
    DRY      . 2  188.70   0.00     0.00    69.97     48.77    4.24
    DRY      . 3  207.38   0.00     0.00    76.89     53.59    4.66
    DRY      . 4  210.29   0.00     0.00    77.97     54.34    4.73
    DRY      . 5  213.23   0.00     0.00    79.06     55.10    4.79
    DRY      . 6  215.79   0.00     0.00    80.01     55.77    4.85
    DRY      . 7  219.67   0.00     0.00    81.45     56.77    4.94
    DRY      . 8  223.63   0.00     0.00    82.92     57.79    5.03
    DRY      . 9  227.88   0.00     0.00    84.49     58.89    5.12
    DRY      . 10 232.20   0.00     0.00    86.10     60.01    5.22 ;

TABLE VCI(I,T,C) added variable cost due to irrg ($ per acre)
              COTTON    CORN    PEANUTS  SORGHUM    WHEAT   LIVESTOCK
    IRRLEPA  . 1  112.15   259.21  341.73  76.18     60.31    0.00
    IRRLEPA  . 2  112.37   259.73  342.42  76.33     60.43    0.00
    IRRLEPA  . 3  123.50   285.44  376.32  83.88     66.41    0.00
    IRRLEPA  . 4  125.23   289.44  381.59  85.06     67.34    0.00
    IRRLEPA  . 5  126.98   293.49  386.93  86.25     68.28    0.00
    IRRLEPA  . 6  128.50   297.01  391.57  87.29     69.10    0.00
    IRRLEPA  . 7  130.82   302.36  398.62  88.86     70.34    0.00
    IRRLEPA  . 8  133.17   307.80  405.79  90.46     71.61    0.00
    IRRLEPA  . 9  135.70   313.65  413.50  92.17     72.97    0.00
    IRRLEPA  . 10 138.28   319.61  421.36  93.93     74.36    0.00
    IRRFURROW. 1  104.74   305.76  0.00    84.64     60.31    0.00
    IRRFURROW. 2  104.95   306.37  0.00    84.81     60.43    0.00
    IRRFURROW. 3  115.34   336.70  0.00    93.21     66.41    0.00
    IRRFURROW. 4  116.96   341.42  0.00    94.51     67.34    0.00
    IRRFURROW. 5  118.59   346.20  0.00    95.83     68.28    0.00
    IRRFURROW. 6  120.02   350.35  0.00    96.98     69.10    0.00
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    IRRFURROW. 7  122.18     356.66   0.00     98.73       70.34     0.00
    IRRFURROW. 8  124.38     363.08   0.00     100.51      71.61     0.00
    IRRFURROW. 9  126.74     369.98   0.00     102.42      72.97     0.00
    IRRFURROW. 10 129.15     377.01   0.00     104.36      74.36     0.00
    DRY      . 1  0.00       0.00   0.00     0.00        0.00     0.00
    DRY      . 2  0.00       0.00   0.00     0.00        0.00     0.00
    DRY      . 3  0.00       0.00   0.00     0.00        0.00     0.00
    DRY      . 4  0.00       0.00   0.00     0.00        0.00     0.00
    DRY      . 5  0.00       0.00   0.00     0.00        0.00     0.00
    DRY      . 6  0.00       0.00   0.00     0.00        0.00     0.00
    DRY      . 7  0.00       0.00   0.00     0.00        0.00     0.00
    DRY      . 8  0.00       0.00   0.00     0.00        0.00     0.00
    DRY      . 9  0.00       0.00   0.00     0.00        0.00     0.00
    DRY      . 10 0.00       0.00   0.00     0.00        0.00     0.00  ;


SCALAR  EF   Energy Use Factor for Electricity /0.164/;
*          Unit is KWH/Feet lift / acre inch

SCALAR  PSI  System Operating Pressure  /15/;
*          Unit is pounds per square inch

SCALAR  EP   Energy price   /.11/;
*          Unit is $/kwh for electricity

SCALAR  EFF  Pump engine efficiency /.60/;


TABLE HC(C,T) HARVEST COST PER UNIT OF PRODUCTION EXTENSION
* Units
*Cotton($/lb lint),Corn($/bu),Peanuts ($/lb),Sorghum ($/lb),Wheat ($/bu)
             1        2        3        4        5        6        7        8        9        10
    COTTON    0.1430   0.1433   0.1575   0.1597  0.1619   0.1639   0.1668  0.1698  0.1730  0.1763
    CORN     0.3123   0.3129   0.3439   0.3487  0.3536   0.3579   0.3643  0.3709  0.3779  0.3851
    PEANUTS   0.0414   0.0415   0.0456   0.0462  0.0468   0.0474   0.0483  0.0491  0.0501  0.0510
    SORGHUM   0.0065   0.0065   0.0071   0.0072  0.0073   0.0074   0.0075  0.0077  0.0078  0.0080
    WHEAT     0.5343   0.5354   0.5884   0.5966  0.6049   0.6122   0.6232  0.6344  0.6465  0.6588
    LIVESTOCK 0.0000   0.0000   0.0000   0.0000  0.0000   0.0000   0.0000  0.0000  0.0000  0.0000
;


