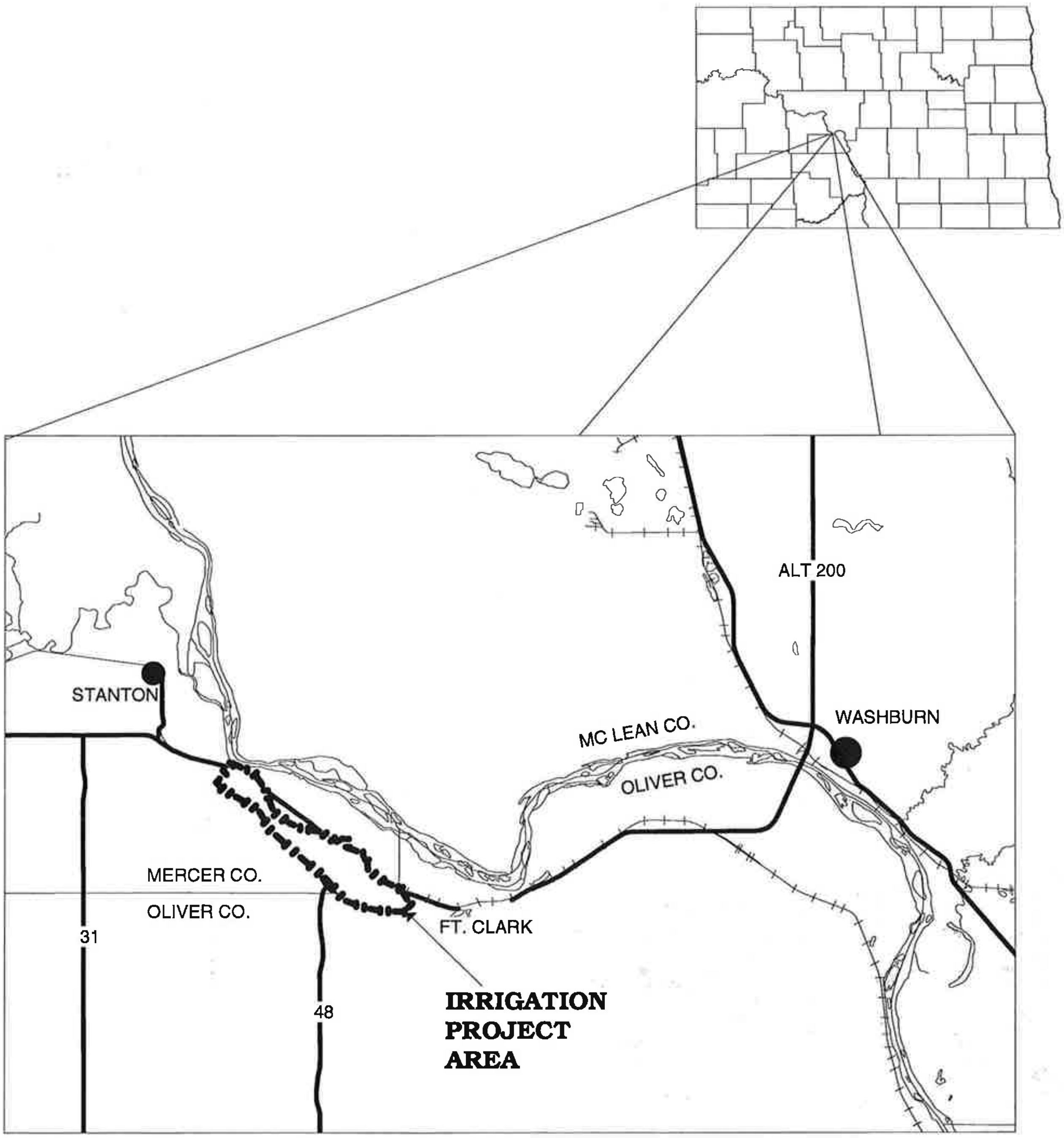
INVESTIGATION REPORT

FORT CLARK IRRIGATION

SWC PROJECT NO. 287



NORTH DAKOTA
STATE WATER COMMISSION
NOVEMBER 1998

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I. Introduction

Agriculture continues to be the backbone for the economy in the state of North Dakota. In 1996 farm products were valued at close to $4 billion, and ninety percent of the land use was associated with agriculture. For over 100 years, farmers in this area have fought the harsh conditions and managed to provide food and a steady income for their families. Over the past several decades, irrigation has been developed in North Dakota to assist the farmers in growing these valuable crops. In 1996, 238,000 acres were permitted for irrigation. There are over 6 million acres of irrigable lands in this state, and that is why irrigation projects are important to the people of North Dakota. One of these important projects was the Fort Clark Irrigation Project. It was authorized by the Flood Control Acts of 1944-46 which is under the Pick-Sloan Missouri River Basin Program. Its development was intended to provide adequate water resources to farmers in a designated unit for the purpose of growing crops. Construction of the irrigation facilities began on April 25, 1953 and was completed on August 1, 1953. Operation and maintenance is performed by the Bureau of Reclamation with funds advanced from the Fort Clark Irrigation District under a contract between the United States and the district, executed on April 13, 1954.

Following the drought of the late 1980's, the Fort Clark Irrigation District realized how beneficial the project was to local farmers. The district drafted a letter to Senator Burdick in September of 1988 informing him that the facilities were in need of some repairs and renovations, and due to the high costs, funding would be necessary to achieve this. The State of North Dakota agreed to help and the first step was to do a preliminary engineering study, which was to be done by the ND State Water Commission. A copy of this agreement is included in the Appendix. After being delayed by priority flooding issues for a few years, the project is being reinvestigated to determine a list of feasible alternatives. The alternatives are discussed in this report with a cost estimate for each one. The alternatives range from the very basic and low cost up to the most elaborate and expensive. The alternatives are given to the irrigators in Fort Clark District, in order for them to choose which one best suits their needs and financial capabilities. After choosing the most feasible alternatives, they can submit their choices to a private engineering firm for formulation and design. After the final design is completed and construction is finished, the Fort Clark District may once again have a thriving irrigation system. Combined with local processing and good marketing, a well managed irrigation system can open up new opportunities for the farmers and help to expand and diversify North Dakota's agriculture economy.

