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Challenges for the Treatment and Discharge of Low Salinity Wastewater

Background

In 1999, Southern Minnesota Beet Sugar Cooperative (SMBSC) undertook an expansion and modernization project that would ultimately allow the Renville factory to process approximately 3 million tons of beets during a typical 180 day beet slice campaign. With the installation of fluidized-bed steam pulp driers and miscellaneous other processes that would condense vapor, historically lost to evaporation, it was estimated that the proposed increase in production would essentially double the amount of wastewater to be disposed of each year. This started SMBSC down a road that would ultimately lead to a wastewater treatment facility and a new National Pollutant Discharge Elimination System (NPDES) permit. The NPDES permit would be unique to the beet sugar processing industry. Phosphorous trading would be used to off-set a point source discharge with various types of non-point source mitigation projects and strict salinity based permit limits, not traditionally included in a surface water discharge permit, would make compliance very difficult, if not impossible.

Over the next five years, several operational strategies were explored. By the time the NPDES permit was renewed late in 2004, the Minnesota Pollution Control Agency (MPCA) and SMBSC had arrived at a solution that was designed to comply with the permit limits and protect the environment.

Prior to the expansion, all wastewater was stored in the existing pond system, which occupies approximately 160 acres and has a total capacity of 250 million gallons. From early May through mid-October, the stored wastewater was applied by spray irrigation on 1,100 acres of land adjacent to the factory, using reed canary grass as a forage crop (see Attachment I). Each year approximately 175 million gallons of wastewater were treated in this manner.

Within the context of the proposed expansion, a decision had to be made concerning the treatment of what was expected to be an additional 170 million gallons of wastewater per year. The initial discussions centered on expanding the land application system, which would include the construction of new wastewater storage ponds. Some of the more significant factors considered were:

1. Availability of land;
2. Soil suitability for application of wastewater; and
3. Effects of the overall treatment system on odors and hydrogen sulfide emissions.

Land availability was uncertain and purchase prices would be driven by the requirement to secure another 1,000 acres of land within reasonable proximity of the factory site. As many as 100 acres of additional land were expected to be used in the constructing the new ponds. As to the suitability for spray irrigation, area soils are a clay loam, which hydraulically limits the amount of wastewater that can be applied to a maximum of 325,000 gallons per acre per year. In practice, these levels are rarely achieved; therefore additional land must be available, above and beyond the theoretical requirement of 500 acres.

During the late 1990's, the potential of odors and hydrogen sulfide emissions from agricultural and industrial operations in Renville County were a major public concern. The political climate was such that a candidate for Lieutenant Governor was selected for their stand on various environmental issues, including hydrogen sulfide emissions from local feed lots. While the expansion of the land application system and additional pond storage space would have allowed for effective treatment of wastewater, it would exacerbate the odor and hydrogen sulfide emission problems. To be as good a neighbor as possible, SMBSC decided to construct a wastewater treatment facility.

Wastewater Treatment Facility

The facility consists of: 1) primary treatment of the beet wash water for mechanical removal of topsoil and some organics, 2) anaerobic treatment of water high in biochemical oxygen demand, 3) secondary treatment of the anaerobic effluent and 4) tertiary treatment to meet stringent permit limits on phosphorous and dissolved oxygen.

Construction of the wastewater treatment facility began in April 1999, immediately after receipt of the required NPDES and Air Emission permits. The system was designed to treat a maximum of 2 million gallons per day, with the treated effluent being directly discharged to surface waters.

Primary Treatment

A 150-foot diameter Eimco clarifier is used to settle the soil from the water in the beet wash water loop. The overflow of the clarifier or clarified water is returned to the wash house for re-use, with excess water from the loop being routed to an equalization pond. The equalization pond is used to provide a more uniform hydraulic flow and organic loading to the wastewater treatment processes. The equalization pond covers an area of 29 acres and provides an average hydraulic retention time of about 20 days. The underflow from the clarifier, or settled soil slurry, which contains five to ten percent solids, is pumped to Broadbent horizontal solid bowl decanters, where additional water is separated from the soil. The centrate or decanted water is pumped to the equalization pond for storage and treatment. The centrate contains 1,500 to 3,000 mg/L of total suspended solids, depending upon soil type and the pH of the wash water loop. The moisture content of the centrifuged soil exiting the decanters is in the range of 45 to 50 percent. At these moisture levels, the soil can be piled, making it possible to haul the soil with standard live-bottom and tandem dump trucks. The soil is stored on site for use as a cover material or can be land applied on agricultural land at rates up to six inches thick.