PARAMETER IC(I)  PER ACRE INITIAL COSTS OF SYSTEMS

   / IRRLEPA   549.36
     IRRFURROW  14.7
     DRY  0  /;

PARAMETER L(I)   PER ACRE LABOR HOURS (irrigation system)

   / IRRLEPA    .7680
     IRRFURROW  3.65
     DRY  0 /;

TABLE MC (I,T)   MAINTANIENCE COST BY YEAR (.08*IC)
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              1      2      3      4      5      6      7      8      9      10
    IRRLEPA       31.08   31.92   32.62   33.40   34.24   35.10   35.94   36.84   37.79   38.78
    IRRFURROW      0.83    0.85    0.87    0.89    0.91    0.94    0.96    0.98    1.01    1.03;



PARAMETER DP(I)  PER ACRE DEPRECIATION COST OF IRRIGATION SYSTEM;

   DP(I) = 0.05*IC(I);

TABLE LC(I,T)  Per Acre LABOR COST ($10 per hr)

              1      2      3      4      5      6      7      8      9      10
    IRRLEPA       7.68    7.92    8.16    8.38    8.59    8.82    9.06    9.31    9.55    9.80
    IRRFURROW     36.5   37.63   38.76   39.81   40.80   41.90   43.08   44.24   45.39   46.57 ;



*    DISCOUNT RATE AND FACTOR PARAMETERS
*****************************************************************

SCALAR RHO1 DISCOUNT RATE /0.050/;

SCALAR DISC1 DISCOUNT ;
   DISC1 = 1/(1+RHO1);

PARAMETER DELTA1(T)  DISCOUNT FACTOR ;
 DELTA1(T) = (DISC1**(ORD(T)-1));

*****************************************************************
 VARIABLES
*****************************************************************
  YLDLEPA(I,C,T)  PER ACRE YIELD CROP C SYSTEM I TIME T
  YLDFURROW(I,C,T) PER ACRE YIELD CROP C SYSTEM I TIME T
  HARC(I,C,T)     PER ACRE HARVEST COST
  GR(I,C,T)       PER ACRE GROSS REVENUE
  CROPPERC(I,C,T) PER ACRE PERCENTAGE OF CROP C in SYSTEM I
  ST(T)           SATURATED THICKNESS (feet)
  LIFT(T)         PUMP LIFT PERIOD T (feet)
  WP(I,C,T)       PER ACRE WATER PUMPEP BY CROP (AC IN per AC)
  GPC(T)          GROSS PUMPING CAPACITY (acre inch per acre)
  PC(I,C,T)       PUMPING COST SPRINKLER ($'s per acre)
  TCOST(I,C,T)    PER ACRE TOTAL COST BY CROP AND SYSTEM
  NETR(I,C,T)     PER ACRE NET RETURN BY CROP  AND SYSTEM
  NR(T)           PER ACRE WEIGHTED NET RETURN AT T
  NPV1            NPV OF 1 WEIGHTED ACRE OVER T YEARS
  NPVTMAX         NPV OF 1 WEIGHTED ACRE OVER TMAX YEARS
*****
  NPVTOTR         NPV TOTAL COUNTY RETURN OVER TMAX YEARS
*****
  FCI(I)          PERCENT OF SYSTEM (IRR VS DRY) IN USE IN YR 10
  FCA(C)          PRECENT OF EACH CROP (IRR & DRY) GROWN IN YR 10
  CROPAC(C,T)     PERCENT CROP C ACRES (I&D)TO TOTAL ACRES (I&D)
  IRRI(I,T)       PERCENT CROPLAND IN EACH IRRIGATION SYSTEM
  IRCROP(C,T)     PERCENT CROP C IRRI TO TOTAL CROP AC (IRR & DRY)
*****
```

```
  TVWATER(T)     TOTAL COUNTY PUMPING IN YEAR T (ACRE FEET)
*****
  WT(T)          AVG WATER USE ALL ACREAGE (I&D) (AC IN per AC);

POSITIVE VARIABLES
     CROPPERC, LIFT, WP, TCOST, PC, YLD, WT, ST;

*****************************************************************
EQUATIONS
*EQUATIONS DEFINED
*****************************************************************
*PRODUCTION FUNCTIONS (Derived from CROPMAN Model and Data)

  IRRCROPLEPA(I,C,T)     IRRIGATED CROP RESPONSE TO APPLIED WATER (CP)
  IRRCROPFURROW(I,C,T)   IRRIGATED CROP RESPONSE TO APPLIED WATER (CP)
  DRYCROP(I,C,T)         DRYLAND CROP YIELDS (FROM EPIC DATA SET)

*  Irr Cotton yield (lbs per ac)
*  Irr Corn yield (bu perac)
*  Irr Peanut yield (lbs per ac)
*  Irr Sorghum yield (bu per ac)
*  Irrigated Winter Wheat(bu per ac)
*  Dryland Corn yield (bu per ac)
*  Dryland Cotton yield (lbs per ac)
*  Dryland Peanut yield (lbs per ac)
*  Dryland Grain sorghum yield (bu per ac)
*  Dryland Winter wheat yield (bu per ac)

