AQUIFER ENHANCEMENT INVESTIGATIONS
1980 - 1986

PROJECT 2.1
WATER RESOURCES DEVELOPMENT
UNDER THE
CANADA-ONTARIO INTERIM SUBSIDIARY AGREEMENT ON WATER DEVELOPMENT
FOR REGIONAL ECONOMIC EXPANSION AND DROUGHT PROOFING
AQUIFER ENHANCEMENT INVESTIGATIONS
1980 - 1986

Winnipeg, Manitoba
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Under the Canada Manitoba Interim Subsidiary Agreement on Water Development for Regional Economic Expansion and Drought Proofing funds were made available to the Water Resources Branch to conduct Water Management Investigations. One segment of this program was Aquifer Enhancement Investigations. Aquifer Enhancement Investigations were initiated to establish the technical feasibility of improving the freshwater supply capability of selected aquifers. One mechanism for aquifer enhancement that has potential in Manitoba is artificial recharge. Artificial recharge involves the transfer of good quality water from a donor source to a recipient aquifer to increase the yield and/or improve the water quality of the recipient aquifer.
CHAPTER 2

OBJECTIVES

The objective of the Aquifer Enhancement Investigation program was to establish the technical feasibility of artificially recharging selected aquifers in Manitoba. This was to be achieved by carrying out a pilot artificial recharge project at a specific site and then using the experience gained to develop criteria that could be applied to other potential artificial recharge sites.
CHAPTER 3

METHODOLOGY

3.1 Literature Review

As an initial step in this investigation a literature review of artificial recharge projects was conducted. This review indicated that successful artificial recharge projects had been carried out on an extensive scale in the United States and Israel. In particular, artificial recharging by means of spreading basins has been done in Los Angeles (Todd, D.K. 1980) and Fresno, California (Nightingale, H.I. and Bianchi, W.C. 1973; Bianchi, W.C. and Lang, G.J. 1974; Nightingale, H.I., Ayars, J.E., McCormick, R.L. and Cehrs D.C. 1973) and on Long Island, New York (Bagone, S.E. and Vecchioli, J. 1975; Guerrero, A.A. 1981). On Long Island approximately 2100 recharge basins, many of which are abandoned gravel pits, are utilized to recharge aquifers with storm runoff water. In Israel approximately 79,000,000 m$^3$ (64,000 acre feet) of water are artificially recharged on a yearly basis into the Coastal Plains aquifer by means of wells and spreading basins (Sellinger, A. and Aberbach, S.H. 1973; Goldshmidt, J. 1974). Results of the work reviewed were favourable and indicated that artificial recharging could be carried out on a large scale to enhance existing groundwater supplies.
In addition, Mr. J. Korol, while with the Water Resources Branch, carried out a pilot project to recharge fresh water into a saline fractured limestone aquifer by means of recharge wells. A review of the literature available on this project indicated that positive results were achieved and that this concept was feasible, although a considerable expenditure of funds and a significantly long time frame would be needed to fully complete the project (Korol, 1980).

3.2 Experimental Site Selection

It was initially proposed that the major activity to be carried out under Aquifer Enhancement Investigations would be a continuation of the work started by Mr. Korol. This would involve a long term injection test in which fresh runoff water would be injected by means of recharge wells into an extensive bedrock aquifer containing saline water. However, because the effect on water levels could not be accurately predicted until a reliable model was developed, it was decided not to proceed with this project. In addition, the long time frame required to fully complete this project made continuing with it problematical. Instead, it was decided that Aquifer Enhancement would concentrate on artificial recharge of sites where the project could be completed within the term of the Interim Agreement.

A number of sites suitable for carrying out an experimental artificial recharge project were considered. Among these were Elie, Winkler and Miami. In assessing the different sites the following criteria were used:
1. The site must be able to infiltrate raw water at a sufficiently high rate to justify the cost of the plan.

2. There must be sufficient storage volume beneath and around the recharge site to permit below ground retention of a substantial amount of water without causing any unacceptable problems.

3. A suitable donor source must be located in proximity to the potential recharge site.

4. Conditions adjacent to the recharge site must be favourable for the installation of recovery wells that can be placed so as to recover an economically acceptable amount of water.

In addition it was felt that a sufficient need for artificial recharge at a particular site must be demonstrated. This was particularly true at Elie because of the following circumstances:

Prior to 1985 the town of Elie received its water from a well developed in the southern portion of a fresh water sand, silt and gravel aquifer called the Elie Aquifer. Water quality in the Elie Aquifer is generally very good with conductivities ranging from 400 micromhos/cm to 900 micromhos/cm. Water quality in the limestone bedrock aquifer, which underlies the Elie area, is poor and the water is unsuitable for consumption. Conductivities of this water are in the order of 4500 to 5000 micromhos/cm.

