<u>1994 Research Project Abstract</u>
For the period ending June 30, 1995
This project was supported by the MN Future Resources Fund.

TITLE: Quantify Pesticide and Fertilizer Runoff from Golf Courses
PROGRAM MANAGER: John M. Barten
ORGANIZATION: Suburban Hennepin Regional Park District
LEGAL CITATION: M.L. 93 Chapt.172, Sec. 14, Subd. 7(a)
APPROPRIATION AMOUNT: $49,000

STATEMENT OF OBJECTIVES

To monitor surface runoff from golf courses in the Twin Cities Metropolitan Area and assess the impact of the runoff on downstream waterbodies.

RESULTS

A total of 67 rainfall runoff samples were collected from four golf courses in the Twin Cities Metropolitan Area (TCMA) during the ice free season of 1994. The concentrations of nitrogen and phosphorus in the runoff water were higher than for typical urban residential area runoff. However, because rainfall runoff volume at the four courses was only 6 percent of total rainfall, the quantity of nutrients exported from the courses was very low. The mean phosphorus and nitrogen export rates were 0.13 lbs/acre and 1.54 lbs/acre respectively. These export rates were only 10 percent of export rates reported for urban residential areas.

Detectable concentrations of fungicides were observed in 40 of 59 runoff samples, 60 percent of samples. However, the quantity of fungicides leaving the golf courses was very small, 0.00017, 0.00003, and 0.00003 pounds/acre for CHIPCO, DACONIL, and BANNER respectively. Less than 0.2 percent of the fungicides applied to the golf courses was exported with runoff water.

The study indicates that golf course are not a significant source of nutrient loading to adjacent waterbodies. The export rate of phosphorus from golf courses was similar to that from open areas, considered a desirable land use from a water quality perspective. The loading rate to one adjacent lake was found to be between 2.6 and 0.9 percent of the total, despite the golf course representing 16 percent of the lake watershed.

PROJECT RESULTS USE AND DISSEMINATION

The project results have been shared with the Ecological Services Section of the MN DNR at a recent meeting. The DNR will use the data to assist with their review of new golf course construction permits. Preliminary data have also been shared with numerous County Zoning officials in Minnesota as they have been reviewing golf course construction permits. Hennepin Parks is developing an environmentally sensitive lawn care program as part of an adult environmental education program which will use the data. A separate report detailing the project results has been produced, and will be made available to State agencies, golf course superintendents, and other groups involved in golf course review and management. A summarized version of the report will be published in a scientific journal.

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Date of Report: July 1, 1995

LCMR Research Work Program 1993 - Summary

I. Project Title: QUANTIFY PESTICIDE AND FERTILIZER RUNOFF FROM GOLF COURSES

Program Manager: John M. Barten
Agency Affiliation: Suburban Hennepin Regional Park District
Address: 3800 County Road 24
Maple Plain, Minnesota 55359
Phone: (612) 476-4663

A. Legal Citation: M.L. 93 Chpt.172,Sect.14 ,Subd. 7(a)

Total Biennial LCMR Budget: $49,000

Balance: $0

Appropriation Language as drafted 7/27/92: Subd. 7(a). This appropriation is from the future resources fund to the commissioner of the pollution control agency for a contract with suburban Hennepin regional park district for a study of the quantity of pesticides and fertilizer runoff water from golf courses and an assessment of the impact of these contaminants on downstream waterbodies. This appropriation must be matched by $49,000 of nonstate funds.

B. LMIC Compatible Data Language:

C. Status of Match Requirement:
Match Required: $49,000
Funds raised to Date: $73,667

II. Project Summary:

Historically, a wide variety of pesticides and fertilizers have been applied to golf courses in order to maintain high-quality turf on greens and fairways. For instance, over 20 different fungicides are used on courses in Minnesota. Because of this heavy use, golf courses have been implicated as a significant source of water pollution. The location of many golf courses adjacent to waterbodies has exacerbated this problem by making lakes and streams the direct receiving body of golf course runoff. Unfortunately, data regarding actual runoff water quality from golf courses under normal operating conditions is lacking.

The primary goal of this study is to determine the quality of runoff from golf courses under normal operating conditions. Runoff from representative areas of three courses in the Twin Cities Metropolitan Area will be collected with automatic samplers during rainstorm events. Rainfall will be measured with tipping bucket rain gauges at each sample site. The total quantity of runoff water and associated pollutants will be calculated from the monitoring data. The potential impact of the nutrients on downstream waterbodies will be estimated using computer models.

III. Statement of objectives:

A. Monitor surface runoff from golf courses.
B. Assess impact of contaminants on adjacent waterbodies.

IV. Research Objectives

A. Title of Objective: Monitor surface runoff from golf courses

A. Status: Selection of sample sites was completed in late March, 1994. Permission was obtained to establish sample sites on Baker National Golf Course, Meadowbrook Golf Course, Woodhill Country Club, and Minikahda Country Club. Sample site construction began in December of 1993 and was completed in April, 1994. Flow meters and automatic samplers were installed at three sites in April, 1994. However, installation of monitoring equipment at the Minikahda site was delayed until May. Because two sample sites were established at the Minikahda Club, it was necessary to purchase an additional flow meter and automatic sampler. The sampling equipment did not arrive until May.

Sample collection was initiated in April, and three runoff events and one base flow event were sampled as of June 20, 1994. Sample collection continued through November 1, 1994 at all five sites. A total of approximately eleven rainfall runoff events were sampled at each site during the monitoring period. Because of the site characteristics, more samples were collected at the Woodhill and Meadowbrook sites than at Baker National and Minikahda Country Club. Continuous flow records were obtained at all sites. Analytical results from the laboratory have been received for all samples collected prior to October. The remainder of the results are expected shortly.

A contract for the analysis of the golf course water samples was awarded to Interpoll Laboratories, Inc. of Circle Pines, Minnesota on April 7, 1994. The laboratory was selected by competitive bid.

Agreements with the Hennepin Conservation District and the Minnesota Golf Course Superintendents Association for the use of flow meters and automatic samplers were completed in March, 1994. The Hennepin Conservation District supplied two sampling units as an in-kind contribution to the project, and the Golf Course Superintendents Association supplied one unit. Two additional units are being supplied by Hennepin Parks.

The sample equipment was removed from all sites after November 1, 1994. The equipment was removed to prevent damage due to freezing as the weather turned colder.

Problems: Difficulties were experienced with locating sample sites. Golf course operators were reluctant to allow sampling on their course for fear that negative results would force them to change their management practices. As a result, permission to establish sample sites was difficult to obtain, and permission from two courses was revoked wever, four golf courses are currently g sampled.

The Twin Cities Metropolitan area received lower than normal precipitation for the past two months. In addition, dry antecedent moisture conditions at the time of rainstorm events reduced the amount of runoff. As a result, only three rainstorm events produced sufficient runoff to sample.

Some major equipment breakdowns have occurred over the past two months. Two of the ISCO samplers had computer problems which required the replacement of the main programming chip in the units. In addition, the probe cable to one of the FLOWTOTE units was cut by a golf course employee. This cable will also have to be replaced.

A 2.5 inch rainstorm on April 25, 1994 washed away the new sod around the sample site at the Baker National Golf Course. The sod was placed following construction of the sample site.

Problems were encountered at the Minikahda inlet site with debris accumulating on the flow meter probe. The drainage area upstream of the golf course contains approximately 1400 acres of residential area. Debris entering the storm sewer system accumulated on the probe causing a significant amount of drift in the recorded water level. The probe was cleaned three times a week.

A number of runoff events at each site were not sampled due to malfunctions in the automatic sampling equipment. The malfunctions were caused by a variety of factors including lightening strikes, power failures, shorts in the electrical components, leaks in vacuum lines and vandalism.

Progress: Despite the reluctance of some golf course operators, permission has been received to locate sample sites on four golf courses in the Twin Cities metropolitan area. Sample equipment was installed in April and May, and three rainstorm events have been sampled. Analysis of the flow data collected to date is ongoing. Results from the sample analysis is expected shortly from the laboratory.

Samples were collected from approximately eleven rainfall runoff events at each site during 1994. Samples were iced and delivered to the laboratory within 36 hours of collection. Duplicate samples were sent to the laboratory when sample volume was sufficient.

A.1. Activity: Select sample sites and construct and install sampling stations.

A.1.a.Context within the project. The majority of available data on runoff quantity and quality from turf areas was collected from experimental plots with controlled application of fertilizers, pesticides, and rainfall (Spectrum Research, .c. 1990. This objective will collect q ity and quality uata on actual green and fairway runoff fr... golf courses under normal operating conditions.