Anaerobic Treatment

Wastewater from the equalization pond, which contains a mixture of excess beet wash water, decanter centrate, and other process wastewaters, is pumped to the anaerobic treatment process. An equalization tank is used to provide an additional 24 hours of storage at the wastewater treatment facility. The up-flow anaerobic sludge blanket reactor (UASB) designed by Biothane Corporation is capable of treating a flow of up to 1.5 million gallons per day, with a maximum organic loading of 127,000 pounds of biochemical oxygen demand (BOD) per day. A portion of the biogas generated from the anaerobic process is used in a water heater to provide heat to the wastewater entering the treatment process. Approximately 190 cubic feet per minute of biogas containing 70 percent methane is used to power the water heater that requires an input of 8-million BTUs/hr. Excess biogas is burned in a flare located adjacent to the anaerobic reactor.

Aerobic Treatment

The anaerobic treatment process is followed by a complete mix aerobic system that was designed by Applied Technologies, Incorporated. There are two aerobic tanks fitted with coarse bubble diffusers to provide aeration and mixing. Two secondary clarifiers follow the aerobic tanks to provide for removal of aerobic biomass. The use of two independent systems provides for excellent flexibility in the turn-down rate required to transition from the beet slice campaign to juice run operations. Each of the two separate systems is capable of treating 1-million gallons per day. An anoxic zone in the center of each aerobic tank provides for de-nitrification. Excess biomass is wasted to a storage tank using an Ashbrook gravity belt thickener. Biomass is land applied two times per year, at agronomic rates based upon the nitrogen content.

Tertiary Treatment

Treatment of the aerobic effluent through Eimco traveling bridge sand filters and a re-aeration tank allows compliance with very stringent traditional water quality parameters, i.e. BOD, total suspended solids (TSS), ammonia nitrogen, phosphorous and dissolved oxygen.

During June 2005, a chlorination and de-chlorination system will be added as part of the tertiary treatment processes. While no sanitary wastes are treated through the wastewater treatment facility, SMBSC does occasionally have difficulty meeting the fecal coliform permit limit. Fecal coliform is used as an indicator organism that would suggest that there is a possibility that other human pathogens could be present. Assays performed on biosolids and treated wastewater effluent samples have proven negative for human pathogens such as salmonella, enteric virus and helminth ova.

NPDES Permit Evolution

SMBSC's first NPDES permit allowing for direct discharge of treated wastewater to surface waters was issued in April 1999. When establishing permit limits, the MPCA may use standards based on Minnesota state water quality standards, federal categorical standards, which are applicable to specific industrial categories, or a combination of these standards. In addition, the MPCA may also derive standards which are site-specific to a particular discharge. These site-specific standards may be based on toxicity studies, best professional judgment analysis, and technology based standards and in some instances, standards developed by other U.S. states or other governments. For industrial categories, the MPCA uses the federal categorical standards, required by Minnesota Rule and U.S. Code of Federal Regulations, and state standards.

Since the permit was issued prior to construction and operation of both the wastewater treatment and the expanded processing facilities, compliance with promulgated limits was assumed possible. The processes for treating traditional pollutants were well understood and data collected over the next five years would bear this out. Salinity related pollutants were another story, and operation of the treatment facility proved that estimates of compliance were incorrect.

SMBSC was unable to meet the salinity related discharge limitations of the original permit. A number of salt reduction efforts through recycle, chemical substitution, equipment replacement and other actions were implemented. As part of the NPDES permit requirements, a Dissolved Minerals Reduction Program was submitted to the MPCA.