A plot of water consumption from the Elie town well and conductivity of this water on a yearly basis is shown in Figure 1. As can be seen consumption has increased from slightly over 9 000 m$^3$ (2 million gallons) a year to approximately 29 500 m$^3$ (7.5 million gallons) a year in the period from 1971 to 1982. In this
corresponding time conductivity readings have steadily increased from approximately 900 micromhos/cm to over 2200 micromhos/cm.

With increased usage a serious quality deterioration has occurred in the Elie town water supply. As withdrawals from the town well increase a further decrease in water quality can be expected. This is due to the fact that at the Town well saline water from the underlying bedrock is advancing into the fresh water zone. It was felt that artificially recharging the Elie Aquifer would provide a possible solution to these serious water quality problems.

After a review of the potential sites based on the above criteria, and taking into consideration the serious water quality deterioration that had taken place, it was decided to carry out a pilot artificial recharge project at Elie.

3.3 Experimental Site Development

The town of Elie is located approximately 32 km (20 miles) west of Winnipeg along the Trans Canada Highway (Figure 2). The area under study centres on the Elie gravel pits which were located approximately 4 km (2.5 miles) northeast from the town in 19-11-2W.

In 1964, M. Rutulis of the Water Resources Branch carried out a groundwater supply investigation for a water supply for the Town of Elie (Rutulis, 1964). This work led to the definition of a fresh water aquifer which came to be called the Elie Aquifer (Figure 3). The Elie Aquifer consists basically of outwash deposits of silt, sand and gravel. In the east half of 19-11-2W the outwash deposits have formed a ridge in the plain which has been mined for
aggregate. This is known as the Elie gravel pits. The outwash deposits extend for approximately one mile southwest from the gravel pit area. Away from the pit area the outwash deposits are overlain by lacustrine clay which feathers out against the slopes of the ridge. Southwest of the ridge the outwash is laid down directly on the underlying carbonate bedrock. The bedrock appears to be very fractured at the outwash-bedrock contact. In some places a thin layer of gravel overlies the bedrock. The test work of Rutulis indicated that the outwash deposits and fractured bedrock in SW-19-11-2W were the most permeable part of the aquifer and a well to supply the town of Elie was installed in this area in 1968. In addition, a community well had been installed in the pit area in the early 1950's and supplied both farmers and the town until installation of the town well. This well is now only used for farm supply. Additional test drilling has also been carried out in the Elie Aquifer area at various times by A. Pedersen and by F.W. Render of the Water Resources Branch (Pedersen, 1982, Render, 1982).

The major recharge area for the Elie Aquifer is the Elie gravel pits (Figure 2). As the ridge in which the pits are located is topographically higher than the surrounding plain snowmelt and precipitation tend to drain off the ridge and away from the pit area. Due to the presence of the overlying lacustrine clay very little of this water reaches the aquifer as recharge. Essentially the only recharge the aquifer receives is from snowmelt in the pit area and direct precipitation on the pits themselves.

Initial analysis of the data available indicated that by artificially recharging the Elie Aquifer utilizing the Elie gravel pits it should be possible to store a minimum of 68,160 m$^3$ of water (15 million gallons) in the aquifer.
Three sources of recharge water were considered. These were: runoff water from the surrounding drainage ditch system, water from the La Salle River, and water from the Assiniboine River. Due to a more reliable source of supply than from local drains and easier access than from the Assiniboine River it was decided to attempt recharging with water from the La Salle River. After deciding that the La Salle River would provide a dependable source of recharge water a method of conveying the water to the Elle gravel pits was investigated. A conceptual plan was developed based on using the existing agricultural drainage system. A number of factors were considered in this plan such as:

1. Water would only be diverted during spring runoff periods when it was felt that the quality of the recharge water would be excellent. (The diversion of water from the Assiniboine River into the La Selle River, initiated in 1984 has changed this factor).

2. The water transfer system would be designed to function by gravity once water was lifted from the La Salle River into the drainage system. In order to accomplish this it was planned to construct a pumping station at the La Salle River and equip it with two pumps each capable of pumping at least 0.06 m³/s (2.1 cfs).

3. The already present drainage system had been designed to agricultural standards and the capacity was restricted by the size of the smallest culvert installation. This capacity was in the order of 0.28 m³/s (10 cfs).
4. A flow metering station capable of measuring at least 0.14 m$^3$/s (5 cfs) would be constructed to record the volume of water entering the Elie pits.

5. Any new channel construction that had to be carried out to complete the water transfer system from the agricultural drainage system into the pits would be done on municipal property negating the need to purchase right of way.