Data collected through this project will be representative of average golf courses conditions. Study sites will be selected to provide data on runoff from different soil types, slopes, and vegetation patterns.

A.1.b. Methods: Sample sites on three golf courses in the Metropolitan area will be selected by a committee composed of the following organizations: the Minnesota Department of Agriculture, Metropolitan Council, Hennepin Conservation District, Elm Creek Watershed Management Commission, Hennepin County Extension Service, MN Golf Course Superintendents Association, and Hennepin Parks.

Sampling stations equipped with flow meters, automatic samplers, and tipping bucket rain gauges will be installed at each sample site. Runoff data will be collected for one complete frost free season.

A.1.c. Materials: The primary flow measuring devices will be constructed of treated plywood lined with fiberglass resin where necessary. The weirs will be installed using a tractor mounted backhoe. The flow meters and sampling equipment enclosures will be constructed of three eighth inch thick steel plates welded together. The sample equipment enclosures will be mounted on steel posts adjacent to the sample sites.

A.1.d. Budget: $3,950 **Balance:** $0

A.1.e. Timeline:

	7/93	9/93	11/94
Select sampling sites	****		
Construct and install primary flow measuring devices		****	
Install monitoring equipment		****	
Remove monitoring equipment			****

A.2. Activity: Collect and analyze golf course runoff samples

A.2.a. Context within the project: The monitoring program is designed to determine the specific nutrients and pesticides which may be moving off of golf courses into adjacent waterbodies. Measurement of the runoff volume at each sample site will allow the calculation of the quantity of pollutants leaving golf courses. Once this information has been collected, the impact of golf course runoff on waterbodies can be estimated.

A.2.b. Methods: Runoff volume from the three selected sites will be continuously monitored with a computerized flow meter for one operating season (April 94 - October 94). Runoff water samples will be collected with an automatic sampler connected to the flow meter. One composite sample will be collected at each site during a minimum of fifteen rainstorm events.

The water quality analysis will be performed by a certified analytical laboratory selected by competitive bid. An approved quality control/ quality assurance plan from the laboratory must be received prior to entering into a contract.

All water samples will be analyzed for the presence of selected nutrients (nitrogen and phosphorus), pesticides (fungicides), and heavy metals (mercury and cadmium).

Samples will be analyzed only for the fungicides applied during 1993 and 1994 because of the high cost of analysis.

Data analysis of the monitoring results will include calculation of pollutant runoff on a per acre basis. The area of each golf course contributing runoff to each sample site will be measured. The total loading from the entire course will then be calculated.

Records of all fertilizer and pesticide applications during the fall of 1993 and operating season of 1994 will be obtained for each golf course sample site. Total quantities applied and the percent found in runoff water will be calculated.

A.2.c. Materials: Flow level measurements will be taken with ISCO 3220 automatic recorders equipped with pressure transducers. Water samples will be collected with ISCO model 3700 automatic samplers. Rainfall will be collected with Campbell Scientific, Inc. TE525 tipping bucket rain gauges. The automatic flow data recorders will be downloaded to a laptop computer. Additional equipment needed will include coolers, vehicles, pH meter, and a conductivity meter.

A.2.d. Budget: $ 80,000 **Balance:** $0

A.2.e. Timeline:

	3/94	4/94	10/94	3/95
Contract with commercial lab	****			
Sample collection		***************		
Data analysis			**************	

B. Title of Objective: Assess impact of contaminants on adjacent waterbodies.

B. Status: Approximately 71 samples of golf course runoff were collected during the study. The average total phosphorus concentration, soluble phosphorus concentration, total nitrogen concentration, nitrate nitrogen concentration, and total suspended solids concentration were 0.69 mg/l, 0.48 mg/l, 3.41 mg/l, 1.17 mg/l, and 108 mg/l respectively.

These concentrations are higher than runoff from other urban residential or commercial areas. Fungicides were found in approximately 40 percent of all samples collected during the study. The most frequently occurring fungicide, DACONIL, was found in 36 percent of the samples, followed by BANNER in 16 percent, CHIPCO in 5 percent, and 2,4-D in 3 percent of all samples.

Problems: Initial attempts to work with the runoff data were unsuccessful because the existing computer units owned by the Park District have only 386 processing chips in them. The software needed to work with the large data files generated by the flowmeters, require a 486 processing chip to run efficiently. Hennepin Parks is exploring the feasibility purchasing a 486 unit in 1995.

A number of computer problems resulted in significant delays in the analysis of the data. We began working with the golf course data last

Decembe: .nitially we had problems with a lack o .ory and lack of speed of ..e computers. We were able to access al. our data files, but the software ran very slowly, with frequent "insufficient memory" crashes. To correct this problem, we purchased a computer with a Pentium processor.

During the time we were purchasing the computer, ISCO, one of the flow meter manufacturers, released a new version of their data management software. Unfortunately, when we loaded the new software into the new computer we were unable to even open up the data files. Initially, we assumed that there was a problem with the new computer. However, after numerous attempts by our computer support company to open the data files, they determined the problem was with the data diskettes. The new ISCO software inserted some command into the data files which did not allow them to be opened. We attempted to correct the problem by working with ISCO technical support staff in numerous telephone conversations, but were unable to do so. We were, therefore, forced to send the data diskettes to the ISCO company in Lincoln, Nebraska. This entire process caused a two month delay in the data analysis.

Currently the data files have been fixed by ISCO and returned to Hennepin Parks. We are now able to open the files. However, there is one major remaining problem. The Flow data in the field is collected by a probe which converts pressure to a water level measurement. The probes typically have a certain amount of drift, and will record, for example, a water level of 6 inches when the level is actually 5 inches. The drift is corrected by installing a staff gauge at the monitoring stations. Each time the site is visited, the drift is corrected by adjusting the meter to read the same as the staff gauge. During the data collection last summer, the meters were adjusted three to five times per week.

Prior to converting the water levels recorded by the data logger into flow, the readings must be corrected for the probe drift. The ISCO software allows these corrections to be made automatically by specifying the beginning and end periods of the drift, and the magnitude of the correction. The software then proportionately changes all of the readings, in the specified time block, to generate the true water levels. Unfortunately, for unknown reasons, the data files from one of the data loggers will not allow us to make the necessary corrections with either the old or new versions of the ISCO software. Therefore, we will have do make the changes with a spreadsheet program.

Because each one day period contains 120 readings, each of which must be manually adjusted for probe drift, the time necessary to modify the data files in a spreadsheet is significantly longer than in the product software. I am estimating it will take 60 to 80 hours to correct the level readings.

Progress: An extensive amount of data has been accumulated on the runoff quantity and quality at the golf course sites. All runoff quantity data is in computer data file format. The quality data has been entered in a data base program. Data analysis is proceeding, with all flo. a analysis completed for two of the sit Calculation of the amou.. of fertilizers and pesticides applied to . study watersheds is being completed, as well as the amount of applied material being transported off site.

B.1. Activity: The runoff quality data generated by the monitoring phase of the project will be used as input for computer models to estimate the impact of a typical golf course on lake and stream water quality.

B.1.a. Context within the project: Because of the large number of chemicals used on golf courses, they are perceived as being a significant source of nonpoint source pollution. However, because of the lack of runoff data, no analysis of the true impact of golf courses has been done. This objective will estimate the percent of nonpoint source pollution loading which can be attributed to golf courses on a watershed specific basis.

B.1.b. Methods: Data from the three sample sites will be used to calculate an average export value for pollutants found in golf course runoff water. The total pollutant export from a number of golf courses will be calculated and compared to the total export of the watershed in which the course is located. The percent of watershed nonpoint loading which can be attributed to golf courses can then be estimated.

The total nutrient loading data for three watersheds will be input into the Reckhow and Simpson lake quality model. Reducing the total loading by the percent attributed to golf course runoff and examining the change in predicted water quality will allow an estimate of the impact of golf course runoff on water quality.

The impact of golf course runoff on adjacent streams and wetlands will be estimated using the SWMM model. The model will be used to predict pollutant concentrations in the receiving streams. The predicted concentrations will be compared to USEPA and State of Minnesota standards to determine the potential impact of the golf course runoff water.

The P8 and DETPOND models will be used to estimate the effect of best management practices on the quality of runoff from golf courses. Best management practice guidelines for golf course operators will be prepared from the model results.

B.1.c. Materials: Materials to be used for this objective consist of existing computer models, watershed runoff data, and an IBM PC computer owned by Hennepin Parks.