II. Study Area Description

The Fort Clark unit extends along the west bank of the Missouri River for approximately 6 miles from the town of Fort Clark, ND, to within 2 miles of Stanton (See appendix - Map1). The project is located in Mercer and Oliver Counties, with the majority in Mercer County. The topography of the land has a gentle slope, but slightly rolling in some places. Drainage of the bench area is aided by several deep and narrow ravines which cut across the unit. The soil near the surface varies from a loamy sand to clay loam, and a fine sandy loam to silt loam. The subsoil also varies from sandy clays to clay loams. Because the soils in the region have good internal drainage and a good infiltration rate, they are suitable for irrigation. The pH ranges from 7.8 - 8.2 in the surface and 7.8 - 9.0 in the subsoil. The area has a semi-arid continental climate. The growing season is approximately 115 days, and total annual precipitation is 15 inches with 88% usually falling between April and September. Moisture deficiency determines more than any other factor in the production of crops. The primary crops grown in the area are spring wheat, corn, and alfalfa, with some interests in potatoes and beans. The potential yield for some of these crops is 25-30 bu per acre, and greater than 2 tons per acre of hay, but an adequate water supply must be available, especially in the drier, warmer months.

III. Irrigation System Description

Originally, this system was designed to irrigate up to 2,000 acres of bench and river bottom farmland (See appendix - Map2). Today, irrigators in the area want the system to serve approximately 1,500 acres. This includes 1400 acres by canal B and 100 acres by canal A. The farmers in this area chose to use a surface flood irrigation system when the project was first initiated. This means the water is applied over the surface by gravity, rather than being pumped through sprinklers. The water is distributed throughout the field with the use of furrows. The fields are graded so the water flows down the furrows and percolates into the soil, providing the plants with the needed moisture. It is the most widely practiced irrigation method in the world, but constitutes less than one fourth of acres irrigated in North Dakota. The majority of the acres are irrigated by sprinklers. Flood irrigation requires a lot of labor and maintenance, and it has a lower application efficiency than sprinklers, due to runoff losses and deep percolation. There are two components in a typical surface irrigation system. The first one is called the delivery system, and the second is called the application system. Because of the complexity of designing several alternatives for the application system, this report will only consider the delivery system. The individual irrigators can determine themselves what application technique to use in their own operation.

The delivery system includes everything from the water source to the movable gates or turnouts along the fields. Turnouts are used where the water discharges from the canal into a lateral or into a farmer's field. They are located on the side of the canal, and can be opened or closed to regulate the discharge flow rate. The delivery system can be further broken down into four basic segments. These are the supply works, transmission line, canal system, and relift stations. The report will take a look at each of these components separately and determine what repairs needs to be done and from that generate a list of alternatives.

A. Supply Works

The first component is the supply works which is the pumping plant located on the south bank of the Missouri River in the SE 1/4 SE 1/4 Section 17 R84W T144N. There are three items of concern with respect to the supply works. The first one is the available river access, including the sand bar located in front of the pumping plant. This sandbar is a result of the bend in the river and continues to be a problem during low flows. Second is the pumps located at the inlet. Originally there were three vertical turbine pumps installed at the inlet, two with a capacity of 15 cfs each to supply canal B , and one with a capacity of 10 cfs to supply canal A. The two used for canal B had a total dynamic head or lift of 95 ft each, and the one used for canal A had a lift of 45 ft. Today, there is only one pump supplying canal B. Canal A is no longer being supplied from this inlet. When the power plants were built in the area, canal A was discontinued. Recently, Basin Electric began supplying the lower end of canal A with water from their facilities. Canal A is not included in the scope of the study and thus will not be discussed for the remainder of the report.

The third item is the electrical components of the pumping plant, including the transformers, starters, switchgear, and power supply. The pumps use three-phase WAPA (Western Area Power Administration) power at 2300 volts to drive 200HP motors. The irrigators must pay for the use of transmission lines in the area. Since the original construction of the Fort

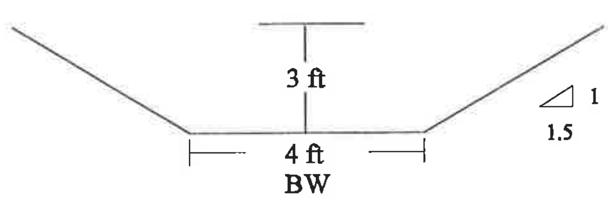
Clark Irrigation System, large scale development of thermoelectric powerplants has impacted the area. Two plants have been constructed near the pumping plant. They are United Power Associates and Basin Electric. They are both coal powered electricity plants, and are located downstream of the irrigation system inlet. UPA owns approximately 400 acres in the district and rents approximately 80 irrigated acres to local farmers. While Basin owns approximately 2400 acres in the area and rents approximately 750 irrigated acres to the local farmers. Many people in the area have decided to discontinue their farming practices and work for the power plants instead. Because of this, improving the conditions of this irrigation system is important so agriculture is not entirely discontinued in the area.

B. Transmission Line

The transmission line consists of two 24 inch welded steel pipes extending southward from the two pumps supplying canal B. These two pipes are joined in a concrete manifold into one 36 inch concrete pipe. This 2000 ft pipe transports the water from an elevation of 1695 ft up to 1745 ft, at the beginning of canal B (See Appendix - Map 2). Here it empties into an open concrete basin that is 80" deep, 84" long, and 48" wide, giving it a volume of 1400 gallons. From this basin the water flows downstream in the open channel, which is the third component, the canal system.

C. Canal System

Typical Canal B Cross-Section



The existing canal system is made up of canal B and its laterals (See appendix - Map 2). Canal B was designed to irrigate up to 1400 acres, and is approximately 12.7 miles long with its laterals. It has a range in bottom width from 2-6 ft, and 1.5:1 side slopes, and has a designed diversion capacity of 30 cfs. From this canal, irrigators receive water for their fields either directly from the main channel, or from a lateral that stems off of the main channel. The water is discharged through a turnout. At each turnout the water is managed by movable gates that are regulated by the farmers and the ditchrider. The ditchrider is an employee of the District, and has the responsibility to manage water deliveries in a certain zone or along the canal. The ditchrider often collects water orders, opens and closes turnouts, and maintains water levels and flows in the canal and its laterals. From these turnouts the water is routed by furrows to irrigate the graded fields. Some fields may contain more than one turnout to accomplish this.

D. Relift Stations

The final component of the delivery system are the two relift stations used to pump water to two different locations higher in elevation than canal B (See Appendix - Map 2). One is located toward the beginning of canal B and is used to supply lateral # 2. Lateral #2 is approximately 7,000 ft long, and is supplied by a pump that has a capacity of five cfs. This lateral has not been in service for approximately four years, and the land around the upper end of this lateral is now used to graze cattle. The second relift station is used to supply the last 4,000 ft of canal B. Due to the failure of the existing pump, a used pump with a capacity of 2.7 cfs, was purchased from Agri Industries and installed a few years ago. Each of these components need to be addressed in order to assist in determining proper alternatives for the project. An investigation was therefore needed to determine what condition each of these components were in at present time. The following is the findings of the investigations for each component.