The program detailed the installation of flow meters and specific conductivity monitoring in several locations of the factory. Efforts continue to reduce dissolved mineral inputs to the wastewater streams, working towards a goal of reducing the total dissolved solids in the treatment facilities final effluent. Although salt reduction efforts will continue, it is believed that they have been currently maximized to the extent technically feasible given existing sugar beet processing technology. This position is supported by the MPCA's willingness to modify salinity based permit limitations. Tables I and II summarize the traditional and non-traditional NPDES permit limits that the MPCA has developed for the treated wastewater effluent. Table II clearly shows the evolution of the salinity based parameters from one permit to the next.

Table I. Comparison of the More Traditional Permit Limits

Traditional Pollutants	1999 Permit	2004 Permit
Carbonaceous Biochemical Oxygen Demand (CBOD) – mg/L	15	15
Total Suspended Solids (TSS) – mg/L	30	30
Ammonia Nitrogen – mg/L	1.4 Jun - Sep 4.4 Oct - Nov 7.7 Dec – Mar 2.6 Apr - May	1.4 Sep 4.4 Oct - Nov 7.7 Dec – Mar No Discharge
Phosphorous – mg/L	1.5	0.75
Dissolved Oxygen (DO) – mg/L	6.0	6.0
pH – S.U.	6.5 - 8.5	6.5 - 8.5
Temperature - C°	30	30
Fecal Coliform – colonies/100 ml	200 Apr - Oct	200 Sep – Oct

Table II. Comparison of Non-Traditional Permit Limits

Non-Traditional Pollutants	1999 Permit	2004 Permit
Chloride – mg/L	100	230
Specific Conductance – μmhos/cm^2	1,500	3,750
Sulfate – mg/L	1,000	1,000
Turbidity – NTU	25	25
Bicarbonates	305	Monitor Only
Sodium - percent of Cations	60	Not Applicable
Toxicity – TUa*	Chronic	0.9999 Acute
Chlorine – mg/L	Not Applicable	0.04

* - An Acute Toxicity Unit (TUa) is the reciprocal of the effluent concentration (percent by volume) that causes 50 percent effect or mortality to organisms for acute exposures. An effluent is considered acutely toxic if mortality or immobilization of the aquatic test species is 50 percent or greater in 100 percent effluent.

Receiving Water and Discharge Relocation

In 1999, the permit was issued with a surface water discharge to County Ditch 37 (see Attachment II). The receiving water stream flow is termed intermittent. There are periods throughout the year when flow through the ditch is essentially zero. This can occur during dry periods in the summer months, when isolated areas can become stagnant, as well as cold periods during the winter when the entire stream can freeze. With intermittent flow conditions such as these, the MPCA did not allow the consideration of a mixing zone within the receiving water stream. The assumption was made that the treated wastewater effluent would make up the entire flow in the receiving stream. Without the ability to utilize a mixing zone, all water quality parameters would have to be met at the discharge outfall. This "end-of-pipe" approach tightens permit limits and affords a higher level of protection to the immediate downstream stretches of the receiving waters.

The upper reaches of County Ditch 37 consist of tiled field inlets that drain to an enhanced drainage ditch, via clay, cement and plastic tile lines. The Renville county ditch system was constructed to provide drainage and improve the area for agriculture. Approximately one mile downstream of the discharge outfall, County Ditch 37 converges with an Outstanding Resource Value Water (ORVW) known as Beaver Creek. The State of Minnesota has designated various classifications, to describe intended uses for surface waters. County Ditch 37 is classified as a 2B, 3B, 4A, 4B, 5 and 6-surface water, which designates the water in County Ditch 37 as acceptable for aquatic life and recreation, industrial consumption, agriculture and wildlife, aesthetic enjoyment, navigation and other uses.

The re-issued permit in 2004 mandated the relocation of the discharge outfall from County Ditch 37 to County Ditch 45. The upper reaches of County Ditch 45 are very similar to those described for County Ditch 37. The lower reaches of County Ditch 45 however, differ significantly from the Beaver Creek watershed. Portions of County Ditch 45 are classified as a Class 7 Limited Resource Value Water, significantly limiting the intended uses of the stream. It was recommended that the SMBSC discharge be relocated because it was believed that the seasonal discharge proposed would not adversely impact the assigned uses or pose adverse environmental impacts on County Ditch 45 and the downstream receiving water, Sacred Heart Creek. In fact, due to the intermittent flow characteristics of the upper reaches of County Ditch 45, it was believed that the stream flow characteristics could be improved. During the summer months, low flow periods often let the water collect in isolated pools that can become stagnant. The discharging of non-contact cooling water that could occur through the summer months would provide a consistent flow to the receiving water.

