PILOT WATERSHED STUDY

SOIL AND WATER ENVIRONMENTAL ENHANCEMENT PROGRAM

REPORT #8: EXECUTIVE SUMMARY

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1.0 INTRODUCTION

1.1 Background

The Soil and Water Environmental Enhancement Program (SWEEP) was initiated in 1986 with an overall mandate to:

- reduce Ontario's Non-Point Source (NPS) loadings of phosphorus to Lake Erie from agricultural sources by 200 tonnes; and
- maintain or improve the productivity of the primary agricultural sector in Southwestern Ontario by reducing or correcting soil erosion and degradation.

The Pilot Watershed Study (PWS) is a major SWEEP sub-program aimed at evaluating and demonstrating the benefits of established conservation farming systems at the watershed and smaller scales. Figure 1.1 shows the overall SWEEP organizational structure and the PWS sub-program relationship to the Program. Cooperating agencies; Environment Canada (EC), Agriculture Canada (AC), and the Ontario Ministry of the Environment (MOE) are identified. Beak Consultants Limited (BEAK) is the prime contractor responsible to AC and MOE. Ecologistics Limited (ECOLOGISTICS) is a sub-contractor to BEAK responsible for site selection and the agronomic program of the PWS.

The PWS started in 1987 with detailed study design, staffing, training, cooperator enlistment, and watershed selection. Farm plans were initiated in August, 1988 and environmental monitoring began later the same year.

Monitoring and evaluation were conducted from late 1988 until mid 1992.

Figure 1.2 shows the location of PWS subject areas within the Lake Erie Watershed. These are situated within different yet common agricultural and physical settings.

The PWS has the following key features:

- four year implementation and monitoring period;
- **test** (conservation oriented systems) and control (conventional systems) paired watershed design;
- pro-active agronomic management involving annual farm planning, cooperator compensation program, ongoing producer extension program, availability of conservation-type farm implements, detailed cooperator record keeping, crop scouting and productivity analysis, and farm level socio-economic evaluation;
- intensive and continuous environmental monitoring at plot, field and watershed scales;
- detailed soil survey and soil quality monitoring;
- extensive environmental monitoring program including meteorology, hydrology and water quality; and
- detailed evaluation involving the application of two modelling systems for farm planning and systems evaluation.

The paired watershed study design is a unique approach which relies upon direct comparisons between the **test** and **control** areas as the primary method of environmental and agronomic evaluation. The effects of scale, at whole watershed, farm, field and plot scales are also a fundamental aspect of the study design which systematically addresses the relationship between producer attitudes and adoption as well as between measurable benefits, complexity, and scale.

1.2 Objectives of the Pilot Watershed Study

Objective Regarding Study/Approach

To achieve a high level of adoption of the most appropriate soil and water conservation practices among farm operators utilizing lands in the **test** sub-watersheds.

Objective Regarding Effectiveness

To determine the nature and degree of changes in relevant soil and water quality parameters and crop yields as influenced by "basin-wide" soil and water conservation practices.

Objective Regarding Information Dissemination

To prepare information about sub-program activities and results and to transmit this to participating farmers and other related SWEEP sub-programs.

1.3 Report Structure

The overall PWS reporting has been sub-divided into the following categories:

- Report #1, Study Area Selection, Description and Climate;
- Report #2, Implementation of Conservation Systems;
- Report #3, Evaluation of Conservation Systems, Social Factors;
- Report #4, Evaluation of Conservation Systems, Soils and Crops;
- Report #5, Evaluation of Conservation Systems, Hydrology;
- Report #6, Evaluation of Conservation Systems, Water Quality;
- Report #7, Modelling; and
- Report #8, Executive Summary

Each report is a stand alone document including a summary, descriptions of objectives, methodologies, observations, discussion, and summarized listings of relevant data where applicable. The Executive Summary is a compilation of summaries with emphasis on conclusions and recommendations extracted from the seven technical reports.

2.0 STUDY AREA SELECTION, DESCRIPTION AND CLIMATE

2.1 Objectives

The objectives of the study components documented in this report were as follows:

- select three matched pairs of agricultural watersheds in the Lake Erie drainage basin suitable for conversion to conservation farming systems;
- compile physical and social information on these watersheds to allow for agronomic and environmental analysis; and
- monitor meteorology as a primary causative factor in crop performance and erosion - transport processes.