*COST CALCULATIONS

  HARVCST(I,C,T)        PER ACRE HARVEST COST ($'s per acre)
  COSTPUMPLEPA(I,C,T)   PER ACRE IRRIGATED PUMPING COST ($'s per acre)
  COSTIRRLEPA(I,C,T)    TOTAL COST FUNCTION BY IRRI CROP ($'s per acre)
  COSTPUMPFURROW(I,C,T) PER ACRE IRRIGATED PUMPING COST ($'s per acre)
  COSTIRRFURROW(I,C,T)  TOTAL COST FUNCTION BY IRRI CROP ($'s per acre)
  COSTDRY(I,C,T)        TOTAL COST FUNCTION BY DRY CROP ($'s per acre)

*REVENUE CALCULATIONS

  GREV(I,C,T)          GROSS REVENUE ($'s per acre)
  NETRE(I,C,T)         NET RETURN FOR EACH CROP ($'s per acre)
  REVENUN(T)           WEIGHTED AVERAGE REVENUE IN YEAR T ($'s per acre)
*****
  NPVAGR               NPV OF COUNTY AGRICULTURAL RETURN FOR TMAX YEARS
*****

*WATER CALCULATIONS

  PUMPAGE(T)           WATER PUMPAGE IN T (acre inches per acre)
  MOTION(T)            LIFT IN PERIOD T (feet of lift in T)
  SAT(T)               SATURATED THICKNESS IN T (feet)
  GROSS(T)             GROSS PUMPING CAPACITY (acre incher per acre)
*****
  WATERVOL(T)          TOTAL COUNTY PUMPING YEAR T (ACRE FEET)
*****
```

```
*****

  IRRLAND(T)          IRRIGATED ACREAGE CAN NOT EXCEED YEAR 1 IRR ACREAGE
  PEANUTC(C,T)         IRRIGATED PEANUT ACREAGE CAN NOT 33.3% IRR ACREAGE
  PEANUTC1(T)          IRRI PEANUT ACRES LESS THAN TWICE YEAR 1 LEVEL
  MINWPLEPA(I,C,T)     MIN WATER APPLICATION PER ACRE CROP C
  MINWPFURROW(I,C,T)    MIN WATER APPLICATION PER ACRE CROP C
*****

*CONSTRAINTS
  LANC(T)             Land constraint in each period t (1 weighted acre)
  CROPCON(I,C,T)        Acres in each crop in T must be at least 33% of T-1
  WAPPLDL(C,t)         no water is applied to dryland acres (=0)
  WATER(t)            Per Acre Water Constraint (acre inches-GPC variable)
  DRYCORN(I,C,T)        No Dryland Corn
  DRYPEANUTS(I,C,T)     No Dryland Peanuts
  IRRLEPALIVESTOCK (I,C,T)  No Lepa Irrigated Livestock
  IRRFURROWLIVESTOCK (I,C,T)  No Furrow Irrigated Livestock
  IRRFURROWAC (T)  Total furrow acres cannot exceed intial totals (all crop)
  IRRLEPAAC (T)  Total lepa acreas cannot exceed intial totals (all crop)
  DRYCON (T)           DRYLAND ACRES MUST INCREASE OR CONSTANT (AVOIDS BANKING)
  WATERUSE(I,C,T)       WATER PUMPING RESTRICTION AVOIDS BANKING
*CROP ACREAGES

  FINIR(I)            YR 60 PERCENT BREAKDOWN OF AGGREGATE IRR VS NONIRR
  FINA(C)             YR 60 PERCENT BREAKDOWN OF INDIVIDUAL CROP ACREAGE

*OBJECTIVE FUNCTION

  OBJ1              OBJECTIVE FUNCT (NPV 1 WEIGHTED ACRE FOR T YEARS)
  OBJTMAX             TRUNCATED NPV (NPV 1 WEIGHTED ACRE FOR TMAX YEARS)

*ACREAGE DATA

  TOIRRI(I,T)         PERCENT ALL IRRIGATED ACRES TO ALL CROP ACRES (I&D)
  TOCROP(C,T)          PERCENT ALL ACRES IN CROP C TO ALL CROP ACRES (I&D)
  IRRCRO(C,T)         PERCENT CROP C IRRI ACRES TO ALL CROP ACRES (I&D);

**********************************************************************
* EQUATION (FUNCTIONAL FORMS SPECIFIED)
**********************************************************************
* IRR CROP YIELD RESPONSE TO WATER, AND DRYLAND YIELD FUNCTIONS
**********************************************************************

   IRRCROPLEPA("IRRLEPA",C,T)..  YLD("IRRLEPA",C,T)=E=PFLEPA(C,"B0")
          + PFLEPA(C,"B1")*WP("IRRLEPA",C,T) + PFLEPA(C,"B2")*
           (SQR[WP("IRRLEPA",C,T)]);
   IRRCROPFURROW("IRRFURROW",C,T)..  YLD("IRRFURROW",C,T)=E=PFFURROW(C,"B0")
          +PFFURROW(C,"B1")*WP("IRRFURROW",C,T)+PFFURROW(C,"B2")*
           (SQR[WP("IRRFURROW",C,T)]);