B.1.d. Budget: $14,050

B.1.e. Timeline:

	1/95	3/95	5/95	7/95
Computer modeling	**************			
Prepare draft BMP's		****		
Guideline review by affected stakeholders			****	
Finalize guidelines				****

V. Evaluation: This monitoring program success can be evaluated on the basis of the following criteria:

- Selection of study sites which are representative of average golf course conditions.
- Collection of composite samples from three golf course study sites for a minimum of fifteen rainfall runoff events during the 1994 summer season occurs.
- The criteria described in the Quality Assurance/ Quality Control plan are complied with for the analysis of all samples, resulting in statistically valid data.
- Mean pollutant concentrations in golf course runoff water can calculated with a 90 percent degree of certainty.
- Best management practices which reduce pollutant runoff from golf courses can be developed and implemented.

VI. Context within field: Recent surveys suggest that Minnesota has a higher number of golfers per capita than any other state. The construction of golf courses is an integral part of many new housing developments and Minnesota has an extensive number of existing courses. Unfortunately the impact of existing courses and potential impact of new courses on surface water resources in Minnesota has not been investigated.

Recent work in Wisconsin (Bannerman et. al., 1992) has demonstrated that lawns can be a significant source of nutrients to stormwater. Because fertilizer applications on golf courses are similar to lawns, the potential exists for golf courses to be a source of nutrients to surface waterbodies.

Recent research has also demonstrated that runoff water from urban areas contains a significant number of pesticides (Bannerman, 1992). Because many golf courses are located in urban areas, they are a potential source of some of these pollutants.

VII. Benefits: This study will provide information on the type and quantity of pollutants in golf course runoff water. This information can be used to determine if golf courses negatively impact waterbodies in Minnesota. In order to protect surface water resources from nonpoint source pollution, the magnitude of the potential pollutant sources must be quantified. By collecting runoff directly from golf courses, this study will provide information on this component of watershed runoff.

This study will provide watershed management organizations, soil and water conservation districts, and other local governmental units with the information necessary to determine if golf courses constitute a threat to surface water resources. Watershed management planning will improve as a result of the new information.

The information collected during this study will also help to site new golf courses and improve design to minimize impacts to adjacent waterbodies. The data will al ndicate the need for golf course runoff atment systems and improve golf course management practices.

VIII. Dissemination: Data will be provided to the State STORET computer data system. The Minnesota Golf Course Superintendents are one of the project cooperators and are very interested in the study data. The study results will be distributed to golf course superintendents through their monthly newsletter. Study results will be provided to county extension agencies, soil and water conservation districts, and watershed management organizations statewide. Through the existing nature center programs, Hennepin Parks will provide the project information to the general public.

IX. Time: N/A

X. Cooperation:

1. Paul Wotzka
   Minnesota Department of Agriculture

   Mr Wotzka will represent the MN Department of Agriculture on the interagency committee which will be established to select sample sites, review data, and review BMP selection. The Dept of Agriculture may also do a portion of the laboratory analysis.

2. Joel Settles
   Director
   Hennepin Conservation District

   Mr. settles will represent the Hennepin Conservation District on the interagency advisory committee. The Hennepin Conservation District has also been asked to donate flow monitoring and sampling equipment to the project.

3. Gary Oberts
   Environmental Planner
   Metropolitan Council

   Mr. Oberts will represent the Metropolitan Council on the interagency advisory committee.

4. Fred Moore
   Chairperson
   Elm Creek Watershed management Commission

   Mr. Moore will represent the Elm Creek WMO on the interagency advisory committee. The Elm Creek WMO has committed $2,000 to the project.

5. Gaylon Reetz
   MN Pollution Control Agency

   Mr. Reetz will represent the agency on the interagency advisory committee.

6. ın M. Barten
   Hennepin Parks

   Mr. Barten will serve as the project manager for the study. Twenty five percent of Mr. Barten's time will be allocated to the project during the two year study. One half of his time will be spent on Objective A and one half on Objective B.

7. Pioneer Sarah Creek WMO

   The Pioneer Sarah Creek WMO committed $2,000 in matching funds to the project.

8. Minnehaha Creek Watershed Management District

   The MCWD committed $2,000 in matching funds to the project.

9. Riley-Purgatory Creek Watershed Management District

   The Riley-Purgatory Creek WMO committed $2,000 in matching funds to the project.

10. Lake Minnetonka Conservation District

    The LMCD committed $2,500 in matching funds to the project.

XI. Reporting Requirements: Semiannual status reports will be submitted not later than Jan 1, 1994, July 1, 1994, Jan. 1, 1995 and a final status report by June 30, 1995.

XII. Literature Cited

Bannerman, R.T., Owens,D.W., Dodds, R., and Huges,P.,1992. Sources of pollutants in Wisconsin stormwater. Report for the U.S. Environmental Protection Agency. Grant Number C9995007-01. 24pp.

Barten, J.M. 1991. Baker National Golf Course leachate study: preliminary results. Report prepared for the Minnesota Golf Course Superintendents Association.

Spectrum Research, Inc. 1990. Environmental Issues Related to golf course construction and management: a literature search and review. A final report submitted to the United States Golf Association. 234pp.

Date of Report: ~~September 2, 1992~~
~~December 29, 1992~~
~~May 10, 1993~~
July 1, 1995

LCMR Final Report - Detailed for Peer Review - Research

I. Project Title: QUANTIFY PESTICIDE AND FERTILIZER RUNOFF FROM GOLF COURSES

Program Manager: John M. Barten
Agency Affiliation: Suburban Hennepin Regional Park District
Address: 3800 County Road 24
Maple Plain, Minnesota 55359
Phone: (612) 476-4663

A. Legal Citation: M.L. 93 Chpt.172,Sect.14 ,Subd. 7(a)

Total Biennial LCMR Budget: $49,000

Balance: $0

Appropriation Language as drafted 7/27/92: Subd. 7(a). This appropriation is from the trust fund to the commissioner of the pollution control agency for a contract with suburban Hennepin regional park district for a study of the quantity of pesticides and fertilizer runoff water from golf courses and an assessment of the impact of these contaminants on downstream waterbodies. This appropriation must be matched by $49,000 of nonstate funds.

B. LMIC Compatible Data Language:

C. Status of Match Requirement:
Match Required: $49,000
Funds raised to Date: $49,000

II. Project Summary:

Historically, a wide variety of pesticides and fertilizers have been applied to golf courses in order to maintain high-quality turf on greens and fairways. For instance, over 20 different fungicides are used on courses in Minnesota. Because of this heavy use, golf courses have been implicated as a significant source of water pollution. The location of many golf courses adjacent to waterbodies has exacerbated this problem by making lakes and streams the direct receiving body of golf course runoff. Unfortunately, data regarding actual runoff water quality from golf courses under normal operating conditions is lacking.

The primary goal of this study is to determine the quality of runoff from golf courses under normal operating conditions. Runoff from representative areas of three courses in the Twin Cities Metropolitan Area will be collected with automatic samplers during rainstorm events. Rainfall will be measured with tipping bucket rain gauges at each sample site. The runoff volume occurring during the rainstorms will be measured with automatic flow level recorders. The total quantity of runoff water and associated pollutants will be calculated from the monitoring data. The potential impact of the nutrients on downstream waterbodies will be estimated using computer models.

III. Statement of objectives:

A. Monitor surface runoff from golf courses.

B. Assess impact of contaminants on adjacent waterbodies.

IV. Research Objectives

A. Title of Objective: Monitor surface runoff from golf courses

A. Status: Sample sites were selected on four golf courses, Baker National Golf Course, Woodhill Country Club, Meadowbrook Golf Course and the Minikahda Club in the Twin Cities Metropolitan Area (TCMA), Figure 1. Two of the sites, the Minikahda Club and Meadowbrook Golf Course, were located in highly developed urban areas of Minneapolis and St. Louis Park, respectively, and two of the courses, Baker National and Woodhill Country Club were located in more rural areas. Two of the course were public and two were private.

Five sample sites were established at the four golf courses. Because the Minikahda Club received runoff from a large upstream watershed, a sample site was established both upstream and downstream of the course. All of the sample site watersheds contained some areas which were not golf course turf. The Baker National watershed for example contained approximately 600 feet of a 10 foot wide blacktop cart path. However, the non-turf areas never accounted for more than 3 percent of the study watershed.

A flow meter probe consisting of a pressure transducer level sensor and a velocity sensor was installed at three of the sites. At two of the sites a pressure transducer level sensor was installed. The probes were connected to data loggers housed in steel boxes adjacent to the sample sites. Flow at the sites was calculated by the data logger as the product of the velocity and depth of water in the pipe. Automatic samplers with a stainless steel intake strainer and [illegible]et of teflon intake line were also installed a e sites. The samplers were slaved to the flow rs and set to collect water samples at discrete ..ow intervals during runoff events. The flow meters were also used to trigger the samplers to initiate sample collection. Samples were discharged into a four liter glass container in the sampler.