IV. Investigations

This system is adequately designed and seems to work well with the local irrigators, but time has taken its toll, and repairs and renovations are needed to upgrade the system to make it more efficient. In the summer of 1991, the Mercer County WRD wrote to the State Water Commission requesting assistance in completing a feasibility study for these repairs and upgrades. An agreement between the State Water Commission and the Mercer County WRD was signed on September 18, 1991, stating that the State Water Commission would conduct an investigation and submit a report to the Fort Clark Irrigation District. This report would contain alternative designs and their cost estimates for the renovations. A deposit of $3,500 was received on October 15, 1991, to partially defray the cost of the investigation. During this time, several visits to Fort Clark were taken to gather valuable information about the system. A field survey was also done in May of 1992, to obtain spatial data on the project. This data was entered into a computer modeling program to determine flow characteristics of the open channel, and to determine what areas of the canal need improvements in order to obtain an efficient system.

A recent tour of the Fort Clark Irrigation District was taken on February 13, 1998. This tour was important in obtaining current information on the condition of the system and its overall appearance. The items investigated are given below with a description for each one.

A. Supply Works

The supply works can be broken down into three separate topics. One is the river access, another are the pumps, and the last part are the electrical components. Beginning with the river access, we observed a large sandbar located directly in front of the inlet. Due to a shift in the thalweg, or deepest part of the river, silting has occurred on the bend, creating this sandbar. The

sandbar extends approximately 100 ft into the river and continues upstream for about one mile. The sandbar could prove to be detrimental to the system for several reasons. One reason is, as water is pulled through the pumps, it carries with it large amounts of sedimentation. These sediments could damage the impeller or other parts of the pump. Also, the sediments are deposited in the channel, creating flow problems for the system. Finally, during low flows, the water level may be too low to flow past the sandbar well enough for the pump to receive adequate water. This sandbar is an issue that should be addressed if the system is going to operate with any efficiency.

Another issue investigated at the inlet was the pumps. There are two pumps located at the inlet. One is on the pipe once used to serve canal A, and the other is on one of the pipes that serves canal B. The pump that serves canal B was overhauled six years ago at a cost of $7,300. It is the only pump that is operating at the inlet as of today. In October of 1991, the NDSU Extension Service calculated the efficiency of this pump. They calculated the efficiency to be approximately 80%, which is 90% of the standard pumping plant efficiency of 88%. A worksheet showing these calculations is available in the appendix, along with the pumps curves. Along with the efficiency report, the NDSU Extension Service also enclosed several publications to assist on scheduling and annual maintenance on the pumps.

Repairs are also needed on the electrical components of the pumping plant. Included in this are the transformers, switchgear, power supply, and the motor starters. They appear to be showing signs of neglect and exposure and should be inspected by a master electrician in order to determine the proper diagnosis.

B. Transmission Line

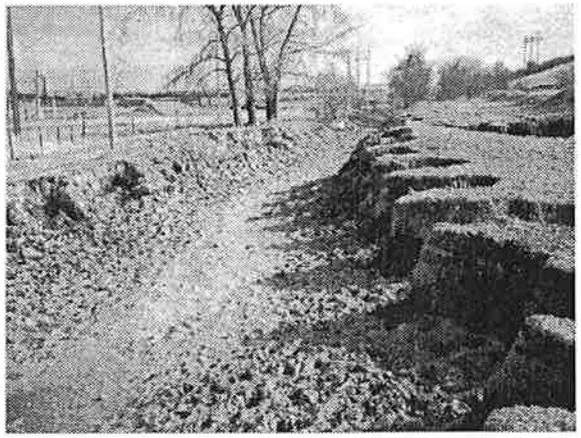
The next part of the investigation deals with the transmission pipe leading from the pumping plant to the beginning of canal B. We determined that there must be a tremendous amount of water leaking from the inlet pipes, because of all the ice that was formed around the pumps. This is most likely resulting from water flowing downhill from cracked or disjointed pipe leading up the hill. Also, a low spot in a field located between the inlet and the beginning of canal B accumulates water every summer. Because it is a spot lower in elevation than most of the surrounding areas, any water that escapes from the pipe will gradually flow in that direction. This means the pipe may contain cracks, and a replacement or repairs may need to be done to improve the conditions. Also, this pipe is jointed concrete, and it is possible segments have separated, which could account for some of the losses. Once the overall condition of the pipe is determined, several options can be looked at, and these are listed in the Alternatives Section of the report. The alternative chosen depends on the overall damage of the pipe, and the amount of available funds.

C. Canal System

The next part of the system that was investigated was the canal system. The canal system is functioning today, but there are improvements which could be made. If a few things are improved and repaired, the system could operate with greater efficiency and achieve better results.

First of all we found that a large number of deposits have settled along the bottom of the channel, with a majority found at the beginning of canal B. The reason for this is the sand bar located in front of the inlet station. The deposits are transported from the inlet through the transmission pipe and then deposited along canal B as the water slows down enough for the sediments to settle out. Also, a large amount of these deposits were found in front of various structures located in the canal. These structures are used to slow the flow of the water and then back the water up to maintain a water surface elevation that is high enough to flow through a particular turnout. These structures do what they are designed to do, but they tend to create a large amount of deposits, due to the low velocities. In time these deposits can drastically affect the flows in the channel. These deposits may have to be removed in order to return the system back to its original design and shape. The deposits that are removed can be used in restoring parts of the channel that have been worn away or damaged.

Some of these areas are the ones that have been destroyed by cattle. The cattle are allowed to walk up and down certain stretches of the channel, and because of this, the channel's banks have been severely damaged. These stretches of canal need immediate improvements if the system is



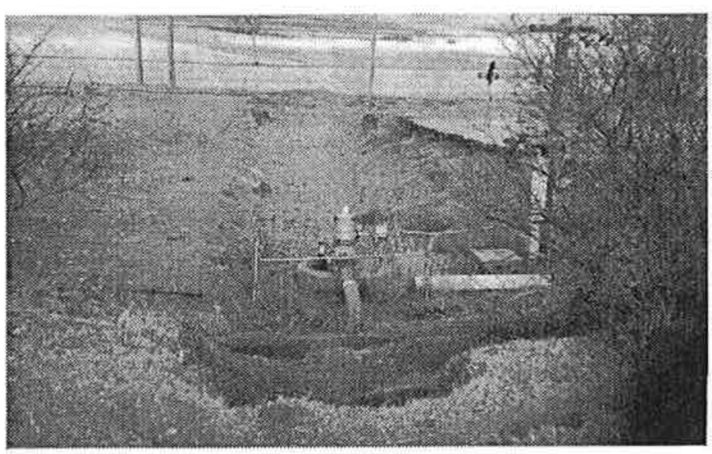
to operate properly. The hydraulic properties of these stretches are extremely inefficient. As the water flows into one of these areas the energy is dissipated, and the velocity is greatly reduced. This makes it extremely difficult to route the water to the first relift station. Measurements were taken on the area, and the volume of soil needed to restore the channel was determined. These calculations can also be viewed in the appendix. As mentioned before, the soil removed from the channel in some areas could be used to restore the channels in others.