A review of this conceptual plan indicated that it was feasible. A presentation of this plan was made to the Rural Municipality of Cartier who gave their approval. Plans were then finalized to carry out the necessary construction work. The major points of the conceptual plan developed for the water transfer system are shown in Figure 4.
CHAPTER 4
SUMMARY OF ACTIVITIES

4.1 Water Transfer System Construction

Construction of the water transfer system was carried out during the 1982 field season. This work was supervised by the Engineering and Construction Branch of the Department of Natural Resources. The as constructed plan of the system is shown in Figure 5. A summary of the work follows:

1. A pumping station was established at the La Salle River in order to lift water from the river into the drainage system. This pumping station consisted of a 1.8 m (6 foot) diameter concrete culvert with an intake into the river situated in an earth block in the drain. Electrical service was installed at the pumping station to allow for the use of electric pumps.

2. A 600 mm (24 inch) diameter culvert was cored through PR 248 at the northeast corner of 23-11-3W. This allowed the drain north of 23-11-3W to be joined to the Barickman Coulee Drain which runs north of the Elie gravel pits in section 19-11-2W and eventually to the Assiniboine River.
3. An angle iron frame stop log structure was installed on each of the culverts in the Barickman Coulee Drain at the road crossing in NE-19-11-2W. These stop log structures, when in operation, would allow flow in the Barickman Coulee Drain to be diverted south and west into the Elie gravel pits. By removing the stop logs, water of questionable quality would continue down the drainage system to the Assiniboine River.

4. Approximately 760 m (2500 linear feet) of channel was excavated south from the stop log structures and then west into the gravel pits. This involved the moving of 16,440 m$^3$ (21,500 cubic yards) of material and an excavation depth in the order of 4.6 m (15 feet) at the entrance to the gravel pits.

5. A flow metering station was established in the new channel south of the stop log structure. This consisted of two 254 mm (10 inch) diameter steel pipes buried beneath the channel bottom. An earth block was placed in the channel at this point to ensure that all flow would pass through the buried pipes. Provisions were made so that one of the pipes could be equipped with a flow meter capable of recording both instantaneous and total flow.

4.2 Monitoring Network Installation

In order to further define the aquifer and to establish a monitoring network, a test drilling program was carried out during the 1982 field season. To ensure that continuous formation samples were obtained, a cable tool drilling rig using P.F.R. type clay excavators and a split spoon sampler (Plan M-338, Manitoba Water Resources Branch) were utilized.
A total of seven test holes were drilled in the Elie gravel pit area and permanent observation wells were established at five of the test sites. The locations of these test holes and observation wells are shown in Figure 6. Observation wells 82-1, 82-2, 82-3 and 82-4 were established in the silt, sand and gravel deposit. Observation well 82-5 was established adjacent to well 82-2 in the underlying carbonate bedrock.

The observation wells established in the overburden material were all constructed of 127 mm (5 inch) diameter black iron well casing with 1.5 m (5 feet) of 102 mm (4 inch) diameter stainless steel well screen on the bottom. The well screens are of differing slot sizes depending on the grain size of the material in which the well was completed.

In order to prevent possible contamination of the silt, sand and gravel fresh water aquifer by water from the carbonate bedrock careful construction procedures were followed when installing observation well 82-5. A 203 mm (8 inch) diameter black iron well casing driven into the dense till was stopped 5.7 m (18.8 feet) above the bedrock surface. A 203 mm (8 inch) diameter open hole was drilled through the remaining till until the bedrock surface was encountered. A 127 mm (5 inch) diameter black iron well casing was then seated into the bedrock. The resulting annulus was then filled with cement grout from bedrock surface to ground level. Once the cement had set an open hole was drilled in the bedrock to establish a bedrock well.
In addition to the work carried out in the Elie area under Aquifer Enhancement Investigations, 12 test holes were drilled in the Elie Aquifer area by Mr. F.W. Rendell in 1981 as part of Aquifer Capacity Investigations. At three of these sites permanent observation wells were installed. (Elie 81-4, 81-7, 81-11). Observation well 81-4 is completed in the silt, sand and gravel deposit while wells 81-7 and 81-11 are completed in the underlying carbonate bedrock. The drilling carried out under Aquifer Capacity Investigations was performed by the P.F.R.A. using a cable tool drilling rig and following standard P.F.R.A. drilling techniques. The locations of all observation wells and test holes drilled as part of the Interim Subsidiary Agreement on Drought Proofing are shown in Figure 7.

The monitoring network in and around the Elie gravel pits consisted of eight observation wells. Five observation wells were established in the silt, sand and gravel aquifer and three were established in the carbonate bedrock. All observation wells were equipped with continuous automatic water level recorders. In addition all wells were constructed so that chemical sampling could be readily carried out.