Each site was visited a minimum of three times weekly to verify proper operation of the flow meters and samplers. Data was retrieved from the data loggers with a laptop computer at least once a week to minimize data loss.

Flow weighted composite samples were collected at each of the sample sites with an automatic sampler. Samples were placed in bottles, iced, and delivered to a laboratory for analysis. Samples were collected immediately after the end of the rainfall runoff flows, and delivered to the laboratory on the day of collection. Duplicate samples and field blanks were provided as a quality assurance check.

Sample analysis was completed by a commercial laboratory selected by competitive bid. Laboratory methods for the analysis of nutrients and herbicides followed EPA approved methodologies. Fungicide analysis was completed with methods developed by the laboratory in cooperation with the fungicide manufacturer. Sample bottles were supplied by the laboratory and contained the appropriate preservative.

Water samples were analyzed for the presence of the following parameters:

PARAMETER	DETECTION LIMITS
Total Phosphorus	0.02 mg/l
Soluble reactive phosphorus	0.02 mg/l
Total Kjeldahl nitrogen	0.05 mg/l
Ammonia nitrogen	0.05 mg/l
Nitrate & nitrite nitrogen	0.01 mg/l
Suspended solids	1.00 mg/l
Total dissolved solids	4.00 mg/l
pH	
Conductivity	
Mercury	0.20 ug/l
Cadmium	4.00 ug/l
2,4-D	2.00 ug/l
Dicamba	2.00 ug/l
MCPP	2.00 ug/l

Because of the large number of fung. .es used on golf courses and the high cost of analysis, it was not considered feasible to measure the concentration of each fungicide for each sample event. Samples were, therefore, analyzed only for specific fungicides applied during the 1994 season. Records from the Baker National Golf Course indicate that in most years only three or four different fungicides are applied to a given course.

Gauges were installed at four sites to measure rainfall occurring during the study. Tipping bucket gauges were installed at the Woodhill Country Club pump building and approximately one half mile southwest of Baker National Golf Course, at a gatehouse site. Total volume gauges were installed at the sample site at the Meadowbrook course and one quarter mile southwest of the Baker National Golf Course site. In addition, data from an existing tipping bucket gauge maintained by the Minneapolis Park Board at the Minikahda Club was obtained for the study. Rainfall data at the Minikahda, Meadowbrook and Baker Gatehouse sites were not available until May of 1994. Only the Baker Park total rainfall gauge was operational in April. Therefore, it was necessary to use the April data from this site for the other courses.

Rainfall was below the 136 year regional average at the four rain gauge sites in May and June of 1994, but above average in at most of the sites during the other months. Rainfall amounts varied widely at the four sample sites, especially in August. The Meadowbrook Golf course recorded 6.7 inches of rainfall while the Baker Gatehouse site received only 2.9 inches. Total rainfall amounts also varied widely for individual events. Overall the Minikahda course received the most rainfall, 27.9 inches and the Baker course received the least, 23.9 inches. The total rainfall at all sites was above the 136 year regional average of 21.33 for the study period.

Flowmeters and automatic samplers were installed at Baker National Golf Course on April 8, 1994, at the Meadowbrook Golf Course on April 11, 1994, and at the Woodhill Country Club on April 14, 1994. Due to a shortage of data loggers which occurred when it became necessary to install two units at one course, samplers were not installed at the Minikahda Club until May 13, 1994, when an additional unit was purchased.

The amount of runoff measured at the four sites varied from 3.3 acre-feet at the Woodhill Country Club to 16.4 acre-feet at the Meadowbrook Golf Course. The difference was due mainly to the different watershed

PARAMETER	MEAN	STD DEV	MEDIAN	RANGE	OBSERVATIONS
TOTAL PHOSPHORUS (mg/l)	0.521	0.566	0.34	0.08 - 3.10	67
SOLUBLE REACTIVE PHOSPHORUS (mg/l)	0.335	0.408	0.22	0.20 - 2.30	67
TOTAL KJELDAHL NITROGEN (mg/l)	3.104	2.101	2.3	0.50 - 8.20	65
AMMONIA NITROGEN (mg/l)	0.724	0.626	0.5	0.08 - 3.00	68
NITRATE AND NITRITE NITROGEN (mg/l)	1.307	1.997	0.68	0.01 - 12.0	68
TOTAL DISSOLVED SOLIDS (mg/l)	426.3	216.5	410	120. - 970	54
TOTAL SUSPENDED SOLIDS (mg/l)	59.7	76.6	32.5	4.00 - 430.0	54
pH	7.162	0.414	7.13	6.17 - 7.96	59
CONDUCTIVITY (umho/cm)	593.4	287.1	608	138. - 1452	54
DACONIL (ug/l)	0.483	1.355	0.00	0.00 - 8.30	59
BANNER (ug/l)	0.579	1.517	0.00	0.00 - 9.00	59
CHIPCO (ug/l)	0.29	1.396	0.00	0.00 - 9.80	59
PENTACHLORONITROBENZENE (ug/l)	0.00	0.00	0.00	0.00 - 0.00	8
2,4-D (ug/l)	0.203	1.562	0.00	0.00 - 12.0	59
MPCC (ug/l)	0.00	0.00	0.00	0.00 - 0.00	59
DICAMBIA (ug/l)	0.00	0.00	0.00	0.00 - 0.00	59
MERCURY (ug/l)	0.348	1.359	0.00	0.00 - 7.50	31
CADMIUM (ug/l)	0.63	1.904	0.00	0.00 - 8.00	27

Table 6. Mean, standard deviation, median, and range of parameters in 67 runoff samples from golf courses in the TCMA, 1994.

sizes and rainfall volumes. The percent of rainfall leaving the courses as runoff was similar at all four sites, 5.8, 7.8, 5.0, and 5.2 at Baker, Meadowbrook, Woodhill, and Minikahda respectively. These values are much lower than those reported by Smith (1995), who found that 42 percent of rainfall water left simulated golf course fairways as runoff. The runoff rates in this study were also much lower than typical urban area coefficients which range from 0.2 to 0.7 for residential and commercial areas. The runoff coefficients found in this study are comparable to those estimated for undeveloped areas. The slightly higher value for the Meadowbrook site is probably due to the high percentage of steep slopes found on the course.

Although base flow did occur at all of the sites during the study period, it was negligible except at the Minikahda Club. The 1168 acre watershed above the course delivered over 564 acre-feet of water to the course, over half during non-rainfall periods. The watershed contains a large wetland complex upstream of the golf course. The wetlands apparently store water and release it after stormwater flows have abated.

The mean, median, range, and standard deviation of the parameters found in 67 runoff water samples are shown on Table 6. As the table shows, there was a wide range in the concentration of most parameters during the study period. For example the total phosphorus concentration ranged from 0.08 mg/l to 3.1 mg/l, and the total Kjeldahl nitrogen concentration ranged from 0.50 mg/l to 8.2 mg/l. The mean concentrations of total phosphorus, soluble reactive phosphorus, total Kjeldahl nitrogen, and nitrate & nitrite nitrogen from the golf course sites were higher than concentrations reported for urban residential or commercial areas (Brach, 1989). However, the concentration of total suspended solids was lower.

The mean concentrations of total phosphorus and soluble reactive phosphorus, 0.52 and 0.34 respectively, were significantly different ($p<0.05$). In addition, the sum of the ammonia nitrogen and the nitrate & nitrite concentrations were significantly less than the total Kjeldahl nitrogen concentration. This suggests that a significant amount of the nutrients leaving the golf courses are in a particulate form. This was unexpected because loss of soil under well established turf is typically very low. However, visual inspection revealed the presence of grass clippings in most of the samples. The majority of the suspended material may be from clippings caused by the frequent mowing of the courses. Management practices which remove them from the runoff stream could reduce the export of nut nts from golf courses.

The mean parameter concentrations at each of the sample sites are shown in Table 7. Differences between the sites for each parameter were determined by ANOVA procedures. Preliminary analysis of the data indicated that although the means were normally distributed, they did not have equal variances. Therefore, ANOVA procedures were performed on the normal log of the concentrations.

For most of the nutrient parameters, the mean concentrations at the Minikahda inlet and outlet sites were significantly lower ($p<0.05$) than at the other sites, and the mean concentrations at the Meadowbrook site were higher (Table 8). The mean total phosphorus concentrations at the Minikahda sites was not significantly different from the Woodhill Country Club. The concentrations of most parameters at Baker National and the Woodhill Country Club were not significantly different.