   DRYCROP("DRY",C,T)..  YLD("DRY",C,T)=E=DY("DRY",C,T);

*COST CALCULATIONS

  HARVCST(I,C,T)..       HARC(I,C,T)=E= (YLD(I,C,T) * HC(C,T));
```

```
  COSTPUMPLEPA("IRRLEPA",C,T)..   PC("IRRLEPA",C,T)=E=((EF*(LIFT(T)+2.31*PSI)*EP)
                  /(EFF))*WP("IRRLEPA",C,T);

  COSTPUMPFURROW("IRRFURROW",C,T)..   PC("IRRFURROW",C,T)=E=((EF*(LIFT(T)*EP))
                  /(EFF))*WP("IRRFURROW",C,T);

*The VALUE 2.31 is the height of a column of water that will exert 1 psi

  COSTIRRLEPA("IRRLEPA",C,T)..   TCOST("IRRLEPA",C,T)=E=PC("IRRLEPA",C,T)+
      MC("IRRLEPA",T)+ DP("IRRLEPA")+LC("IRRLEPA",T)+VCD("IRRLEPA",T,C)+
      VCI("IRRLEPA",T,C)+HARC("IRRLEPA",C,T);
  COSTIRRFURROW("IRRFURROW",C,T)..
TCOST("IRRFURROW",C,T)=E=PC("IRRFURROW",C,T)
      +
MC("IRRFURROW",T)+DP("IRRFURROW")+LC("IRRFURROW",T)+VCD("IRRFURROW",T,C)
      +VCI("IRRFURROW",T,C)+HARC("IRRFURROW",C,T);
  COSTDRY("DRY",C,T)..   TCOST("DRY",C,T)=E=VCD("DRY",T,C)+HARC("DRY",C,T);

*REVENUE CALCULATIONS

   GREV(I,C,T)..     GR(I,C,T)=E= P(C,T)*YLD(I,C,T);
   NETRE(I,C,T)..    NETR(I,C,T) =E= GR(I,C,T) - TCOST(I,C,T);
   REVENUN(T)..      SUM(I,SUM(C,NETR(I,C,T)*CROPPERC(I,C,T)))=E=
              NR(T);

*WATER CALCULATIONS

   PUMPAGE(T)..      WT(T) =E= SUM(C, CROPPERC("IRRLEPA",C,T)*
              WP("IRRLEPA",C,T) + CROPPERC("IRRFURROW",C,T)*
              WP("IRRFURROW",C,T));
   MOTION(T+1)..     LIFT(T+1)=E=LIFT(T)+((ICI("IRRLEPA")+ICI("IRRFURROW"))/AREAAQ)*
              ((1/SPECYLD)*((WT(T)-RECHARGE)/12));
   SAT(T+1)..        ST(T+1) =E= ST(T)-((ICI("IRRLEPA") + ICI("IRRFURROW"))/AREAAQ)*
              ((1/SPECYLD)*((WT(T)-RECHARGE)/12));
*              [The 12 in the denominator converts inches to feet]

   GROSS(T).. GPC(T) =E= (4.42*IWellYld/IAcPerWell)*(SQR[ST(T)/ISATTHK]) ;

*          Units of IWellYld/IAcPerWell is GPM/Acre
*          The factor 4.42 assumes 2000 hours of pumping per season and
*          has the units of AcIn/GPM. Thus, GPC unit is AcIn/Ac.
*          2000hrs*60min/hr / 43560 cuft/acft / 7.48 gal/cuft * 12in/ft
*          = 4.42 AcIn/GPM    {(min*acft/gal)*(in/ft)} = acin/(gal/min)

*CONSTRAINTS

   LANC(T)..         SUM(C,SUM(I,CROPPERC(I,C,T)))=E=1 ;
   CROPCON(I,C,T)..  CROPPERC(I,C,T)=G=0.666*CROPPERC(I,C,T-1);
   WAPPLDL(C,T)..    WP("DRY",C,T)=E= 0;
   WATER(T)..        SUM(C, (CROPPERC("IRRLEPA",C,T)*WP("IRRLEPA",C,T)) +
             (CROPPERC("IRRFURROW",C,T)*WP("IRRFURROW",C,T)))=L=GPC (T) ;
   DRYCORN(I,C,T)..      CROPPERC("DRY", "CORN", T) =E= 0;
   DRYPEANUTS(I,C,T)..   CROPPERC("DRY", "PEANUTS", T) =E= 0;
   IRRLEPALIVESTOCK(I,C,T).. CROPPERC("IRRLEPA", "LIVESTOCK", T) =E= 0;
   IRRFURROWLIVESTOCK(I,C,T).. CROPPERC("IRRFURROW", "LIVESTOCK", T) =E= 0;
   IRRFURROWAC(T)..  SUM(C,(CROPPERC("IRRFURROW",C, T)))=L=.1934;
```