4.3 Water Quality Sampling Program

Prior to an experimental transfer of water from the La Salle River to the Elie gravel pits taking place a meeting was held with N. Brandson, Chief, Environmental Assessment and Review Process at which an outline of the proposed artificial recharge project was presented. Mr. Brandson concluded that an environmental assessment of this project would not be required
provided that a number of criteria were met (Brandson, 1982). One of these criteria was that a recharge water sampling program based on parameters established in discussions between personnel from the Water Resources Branch and the Environmental Management Division be carried out prior to any recharging taking place. The water quality parameters developed in conjunction with Mr. Dennis Brown of the Environmental Management Division involved determination of a large number of chemical constituents some of which could be carried out by the W.M. Ward Provincial Laboratory and others which could only be determined by an outside laboratory. The analyses to be performed by an outside agency involved testing for various agricultural pesticides which were used by farmers in the area.

To obtain the required information a water quality sampling program was instituted in April 1983. Surface water samples were taken from the La Salle River at the pumping station and one mile upstream of the pumping station and from the Marickman Coulee Drain immediately upstream of the stop log structure when water was present in this drainage system.

In addition to the analyses performed by the Provincial Laboratory, Enviro-Test Labs of Edmonton analysed the samples for the following agricultural pesticides:

- TRIALLATE
- DICAMBA
- DICLOFOP METHYL
- TREFLAN
- NCPA
- SUTHION
- BROMOXYNIL

Costs for these latter analyses were in the order of $500.00 per sample. It took two to three weeks for the results to be obtained.
Initial results of the water quality testing indicated the presence in the La Salle River water of certain undesirable chemical constituents (mainly agricultural pesticides). In general, Triallate was detected in all samples taken from the La Salle River. Concentrations ranged from trace amounts to 0.15 μg/L. Treflan was also detected in almost every sample taken from the La Salle River. Concentrations were generally only trace amounts and ranged up to 0.16 μg/L. Minor amounts of all other agricultural pesticides analysed for, with the exception of Bromoxynil, were also detected. In most cases only trace amounts were reported.

In view of the presence of these undesirable chemicals the Environmental Management Division advised that approval to transfer water from the La Salle River to the Elie Aquifer would not be granted for the spring runoff period of 1983.

Subsequently it was decided in consultation with the Environmental Management Division that a sampling program to provide background information on the presence of agricultural pesticides in surface and groundwater would be carried out. The surface water sampling program would consist of a monthly sampling from sites on the La Salle and Assiniboine Rivers. This sampling program would be consistent with that already carried out during the spring runoff period. The groundwater sampling program would consist of a one-time only sampling of the Elie Aquifer consistent with that carried out for surface water. The surface water sampling program was carried out between June 1983 and March, 1984. The one-time groundwater sampling was done in June 1983. In addition it was agreed that a joint effort by personnel from Environment and Water Resources would be made to obtain information on agricultural pesticides in groundwater and the health implications of the
chemicals detected in the La Salle River water.

The results of this sampling program revealed that all samples from both La Salle River sites were found to contain at least trace amounts of Triallate. However, the concentrations detected were almost all only trace amounts with the maximum concentration detected being 0.05 µg/L. In addition, concentrations of Treflan were also detected in the samples taken from the La Salle River at the pumping station; the maximum being 0.24 µg/L. Trace amounts of both MCPA and Diclofop methyl were found in samples from both La Salle River sample locations.

Generally the only agricultural pesticides found in the Assiniboine River were also Triallate and Treflan and these were only detected in trace amounts.

The only agricultural pesticides detected in the groundwater sampling was Treflan. This chemical was found in trace amounts in observation wells 82-3 and 81-4 and the Elie community well.

Prior to the 1984 field season it became apparent that permission to carry out an experimental transfer of water from the La Salle River to the Elie Aquifer would be held in abeyance due to the presence in the recharge water of undesirable agricultural pesticides. No suitable method had been found to treat or remove these chemicals from the source water and concerns were raised over the possible health implications of these chemicals. It also appeared unlikely that a solution to this water quality problem would be forthcoming in the near future. Therefore it was decided that as the Elie artificial recharge project was essentially a research project possible contamination of the aquifer by
introduction of these chemicals into the groundwater system would not be justified and that all activities associated with this project would be discontinued at the end of fiscal 1983.

It is interesting to note that at the time this work was carried out the town of Elie had only a marginal water supply due to the serious water quality deterioration. It was likely that at some not too distant future time a new water source would have to be considered and a decision would have to be made as to whether water possibly containing agricultural pesticides would be taken directly from the La Salle River, which flows through Elie, or recharged into the Elie Aquifer and then taken for municipal supply.