No significant differences were found for any parameters between the Minikahda inlet and outlet sites, suggesting that the course did not significantly increase nutrient loadings in the stream flow.

Detectable concentrations of at least one fungicide were observed in 40 of 59 runoff water samples. Daconil, the most frequently observed fungicide, was detected in 34 samples. Daconil was also the most frequently applied fungicide. Banner was detected in 14 samples, and Chipco in 4 samples. Both Daconil and Banner were detected in the same sample on 12 occasions, and Daconil and Chipco were both detected in 3 samples. Pentachloronitrobenzene (PCNB) was not detected in any of the samples. Overall, at least one fungicide was found in approximately 60 percent of all samples.

Surprisingly, the Minikahda inlet site had detectable concentrations of either Daconil or Banner in 6 of 10 samples. The source of the fungicide is uncertain. It may originate in the watershed upstream of the course or from a small (less than 5 acre) watershed of the course upstream of the corrugated metal pipe discharge point. The Minikahda outlet site had the lowest frequency of detectable fungicide concentrations, 40 percent. This occurred despite the fact that fungicide application was heaviest on this course. During at least one runoff event, Daconil was detected at the Minikahda inlet site, but not at the outlet site. Presumably, physical and/or biological processes in the drainage ditch or the ponds along the ditch reduced the concentrations of fungicides in the stream flow.

SITE	MEAN (STD DEV)	RANGE	OBSERVATIONS
TOTAL PHOSPHORUS (mg/l)			
BAKER	0.479 (0.248)	0.10 - 1.00	14
MEADOWBROOK	0.892 (0.677)	0.20 - 2.80	18
WOODHILL	0.476 (0.654)	0.08 - 3.10	20
MINIKAHDA IN	0.204 (0.089)	0.10 - 0.37	11
MINIKAHDA OUT	0.177 (0.076)	0.08 - 0.32	15
SOLUBLE REACTIVE PHOSPHORUS (mg/l)			
BAKER	0.273 (0.148)	0.04 - 0.52	14
MEADOWBROOK	0.596 (0.526)	0.10 - 2.30	18
WOODHILL	0.329 (0.444)	0.03 - 2.10	20
MINIKAHDA IN	0.076 (0.064)	0.02 - 0.21	11
MINIKAHDA OUT	0.087 (0.456)	0.02 - 0.20	15
TOTAL KJELDAHL NITROGEN (mg/l)			
BAKER	2.896 (1.952)	0.87 - 6.30	13
MEADOWBROOK	5.813 (1.420)	3.20 - 8.20	16
WOODHILL	2.405 (1.238)	0.50 - 5.50	21
MINIKAHDA IN	1.198 (0.559)	0.59 - 2.60	11
MINIKAHDA OUT	1.373 (0.445)	0.81 - 2.50	15
AMMONIA NITROGEN (mg/l)			
BAKER	0.412 (0.170)	0.20 - 0.73	14
MEADOWBROOK	1.504 (0.734)	0.40 - 3.00	18
WOODHILL	0.528 (0.180)	0.20 - 0.81	22
MINIKAHDA IN	0.271 (0.166)	0.07 - 0.56	10
MINIKAHDA OUT	0.351 (0.269)	0.80 - 1.20	14
NITRATE & NITRITE NITROGEN (mg/l)			
BAKER	0.321 (0.301)	0.01 - 1.10	14
MEADOWBROOK	1.947 (1.642)	0.47 - 7.00	18
WOODHILL	2.149 (2.900)	0.18 - 12.0	21
MINIKAHDA IN	0.321 (0.147)	0.09 - 0.59	11
MINIKAHDA OUT	0.281 (0.164)	0.08 - 0.60	15
TOTAL DISSOLVED SOLIDS (mg/l)			
BAKER	265.8 (150.6)	120 - 500	12
MEADOWBROOK	447.1 (127.5)	200 - 700	14
WOODHILL	573.9 (235.5)	220 - 970	18
MINIKAHDA IN	275.6 (123.7)	130 - 450	9
MINIKAHDA OUT	360.0 (194.2)	140 - 720	11
TOTAL SUSPENDED SOLIDS (mg/l)			
BAKER	69.8 (75.1)	5.0 - 240.0	13
MEADOWBROOK	87.1 (60.0)	9.0 - 210.0	15
WOODHILL	51.5 (103.6)	4.0 - 430.0	16
MINIKAHDA IN	26.4 (46.8)	4.0 - 150.0	9
MINIKAHDA OUT	18.9 (13.4)	7.0 - 44.0	10

Table 7. Mean, standard deviation and range of selected parameters in runoff from individual golf course sites, 1994.

SITE	MEAN (STD DEV)	RANGE	OBSERVATIONS
DACONIL ug/l)			
BAKER	0.234 (0.281)	0.00 - 0.74	11
MEADOWBROOK	0.117 (0.169)	0.00 - 0.55	15
WOODHILL	1.136 (2.258)	0.00 - 8.30	19
MINIKAHDA IN	0.448 (0.761)	0.00 - 2.40	10
MINIKAHDA OUT	0.187 (0.343)	0.00 - 1.10	14
BANNER (ug/l)			
BAKER	0.267 (0.640)	0.00 - 2.00	11
MEADOWBROOK	0.440 (1.086)	0.00 - 4.00	15
WOODHILL	0.737 (1.404)	0.00 - 4.80	19
MINIKAHDA IN	0.850 (2.240)	0.00 - 7.10	10
MINIKAHDA OUT	0.800 (2.432)	0.00 - 9.00	14
CHIPCO (ug/l)			
BAKER	0.373 (1.236)	0.00 - 4.10	11
MEADOWBROOK	0.213 (0.568)	0.00 - 1.80	15
WOODHILL	0.516 (2.248)	0.00 - 9.80	19
MINIKAHDA IN	0.000 (0.000)	0.00 - 0.00	10
MINIKAHDA OUT	0.000 (0.000)	0.00 - 0.00	14
2,4-D (ug/l)			
BAKER	1.091 (3.618)	0.00 - 12.0	11
MEADOWBROOK	0.000 (0.00)	0.00 - 0.00	15
WOODHILL	0.000 (0.00)	0.00 - 0.00	19
MINIKAHDA IN	0.450 (1.423)	0.00 - 4.50	10
MINIKAHDA OUT	0.000 (0.00)	0.00 - 0.00	14
CADMIUM (ug/l)			
BAKER	0.000 (0.00)	0.00 - 0.00	6
MEADOWBROOK	0.500 (1.414)	0.00 - 4.00	8
WOODHILL	1.300 (2.830)	0.00 - 8.00	10
MINIKAHDA IN	0.000 (0.00)	0.00 - 0.00	4
MINIKAHDA OUT	0.000 (0.00)	0.00 - 0.00	3
MERCURY (ug/l)			
BAKER	0.000 (0.00)	0.00 - 0.00	8
MEADOWBROOK	1.020 (3.234)	0.00 - 7.50	10
WOODHILL	0.060 (0.135)	0.00 - 0.40	10
MINIKAHDA IN	0.000 (0.00)	0.00 - 0.00	4
MINIKAHDA OUT	0.000 (0.00)	0.00 - 0.00	3

Table 7 Continued. Mean, standard deviation and range of selected parameters in runoff from individual golf courses, 1994.

The concentrations of the fungicides in the runoff water were low, with a mean of 0.48 ug/l, 0.58 ug/l, and 0.29 ug/l for Daconil, Banner and Chipco respectively, (Table 6). There were no significant differences between the mean fungicide concentration at the different sample sites as determined by ANOVA procedures, ($p<0.05$).

Only one of three herbicides, 2,4-D, was detected in runoff from the golf course sites. The chemical was detected on only one occasion in runoff water from the Baker National Golf Course. However, 2,4-D was also detected in one sample at the Minikahda inlet site. The detection frequency is significant lower than the 67 percent occurrence for 2,4-D in stormwater runoff reported by Bannerman, (1990). The difference may be due to a lower detection level used by Bannerman as compared to this study. Neither MCPP or Dicamba was detected in any of the runoff samples.

Mercury and cadmium were found in 20 and 8 percent of samples respectively. Only two of the sites, Woodhill and Meadowbrook had detectable concentrations of the two metals. The mean concentrations for the two heavy metals were 0.348 ug/l and 0.63 ug/l respectively for mercury and cadmium. Presumably the mercury export is from residue from applications of a fungicide which is no longer in use. Mercury export would be expected to decrease over time since the metal is no longer used on golf courses.