```
  IRRLEPAAC (T)..  SUM(C,(CROPPERC("IRRLEPA",C, T))) =L=.7514;
  DRYCON (T)..      SUM(C,(CROPPERC("DRY",C,T)))=G=SUM(C,(CROPPERC("DRY", C, T-1)));
  WATERUSE(I,C,T+1).. WP(I,C,T+1)=L=WP(I,C,T);

*FINAL CROP ACREAGE IN AGGREGATE PERCENTAGE TERMS

  FINIR(I)..       FCI(I) =E= sum(C, CROPPERC(I,C,"10"));
  FINA(C)..        FCA(C) =E= sum(I, CROPPERC(I,C,"10"));

*OBJECTIVE FUNCTION

  OBJ1..           NPV1 =E= SUM(T, DELTA1(T)*NR(T));
  OBJTMAX..        NPVTMAX =E= SUM(SUBT(T), DELTA1(T)*NR(T));
*****
  NPVAGR..         NPVTOTR =E=NPVTMAX*TOTCACRES;
*****
  Tocrop(C,T)..    CROPAC(C,T) =E= SUM(I, CROPPERC(I,C,T));
  TOIRRI(I,T)..    IRRI(I,T) =E= SUM(C,CROPPERC(I,C,T));
  IRRCRO(C,T)..    IRCROP(C,T) =E= SUM(I, CROPPERC("IRRLEPA",C,T) +
               CROPPERC("IRRFURROW",C,T));

*****
  IRRLAND(T)..     IRRI("IRRLEPA",T) + IRRI("IRRFURROW",T)=L=  PIRRACRES;
  PEANUTC(C,T)..   CROPPERC("IRRLEPA","PEANUTS",T+1) =L= 0.3333*
               CROPPERC("IRRLEPA","COTTON", T+1);
  PEANUTC1(T)..    CROPPERC("IRRLEPA","PEANUTS",T) +
               CROPPERC("IRRFURROW","PEANUTS",T)=L= 2*PIPEANUT;
  MINWPLEPA("IRRLEPA",C,T)..  WP("IRRLEPA",C,T) =G= MINWATER("IRRLEPA",C);
  MINWPFURROW("IRRFURROW",C,T)..  WP("IRRFURROW",C,T) =G=
MINWATER("IRRFURROW",C);
*****

*****
  WATERVOL(T)..    TVWATER(T) =E= WT(T)*TOTCACRES/12;
*****
*                ABOVE CONVERTS FROM YEARLY AC/IN TO AC/FT)


*INITIAL VALUES (STARTING VALUES AT T=1 WHERE FX=FIXED CAN NOT CHANGE)
*CROPPERC IS PERCENT OF YR1 CROP C IN SYSTEM I TO TOTAL CROP ACREAGE

  NETR.L(I,C,T)=20;
  CROPPERC.FX(I,C,"1")= (RIACRES(C,I) / RTOTACRES);
  NR.L(T) = SUM(I, SUM(C, NETR.L(I,C,T)*CROPPERC.L(I,C,T)));
  LIFT.FX("1")=ILIFT;
  ST.FX("1")=ISATTHK;

  MODEL OGALLALA /ALL/;
     OPTION RESLIM = 100000;
     OPTION ITERLIM = 100000;
     OGALLALA.OPTFILE = 1;
*     USE "MINOS 5 OPTION FILE TO INCREASE MAJOR ITERATIONS TO 1000"
*     "MINOS 5 OPTION FILE IS NAMED MINOS5.OPT"
     SOLVE OGALLALA USING NLP MAXIMIZING NPV1;

* If do not want ascii files printed use $ontext to read as text
```

```
* and not as GAMS code.  Must insert a $offtext to read as code
* at appropriate point.
*
$ontext

* Reading as GAMS CODE again

$offtext
****** Directly writing into ExcelSpreadsheet ***********

******** Saturated Thickness Data ***********************
* Make sure writing to correct county Excel Spreadsheet file

*Vaiables to be saved written to filename.GDX file
*Only one unload per run as repeated unloads erase GDX file

execute_unload "FloydBase120.gdx" ST.L LIFT.L GPC.L NR.L WT.L WP.L YLD.L
            GR.L HARC.L PC.L TCOST.L NETR.L CROPPERC.L
            NPV1.L NPVTMAX.L  TOTCACRES

*Writing Data to named Excel (one execute statement per variable)
*rng=sheetpage and cell where each write begins
*Rdim=1 writes many rows in one column!!!