4.4 Summer Rainfall Events

On June 16, 1984 the Elie area received a record amount of precipitation for a 24 hour period. This rainfall has been estimated at 200 mm (7.9 inches). As a result a large volume of water entered the Elie gravel pits. This water was a combination of direct precipitation on the pits and overland runoff from the fields in NE-19-11-2W and the northern portion of SE-19-11-2W. As a result of the construction of the drain south and west from the Barickman Coulee Drain an artificial drainage area was created for the pits. Surface runoff that would normally pond in the surrounding fields or flow to the poorly defined roadside ditches, was now able to enter the newly constructed drain and flow into the pits.
The diversion system, as it was initially planned, did not function. Water flowing down the Barickman Coulee Drain went directly to the Assiniboine River. Any water that entered the Elie pits came off the surrounding fields or as a result of direct precipitation and not from the agricultural drainage system. There was never any intent during this period to divert water into the Elie gravel pits.

On June 18 two staff gauges were installed in the pits to measure the level of the remaining runoff water. At that time the elevation of the water surface was 240.395 m (788.74 feet). Using this elevation and the information from a subsequent survey of the pit area on a 20 m by 20 m grid it was possible to estimate the area of the pits under water on June 16 at 21,914 m² (235,900 square feet). This agreed favorably with the mined out area of the gravel pits taken from aerial photographs (estimated at 29,368 m² (316,000 square feet). Using the calculated depth of water at each of the grid points the total volume of water remaining in the gravel pits on June 18 was calculated to be 18,204 m³ (4,011,000 gallons).

All observation wells in the aquifer showed a response to this recharge event. This can be seen from the hydrographs shown in Figures 8, 9, 10, 11 and 12. The most significant response occurred at observation well 82-2 which recovered 1.87 m (6.14 feet) by June 18, following which it started to decline. This large response was to be expected as well 82-2 is the closest observation point to the gravel pits and formation sampling and aquifer testing had indicated a relatively high transmissivity as compared to other wells. All observation wells had shown a recovery of at least 0.32 m (1.05 feet) by June 18. Well 82-4, which is constructed in very fine silty sand recovered 0.32 m (1.05 feet) while wells 82-1 and 82-3,
which are the most distant from the gravel pits recovered 0.35 m (1.15 feet) and 0.33 m (1.08 feet) respectively. Observation well 81-4 recovered 0.93 m (3.05 feet) by June 18.

It has been estimated from the observation well data that a water level rise of at least 0.30 m (one foot) occurred over an area of approximately 220,179 m² (2,370,000 square feet) by June 18. Assuming a porosity of 0.20 the volume of water taken into storage in the aquifer is 13,420 m³ (2,958,000 gallons). In addition some 18,204 m³ (4,011,000 gallons) of water remained in the pits on that date.

The volume of water taken into storage is a conservative value as water levels at some monitoring stations rose in excess of 0.30 m (one foot).

On June 21, the volume of water remaining in the pits was calculated as 15,870 m³ (3,494,000 gallons). The amount of net evaporation during the period from June 18 to 21 was calculated to be 418 m³ (92,000 gallons). Therefore, 1916 m³ (425,000 gallons) of water infiltrated into the aquifer between June 18 and June 21.

During the early evening of June 21 a second major rainstorm occurred in the Elie area. It is estimated that an additional 89 mm (3.5 inches) of rain fell on June 21. As was the case on June 16 a significant volume of water again entered the Elie pits adding to the volume already present. On June 22 the gauge boards were completely underwater. The amount of extra water added to the pits was therefore at least 0.24 m (.79 feet). This gives an additional volume of approximately 4720 m³ (1,036,000 gallons). Therefore on June 22 there was at least 20,590 m³ (4.5 million gallons) of water in the Elie pits.
By June 25 water levels had declined to approximately the same level as on June 18. It was calculated that 18,133 m$^3$ (4 million gallons) of water were in the pits on this date. During the period June 22 to 25 net evaporation was calculated to be 204 m$^3$ (45,000 gallons). Therefore some 2253 m$^3$ (496,000 gallons) of water infiltrated into the aquifer during this period.

Water levels then continued to decline during the summer months until only a few isolated areas in the pits contained water. It was calculated that on September 26 only 1090 m$^3$ (240,000 gallons) of water remained in the pits.

During the period June 25 to September 26 it was calculated that 17,043 m$^3$ (3,760,000 gallons) of water infiltrated to the aquifer or evaporated. The amount of net evaporation from the Elie gravel pits during this time period was calculated as 3134 m$^3$ (690,000 gallons). Therefore as much as 11,909 m$^3$ (3,070,000 gallons) of water infiltrated into the Elie aquifer during this period.