By discharging to County Ditch 45, the regulatory requirement to meet chronic toxicity standards, as required in the 1999 permit, does not apply. The discharge would meet all applicable discharge standards, including the acute toxicity standard, should a proposed variance for the salinity parameters be approved.

The discharge of treated wastewater effluent from SMBSC's wastewater treatment facility occurs only September 1 through March 31. This will prevent the affected aquatic species from being subjected to chronic toxicity from salinity related constituents. Discharge during this period is also not expected to negatively affect fish spawning activity in the downstream reaches of County Ditch 45 and Sacred Heart Creek.

Variance

The regulatory process that allows certain permit limits or water quality standards to be suspended or modified for a site-specific circumstance is known as a variance. SMBSC requested and was granted a variance for several salinity related parameters during the proposed discharge period of September 1 through March 31. The variance was sought on the basis that complying with the original permit salinity limits was not technically or economically feasible and that the seasonal variance would not result in environmental harm or impact the users of the receiving water.

The ultimate uses of the receiving water determine in a large part the specific permit limits that are applicable to a point source for the non-traditional pollutants.

Chloride

The original limitation for chloride was 100 mg/L, which is based on Minnesota's industrial use water quality classification. A chloride limit of 230 mg/L was proposed, since the use of the receiving water for industrial consumption is not applicable to

SMBSC's site-specific case, because flows are not adequate for industrial withdrawal. This proposed limit does comply with the aquatic life and recreational use standard and is designed to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life and their habitats.

Specific Conductance

The original permit limit for specific conductance was 1,500-μmhos/cm^2. There is an empirical relationship between total dissolved solids (TDS) concentrations and specific conductivity. The relationship between TDS and specific conductivity in SMBSC's treated wastewater effluent has been found to be 1:1.50, respectively. Since specific conductivity is a quick and reliable method of measuring the ionic concentrations of waters, the MPCA has adopted this method as a surrogate measurement of the salinity related parameters of total salinity, total dissolved solids and bicarbonates.

The proposed permit limitation was 3,750-μmhos/cm^2 as a monthly average. Specific conductance limits are applied to point source discharges to allow the use of the receiving water for crop irrigation and livestock consumption. In this case, the receiving water is not routinely used for irrigation or livestock consumption. In fact, during the September 1 through March 31 discharge period, the use of the receiving water for irrigation or livestock watering is essentially non-existent. The concern over specific conductivity of the discharge then is that it may pose chronic or acute toxicity to aquatic life including fish. A series of toxicity tests were conducted to ascertain the safe levels of specific conductivity that could be discharged. Toxicity testing confirmed that a site specific limit of 3,750-μmhos/cm^2 would not cause acute toxicity to the test species, i.e. fathead minnow, ceriodaphnia duba, and daphnia magna. The limited discharge period of September 1 through March 31 will prevent the affected aquatic species from being subjected to conditions that would cause chronic toxicity.

Bicarbonate and Sodium Percent of Cations

Both the bicarbonate and sodium percent of cations limits were dropped from the re-issued permit. The original permit limits of 305 mg/L and 60 percent respectively, were based on a crop irrigation standard. Waters with elevated bicarbonate levels that are used for irrigation on certain types of soil have the potential to lead to iron deficiency for certain plants. The basis of the sodium standard for irrigation waters is intended to minimize the impacts to the soil structure, infiltration and permeability rates.

As above, the receiving water is not used for crop irrigation and in any case, crop irrigation would not occur during the period of variance applicability or discharge, September 1 through March 31.