Another issue involving the canal system is seepage losses. Several stretches along the channel are losing significant water due to seepage through the soil. The actual amount of seepage losses depends on the volume of water flowing through the channel and the hydraulic conductivity of the soil. Physical factors affecting the hydraulic conductivity are the soil particle size, distribution, and shape, and the porosity of the soil. Reducing seepage losses are important because it improves the overall efficiency of the irrigation system, and allows more water to be delivered with less effort. Only the areas which show large amounts of seepage need immediate attention, the other areas can be dealt with at a later time if more funds are made available.

Besides a few of the mentioned troubled areas, the canals are capable of handling the necessary volume of water needed for the irrigation system. Survey data that was gathered a few years ago, was entered into a computer modeling program called HEC-RAS. This program allowed us to view the system, and determine the flows that the canal was capable of handling. There were a few areas along canal B that showed signs of deterioration. If the system was upgraded to approximately 25 cfs, some of these areas might have flooding concerns. These areas can be built up in order to contain the necessary flows. The information pertaining to the improvement of these areas and their locations can be viewed in the appendix.

D. Relift Stations

The final part of the system that was investigated are the two relift stations. The first one is located on the upper third and serves lateral #2, and the other one is located on the lower third and is used to service the last part of canal B. The first relift station has a capacity of 5 cfs, and has been out of service for more than four years. The pump located at the station was making a loud noise, and will need some repairs if future use is desired. Cattle have destroyed the approach works associated with the relift, and also the fencing around the pump.



As mentioned before, restoration is needed to the surrounding banks and inlet, if the pump is going to adequately receive any water. Lateral #2 is approximately 7,500 ft long and can serve approximately 100 acres. However, this lateral has not been used since the pump was turned off, and has become clogged with vegetation. Once the pump is repaired and water flow is returned to the lateral, this vegetation will disappear. The irrigators must decide if supplying 100 acres with water is worth the cost of restoration and repair of this relift station. The second relift station services the last 4,000 ft of canal B. A used pump was purchased from Agri Industries with a capacity of 2.7 cfs. This serves approximately 150 acres. Piping extending from the pump to the drop structure is in need of replacement. Repairs are also needed on the inlet channel for this relift station including the side walls, which need reinforcing to prevent from collapsing.

From these investigations, we can determine alternatives to restore the Fort Clark Irrigation System, and increase its overall efficiency. One can then determine from this list of alternatives which one suits their needs best. Keep in mind that some alternatives are more expensive than others, and before one can be chosen, it is important to determine who is interested and how many acres the system will serve. Then the district should determine a maximum cost per acre to spend on the project. From this, a couple of alternatives can be chosen, and then a preferred one based on overall support, and available funds. The alternatives are broken down into four separate selections. The first choice will be the no action alternative. The remaining three choices primarily depend on one major decision, and that is whether or not to continue with the open channel, replace it with a pipeline system, or to apply a hybrid of the two. Tables in the appendix list all of the alternatives and their approximate costs, including materials, engineering, and labor.

V. Alternatives

As with any decision made in the interests of the Fort Clark Irrigation District, the ones made following this report must reflect the views of the entire District. The purpose of this report is to give a list of alternatives for the irrigators to choose from. They are entitled to apply an alternative to any component of the system that they feel is necessary. This is dependent upon what funds are available and overall support.

A. No Action -

The existing condition of the system would remain the same and no repairs or changes would take place. This alternative can be used for the entire project, or it can be used on certain components. The District may feel that one component deserves attention and others do not. As an example, if the district decided to continue with the open channel delivery system, the no action alternative for the pumping plant would be to leave it as it is, and continue to use one pump to supply canal B. Due to the high water demand in July and August, adequate water has not been supplied to the entire district when needed. Because of this, continuing to supply the district with one pump is not recommended.

B. Open Channel -

The open channel alternative is one that involves keeping the existing canals. This alternative is further broken down into two separate alternatives. One is keeping the existing design and making various improvements and repairs to the system, while trying to return the system back to its original configuration. The other one entails modernizing the design to make it more efficient. This includes making changes to the pumping plant, transmission line, canals, and the relift stations. One must keep in mind, that not one particular alternative has to be chosen. Rather, parts of each alternative can be chosen to accommodate what changes the District wants to see done, and what funds are available. They are grouped this way to ease in the decision making process.

1. Existing Design

As noted above alternative B-1 is keeping the open channel and its existing design while making minor improvements to return the system back to its original configuration.

a. Supply Works

The first part that the alternative will address is the supply works including the river access, pumps, and the electrical components. When dealing with the river access the primary issue is the sand bar located in front of the inlet. There are a couple of practical options to alleviate this. The first option is one that has been done in the past, to partially remove the sandbar with the use of a dredge, or a long boom excavator. The results of this procedure have been good, and tend to last for approximately 5-10 years, depending on the amount of sand removed and characteristics of the river. The removal of this sandbar will benefit the system by providing adequate water supply during low flows, decreasing the amount of silting occurring in the channel, and preventing further damage to the pumps by the transportation of solids. Another option involving the removal of the sandbar is to construct a permanent structure downstream of the sandbar, to provide access for an excavator. This structure may also create some eddies in the inlet and help to scour away the sandbar, which is why positioning it downstream of the sandbar would be important. The overall cost of this procedure depends on the method chosen and total amount of the sandbar removed. A cost estimate is available in the appendix.

The next component to discuss in the B-1 alternative are the pumps located at the inlet. As noted above there is only one pump being operated at the inlet today. This is not supplying enough water during the peak demands months for the entire district. One option would be to repair the other existing pump and use both of them to supply the canal. This would provide more water for use in the peak demand months. Because the two pumps are identical, the flow would be increased to approximately 20-25 cfs. If the channel is repaired and improvements are made, canal B could handle the extra flow. Repairs were made to the pump being used six years ago, at a cost of $7,300. This is maybe the cost to repair the other pump today, however to get an accurate estimate, a pump specialist would have to visit the site.