Based on the above calculations, a conservative estimate of the volume of water that infiltrated into the Elie Aquifer as a result of the June, 1984 rainstorms is 31,498 m$^3$ (6.9 million gallons) which is approximately equal to the yearly consumption for the Town of Elie.

A summary of these calculations is shown in the following table.
<table>
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<th>DATE</th>
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VOLUMES ARE IN m³

As can be seen from the hydrographs of the Elie observation wells (Figures 8 to 12), water levels in all wells recovered significantly due to the recharge caused by the two June rainstorms. The most significant recovery occurred in observation well 82-2, where water levels rose some 2.1 m (6.9 feet). This rise was extremely rapid and was followed by a similarly rapid decline in water levels. This pattern is similar to that shown for spring recharge periods such as 1987. However, the amount of water level rise was approximately 2.5 times as large.

This pattern of rapid water level rise followed by a rapid decline was generally observed in all the other observation wells with the exception of well 82-1. However, in the case of wells 82-3, 82-4 and 81-4 the water level rise was not as great nor was the decline as rapid as for well 82-2. Water levels in well 82-1 were maintained near the peak for approximately four months before starting to decline.
The amount of water level recovery ranged from 2.1 m (6.9 feet) in observation well 82-2 to 0.8 m (2.6 feet) in well 82-1. The average recovery for all five wells was 1.36 m (4.5 feet). Prior to the spring recovery of water levels in 1985 a significant decline in water levels had taken place but water levels were still, on average, some 0.56 m (1.8 feet) above the levels recorded prior to previous spring recoveries. This was particularly evident in the hydrograph of well 81-4 and was further evidence that a significant amount of the water that was recharged in 1984 was still present in the aquifer.

In order to ensure that no accidental flooding of the Elie pits could occur in the future an earth block was placed in the diversion channel upstream from the pit entrance. This block will prevent any runoff from the surrounding fields from entering the pits. A gated culvert was placed through the block to allow the diversion system, at some future date, to be put into use.

It should be noted that, although the flooding of the Elie pits was inadvertent, it did provide evidence that artificial recharge of the Elie Aquifer is both feasible and practical.

4.5 Followup Sampling 1984

Due to the accidental inflow of runoff water to the Elie pits and subsequent recharging of the Elie Aquifer it was felt that undesirable chemicals could possibly have entered the groundwater system. With this in mind it was decided that additional chemical monitoring should be carried out. Sampling was carried out in the same manner as previous samplings with particular attention given to
agricultural pesticides.

Sampling from surface water sources was carried out on a one time only basis. Samples were taken from the previously sampled locations on the La Salle River, two sites Barickman Coulee Drain, Diversion Channel and in the Elie gravel pits. This sampling was carried out on June 26, only a few days after the second major rainfall.

The samples collected from both locations on the La Salle River contained at least trace amounts of all seven agricultural pesticides for which the analysis was done. The highest concentrations recorded were for the chemical Bromoxynil (~1.5 ug/L at the pumping station; 2.4 ug/L one mile upstream). Very minor amounts of the chemicals Treflan, Dicamba and Guthion were detected.

In the sample taken from the Barickman Coulee Drain at the stop log structure Treflan and Guthion were not detected while only a trace amount of Bromoxynil was recorded. Significant concentrations of Diclofop-methyl (3.5 ug/L) and Dicamba (1.9 ug/L) were found.

The sample taken from the diversion channel into the Elie pits showed at least trace amounts of all seven chemicals except for Treflan which was not detected. The highest concentration reported was again for the chemical Bromoxynil at 1.9 ug/L.

Water taken directly from the Elie pits had no detectable Treflan or Guthion and only minor amounts of the other chemicals with the exception of Bromoxynil. The amount of Bromoxynil detected was reported to be 2.0 ug/L.
Because agricultural pesticides had been detected, sampling from groundwater sources was continued over a period of three months with samples taken from observation wells 82-2, 82-4 and 81-4. In addition samples were also taken from the Elie town well and the Elie community well.

Observation well 82-2 was sampled on July 4, 18 and August 1st. On all occasions minor amounts of MCPA were detected. Significant amounts of Bromoxynil were found on all samplings (2.2 ug/L, 2.7 ug/L and 0.7 ug/L respectively).

A trace amount of the chemical Bromoxynil was detected in observation well 81-4 when it was sampled in September and trace amounts of this chemical were detected in the Elie community well on the two occasions it was sampled. In addition a trace amount of MCPA was also detected in the Elie community well. A minor amount of Guthion (.2 ug/L) was detected in the one sampling of the Elie town well.