Problems:

Selection of sample sites for the study was initially very problematic. Sites meeting the necessary criteria were difficult to locate, and when found, permission to establish a sampling station was not always possible to obtain. One of the main criteria for sample site selection became the willingness of the course managers to participate in the study. Therefore, although the Minikahda Club required two sample stations to monitor water quality, it was selected for the study because of the willingness of the course managers to cooperate in the project.

As a result of the problems with obtaining permission to install sample sites, the four courses included in the study do not have the full range of soil types and topography found on golf courses in the TCMA. For example, none of the sample sites have the sandy soils typical of the north and south TCMA areas. Topography of the courses is also more uniform than desired. All four courses in the study have some slopes greater than 12 percent, which is not true of all courses in the TCMA. Overall, however, the four golf courses do reflect a range of soils, topography, and management typical of most courses in the area.

A number of problems were experienced with some of the monitoring equipment during the study. The level sensor probe measurements at the Minikahda outlet site had a tendency to drift during June of 1994. The difference between the actual water level and that recorded by the data logger was typically more than one inch. During the analysis of the data the water levels were adjusted assuming that the probe drift was constant over time. The probe was replaced in July when a new one was purchased.

The probe cable at the Minikahda Inlet site was inadvertently cut with a lawn mower, which caused a loss of data for approximately one week in late May. In addition, for significant time periods, the velocity sensor at the Minikahda Inlet site provided negative readings. The cause of the problem was discovered to be the amount of debris and scum which coated the probe. The probe was cleaned at least three times weekly, but within 24 hours of cleaning would provide erroneous readings. However, the level measurements made by the same probe were found to be in agreement with the staff gauge readings on almost all occasions. Therefore, a stage discharge curve was developed from level and velocity readings taken within 12 hours of probe cleaning. The discharge from the equation was in close agreement with the flow from the Minikahda outlet station.

Some data was lost at the Meadowbrook site during the computer downloading of the data logger. The cause of the data loss was not determined. Missing flow values were estimated from a regression equation relating rainfall and runoff for events where data was collected.

A significant time delay in the analysis of data from the Baker site was experienced due to a computer software problem. A new version of the data logger software would not open the data files created during the study. Therefore, it became necessary to send the data diskettes to the manufacturer for correction. This required a number a number of months to facilitate, however, it appeared that all data was saved through the process.

Progress: Completed

A.1. Activity: Select sample sites and construct and install sampling stations.

A.1.a.Context within the project. Data currently available are inadequate to determine if golf courses negatively impact water resources. The majority of available data on runoff quantity and quality from turf areas was collected from experimental plots with controlled application of fertilizers, pesticides, and rainfall (Spectrum Research, Inc. 1990. This objective will collect quantity and quality data on actual green and fairway runoff from golf courses under normal operating conditions. The data will provide information on one component of nonpoint source runoff which has not been adequately studied.

Data collected through this project needs to be representative of average golf courses conditions. Therefore, study sites will be selected to provide data on runoff from different soil types, slopes, and vegetation patterns. A major assumption of this study is that application rates of fertilizers and pesticides will not vary significantly between golf courses. Fertilizer applications are usually based on the type of vegetation grown. Since most golf courses in the Metro area grow similar grass species, the fertilizer application rates while not identical, are similar.

A.1.b. Methods: Sample sites on three golf course in the Metropolitan area will be selected using the following criteria:

- Soil type
- Average land slope
- Vegetation type
- Accessibility
- Suitability for flow measurements
- Land use of the sample site watershed is 100 percent golf course
- Sample site watersheds will be a minimum of 25 acres in size
- Fertilizer and pesticide use will follow normal procedures

The minimum sample site watershed area was estimated using the SCS TR55 hydrologic model. This model suggests that for a 0.5 inch rain fall event, a 25 acre watershed will produce an adequate volume of runoff to sample. Analysis of rainfall data for the Metro area indicates that approximately 20 rainfall events of 0.5 inches or greater occur each year.

A committee with representatives from the Minnesota Department of Agriculture, Metropolitan Council, Hennepin Conservation District, Elm Creek Watershed Management Commission, Hennepin County Extension Service, MN Golf Course Superintendents Association, and Hennepin Parks will be formed to select the sample sites.

Sampling stations will be installed at each sample site. Primary flow measuring devices (v-notch weirs or Parshall flume) will be constructed and installed at the discharge channel of representative sub-watershed areas of three golf courses. Flow meter and sampling equipment enclosures will be installed at each site. A tipping bucket rain gauge will also be installed in an open area of the golf course adjacent to each sample site.

A.1.c. Materials: The primary flow measuring devices will be constructed of treated plywood with a one quarter inch thick by three inch wide metal plate forming the crest of the v-notch weir. The Parshall flumes will be constructed of treated plywood lined with fiberglass resin. The weirs will be installed using a tractor mounted backhoe. The flow meters and sampling equipment enclosures will be constructed of three eighth inch thick steel plates welded together. Access to the equipment will be through a padlocked door. Connector cables from the meter to sampling probes will be enclosed in conduit from the sample enclosure to the stream channel. The sample equipment enclosures will be mounted on steel posts adjacent to the sample sites.

A.1.d. Budget: $3,950

A.1.e. Timeline:	7/93	9/93	11/94
Select sampling sites	****		
Construct and install primary flow measuring devices		****	
Install monitoring equipment		****	
Remove monitoring equipment			****

A.2. Activity: Collect and analyze golf course runoff samples

A.2.a. Context within the project: The monitoring program is designed to determine the specific nutrients and pesticides which may be moving off of golf courses into adjacent waterbodies. Measurement of the runoff volume at each sample site will also allow the calculation of the quantity of pollutants leaving golf courses. Once this information has been collected, the impact of golf course runoff on waterbodies can be estimated.

A.2.b. Methods: Runoff volume from the three selected sites will be continuously monitored for one operating season (April 94 - October 94). The height of flow over a primary measuring device will be measured with a level recorder equipped with a pressure transducer. The flow volume will be calculated from the discharge equation of a 90 degree v-notch weir. The computerized level recorder will be downloaded with a laptop computer biweekly. The level recorder will be calibrated with a staff gauge installed at the same location as the pressure transducer.

Runoff water samples will be collected with an automatic sampler slaved to the flow meter. One composite sample will be collected at each site during a minimum of fifteen rainstorm events. Composite samples will be obtained by programming the flow meter to trigger sample collection each time a predetermined volume of rainfall runoff has passed through the v-notch weir or Parshall flume. The total volume of runoff produced by different rainfall events will be estimated with the TR55 and DETPOND models prior to the sample season. Samples will be removed from the samplers immediately after the completion of the runoff event, put on ice, and transported to the analytical laboratory. Prior to transport to a laboratory the pH and conductivity of the samples will be measured.

The water quality analysis will be performed by a certified analytical laboratory selected by competitive bid. An approved quality control/ quality assurance plan from the laboratory must be received prior to entering into a contract. At a minimum the QA/QC plan must include the following:

- A minimum of one method blank per sample set.
- One duplicate analysis or one matrix spike duplicate at a 10 percent frequency or one per sample set.
- One matrix spike at a 10 percent frequency or one per sample set.
- One known performance evaluation sample or method standard at a frequency of one per sample set.

All water samples will be analyzed for the presence of the following nutrients and pesticides:

PARAMETER	**COST**
Total Phosphorus	$25.00
Soluble reactive phosphorus	$25.00
Total Kjeldahl nitrogen	$20.00
Ammonia nitrogen	$15.00
Nitrate & nitrite nitrogen	$15.00
Suspended solids	$15.00
Total dissolved solids	$15.00
pH	$10.00
Conductivity	$10.00
Mercury	$25.00
Cadmium	$25.00
2,4-D	$100.00

Because of the large number of fungicides used on golf courses and the high cost of analysis, it will not be feasible to measure the concentration of each fungicide for each sample event. Samples will be analyzed only for the compounds applied during the 1993 and 1994 season up to a maximum of ten. Since the primary objective of this study is to determine the quantity of pollutants in golf course runoff, not to determine the runoff rate of individual fungicides, this limitation should not adversely affect the study results. In addition, records from the Baker National Golf Course indicate that in most years only three or four different fungicides are applied to a given course.

The most commonly used fungicides include the following:

Triazole
Thioallophanate ethyl
Thiophanate-methyl
Chloroneb
Propamocarb hydrochloride
Benomyl
Isofenphos
Metalaxyl
Chlorothal
Chlorothalonil
Iprodione
Pentachloronitrobenzene
Fenarimol
Thiram
Anilazine
Xylene

The approximate cost of the fungicide analysis will be $100.00 per sample per parameter.