execute 'gdxxrw.exe FloydBase120.gdx var=st.L rng=GamsData!a2 rdim=1'
execute 'gdxxrw.exe FloydBase120.gdx var=lift.L rng=GamsData!c2 rdim=1'
execute 'gdxxrw.exe FloydBase120.gdx var=gpc.L rng=GamsData!e2 rdim=1'
execute 'gdxxrw.exe FloydBase120.gdx var=nr.L rng=GamsData!g2 rdim=1'
execute 'gdxxrw.exe FloydBase120.gdx var=wt.L rng=GamsData!i2 rdim=1'
execute 'gdxxrw.exe FloydBase120.gdx SQ=0 var=WP.L rng=GamsData!L2 cdim=0 rdim=3 '
execute 'gdxxrw.exe FloydBase120.gdx SQ=0 var=YLD.L rng=GamsData!P2 cdim=0 rdim=3 '
execute 'gdxxrw.exe FloydBase120.gdx SQ=0 var=GR.L rng=GamsData!T2 cdim=0 rdim=3 '
execute 'gdxxrw.exe FloydBase120.gdx SQ=0 var=PC.L rng=GamsData!AB2 cdim=0 rdim=3 '
execute 'gdxxrw.exe FloydBase120.gdx SQ=0 var=HARC.L rng=GamsData!X2 cdim=0 rdim=3 '
execute 'gdxxrw.exe FloydBase120.gdx SQ=0 var=TCOST.L rng=GamsData!AF2 cdim=0 rdim=3 '
execute 'gdxxrw.exe FloydBase120.gdx SQ=0 var=NETR.L rng=GamsData!AJ2 cdim=0 rdim=3 '
execute 'gdxxrw.exe FloydBase120.gdx SQ=0 var=CROPPERC.L rng=GamsData!AN2 cdim=0 rdim=3'
execute 'gdxxrw.exe FloydBase120.gdx SQ=0 var=NPV1.L rng=GamsData!AS2'
execute 'gdxxrw.exe FloydBase120.gdx SQ=0 var=NPVTMAX.L rng=GamsData!AU2'
execute 'gdxxrw.exe FloydBase120.gdx SQ=0 par=TOTCACRES rng=GamsData!AW2'