However, if the district decides to keep the existing pumps and repair them, repairs would also need to be made to the existing electrical components located at the pumping plant. The condition of the electrical components may be hazardous and are in need of repair for safe operation. Some considerations for updating the existing equipment would be:

1. Weatherproof gear and 208/120v panel for lighting and motor control.
2. Buss bars between the existing substation and new gear would have to be changed.
3. Upgrade conduit and wire connections to motor heaters.
4. Caisson level floats and related control wiring.
5. Thorough cleaning of switchgear with special attention to the 200 HP starters to prevent flashing and possible personal injury.
6. High voltage warning signs on all doors of switchgear and locks on the incoming gates to deny unauthorized access.

Due to the complexity of this issue, the Water Commission recommends the hiring of a certified electrician to assist in determining what other repairs may be needed at the pumping plant. Keep in mind that these repairs should be made before the existing system is put into operation.

The pumping costs associated with this alternative have been determined and can be viewed in the appendix. Costs were determined for the alternatives pertaining to the open channel design and the pipeline design. The costs were determined assuming that two pumps would be operating at the inlet, either using the repaired existing pumps or newly purchased pumps. The costs would be the same for both alternatives using an open channel.

b. Transmission Line

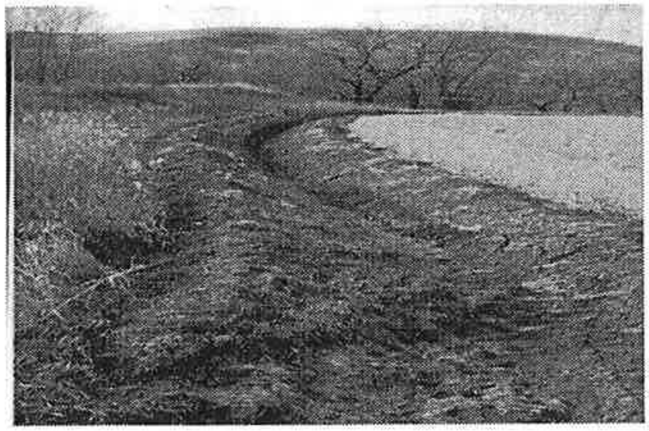
It may contain large cracks or some joints may have become separated, causing significant water losses. If the pipe has separated in one or a few places, an excavation could be made and the joints reconnected. The cost for something like this depends on the number of excavations needed, location, severity, and whether or not any new pieces are needed to assist in reconnecting. If cracks are located throughout the pipe, there are a couple of options to alleviate this. If the number of cracks is low, one option may be to excavate, then patch the cracks with cement. Another option would be to replace certain joints that contain a large number of cracks. Due to the fact that the pipe is underground, determining the exact location of the cracks may be a problem.

A more expensive alternative would be to line the entire pipe with another plastic pipe. If the pipe contains a high number of large cracks over the entire length, a plastic pipe may be inserted on one end and pushed through. The diameter of this pipe could vary, but would need to be between 30-34". This range is large enough to accommodate possible larger flows, but small enough to slide into the existing 36" concrete pipe. If the flow is increased at the inlet to approximately 25 cfs, this would keep the water velocities in the pipe around 5 ft/sec. The remaining area surrounding the plastic pipe would be filled in with a grouting solution. Before this can be done, a thorough pipe cleaning will need to be done to insure proper insertion. This plastic pipe will then protect the pipe and prevent any further seepage of water. Due to the complex installation procedures, a qualified team and equipment would have to be used. A cost estimate is available in the appendix for the alternatives concerning the transmission line.

c. Canal System

After several years of neglect canal B has become silted in and damaged by cattle. In order for the system to operate at optimum efficiency the canals should be restored to their original size and shape. This is even more important if an increased flow is introduced to the system by the addition of another pump at the inlet. This alternative would entail cleaning out the open channel in order to improve the flow characteristics. Over the years deposits have accumulated along the bottom of the canal, decreasing the overall size. These deposits may be a result of the sandbar located in front of the inlet. The upper third of the irrigation district needs the most attention, because most of the deposits drop out through this stretch. Also, a large number of deposits have accumulated behind structures used to alter the flow of the water, and before entering a culvert.

The actual cleaning could be done with the use of a channel dredge or some other form of digging machinery. This process could be done by the irrigators or be contracted to a local company. By doing it themselves the irrigators could save a considerable amount of money. The



soil that is removed from these areas could be used to fill in others that have been destroyed by cattle or erosion. By doing this the overall efficiency of the system would be increased. Once these areas are repaired, a fence could be built around the areas that are frequented by cattle, to assist in preserving the channel.

Another issue involving the canal system is the areas determined in HEC-RAS that need improvements in order to contain the possible maximum flow of 25-30 cfs. Some areas of the canal have banks that would be below the water surface elevation, possibly creating a flooding situation. A dike could be added to assist in containing these flows. The dike could be of triangular shape with 1:1 side slopes, and they could be added to the existing banks. These dikes are only necessary if the system is to be ran at full capacity of 25-30 cfs. The locations and amount of soil needed for these various improvements can be viewed in the appendix. There is a cost estimate available in the appendix for the various procedures associated with the process of cleaning and restoring the channels. The areas located in and around the two lift stations definitely need immediate attention if the system is going to operate efficiently.

d. Relift Stations

The final part of the canal system this alternative will address are the relift stations.

There are two located in the system, with relift #2 in operation and relift #1 being abandoned for the last five years. Relift #2 serves about 100 acres in the end of canal B near the town of Ft. Clark. A new pump was purchased from Agri Industries to service this station, with a capacity of 2.7 cfs. Relift #1 was abandoned for a combination of reasons. One reason was the land associated with this relift was no longer in need of irrigation due to crop selection, and another was that the pump was starting to make loud noises and disturbing neighbors. Before any renovations are to be made to either relift station, the District must decide if this would be beneficial. These relift stations only serve approximately 100 acres each, and it might cost thousands of dollars to repair them.

The first item that must be addressed when discussing the relift stations are the channels servicing the pump stations. The areas have been destroyed by cattle and erosion and need to be built up in order to adequately route water to the pumping station. The soil needed can be used from the soil removed from the cleaning of other parts of canal B. Most concern is for a 300 yard stretch of canal B upstream and downstream of Relift #1. This stretch of channel has been destroyed by cattle, and the flow characteristics are extremely inefficient. In order for the system to operate correctly, this stretch of canal should be built up to its original size and shape. After this stretch is repaired a fence should be constructed to prevent cattle from entering canal B any causing damage to the channel. If the water users in the District want to see water supplied to cattle by the irrigation canals, a separate pump and stock tank could be purchased and placed outside of the fenced area.