A field blank will be submitted with the samples from each rainfall event. Duplicate samples for all parameters will be submitted at a 10 percent frequency. In addition, standard solutions of known concentration of the nutrient parameters will be prepared and submitted as runoff samples to check the accuracy of the laboratory.

Data analysis of the monitoring results will include calculation of the following for each parameter and for each parameter for each sample site:

- mean concentration of each parameter
- Median for each parameter
- Variance and standard deviation
- Standard error of the means
- Coefficient of variation
- Coefficient of variation mean

Significant differences between parameter concentrations at the different sample sites will be determined by ANOVA procedures.

The area of each golf course contributing runoff to each sample site will be measured. The mean pollutant concentrations will be used to estimate loading on a per acre basis. The total loading from the entire course will be calculated from these values. The pollutant export will be normalized by comparing the rainfall occurring during the study to the average rainfall in the Metro area.

Records of all fertilizer and pesticide applications during the fall of 1993 and operating season of 1994 will be obtained for each golf course sample site. Total quantities applied and the percent found in runoff water will be estimated from the mean concentrations determined from runoff samples.

A.2.c. Materials: Flow level measurements will be taken with ISCO 3220 automatic recorders equipped with pressure transducers. Staff gauges will be installed at each sample site to verify the accuracy of the level recorders. Water samples will be collected with ISCO model 3700 automatic samplers equipped with teflon and stainless steel intake lines and glass bottles. Rainfall will be collected with Campbell Scientific, Inc. TE525 tipping bucket rain gauges. The automatic flow data recorders will be downloaded to a laptop computer. Raw data will be converted to ASCII files and entered into a Lotus 1,2,3 program. Additional equipment needed will include coolers, vehicles, pH meter, and a conductivity meter.

A.2.d. Budget: $ 80,000

A.2.e. Timeline:	3/94	4/94	10/94	3/95
Contract with commercial lab	****			
Sample collection		***************		
Data analysis			**************	

B. Title of Objective: Assess impact of contaminants on adjacent waterbodies.

B. Status: Export of pollutants from each course was calculated as the product of the total runoff for a given rainfall event and the flow weighted mean concentration of a pollutant for that event. Total export from base flow during the season was calculated as the product of daily flow and the median concentration of base flow events. For non-monitored rainfall events, export was calculated as the product of the total flow and a concentration calculated by a regression equation between concentration and total flow. In addition, total export from non-sampled events was calculated using both the mean and median of the site flow weighted concentrations. There was no significant difference between the export amounts calculated by the various methodologies.

Export of nutrients from the golf courses in 1994 is shown in Table 9. The export rate for nitrogen and phosphorus from three of the sites, Baker, Minikahda, and Woodhill were an order of magnitude less than the reported export rates of 0.94 lbs/ac and 4.8 lbs/acre for urban residential areas (Brach, 1992). The phosphorus and nitrogen export rate for Meadowbrook was approximately 30 percent of the urban residential areas reported by Brach. There appeared to be no relationship between the amount of fertilizer applied to the courses and the export rate. The pollutant export rates from the four courses compare favorably with those reported for open, undeveloped areas (Table 9).

The very low export rates for phosphorus are probably a response to the small amount of this nutrient applied to the four courses. As indicated earlier, application rates were approximately 20 percent of typical urban lawn rates. Discussions with golf course managers indicate that the application rate for fertilizers is determined by soil tests. Only the amount needed by the soil is applied. Conversely, a recent study of 181 urban lawns found that 67 percent have very high phosphorus levels and still receive over 3 pounds annually (Barten, 1994).

Only very minor quantities of fungicides, pesticides, and heavy metals were lost from the golf courses in 1994. As Table 10 shows, no course lost more than 0.004 pounds of any fungicide from the monitored area. On an areal basis, no course lost more than 0.00013 lbs/acre of any fungicide, (Table 10). Fungicide loss as a percent of applied product was also very small, less than 0.5 percent for all of the courses. Surprisingly, the course which had the most fungicide applied to it, the Minikahda Club, had the least amount of chemical movement off of the course.

Because 2,4-D was found in only one sample, the total export of this herbicide was not calculated since the export rate would have had no statistical significance. The total export of mercury and cadmium were very low, 0.00007 and 0.00089 pounds from Woodhill and Meadowbrook respectively.

The study suggests that, when properly managed, golf courses are not a significant source of nutrient loading to adjacent water bodies. For example, Baker National Golf Course contributes an estimated 26 pounds of phosphorus and 96 pounds of nitrogen to Spurzem Lake. The phosphorus loading to Lake Spurzem from the 1270 acre watershed was estimated by the Reckhow-Simpson Model to range from 1,005 to 2,644 pounds per year. The golf course, therefore, contributes between 0.9 and 2.6 percent of the annual loading to the lake, even though the course represents 16 percent of the watershed.

The fact that there were no significant differences between the inflow and outflow nutrient concentrations at the Minikahda Club also indicates that the effect of the course on the receiving water body, Lake Calhoun, were minimal. As is the case with Spurzem Lake, the Minikahda Club represents a significant portion of the watershed, 13 percent, but did not contribute a significant portion of the nutrient load. In fact, nutrient export from the golf courses reflects loading rates from open areas, generally considered the most desirable land use type from a water quality perspective.

The low nutrient export rate from the golf courses can probably be attributed to the management of the courses. The small quantity of rainfall running off of the turf areas was a major factor in the low pollutant export rate. As indicated previously, the runoff rate was lower than found in previous studies of turf area runoff, and much lower than for urban residential areas. This is probably a function of the management practices on the golf courses which promote rainfall infiltration. These practices include regular aeration, buildup of soil organic matter, and maintenance of vigorous turf growth. The second management factor contributing to the low nutrient export rate was the fertilizer application rates which were lower than for most urban lawns. Not only were nutrient application rates much lower than those for typical residential lawns, but the applications of both fertilizers and pesticides were made with calibrated sprayers and applicators. In addition, the report logs indicated that applications in most cases were made by highly trained, full time employees, and timed to reduce movement off of the courses. Despite the low rates of fertilizer applications, turf quality at the golf courses is generally better than for urban lawns.

Although the quantities of fungicides leaving the golf courses were very small, the presence of the chemicals in 60 percent of samples may be of concern. In years

SITE	TOTAL RUNOFF (Ac-Ft)	RUNOFF (%O RAINFALL	TOTAL PHOSPHORUS (LBS)	PHOSPHORUS EXPORT (LBS/ACRE)	TOTAL NITROGEN (LBS)	NITROGEN EXPORT (LBS/ACRE)
BAKER	5.4	0.058	4.1	0.09	22.5	0.48
MEADOWBROOK	16.4	0.078	44.5	0.33	74.4	0.79
WOODHILL	3.3	0.05	3	0.1	18.5	0.6
MINIKAHDA	16.6	0.052	19.4	0.014	587.1	4.28
MEAN		0.060		0.13		1.54
MINIKAHDA IN	548.4	0.208	315.3	0.27	1667.5	1.42
RESIDENTIAL*				0.94		4.8
OPEN*				0.16		0.92

* VALUES FROM BRACH, 1992

Table 9. Total runoff and nutrient export from four golf courses in the TCMA, 1994.

FUNGICIDE	BAKER	MEADOWBROOK	WOODHILL	MINIKAHDA	MEAN
CHIPCO					
APPLIED TO COURSE (LBS)	2.3	16.7	20.55	62.2	25.4
STUDY AREA (ACRES)	47.6	93.7	30.9	137	77.3
TOTAL EXPORTED (LBS)	0.00035	0.002	0.0023	0	0.00116
PERCENT EXPORTED	0.015	0.012	0.011	0	0.0095
EXPORT RATE (LBS/ACRE)	0.00001	0.00002	0.00007	0.00000	0.00003
DACONIL					
APPLIED TO COURSE (LBS)	9.9	13.9	106.8	574.2	176.2
STUDY AREA (ACRES)	47.6	93.7	30.9	137	77.3
TOTAL EXPORTED (LBS)	0.0041	0.0012	0.0041	0.068	0.0194
PERCENT EXPORTED	0.004	0.01	0.004	0.012	0.0075
EXPORT RATE (LBS/ACRE)	0.00001	0.00002	0.00013	0.00050	0.00017
BANNER					
APPLIED TO COURSE (LBS)	0.31	0	6.3	31	9.4
STUDY AREA (ACRES)	47.6	93.7	30.9	137	77.3
TOTAL EXPORTED (LBS)	0.0013	0	0.0039	0	0.0013
PERCENT EXPORTED	0.44	0	0.062	0	0.1255
EXPORT RATE (LBS/ACRE)	0.00003	0.00000	0.00010	0.00000	0.00003

Table 10. Fungicide export from four golf courses in the TCMA, 1994.

with average temperatures, the frequency of application would probably increase, resulting in an increase in the amount of fungicides lost from a course.