Operational Strategies

Several operational strategies were used over the first three years of operation in an effort to try to meet the salinity requirements of the permit. Initially, two reverse osmosis (RO) units built by GE Osmonics were used to treat a slip stream of the effluent. The units were originally designed to replace a cold lime softening process intended to reduce boiler house softener regenerations. The treated wastewater effluent was evaluated as an acceptable feed stream for RO membranes. The silt density index (SDI) of the wastewater was extremely high and significant modifications were made to the units. SDI is a relative measurement made under specific conditions to indicate the quantity of particulate matter in water. The recovery levels of the modified ROs dropped from the design of 75 percent to about 50 percent. Feed rates to the units averaged 400 gallons per minute (gpm); with permeate flows less than 200 gpm.

The RO quality effluent did meet discharge limitations, with the exception of the sodium - percent of cations limit of 60 percent. The sodium - percent of cations limit is usually associated with land application sites, where relatively high levels of sodium can affect the rates at which water infiltrates the soil. Calcium and magnesium were readily rejected by the reverse osmosis membranes, therefore sodium was the primary cation remaining in the permeate. The inability to meet this limit posed no problems to water quality; in fact this parameter was dropped from the re-issued permit in December 2004.

At best, this was a short term resolution to the salinity problem, but it did allow SMBSC to evaluate the use of RO in treating wastewater effluent. As expected, disadvantages of operating the wastewater treatment facility in conjunction with the ROs outweighed the positive effects. Significant problems noted were: 1) high maintenance costs associated with the multimedia filters and membranes, including membrane and media replacement, 2) frequent cleaning regimes, which reduced operational time of the units and added more cleaning chemicals to the wastewater, 3) relatively low production rates, approximately 29 million gallons were discharged over a six month period, and 4) a higher salt stream, the concentrate was being returned to the storage ponds.

From October 2001 through May 2002, the RO permeate was blended with treated wastewater effluent in an effort to increase discharge rates, while meeting the NPDES permit limits. Permit limits were met, but increasing operational problems with the multi-media filters and RO membranes limited the discharge to only 37 million gallons through the eight month period.

During the 2002-2003 beet slice campaign, SMBSC was able to meet the salinity requirements of the permit to a limited extent by segregating wastewaters by specific conductivity into separate ponds. Water with conductivities less than 1,500 μmhos was treated and discharged. Approximately 23 million gallons was discharged from December 2002 through February 2003. Higher salinity wastewater was stored and then land applied during the next summer. Again, this was a short term solution, because salts continued to be concentrated in the pond system. Conductivity levels increased above 7,000-μmhos/cm^2, where it began to affect the treatment processes. Since there appears to be a direct relationship between conductivity levels and organic loading, the wastewater that was being stored until it could be spray irrigated was relatively high strength. High strength wastewater stored under anaerobic conditions in ponds will be the source of odor complaints and hydrogen sulfide emissions.

Beginning with the 2003 beet slice campaign, the operational focus of the wastewater treatment facility shifted from salinity related issues, to organic based pollutants.

Working under a Water Management Plan (WMP) that was submitted to the MPCA, wastewater from the equalization pond was treated and discharged. The plan called for discharging wastewater that would meet all traditional permit limits, while working to minimize levels of salinity related constituents. A non-contact cooling water loop that had previously been discharged to a separate location was combined with the treated wastewater effluent prior to discharge. The resulting blended effluent had conductivities in the range of 2,800 to 3,600-μmhos/cm^2. The plan was successful, and SMBSC discharged 174 million gallons from October 2003 through March 2004. The hydrogen sulfide monitoring during the summer of 2004 did support that significant improvement had been made and the potential for odor and hydrogen sulfide emissions could be minimized (see Attachment III).

During the 2004 beet slice campaign, SMBSC followed the original WMP and began discharging wastewater on October 1. The specific conductivity of the discharged effluent was limited to a maximum of 3,750-μmhos/cm^2. Actual discharge data through February 11, 2005, confirm that 92 million gallons have been discharged with a specific conductivity of 2,850-μmhos/cm^2. The re-issued permit was received in December 2004 and closely reflected the parameters followed in the WMP. Since the outfall location was moved, 49 million gallons of treated wastewater effluent has been discharged to County Ditch 45.