******** Net Revenue Data ********************************
* When have more than one dimension must carefully unload sets
* writing out three diminsional vector as column (gams convention) vector
* Sq=0 forces to print out zero values, must appear before var statement
* Merge statement prints over entire (i,c,t) indices for each variable
* To use  merge statement index values must already be in spreadsheet
* in correct sequence.  When this is case will only merge data with index
* values in common.
```

APPENDIX L

PRODUCER SURVEYS

L.1 Model Farm Survey.

Name:

1. leased acres

2. owned acres

3. crop acres

4. irrigation technology used

5. power source

6. well depth

7. gallons per minute

8. acres per well

9. operating expenses

10. debt interests rates

11. equipment costs

12. yield history

13. equity %

    a) land
    b) machinery
    c) irrigations system

L.2 Yield Distribution Survey.

Irrigated Cotton (lbs)/acre

	A	B	C	D	E	F
Low	780	670	570	460	360	260
P_{20}	1110	1070	1030	990	950	920
P_{50}	1300	1300	1300	1310	1310	1310
P_{80}	1470	1500	1530	1560	1600	1630
High	1800	1900	2010	2110	2210	2310

Dryland Cotton (lbs)/acre

	A	B	C	D	E	F
Low	100	50	0	0	0	0
P_{20}	240	210	190	160	130	100
P_{50}	370	370	370	370	370	360
P_{80}	530	560	590	620	650	670
High	920	1030	1140	1250	1350	1460

Irrigated Corn (bu)/acre

	A	B	C	D	E	F
Low	70	60	40	30	10	0
P_{20}	140	130	130	130	120	120
P_{50}	150	160	160	160	160	160
P_{80}	170	180	180	190	190	200
High	200	210	220	220	230	240

Irrigated Sorghum (lbs)/acre

	A	B	C	D	E	F
Low	1130	670	220	0	0	0
P_{20}	2620	2450	2290	2130	1970	1810
P_{50}	3420	3420	3420	3420	3410	3410
P_{80}	4180	4330	4480	4630	4790	4940
High	5450	5850	6260	6660	7070	7470

Dryland Sorghum (lbs)/acre

	A	B	C	D	E	F
Low	390	50	0	0	0	0
P_{20}	1260	1090	920	750	580	410
P_{50}	2030	2020	2000	1990	1980	1960
P_{80}	2920	3090	3250	3420	3580	3750
High	3910	4280	4640	5000	5360	5730

Irrigated Wheat (bu)/acre

	A	B	C	D	E	F
Low	70	70	60	60	50	50
P_{20}	90	90	80	80	80	80
P_{50}	100	100	100	100	100	100
P_{80}	120	120	120	120	130	130
High	120	130	130	140	140	140

Dryland Wheat (bu)/acre

	A	B	C	D	E	F
Low	10	10	0	0	0	0
P_{20}	10	10	10	10	0	0
P_{50}	20	20	20	20	20	20
P_{80}	30	30	30	30	40	40
High	40	40	40	50	50	60

APPENDIX M

EXAMPLE FINANCIAL STATEMENTS

Table M.1 Example Income Statement

Income Statement	2008
Receipts	
DCORN	-
FCORN	-
LCORN	279,327
DCOTTON	5,018
FCOTTON	223,128
LCOTTON	422,179
COTTONSEED	147,722
DSORGHUM	-
FSORGHUM	-
LSORGHUM	27,673
DWHEAT	8,765
FWHEAT	-
LWHEAT	212,109
DLIVESTOCK	-
Farm Program Payments	94,680
Insurance total	11,521
Total	1,432,122
Expenses (VC + cash lease)	
DCORN	-
FCORN	-
LCORN	213,715
DCOTTON	10,166
FCOTTON	210,755
LCOTTON	425,602
DSORGHUM	-
FSORGHUM	-
LSORGHUM	50,936
DWHEAT	3,184
FWHEAT	-
LWHEAT	116,645
DLIVESTOCK	-
HARVEST	216,700
	-
Fixed Costs	-
Operating Interest Cost	37,618
Cash Flow Deficit Interest Cst	-
Interest for original Loan-Land	31,625.0
Interest for original Loan-Equip	17,875
Total Expenses	1,316,946
Net Cash Income	115,176

Table M.2. Example Cash Flow Statement

Cash Flow Statement	
Beginning Cash	20,000
Net Cash Income	115,176
Interest Earned on Cash Res	820
Total Inflows	135,996
Principal Payment Loan Land	6,518
Principal Payment Loan Equip	13,957
Repay Deficit Loans	-
Federal Income Taxes	-
Dividends or Family Living	71,623
Total Outflows	92,099
Ending cash Reserves	43,898

APPENDIX N

50/50 DRAWDOWN VALUES

Table N.1 Drawdown values for 50/50 policy.

Year	Saturated Thickness ft											% Allowed
	300	250	200	175	150	135	120	100	80	60	40	
1	296.25	246.875	197.5	172.8125	148.125	133.3125	118.5	98.75	79	59.25	39.5	1.25
2	292.5	243.75	195	170.625	146.25	131.625	117	97.5	78	58.5	39	2.5
3	288.75	240.625	192.5	168.4375	144.375	129.9375	115.5	96.25	77	57.75	38.5	3.75
4	285	237.5	190	166.25	142.5	128.25	114	95	76	57	38	5
5	**281.25**	**234.375**	**187.5**	**164.0625**	**140.625**	**126.5625**	**112.5**	**93.75**	**75**	**56.25**	**37.5**	**6.25**
6	277.7344	231.4453	185.1563	162.0117	138.8672	124.9805	111.0938	92.57813	74.0625	55.54688	37.03125	7.421875
7	274.2188	228.5156	182.8125	159.9609	137.1094	123.3984	109.6875	91.40625	73.125	54.84375	36.5625	8.59375
8	270.7031	225.5859	180.4688	157.9102	135.3516	121.8164	108.2813	90.23438	72.1875	54.14063	36.09375	9.765625
9	267.1875	222.6563	178.125	155.8594	133.5938	120.2344	106.875	89.0625	71.25	53.4375	35.625	10.9375
10	**263.6719**	**219.7266**	**175.7813**	**153.8086**	**131.8359**	**118.6523**	**105.4688**	**87.89063**	**70.3125**	**52.73438**	**35.15625**	**12.10938**
11	260.376	216.98	173.584	151.886	130.188	117.1692	104.1504	86.79199	69.43359	52.0752	34.7168	13.20801
12	257.0801	214.2334	171.3867	149.9634	128.54	115.686	102.832	85.69336	68.55469	51.41602	34.27734	14.30664
13	253.7842	211.4868	169.1895	148.0408	126.8921	114.2029	101.5137	84.59473	67.67578	50.75684	33.83789	15.40527
14	250.4883	208.7402	166.9922	146.1182	125.2441	112.7197	100.1953	83.49609	66.79688	50.09766	33.39844	16.50391