2.2 Climate

Installations

The three pairs of sub-watersheds were monitored in a similar manner. Each pair of sub-watersheds had one main weather station located in one of the sub-watersheds. The main station included automatic instrumentation for monitoring the following parameters at indicated frequencies:

- rate of rain or snow (15 minutes);
- wind speed (5 minutes);
- air temperature (15 minutes);
- solar radiation (15 minutes);
- potential evaporation (daily); and
- volume of rain (daily).

In addition to the main stations, each test sub-watershed outlet had secondary meteorological stations where the following measurements and measurement frequencies occurred:

- rate of rain (hourly);
- air temperature (hourly);
- water temperature (hourly);
- soil temperature at 3 depths (hourly); and
- relative humidity (hourly) at Kettle Creek only.

In addition to these two stations, each pair of sub-watersheds had a set of three or four standard rain gauges spatially distributed to address the heterogeneity of precipitation.

All instruments functioned, with minor upsets, over the period January 1989 to June 1992.

Temperature

In general, all study areas experienced a cooler then normal 1989 and warmer than normal temperatures in 1990 and 1991. Most winter periods were warmer than normal resulting in frequent winter rains and minimum snowpack. Growing season air temperatures did not differ from the normal values significantly. In all, air temperatures were within 1ºC of normals in all areas on an annual basis.

Temperature data were used to calculate Corn Heat Units (CHU) for all sub-watersheds. CHU were found to be below average in all study areas in 1989 and 1990 while 1991 values marginally exceeded the normals. Essex displayed the highest corn heat units, followed by Kettle Creek and then Pittock in all years. This was also the order of recorded total solar radiation, discussed below.

Soil temperatures at depths of 5, 50 and 150 cm were reported for each sub-watershed and compared to air temperature. The shallow 5 cm temperature probe was shown to clearly relate to air temperature as expected with a typical annual range encompassing 26 to 27ºC. The deepest probe was below the frost line and displayed a typical annual range covering approximately 10ºC.

Precipitation

Similar total precipitation trends were evident in each of the study areas. All areas had much lower than normal annual precipitation in 1989, 1991 and the first six months of 1992. All study areas had higher than normal precipitation in 1990.

In general, winter precipitation was lower than normal while growing season totals were near normal. In conjunction with warmer than normal temperatures, winter periods were generally characterized by minimal snow cover and frequent mid-winter thaws. This fact has implications in terms of winter erosion potential and spring runoff volumes discussed in Reports #5 and #6.

Significant differences were noted on a storm-by-storm basis and in the long term between study areas and between single event rain volume measured at different locations within the same study area.

Extreme hourly and daily precipitation is reported for the study period. Maximum hourly and daily precipitation were 66.5 mm/hr and 95.6 mm/day, both in Kettle Creek.

The total number of significant precipitation events, exceeding 60 mm/day was one in each study area. The number of precipitation events exceeding 40 mm/day was 12 in total. The frequency of extreme high precipitation events and associated erosion-runoff events was low during the course of this study.

Wind

Wind speeds recorded during the study were slightly below normal in all areas. Wind speed affects the rate of potential evaporation and snowmelt. The lower than normal wind speeds have not likely been a significant factor in the study results.

Solar Radiation

Solar radiation has direct affects in terms of crop productivity, potential evaporation and rate of snowmelt.

Essex received the most solar radiation through the study period, Kettle Creek received the second most and Pittock receiving the least. This trend corresponds with differences in latitude and is expected. Total solar radiation received was near normal in all areas.