The channel serving relift #2 does not have nearly the problems of relift #1, but it does need some work. Here the major concern is slumping and erosion. Soil continues to erode and to accumulate at the entrance of the pumping station. The soil partially blocks this entrance and stops water from entering the pump. In the past, this soil was removed by the use of a backhoe and placed to the side of the channel. Rather than continually removing the soil from the entrance, the sides should be reinforced and angled correctly to prevent further erosion. The side slopes should be at a 2:1 ratio for loamy clay soil, and the depths of these inlet channels should not exceed 5 feet. Some other options that can be considered are planting grasses, geo-synthetic materials, and rip rap or rock material. These will offer support and help to reinforce the banks of this channel and prevent further erosion. Another option that might be considered at Relift #2 is forming a concrete pad at the end of this channel. This will give it stability and aid in the removal of the deposits.

The second item that must be addressed when discussing the relift stations are the pumps and their electrical components. As noted above, Relift #1 has not been in operation in nearly five years. After the channel is restored, the pump could be repaired and water could be returned to Lateral #2. If the pump is to be repaired, it too, like the channel, should be protected from being destroyed by the cattle. New fencing would have to be constructed around the pumping station. As in the case of the inlet, a certified electrician should inspect the Relift stations to determine what repairs are needed to maintain a safe, efficient pumping plant. At Relift #2, the pump is being used and it is one that was purchased a few years ago from Agri Industries. The electrical components could be viewed by a certified electrician, although it is not a major concern.

The final item to discuss about the Relift stations are the transmission lines extending from the pumps to the beginnings of the canals. There is a lot of seepage occurring near Relift #2, and the transmission line is a suspected source. This seepage issue could gradually become worse and the hillside where the pump station is located could become unstable. Due to the age of the pipe, there may be cracks or holes in the pipe causing this seepage. One possible solution would be to replace this transmission line with new pipe. If this is to be done, it may prove beneficial to keep the transmission line above ground. The distance from the pump site to the canal is relatively short can could easily be accessed above ground. Because the flows in the pipe are minimal, a small diameter pvc pipe could be installed. Another option would be to excavate and repair the pipe, but due to the small distances involved, replacing would be just as cost effective.

This concludes the B-1 alternative. As noted above, this alternative can be chosen for certain components of the system. For the other components, one of the remaining alternatives can be applied to it. It is best to determine what alternative suits each component the best, based on available funds and overall support. The remaining alternatives contain options with higher costs, but ones that make the system more efficient and easier to use. If the funds are available it is suggested to upgrade the system as much as possible.

2. Upgraded Design

The second alternative under the open channel section is the upgraded design. This alternative involves keeping the open channel design, but making some slight modifications to it. This alternative is more expensive than the previous one, but the overall efficiency and ease of operation is increased. Like the previous alternative, this one will give suggestions for each component of the system.

a. Supply works

The first component this alternative will address is the sandbar issue at the inlet. There are a couple of options to employ when attempting to alleviate the problems associated with this sandbar. The first option involves the addition of a floating pump to the inlet. A floating pump could be positioned in the river away from the sandbar. This pump could either supply the existing pump station or be used as the primary pumping unit. There are reasons why neither of these choices will work. In the case of the first choice, the inlet structure and its pumps are not configured to receive water in this manner. The pump station would have to be redesigned and reequipped to handle this option. Because of the required changes, this choice would become highly expensive. The second choice of using a floating pump as the primary pumping unit is also unlikely, mainly because of the huge system head the pump would have to overcome. Due to the high system head, one very large pump, or several smaller pumps are needed. In the case with one large pump, the size of the pump would be too large and thus making it extremely difficult to attach to a floating structure and maintain stability. As with the other case, having several smaller floating pumps is also unlikely, mainly due to the fact that a lot of piping would be necessary to attach the floating pumps to the existing lines. Because of all the extra piping needed, this option would also prove to be highly expensive.

The final option for the sandbar issue is the most complex and involved one. A structure could be built upstream to deter the river channel, and force water to flow against the bank again, and scour away the sandbar. This alternative could be dangerous and would require extensive engineering and investigating to determine its long term affects. Structure support would have to be given to the bank upstream of the inlet to insure stability. For this reason, this option would be rather expensive. This option could take years before any results are observed. Due to the possible severity involving this sort of structure, acceptance would be needed from down stream water users and all forms of the government. Although this alternative seems to work best when looking at overall affects and final outcomes, due to it's complexity, it isn't one that should really be pursued.

The next issue this alternative will address at the inlet are the pumps themselves. This alternative involves purchasing one or two new pumps for the pumping plant. A new pump would cost approximately $20,000. This would dramatically increase the efficiency and capacity of the system, but the overall cost of installing new pumps versus repairing the existing ones, is quite a bit more. If new pumps are to be purchased, the District should look at buying two new ones in order to adequately supply the system. Two pumps with approximately the same hydraulic lift as the existing ones would be sufficient. The lift would need to be between 90-100 ft, depending upon what option was chosen for the transmission line. Also, the total capacity for the pumps should be between 25-30 cfs (11,000 - 13,500 gpm). The last part of the supply works this alternative addresses are the electrical components at the inlet. After viewing these electrical components, it was decided repairs are needed to maintain safe and efficient operation of the plant. If the district decides to purchase new pumps for the inlet, new electrical components would be installed and the cost would be included in the total cost of the new pumps.

b. Transmission Line

The other alternative dealt with keeping the existing pipe and repairing it in someway. This alternative involves removing the existing pipe and replacing it with a new pipe, possibly plastic. A cost estimate is available in the appendix for this option. Due to the high construction costs and length of pipe needed for replacement, this is an alternative which should not receive a lot of attention. If a larger number of acres were being served by this system, then it might be a feasible option, but recently the system has been serving less then 1400 acres. Once again, an amount of money to spend on the various components should be determined, before an alternative is chosen.

c. Canal System

The next issue to discuss is the seepage problem occurring in the canal system. As with any man made earthen channel, seepage can become a problem. Although water conservation is not a major concern with this irrigation system, it still should be addressed. One way to decrease the amount of seepage is decrease the hydraulic conductivity of the channel. Some areas of the channel have been repaired in the past, and this proved to be beneficial. The technique used was simple but effective. A clay liner was applied to the channel to decrease the hydraulic conductivity and thus decrease the amount of seepage losses. United Power Association (UPA) donated the clay that was used for the liner, and it was applied with a dozer and a front end loader. The services and equipment was contracted out, and a cost estimate is available in the appendix. Approximately 1/4 of a mile was lined, and the results were beneficial. This technique could be used again to line other areas of the channel that are experiencing seepage problems.