In addition electrical conductivities were taken at all the observation wells, with particular emphasis placed on well 82-2. A plot of the electrical conductivity versus time for well 82-2 is shown in Figure 13. As expected the influx of fresher water to the aquifer produced a significant decline in conductivity. This situation also occurs every spring when significant melt water recharges the aquifer. During the 1984 recharge event the conductivity of well 82-2 declined to approximately 50 percent of its previous value.
No significant conductivity trends were observed in any of the other observation wells.

Results of this sampling showed that the highest concentrations of agricultural pesticides ever detected in the surface water samples were subsequent to the June 1984 rainfalls. The major chemical detected was Bromoxynil. This was the chemical found in the sample taken directly from the pits. On all three occasions that observation well 82-2 was sampled subsequent to the flooding of the gravel pits Bromoxynil and MCPA were detected. Although only limited groundwater sampling was carried out the information available would appear to indicate that prior to the June 1984 rainstorms the groundwater was free of agricultural pesticides.

A report on chemical sampling was prepared by Manitoba Environmental Workplace Safety and Health summarizing the results of pesticide sampling carried out on the Assiniboine and La Salle Rivers (Williamson, 1984). A number of agricultural pesticides were detected in water from both the Assiniboine and La Salle Rivers.

4.6 Followup Sampling 1985

Due to the presence of certain agricultural pesticides in the groundwater system following the accidental flooding of the Elie pits in June 1984 it was thought that a modified chemical sampling program should be undertaken in 1985. Sampling was concentrated mainly on the groundwater system with five samples taken from observation well 82-2, two samples taken from the old Elie town well and four samples taken from the new Elie town well. (This well was
installed in the Elle gravel pits in 1984 and put into operation in the spring of 1985). In addition four surface water samples were taken from each of the La Salle River and the Elle pits. Sampling was carried out over the period from March 28 to July 31.

On the initial sampling occasion on March 23, 1985 a trace of Bromoxynil was found in observation well B2-2. This chemical was found in water from the new Elle town well when it was initially sampled on April 9. The concentration reported was 0.57 ug/L. The new Elle town well was being pumped to waste on the day of sampling in preparation to being put into service for the town. No other agricultural pesticides were detected in any of the other samples on this occasion and nothing at all was detected in the samples taken in late April, early May.

However, all samples taken on June 13 had concentrations of at least one agricultural pesticide. The results were as follows:

<table>
<thead>
<tr>
<th>Location</th>
<th>Component</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elle B2-2</td>
<td>MCPA - trace</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bromoxynil - 0.12 ug/L</td>
<td></td>
</tr>
<tr>
<td>Elle Town Well</td>
<td>MCPA - 0.43 ug/L</td>
<td></td>
</tr>
<tr>
<td>(NEW)</td>
<td>Diclofop methyl - trace</td>
<td></td>
</tr>
<tr>
<td>Elle Pits</td>
<td>MCPA - 0.43 ug/L</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diclofop methyl - trace</td>
<td></td>
</tr>
<tr>
<td>La Salle River</td>
<td>MCPA - 0.21 ug/L</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bromoxynil - trace</td>
<td></td>
</tr>
</tbody>
</table>

The presence of all these chemicals at that time may be explained by the frequency of precipitation in late May and early June which would tend to transport these chemicals through the groundwater system. Due to the changes made in the water transport system after the accidental flooding any water that may have entered the pits would be as a result of the natural drainage area only.
An additional sampling on July 31 resulted in no agricultural pesticides being detected in any sample.
CHAPTER 5

ACHIEVEMENTS

Although it is unfortunate that environmental constraints have delayed an attempt at artificially recharging the Elie Aquifer, work on this project has produced a number of positive results. These can be summarized as follows:

1. The groundwater recharge following the accidental flooding of the Elie pits during the June 1984 rainstorms has demonstrated that a significant volume of water can be added to storage in the Elie Aquifer in a few days. Consequently there can be no doubt that an artificial recharge project such as the one contemplated for Elie is both feasible and practical.

2. A water transfer system was completed from the La Salie River to the Elie gravel pits. This system will essentially be left in operating condition.

3. A network of wells suitable for chemical and water level monitoring was installed.

4. Benchmark water chemistry information with particular emphasis on agricultural pesticides was collected.
CHAPTER 6
FUTURE CONSIDERATIONS

While the Elie artificial recharge project has been curtailed by environmental considerations, this factor does not necessarily eliminate all artificial recharge projects. It is possible that in the future it may be found that the health effects of the detected agricultural pesticides may not be harmful or that it may be possible to remove these chemicals by treatment thus allowing artificial recharge to be carried out at Elie. In addition artificial recharge projects of the type planned for Elie could possibly be put into operation at other locations. Without investigation it will not be known whether the same water quality constraints that applied at Elie will be present at other sites. It is therefore possible that artificial recharge of the type contemplated at Elie could be carried out at other selected locations.