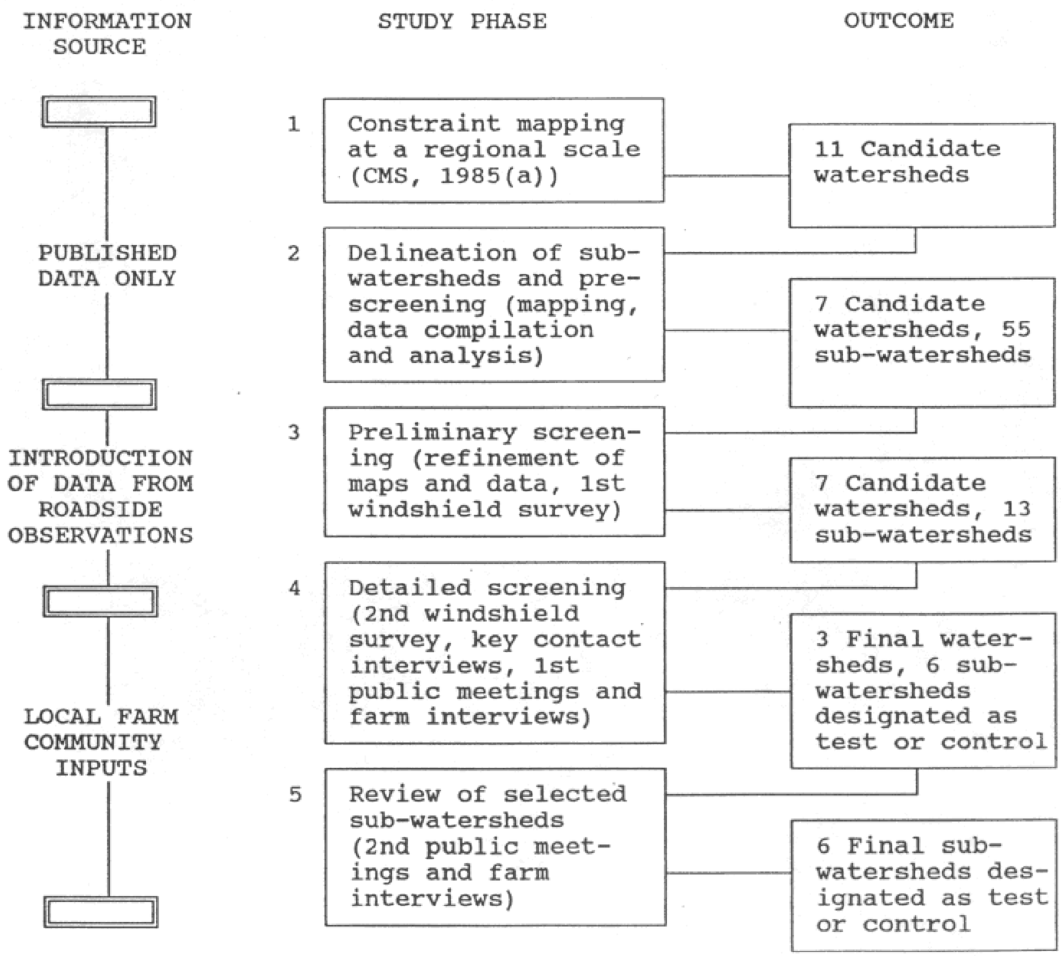
2.3 Watershed Selection

2.3.1 Methodology

The Pilot Watershed Study was designed to be conducted in the Lake Erie watershed within small sub-watersheds. The sub-watersheds were to be approximately 400 ha in size and representative of broader physiographic units. Agriculture within these sub-watersheds was to be carried out on a commercial scale and typify the predominant crops and livestock systems found in Southwestern Ontario. It was particularly important that the selected sub-watersheds be representative of the landscapes that were contributing phosphorus to Lake Erie.

The five phases of the basin selection screening exercise are presented in Figure 2.1. Figure 2.1 illustrates the progression from a general to a more detailed analysis as the focus moved from large candidate watershed areas to specific sub-watersheds. Along the

FIGURE 2.1: APPROACH TO THE SELECTION OF PILOT SUB-WATERSHEDS



way, selection criteria and exclusionary factors were applied. Initially these were based primarily on physical attributes that were readily evaluated with published information applied at a smaller scale.

Each subsequent phase introduced a greater level of detail and expanded the range of criteria from the strictly physical watershed criteria to encompass socio-economic factors that had a bearing on the final selection. The mapping analysis was completed at a larger scale and the data inputs were drawn increasingly from primary data collection efforts. The final phase focused entirely on farm operator characteristics and relied, for these, on inputs from the local farm communities.