Another technique that could be employed, is applying a geosynthetic liner. A thick plastic membrane could be placed in the channel to prevent any water losses. The advantages of a plastic liner over a clay liner is for one, the overall effectiveness of the liner. With the plastic liner there is virtually no seepage what so ever, as compared with the clay liner, where there will still be some seepage occurring. Also, the plastic liner can withstand a greater velocity, and thus a greater volume of water. The plastic liner holds up better over time and can give many more years of service as compared to the clay liner. Eventually the clay liner will have to be reapplied, while the plastic liner may need some minor repairs, but it will last for several years. The plastic liner is easier to apply then a clay liner, and could be done by the irrigators themselves. The only disadvantage of the plastic liner is the cost, but when looking at the longevity, it makes the extra costs worthwhile. A complete cost estimate on the liners is available in the appendix. Only the areas which show large amounts of seepage need immediate attention, the other areas can be dealt with at a later time when more funds are made available.

d. Relift Stations

This alternative would involve purchasing new pumps for the two existing Relift stations. The first step would be to determine the number of acres that the Relift stations would actually be servicing. From this, pumps could be sized and then purchased. Due to the high costs involved with upgrading such facilities, the District should determine whether or not this would be feasible. After the pumps are sized and purchased the next step would be to determine how much work is needed to the inlet works associated with each Relift station. This would include any channel improvements or bank stabilization. If improvements are made to these inlet works, fencing should be constructed to prevent future destruction to the facilities.

The next issue to address with the Relift stations are the transmission lines extending from the pumps to the beginning of the canals. Due to the possibility of large amounts of water leaking from these lines, they should be replaced with new pipe. Because of the low flows associated with these Relift stations, the pipe could be as small as 6-8" pvc. To ease in installation and maintenance, the lines could be installed above ground, due to the short distances involved. A cost estimate is provided in the appendix for the upgrading of the Relift stations.

C. Pipeline -

The next two alternatives involve the introduction of a pipeline to the system, instead of using the existing open channels. A pipeline will bring increased efficiency and ease of operation.

With a pipeline, the District can expand their application techniques to sprinklers with better results. The system could be better regulated and more water could be made available to the lower end fields. A pipeline will be more costly than keeping the existing canals, but less maintenance is needed in the long run. The pipeline could be placed in the existing canal to reduce installation costs. It would then have to be buried to the proper depth and carefully compacted to meet standards. The pipeline would service all of the existing turnouts that are in use as of today. A map of the pipeline layout can be viewed in the appendix. There are 20 sections of mainline, 5 sections in the large branch line, one transmission line, and 6 smaller laterals, totaling approximately 52,000 feet of pipeline. The diameters range in size from 8" up to 30", and the constraints on the size were the water velocities and the friction losses associated with the pipeline. The pipe used in the design is PIP SDR 51 or 80 psi pressure rated pipe. A less pressure rated pipe of 50 psi could be used at a cheaper overall cost. However, this pipe has its limitations in irrigation practices. Due to the smaller rating the pipe loses some of its overall strength. Because of this, the 50 psi pipe cannot be buried as deep as the 80 psi pipe, due to the increased weight from the soil above it. When irrigation pipe is buried shallow it runs the risk of being crushed by passing vehicles and machinery, especially when the pipe is not completely full of water. A cost estimate is available in the appendix, with all of the corresponding lengths of pipe for each diameter for the 80 psi pressure rated pipe.

The pipeline was designed using the SCS ND Pipeline Program. The program designed the pipeline determining the smallest diameter capable of maintaining water velocities less than 5 ft/sec. The flow rate associated with the pipeline was determined by dividing each field by 10, and then assuming a 4" application depth for each of these 1/10 parcels over a 24 hour period. Then it would take 10 days to fully irrigate each field. The 4" application rate was determined by taking the maximum daily uptake of water by corn, which is .3"/day and multiplying that by 10 days. Then this 3" application was divided by the efficiency of a furrow irrigation system which is approximately 75%, and the 4" application depth was determined. This application would be sufficient to supply a field of corn in July during the hottest and driest days of the summer. This design would continually supply water and would run 24 hrs per day for the entire irrigation season. However during the cooler wetter months, not as much irrigation is needed, and thus the system would not have to be ran the entire season at full capacity. The pipeline does have to be designed to handle the peak irrigation months of July and August. A total flow rate for the entire system was determined by adding the individual flow rates needed for each field together. This total flow rate came to be 23.5 cfs (10,560 gpm). The pipeline operates under a pressure head of 55.6 ft (approximately 25 psi). Due to the fact that the pressure in the pipeline is high enough, the relift stations are unnecessary. This will benefit the District by not having to repair the relift stations. However, since there is such a high pressure in the mainline, pressure reducers will need to be installed to control the water at the various outlets. Also, other pipeline appurtenances will need to be purchased if a one is to be installed. The cost for these additions are included in the cost estimate for the pipeline and the overall cost estimate for this alternative can be viewed in the appendix.

The pipeline alternative can be subdivided into two separate alternatives. The first one is a design in which there will be one pump station located at the inlet. The second one is a design in which the existing inlet would be used and a new booster station would be added where the beginning of canal B is today.

1. Single Pump Station

If a single pump station is used, it would have to lift the water to the beginning of the pipeline, which would be located where canal B begins today. Then the pressure would need to be high enough to overcome the friction losses throughout the remaining sections of the pipeline. Since the existing pumps cannot handle the total lift of 160 ft needed from the inlet, new pumps are going to have to be purchased. Since the capacity is high compared to the total lift needed, it would be best to purchase two new pumps and place them both at the inlet. These pumps would need to be vertical turbine pumps and rated for 5500 gpm at 160' total dynamic head. If two pumps were purchased this would increase the system capacity to 11000 gpm or approximately 25 cfs. The horsepower requirement for this type of pump in these conditions would be 250-300 Hp per pump. After viewing the electrical components of the pumping plant, repairs are needed to maintain safe and efficient operation of the plant. If the district decides to purchase new pumps for the inlet, the costs for improving the electrical components would be included in the total cost.

2. Pump Station with Booster

The second alternative under the pipeline design is one in which the existing inlet and a new booster station would be utilized. The inlet pumps would be used to lift the water to the beginning of the pipeline where the beginning of canal B is today. Due to the increased design capacity and lift requirements, one pump would not be sufficient at the inlet. If the existing pump was to be used, the other pump would have to be repaired and installed at the inlet. The total lift once again would need to be approximately 90 ft, with a capacity of 23.5 cfs. Plus, a new pump would have to be purchased and installed at the beginning of the new pipeline, which would be located near the beginning of canal B. This booster station would increase the pressure to overcome the friction losses along the pipeline. The design capacity for the booster station would be 11,000 gpm or 25 cfs at 70' total dynamic head. The required horsepower would be 300 Hp. Other necessary equipment would also need to be installed at this booster station. A cost estimate is available in the appendix for this alternative, and can be compared to the previous alternative involving the purchase of new pumps for the inlet. However, if the district decides to keep the existing pumps and repair them, repairs would also need to be made to the existing electrical components located at the pumping plant. Hiring of a certified electrician would assist in determining what repairs are needed and what the total costs would be. The total cost estimates for both alternatives are provided in the appendix.