Additional Permit Requirements

Bio-Monitoring

To assess the impacts, if any, of the discharge to County Ditch 45, with particular emphasis on impacts related to salinity, an initial bio-monitoring assessment was conducted during October 2004 at three locations in County Ditch 45 and the Sacred Heart Creek watershed, prior to the introduction of the treated wastewater effluent to the watershed.

Beginning in the summer of 2005, the three locations assessed in 2004 will be part of an on-going bio-monitoring program. The monitoring plan consists of procedures for habitat evaluation, fish and benthic monitoring, chemical testing, frequency of monitoring and timing of the monitoring events. Site designation included two downstream sites that would be representative of the SMBSC discharge, in County Ditch 45 and in Sacred Heart Creek. The third site would act as a reference and would be at a location representative of the flow from Sacred Heart Creek, but does not have the influence of the effluent from the wastewater treatment facility. The monitoring will consist of both invertebrate and fish identification. Chemical analysis of the receiving water will be performed at the time of the bio-monitoring sampling and will consist of temperature, flow, dissolved oxygen, calcium, chloride, magnesium, ammonia nitrogen, pH, phosphorous, sodium, specific conductivity and sulfate. The initial samplings will also be screened for cadmium, chromium; copper, lead, zinc, and a list of 22 pesticides (see Attachment IV).

Receiving Water In-Stream Survey

In-stream testing will be conducted at eight locations, with six being located on County Ditch 45 and Sacred Heart Creek. The purpose of monitoring at these locations is to develop chemistry data on County Ditch 45 to assure that the discharge is not causing significant negative impacts. A number of physical and chemical parameters are required to be monitored, including temperature, flow, dissolved oxygen, bicarbonates, chloride, magnesium, ammonia nitrogen, pH, phosphorous, potassium, sodium, specific conductivity and sulfate.

Summary

The first five years of operation of Southern Minnesota Beet Sugar Cooperative's wastewater treatment facility proved that the more conventional pollutants in sugar processing wastewater could be treated and the effluent directly discharged to surface waters, without the more typical use of ponds to provide the final treatment and storage prior to discharge. While the organic solids and nutrient loadings could be reduced to a level that would allow discharge, the wastewater treatment facility had little influence on salinity related compounds and would not allow the discharge effluent to meet certain in-stream water quality standards. The applicability of those water quality standards was questioned and evaluated as to whether they were necessary for the permit limits to be protective of the environment. A balanced approach was required to examine the impacts not only to surface waters, but also the surrounding crop land and ambient air quality.

Evaluation of the various wastewater streams has confirmed that the beet wash water loop was not only a major contributor of biochemical oxygen demand, total suspended solids and nutrients such as ammonia nitrogen and phosphorous; but the soil removed from the beet in the wash water loop was also a significant source of salinity related constituents, such as sodium, chloride, and specific conductance. Salinity levels in the treated wastewater effluent have been proven to be safe for several aquatic species through the use of acute toxicity testing. Evaluation of the biota in the receiving waters over the next few discharge seasons will assess chronic impacts, should any occur. Extensive in-stream analysis will examine the potential for changes in water chemistry as well as changes in stream flow characteristics.

The past practice of storing wastewater that contained high levels of bio-chemical oxygen demand in anaerobic conditions for extended periods, particularly during warm weather months, had to be mitigated. Experience has already proven that odor complaints can be reduced and hydrogen sulfide emissions can be all but eliminated.