By the end of April, 1988 the watershed and the sub-watershed designations had been finalized. The final selections were:

WATERSHED	TEST	CONTROL
Essex	5th Concession drain	2nd Concession drain
Kettle Creek	Madter drain	Holtby drain
Pittock	Webber drain	Goring drain

2.3.2 Conclusions

The virtue of the basin selection approach was that it eliminated most of the unsuitable watershed and sub-watershed areas at an early stage before detailed and costly data collection efforts were initiated. Sub-watersheds that were carried into the final screening phases generally satisfied the physical criteria and further distinctions among them could be made based on farm operator attributes.

It was not enough to assure physical homogeneity across the control and test study areas as would be required under a typical experimental situation. The human dimension was of paramount importance, for without the cooperation of farm operators in each study are the PWS would not be feasible.

The screening process had to locate paired sub-watersheds that exhibited physical similarity, that were representative of major agricultural regions in Southwestern Ontario and that were farmed by individuals who, for the most part, were likely to cooperate with the study team. These demanding requirements necessitated an innovative methodology that enabled the screening of a very large number of candidate areas while still allowing for a degree of site specific investigation that would enable an assessment of local farm communities. The phased approach to screening fulfilled these requirements while making best use of available study resources.

The three selected Pilot Watershed Study areas represented typical farming communities in Southwestern Ontario. Cash cropping and livestock operations predominated. Interest in the Study was high in all areas, with only two out of 78 farmers declining to participate in any way. Similar numbers of farmers operated in each area and the majority of farms were larger commercial operations. Cultural practices were conventional, though experimentation with conservation practices had occurred in all the sub-watersheds.

From a socio-economic perspective, the three pairs of sub-watershed fulfilled project requirements in that they contained commercial farm operators who were familiar with conservation issues, but were generally committed to conventional farming methods at the time of the selection. This enabled a more critical examination of a pro-active approach to encourage the use of soil conservation practices.

From a physical standpoint, the sub-watersheds are considered to be as closely paired as could be expected given the various constraints and objectives that were in effect during the selection process. Differences among sub-watershed paris in shape, size and soils caused somewhat similar hydrologic responses. These differences necessitated a more critical approach in the analysis of monitoring data and encouraged greater reliance on field scale investigations and modelling analysis to help interpret monitoring results from the watershed outlets.

3.0 IMPLEMENTATION OF CONSERVATION SYSTEMS

3.1 Introduction

The mandate of the Soil and Water Environmental Enhancement Program (SWEEP) was to reduce phosphorus loadings to the Lake Erie basin and to maintain or improve agricultural productivity by reducing or correcting soil erosion and degradation. Conservation cropping and tillage systems were identified as the best means to achieve these goals over such a wide geographic region as the Lake Erie watershed. The Pilot Watershed Study (PWS) was developed as a means of evaluating the impact of conservation systems on soil erosion and degradation, water quality and crop production when implemented on a watershed basis.

The development and successful implementation of integrated phosphorus and soil management strategies in agricultural areas is a complex undertaking. Because climate and geology are not manageable parameters in most instances, management of nutrient export and soil erosion in the agricultural environment tends to focus on the structural and non-structural erosion control practices which can be implemented by individual farmers. The potential to reduce nutrient runoff, soil erosion and degradation, as well as factors including ease of implementation, farm community acceptance, agricultural productivity and agricultural cost must all be considered in developing workable control options.

3.2 Objectives

The components of the study documented in this report relate to the following objectives and strategies developed by the study contractors in keeping with the general objectives of the project.

- To achieve a high level of adoption of the most appropriate soil and water conservation practices among farm operators utilizing lands in the test watersheds.

  Strategy: Develop and utilize improved soil and water conservation planning tools for application at the farm and watershed levels.

  Develop and utilize contract arrangements with cooperating farm operators which specify and compensate for participation in the project without "buying" their participation.

- To determine the nature and degree of changes in relevant soil and water quality parameters and crop yields as influenced by "basin-wide" soil and water practices.

  Strategy: Develop and apply mechanisms to encourage adoption of soil and water conservation practices throughout the life of the project in the test watersheds and to discourage adoption in the control watersheds.

  Evaluate improvements to planning tools (models) achieved during the sub-program.