The pumping costs for the alternatives involving a pipeline design are available in the appendix. The pumping costs would be fairly similar for both alternatives with a pipeline design. However, if a booster station is used the demand charge may be increased because of the need for more transmission line use. This would increase the overall pumping cost for this alternative.

D. Hybrid -

The fourth and final alternative involves the combination of two or more alternatives into one hybrid alternative. The District may feel one alternative is better for one component and a different alternative is needed for another component. Another aspect is that one user may want to incorporate sprinklers into their practice and for this needs to install a pipeline. In this situation, that user can proceed with the sprinklers and install a pipeline where it is needed, while the remaining users in the District can continue with the open channel delivery system. However, that user may have to defray the costs of the necessary equipment needed for the installation of a pipeline for his or her own system. The possibilities and combinations of such an alternative are infinite, and because of that, they will not be individually identified. The District can decide which alternatives should be combined to form new and various alternatives. Listed below in the table are a few of the alternatives and their cost estimates.

Alternative	Cost
B-1	$254,400
B-2	$654,000
C-1	$1,925,000
C-2	$1,957,000

VI. Recommendations

This section is provided to give the irrigators a list of recommendations to assist in deciding what alternatives are best for the Fort Clark Irrigation Project. The District should not base their decisions entirely what is listed here. Instead the alternatives that are chosen should be decided upon by the entire District, and the criteria used in making the decisions should include available funds, overall support, and level of importance. The first recommendations involve the transmission line. It is the Water Commission's recommendation that a pipe inspection be made before any improvements are done to this transmission pipe. A video taping of the inside of the pipe can be made through the use of a mobile camera that is started on one end and exits out the other. This footage can be viewed and then be used to determine what repairs are needed and what alternative would be best. The overall cost of would be approximately $1,000, but doing so could save the district much more. The video tape could show a number of things, but mainly whether or not any major cracks exist or if any of the joints are separated. It will also show if whether or not the pipe should be cleaned through the use of a boring machine or a plastic projectile. If a large number of sediments and rocks are found inside the pipe, a thorough cleaning would be beneficial. Cost estimates of these procedures are available in the appendix. Also, due to the overall costs of the different alternatives involving the transmission line we recommend lining the pipe before attempting to replace it. If it is feasible, repairing the pipe in the needed areas would also be beneficial, if the overall costs for repairing certain sections were less than relining the entire transmission line.

The State Water Commission recommends periodic dredging of the sand bar because it is the least costly and it has been proven to be beneficial in the past. A structure could be built downstream of the sandbar, giving access for a backhoe or long boom excavator to clean away the sandbar. The other alternatives may prove to be the better in the long run, but the costs will be much greater, and due to the small size of the district, available funds is the major issue.

We also recommend applying a geosynthetic liner to parts of the channel which need immediate attention and has significant losses. Due to the costs and because some areas of the channel do not possess a seepage problem, it is not feasible to apply a plastic liner to the entire channel. The channel should be observed in late summer or early fall to detect any seepage losses. Greener or thicker brush will be growing in areas where there is a significant amount of water seeping from the channel. This is why observing the channel in the late summer or early fall will be easier, because these areas would be greener than the surrounding areas that are not receiving as much water. The areas which possess the greatest amount of seepage should be lined first, with other areas being lined when funds are made available. The technique used in lining the channel is relatively easy and could be done with the use of a front end loader and a few people assisting in applying it to the channel. If a large amount of funding is not readily available, the cheaper alternative of lining the channel with clay from the surrounding areas would be beneficial. However, if more funds are available, the geosynthetic liner should be applied, due to it's longevity and overall efficiency.

The State Water Commission recommends repairing parts of canal B that were mentioned in the report as being damaged by cattle introduction. Once these areas have been repaired, we recommend constructing a fence around these areas to prevent this sort of damage from happening again. The fence could be either electric or possibly barb wire, whichever serves the District best, and is most cost effective. If some of the local irrigators insist on providing their cattle with water from the canal, a separate pump could be purchased and a stock tank could be supplied and placed outside of the fenced area.

Due to areas in the District not receiving adequate amounts of water in the later months of the season, we also recommend increasing the capacity of the system. This can be accomplished by having the other pump intended to supply canal B repaired. This would raise the number of working pumps at the river inlet from one to two. This could possibly increase the flow in the canal from 12-13 cfs to 25 cfs. This would definitely be an adequate amount of water to supply the entire system today, which consists of approximately 1400 acres. To assist in assuring that water is supplied to the entire system equally, we also recommend implementing a water schedule. This can be used to determine who will receive a certain amount of water on a particular day. A rotating water schedule is an important tool used in water management. A well managed water schedule will increase the reliability and the flexibility of an irrigation system. This will become extremely important in the drier months of the season when moisture is most needed for the crops. To assist in maintaining this schedule, a ditch rider should be put in charge of operating the turnouts. The ditch rider could then route the water to the fields that need the water, and provide water on an equal basis. Also, the ditch rider could arrange regular meetings of the District, to determine if the system is as efficient as it could be, or possibly discuss any issues that may arise.

The State Water Commission also recommends updating the system with available technology whenever possible. As new irrigation technology becomes available one must evaluateota the technology in view of its cost, the potential savings in irrigation costs, and increased profits from improved crop yield or quality. The evaluation will determine whether or not the new technology should be implemented into the system. For instance, in our evaluation, the implementation of a pipeline would not bring a dramatic enough increase in profits to justify the needed spending. Fort Clark already has a well designed and fully functional irrigation system, and does not need a pipeline to improve the conditions. Instead, minor improvements to the areas mentioned will cost a lot less, and the final results would be similar. One must keep in mind that the bottom line is a good crop yield which in turn brings a good profit margin.

Irrigators today face many obstacles from environmental concerns, energy costs, water availability, or competition from other water users. Because of this, the irrigators in North Dakota have learned to adapt in order to maintain a decent way of life. Some ways to continue to adapt may include selecting newer and different crops that may bring a higher profit gain. As North Dakota continues to grow in the agricultural processing markets, the farmers must expand their crop selection in order to accommodate these new industries. As mentioned above, irrigators today must learn to incorporate new technologies whenever it is justified. Finally, they must learn to maintain an efficient and well operated irrigation system. As citizens of North Dakota, we are aware that a drought could devastate the farming community. However, if there are well managed irrigation systems operating throughout the state, the damage from a drought can be lessened dramatically. If agriculture continues to be the backbone for the economy in North Dakota, we must prepare for all possible outcomes, and one way is to insure that irrigation systems are maintained and operating at optimum efficiency.