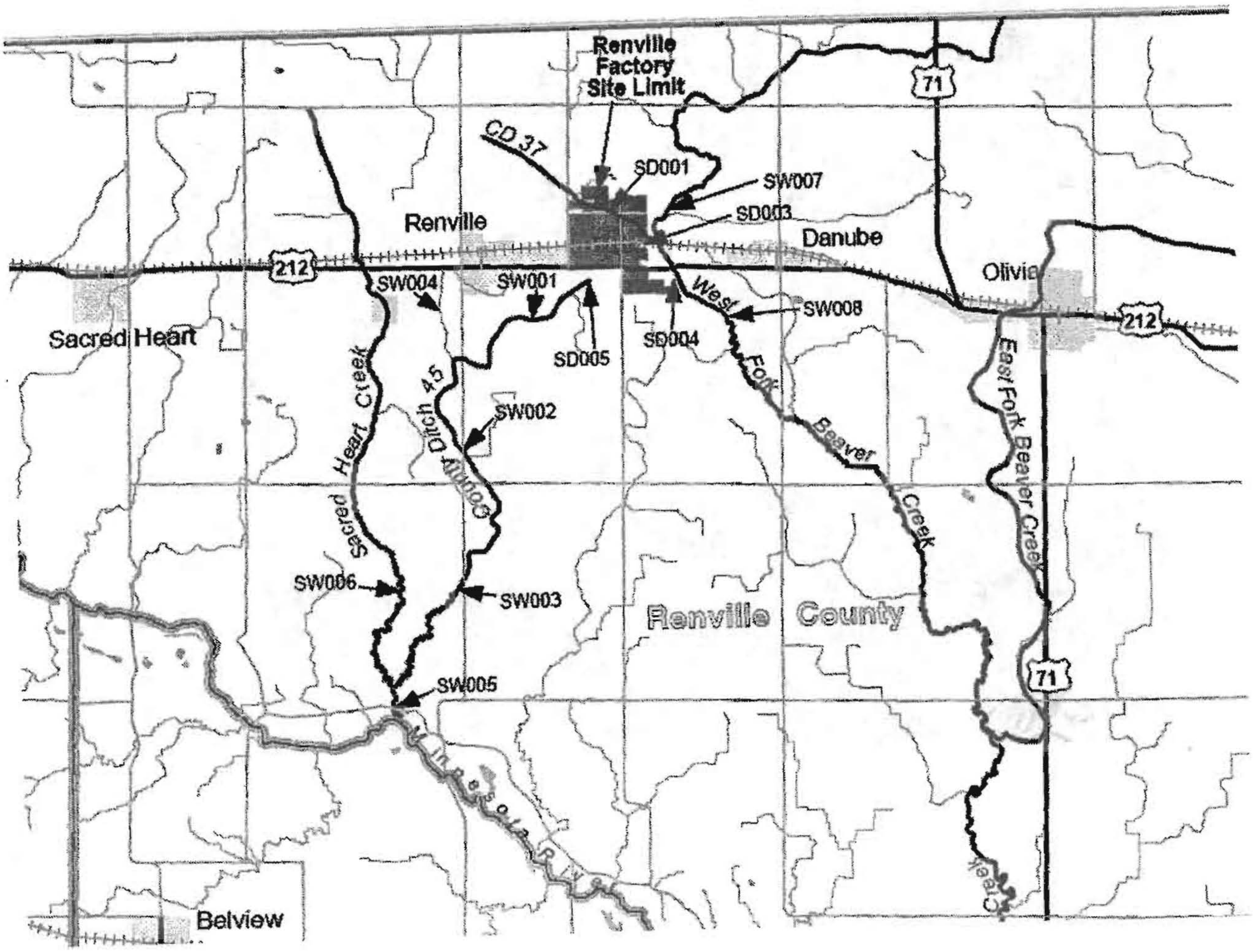
A more thorough understanding of water quality standards and proposed uses of receiving waters allowed the approval of a variance from certain salinity based standards, and the development of permit limits that prevented adverse impacts on surface waters, but allowed efficient operation of the wastewater treatment facility. The next five years of the National Pollutant Discharge Elimination System permit will be used to confirm that the appropriate decisions have been made.