One method of artificial recharge that should be given serious consideration involves a water transfer from one aquifer to another aquifer. If the water quality in both aquifers is similar there should be no water quality objections to proceeding with this type of artificial recharge. To ensure that the water quality will remain unchanged during the water transfer process a completely closed system would have to be utilized. This type of project would be particularly beneficial in areas where hydraulic barriers exist.
and the volume of water available downgradient of the barrier is limited. This type of project could also be used in conjunction with a pressure relief well system where discharge presently going to waste could be used as recharge at another location where it is needed. Two such pressure relief well systems are presently in operation on the Ross Creek and South Lateral drainage systems.

Areas where this type of project could be considered are:
Selkirk
Oak Hammock
Red River Floodway
Ross Creek Drain
South Lateral Drain

Other activities that are essential for aquifer enhancement involve pesticide monitoring and aquifer rehabilitation projects.

A pesticide monitoring project would involve setting up of a pilot project to monitor the fate of pesticides in groundwater. Aquifers like the Assiniboine Delta aquifer that are likely subject to pollution by infiltration of pesticides should be investigated. In addition an experimental project involving the treatment of water to remove pesticides should also be considered.

Aquifer rehabilitation projects would involve investigating areas where water quality deterioration has occurred and establishing effective remedial measures through experimental work. An example of this type of project is the sealing of the salt water well and resulting water quality rehabilitation in the Forbes Road area of south Winnipeg. This project involved first sealing off the lower salt water portion of a borehole from the freshwater
portion. The fresh water zone, which had suffered a water quality
deterioration due to upward movement of the salt water, was then
pumped in an attempt to restore water quality. These remedial
measures have proved to be very effective. (Render, F.W. 1985).
REFERENCES


## APPENDIX A

### SUMMARY OF EXPENDITURES

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Activity</th>
<th>Expenditure</th>
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<tbody>
<tr>
<td>1982 - 1983</td>
<td>CONSTRUCTION OF WATER TRANSFER SYSTEM.</td>
<td>$101,235.14</td>
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<td></td>
<td>MONITORING NETWORK INSTALLATION.</td>
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<td>1983 - 1984</td>
<td>WATER QUALITY SAMPLING PROGRAM.</td>
<td>$39,252.80</td>
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<td></td>
<td>SITE ACCESS IMPROVEMENTS.</td>
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<td></td>
<td>ELECTRICAL HOOKUPS.</td>
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<td>1984 - 1985</td>
<td>WATER QUALITY SAMPLING PROGRAM.</td>
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<td></td>
<td>DIVERSION SYSTEM MODIFICATIONS.</td>
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<td>1985 - 1986</td>
<td>WATER QUALITY SAMPLING PROGRAM.</td>
<td>$10,726.94</td>
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<tr>
<td></td>
<td>TOTAL EXPENDITURE</td>
<td>$163,513.76</td>
</tr>
</tbody>
</table>
FIGURE 1

WATER USAGE

CONDUCTIVITY

0 1 2 3 4 5 6 7 8
0 1000 2000 3000 4000 5000 6000 7000 8000
MILLIONS OF IMPERIAL GALLONS
ELECT. CONDUCTIVITY (MICROMICROS/cm)


MANITOBA
Natural Resources
Water Resources

ELIE WATER USEAGE
AND CONDUCTIVITY
FIGURE 5

"CANADA-MANITOBA INTERIM SUBSIDARY AGREEMENT ON WATER DEVELOPMENT FOR REGIONAL ECONOMIC EXPANSION AND DROUGHT PROJECTS PROJECT E.J. ADAMS ENHANCEMENT INVESTIGATIONS"

Manitoba Natural Resources Water Resources

WATER TRANSFER SYSTEM
LEGEND

△ TEST HOLE
● OBSERVATION WELL

SECTION 19
TWP. 11 - RGE. 2W

DIVERSION CHANNEL
82-4
82-2
82-5

SILT, SAND AND GRAVEL EXPOSURE

81-1
81-2
81-3
81-4
81-5
81-6
81-7
81-8
81-9
82-3
82-1
83-2
83-1

1/2 MILE WEST
81-12
81-11

FIGURE 7

A CANADIAN-MANITOBA INTERIM SUBSIDARY AGREEMENT ON WATER DEVELOPMENT FOR REGIONAL, ECONOMIC EXPANSION AND Drought PROOFING PROJECT™

PROJECT ZI: AQUIFER ENHANCEMENT INVESTIGATIONS

Manitoba Natural Resources
Water Resources

INTERIM SUBSIDIARY TEST DRILLING