15	**247.1924**	**205.9937**	**164.7949**	**144.1956**	**123.5962**	**111.2366**	**98.87695**	**82.39746**	**65.91797**	**49.43848**	**32.95898**	**17.60254**
16	244.1025	203.4187	162.735	142.3931	122.0512	109.8461	97.64099	81.36749	65.09399	48.8205	32.547	18.63251
17	241.0126	200.8438	160.675	140.5907	120.5063	108.4557	96.40503	80.33752	64.27002	48.20251	32.13501	19.66248
18	237.9227	198.2689	158.6151	138.7882	118.9613	107.0652	95.16907	79.30756	63.44604	47.58453	31.72302	20.69244
19	234.8328	195.694	156.5552	136.9858	117.4164	105.6747	93.93311	78.27759	62.62207	46.96655	31.31104	21.72241
20	**231.7429**	**193.119**	**154.4952**	**135.1833**	**115.8714**	**104.2843**	**92.69714**	**77.24762**	**61.7981**	**46.34857**	**30.89905**	**22.75238**
21	228.8461	190.7051	152.564	133.4935	114.423	102.9807	91.53843	76.28202	61.02562	45.76921	30.51281	23.71798
22	225.9493	188.2911	150.6329	131.8038	112.9746	101.6772	90.37971	75.31643	60.25314	45.18986	30.12657	24.68357
23	223.0525	185.8771	148.7017	130.114	111.5263	100.3736	89.221	74.35083	59.48067	44.6105	29.74033	25.64917
24	220.1557	183.4631	146.7705	128.4242	110.0779	99.07007	88.06229	73.38524	58.70819	44.03114	29.3541	26.61476
25	**217.2589**	**181.0491**	**144.8393**	**126.7344**	**108.6295**	**97.76652**	**86.90357**	**72.41964**	**57.93571**	**43.45179**	**28.96786**	**27.58036**
26	214.5432	178.786	143.0288	125.1502	107.2716	96.54444	85.81728	71.5144	57.21152	42.90864	28.60576	28.4856
27	211.8275	176.5229	141.2183	123.566	105.9137	95.32236	84.73098	70.60915	56.48732	42.36549	28.24366	29.39085
28	209.1117	174.2598	139.4078	121.9818	104.5559	94.10027	83.64469	69.70391	55.76313	41.82234	27.88156	30.29609
29	206.396	171.9967	137.5973	120.3977	103.198	92.87819	82.55839	68.79866	55.03893	41.2792	27.51946	31.20134
30	**203.6802**	**169.7335**	**135.7868**	**118.8135**	**101.8401**	**91.65611**	**81.4721**	**67.89342**	**54.31473**	**40.73605**	**27.15737**	**32.10658**
31	201.1342	167.6119	134.0895	117.3283	100.5671	90.51041	80.4537	67.04475	53.6358	40.22685	26.8179	32.95525
32	198.5882	165.4902	132.3922	115.8431	99.29412	89.36471	79.4353	66.19608	52.95686	39.71765	26.47843	33.80392
33	196.0422	163.3685	130.6948	114.358	98.02112	88.21901	78.4169	65.34741	52.27793	39.20845	26.13897	34.65259
34	193.4962	161.2469	128.9975	112.8728	96.74812	87.07331	77.39849	64.49874	51.599	38.69925	25.7995	35.50126
35	**190.9502**	**159.1252**	**127.3002**	**111.3876**	**95.47512**	**85.9276**	**76.38009**	**63.65008**	**50.92006**	**38.19005**	**25.46003**	**36.34992**
36	188.5634	157.1361	125.7089	109.9953	94.28168	84.85351	75.42534	62.85445	50.28356	37.71267	25.14178	37.14555
37	186.1765	155.1471	124.1177	108.6029	93.08824	83.77941	74.47059	62.05883	49.64706	37.2353	24.82353	37.94117
38	183.7896	153.158	122.5264	107.2106	91.8948	82.70532	73.51584	61.2632	49.01056	36.75792	24.50528	38.7368
39	181.4027	151.1689	120.9351	105.8183	90.70136	81.63122	72.56109	60.46757	48.37406	36.28054	24.18703	39.53243
40	**179.0158**	**149.1799**	**119.3439**	**104.4259**	**89.50792**	**80.55713**	**71.60634**	**59.67195**	**47.73756**	**35.80317**	**23.86878**	**40.32805**
41	176.7781	147.3151	117.8521	103.1206	88.38907	79.55016	70.71126	58.92605	47.14084	35.35563	23.57042	41.07395
42	174.5404	145.4504	116.3603	101.8153	87.27022	78.5432	69.81618	58.18015	46.54412	34.90809	23.27206	41.81985
43	172.3027	143.5856	114.8685	100.5099	86.15137	77.53624	68.9211	57.43425	45.9474	34.46055	22.9737	42.56575
44	170.0651	141.7209	113.3767	99.20461	85.03253	76.52927	68.02602	56.68835	45.35068	34.01301	22.67534	43.31165
45	**167.8274**	**139.8561**	**111.8849**	**97.89929**	**83.91368**	**75.52231**	**67.13094**	**55.94245**	**44.75396**	**33.56547**	**22.37698**	**44.05755**
46	165.7295	138.1079	110.4863	96.67555	82.86476	74.57828	66.2918	55.24317	44.19454	33.1459	22.09727	44.75683
47	163.6317	136.3597	109.0878	95.45181	81.81583	73.63425	65.45267	54.54389	43.63511	32.72633	21.81756	45.45611
48	161.5338	134.6115	107.6892	94.22807	80.76691	72.69022	64.61353	53.84461	43.07569	32.30677	21.53784	46.15539
49	159.436	132.8633	106.2907	93.00432	79.71799	71.74619	63.77439	53.14533	42.51626	31.8872	21.25813	46.85467
50	**157.3381**	**131.1151**	**104.8921**	**91.78058**	**78.66907**	**70.80216**	**62.93526**	**52.44605**	**41.95684**	**31.46763**	**20.97842**	**47.55395**

GPM=2.264*ST+.0078336*ST^2-.000282ST^3
ST=Saturated Thickness
Source: Lacewell 1973
Table N.2 Gross Pumping Capacity

Saturated Thickness	GPM
250	614.98
245	610.18
240	604.74
235	598.67
230	592.01
225	584.76
220	576.95
215	568.61
210	559.74
205	550.38
200	540.54
195	530.25
190	519.53
185	508.39
180	496.87
175	484.97
170	472.72
165	460.15
160	447.27
155	434.11
150	420.68
145	407.01
140	393.12
135	379.02
130	364.75
125	350.32
120	335.75
115	321.07
110	306.29
105	291.44
100	276.54
95	261.60
90	246.65
85	231.72
80	216.82
75	201.97
70	187.19
65	172.51
60	157.95
55	143.52
50	129.26
45	115.17
40	101.29
35	87.63
30	74.21