One potential management practice which would significantly reduce the amount of pollutants leaving a golf course would be to install detention basins on the course to collect runoff water. Both the DETPOND and PONDSIZ models suggest that phosphorus and nitrogen export could be reduced by approximately 50 percent if detention basins were constructed. The water in the basins could also be used for irrigation. This would in effect, recycle the fungicides and nutrients and could result in almost zero discharge of pollutants from golf courses. The small volumes of runoff water generated by the golf courses appear to make detention basin construction and irrigation from the basins economically feasible.

As previously mentioned, grass particles were present in many of the runoff samples. Presumably, both nutrients and fungicides are attached to the grass particles. On existing courses where basin construction is not possible, pollutant export could be reduced by installing buffer zones of unmowed vegetation adjacent to water resources and major water collection points. The buffer zones would restrict the movement of grass clippings and associated pollutants into the water bodies.

A primary objective of the study was to determine runoff quality from typical golf courses in the TCMA, and every attempt was made to find and monitor typical courses. It is possible, however, that the courses selected for the study are superior relative to the management practices applied to them. If this is a concern to regulatory agencies, additional monitoring will need to be done.

Problems: Computer modeling of the impact of golf course runoff on adjacent water bodies was problematic because of the low volumes of runoff water and low export of nutrients. The inlake quality did not show any significant changes as a result of the golf courses.

Progress: Completed

B.1. Activity: The runoff quality data generated by the monitoring phase of the project will be used as input for computer models to estimate the impact of a typical golf course on lake and stream water quality.

B.1.a. Context within the project: Because of the large number of chemicals used on golf courses, they are perceived as being a significant source of nonpoint source pollution. However, because of the lack of runoff data, no analysis of the true impact of golf courses has been done. This objective will estimate the percent of nonpoint source pollution loading which can be attributed to golf courses on a watershed specific basis.

B.1.b. Methods: Data from the three sample sites will be used to calculate a statistically significant mean export value for pollutants found in golf course runoff water. Pollutant export values will be calculated on a per acre basis allowing the estimation of loadings from golf courses depending on the course size. The total pollutant export from a number of golf courses will be calculated and compared to the total export of the watershed in which the course is located. The percent of watershed nonpoint loading which can be attributed to golf courses can then be estimated.

The total nutrient loading data for three watersheds will be input into the Reckhow and Simpson lake quality model. The model will be calibrated by selecting watershed systems for which lake quality and nutrient loading data exists. This data is available from the Metropolitan Council, Hennepin Parks, the Pollution Control Agency, and Watershed Management Organizations. Reducing the total loading by the percent attributed to golf course runoff and examining the change in predicted water quality will allow an estimate of the impact of golf course runoff on water quality.

The impact of golf course runoff on adjacent streams and wetlands will be estimated using the SWMM model. The model will be used to predict pollutant concentrations in the receiving streams. The predicted concentrations will be compared to USEPA and State of Minnesota standards to determine the potential impact of the golf course runoff water.

The P8 and DETPOND models will be used to estimate the effect of best management practices on the quality of runoff from golf courses. Best management practice guidelines for golf course operators will be prepared from the model results.

B.1.c. Materials: Materials to be used for this objective consist of existing computer models, watershed runoff data, and an IBM PC computer owned by Hennepin Parks.

B.1.d. Budget: $14,050

B.1.e. Timeline:

	1/95	3/95	5/95	7/95
Computer modeling	**************			
Prepare draft BMP's		****		
Guideline review by affected stakeholders			****	
Finalize guidelines				****

V. Evaluation: This monitoring program success can be evaluated on the basis of the following criteria:

- Selection of study sites which are representative of average golf course conditions.
- Collection of composite samples from three golf course study sites for a minimum of fifteen rainfall runoff events during the 1994 summer season occurs.
- The criteria described in the Quality Assurance/ Quality Control plan are complied with for the analysis of all samples, resulting in statistically valid data.
- Mean pollutant concentrations in golf course runoff water can calculated with a 90 percent degree of certainty.
- Best management practices which reduce pollutant runoff from golf courses can be developed and implemented.

VI. Context within field: Surveys suggest that Minnesota has a higher number of golfers per capita than any other state. The construction of golf courses is an integral part of many new housing developments and Minnesota has an extensive number of existing courses. Unfortunately the impact of existing courses and potential impact of new courses on surface water resources in Minnesota has not been investigated.

To date, the majority of information on golf course runoff quality has been interpolated from studies focusing on turf areas in general (Spectrum Research, Inc.,1990). These studies suggest that fertilizer and pesticide runoff from turf areas is minimal. However, the majority of the information was collected from experimental plots with controlled applications of fertilizers, pesticides, and often rainfall. Data on the quantity and quality of runoff water from golf courses under normal operating conditions is lacking. As a result, the perception that golf courses are a significant pollutant source persists.

Recent work in Wisconsin (Bannerman et. al., 1992) has demonstrated that lawns can be a significant source of nutrients to stormwater. Because fertilizer applications on golf courses are similar to lawns, the potential exists for golf courses to be a source of nutrients to surface waterbodies.

Preliminary data from an ongoing study suggests that leachate water from a golf course green can carry significant concentrations of dissolved nutrients (Barten, unpublished). However, the same study indicated that only six percent of rainfall on a green percolated downward, carrying only minor quantities of pollutants. The majority occurred as runoff, suggesting that pollutant transport by surface runoff water may be a concern.

Recent research has also demonstrated that runoff water from urban areas contains a significant number of pesticides (Bannerman, 1992). Because many golf courses are located in urban areas, they are a potential source of some of these pollutants. However, as previously indicated, actual data on golf course runoff quality is lacking.

VII. Benefits: This study will provide information on the type and quantity of pollutants in golf course runoff water. This information can be used to estimate the impact of golf courses on waterbodies in Minnesota. In order to protect surface water resources from nonpoint source pollution, the magnitude of the potential pollutant sources must be quantified. By collecting runoff directly from golf courses, this study will provide information on this component of watershed runoff.

This study will provide watershed management organizations, soil and water conservation districts, and other local governmental units with the information necessary to determine if golf course runoff constitutes a threat to water resources. Watershed management planning will improve as a result of the new information.

The information collected during this study will also help to site new golf courses and improve design to minimize impacts to adjacent waterbodies. The data will indicate the need for golf course runoff treatment systems and improve golf course management practices.

VIII. Dissemination: Data will be provided to the State STORET computer data system. The Minnesota Golf Course Superintendents are one of the project cooperators and are very interested in the study data. The study results will be distributed to golf course superintendents through their monthly newsletter. Study results will be provided to county extension agencies, soil and water conservation districts, and watershed management organizations statewide. Through the existing nature center programs, Hennepin Parks will provide the project information to the general public.

IX. Time: N/A

X. Cooperation:

1. Paul Wotzka
   Minnesota Department of Agriculture

   Mr Wotzka will represent the MN Department of Agriculture on the interagency committee which will be established to select sample sites, review data, and review BMP selection. The Dept of Agriculture may also do a portion of the laboratory analysis.

2. Joel Settles
Director
Hennepin Conservation District

Mr. settles will represent the Hennepin Conservation District on the interagency advisory committee. The Hennepin Conservation District has also been asked to donate flow monitoring and sampling equipment to the project.

3. Gary Oberts
Environmental Planner
Metropolitan Council

Mr. Oberts will represent the Metropolitan Council on the interagency advisory committee.

4. Fred Moore
Chairperson
Elm Creek Watershed management Commission

Mr. Moore will represent the Elm Creek WMO on the interagency advisory committee.

5. Gaylon Reetz
MN Pollution Control Agency

Mr. Reetz will represent the agency on the interagency advisory committee.

5. Greg Hubbard
Minnesota Golf Course Superintendents Association

Mr. Hubbard will represent the MGCSA on the interagency advisory committee. The MGCSA is considering a request to provide matching funds for the study as well as a request to donate sampling equipment to the project.

6. John M. Barten
Hennepin Parks

Mr. Barten will serve as the project manager for the study. Twenty five percent of Mr. Barten's time will be allocated to the project during the two year study. One half of his time will be spent on Objective A and one half on Objective B.

XI. Reporting Requirements: Semiannual status reports will be submitted not later than Jan 1, 1994, July 1, 1994, Jan. 1, 1995 and a final status report by June 30, 1995.

XII. Literature Cited

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Barten, J.M. 1991. Baker National Golf Course leachate study: preliminary results. Report prepared for the Minnesota Golf Course Superintendents Association.

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