Attachment I

Aerial Photograph of Southern Minnesota Beet Sugar Coöperative

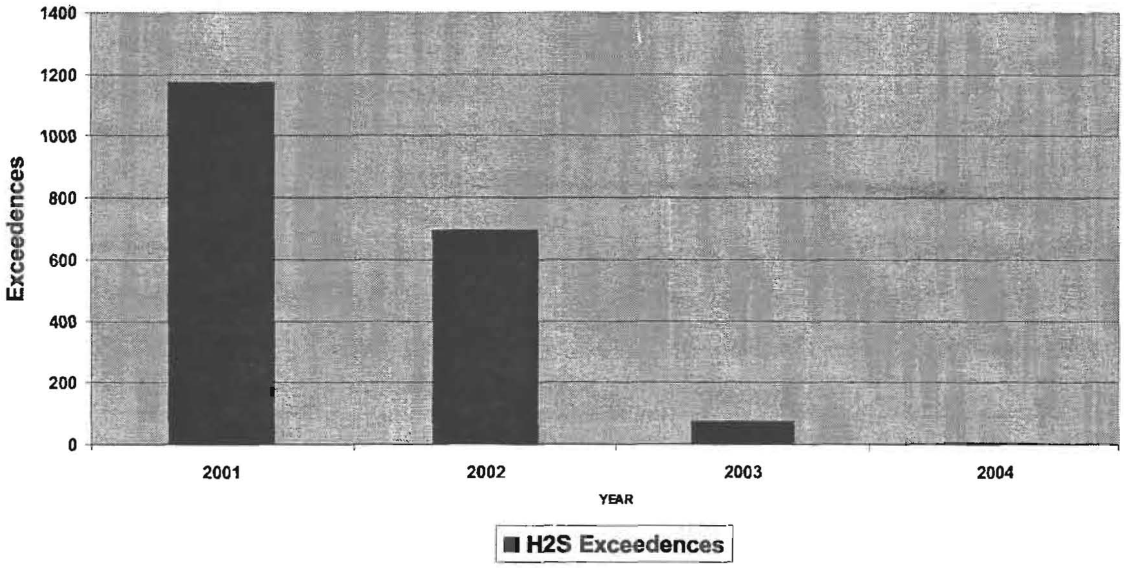
Attachment II

Area Watershed Map



Attachment III

Number of Exceedences of the 30 ppb Hydrogen Sulfide Ambient Air Standard



Attachment IV

List 1 Neutral Pesticides from the Minnesota Department of Agriculture

Chemical Name	Trade Name	Comment
Acetochlor	Harness/Surpass	A selective pre-emergent soybean herbicide in the chloracetanilide family.
Alachlor	Lasso	A common herbicide that is an acetanilide.
Atrazine	Aatrex	A common corn herbicide that is in the triazine family of herbicides.
Des-ethyl atrazine		A degradate product or metabolite of atrazine.
Des-isopropyl atrazine		A degradate product or metabolite of atrazine.
Dimethenamid	Frontier	A common broadleaf herbicide in the chloroacetamides family.
Chlorpyrifos	Lorsban/Dursban	Lorsban is used to control rootworm and cutworms, and Dursban is used to control ants.
Cyanazine	Bladex	A common corn herbicide that is in the triazine family of herbicides.
EPTC	Eptam/Eradicane	A selective herbicide used for control of annual grassy weeds, perennial weeds, and broadleaf weeds.
Ethalfluralin	Sonalan	A selective herbicide used for the pre-emergence control of annual grasses and broadleaf weeds.
Fonofos	Dyfonate	A soil insecticide used to control pests such as corn rootworms and cutworms.
Metochlor	Dual	A broad spectrum herbicide used for general weed control.
Metribuzin	Lexone/Sencor	An herbicide used to selectively control certain broadleaf weeds and grassy weed species.
Pendimethalin	Prowl	A selective herbicide used to control broadleaf weeds and grassy weed species.
Phorate	Thimet	An insecticide/nematicide used to control various insects.
Propachlor	Ramrod	An herbicide used to control grasses and broadleaf weeds.
Prometon	Pramitol	A nonselective herbicide applied before or following emergence, used to control annual and perennial broadleaf weeds and grasses.
Propazine	Milogard	An herbicide used for control of broadleaf weeds and annual grasses.
Simazine	Princep	A pre-emergent herbicide used to control many annual broadleaf and grass weeds.
Terbufos	Counter	An insecticide used to control insects in corn, sorghum, and sugar beets.
Triallate	Far-go	A pre-emergent herbicide federally registered, but restricted to use in CO, ID, KS, MN, MT, NE, NV, ND, OR, SD, UT, WA, and WY.
Trifluralin	Treflan	A pre-emergent herbicide used to control annual grasses and broadleaf weeds.