  Evaluate factors that affect the adoption of soil and water conservation practices and that influence farmer attitudes towards both the practices and the goals of the sub-program.

- To prepare information about the sub-program activities and results and to transmit this to participating farmers and other related SWEEP sub-programs.

  Strategy: Collect and transmit, as required, to the SWEEP sub-program contractor responsible for the farm-level and basin-wide economic analysis.

Prepare information on activities and results for the communications sub-program contractor.

Prepare periodic reports to cooperating farmers on activities and results in written and meeting formats.

3.3 Methodology

To achieve the objectives of the PWS it was evident from the outset that a high degree of interaction between the project proponents and the landowners/farm managers operating within the targeted watersheds was required. Because the project proposed the adoption of conservation practices within the test watersheds a teaching or extension approach was necessary to first increase awareness and identification of the problems and then to encourage the successful adoption of suitable solutions. The strategy used to implement the study was guided by the proactive nature of the PWS and was formulated on the basis of an adoption incentive package and a recognition of the human dimensions to providing technical support in any extension program.

The provision of incentives and technical support was designed to:

- lessen the risk or perceived risk associated with new management practices:
- encourage cooperators to be as open as possible to a variety of new practices which were consistent with their own conservation objectives and farm management systems; and
- compensate for project-related learning, inconveniences, and potential out-of-pocket costs.

A conscious effort was made to ensure that incentives to participate in the study were provided to both test and control cooperators and that these incentives did not distort the basic economic motivations that govern farm operations by "buying" participation.

As a result the implementation of the PWS was achieved by providing the cooperators with access to:

- information;
- experience;
- conservation equipment; and
- financial assistance.

3.4 Conclusions

- The approach and process used during the implementation phase of the PWS was appropriate. Results indicate that study objectives were met.

Information and Education

- The project newsletter was critical to keeping all cooperators and other interested parties informed about the project on a regular basis. Survey results indicated that all cooperators read the newsletter at least sometimes with a majority reading it always.
- The provision of printed material about conservation practices and issues from a variety of sources increased the interest of cooperators and advanced the adoption process. Provision of a one year subscription to the magazine *Successful Farming* caused many favourable remarks from the cooperators and resulted in renewed subscriptions paid by the farmers themselves.
- A responsive technical support system was important to maintaining cooperator interest in adopting conservation practices.

- Meetings, workshops and tours were very important educational tools in the PWS. When asked for input producers indicated a preference for tours to see solutions in practice and meetings with a specific management theme using recognized speakers. During and following the above an increased enthusiasm and interest in conservation practices was often observed amongst the attending cooperators.

- Social functions incorporated in the PWS were useful but not critical to building a working relationship between project staff and cooperators. Socializing between project staff and cooperators occurred during meetings, workshops and especially tours. Although the aim of the social functions that were organized early in the PWS was to foster a family and community involvement in the project the absence of these appeared not to be missed during the latter stages of the study in two of the three pairs of watersheds.

- Community interest increased as the project proceeded. Study staff and cooperators were asked to give presentations and host visitors.

Benefits Package

- See PWS report Evaluation of Conservation Systems: Cooperator Attitude Change.

- In the PWS, as a proactive, targeted project where results were required within a relatively short adoption timeframe, an incentives component including access to information, experience, specialized equipment and financial assistance was required.

  Without the above tools to encourage immediate cooperator participation in the PWS project staff felt that several more years would have been required to achieve the objectives of the project.

- The objectives and timeframe of the project influenced the allocation of resources between and within the different incentives.

  For example achieving a change in crop rotation patterns was not feasible within the PWS and was therefore not emphasized. Significant resources were allocated to providing a complete technical support service to cooperators in order to reduce potential short term adoption risks. In a longer term project the emphasis on these and other items in the incentive component would shift.

- Having completed the implementation phase of the original study, the allocation of resources was appropriate to meet the objectives.

  Comments provided by the cooperators and project staff indicated a general satisfaction with the benefits package. (See also PWS report Evaluation of Conservation Systems: Cooperator Attitude Change.)

Cooperator Agreements and Compensation Payments

- The agreement and compensation schedule used in the PWS were appropriate for the purposes they were intended to serve. The initial content and format of the agreement, amendments and compensation schedule changed very little throughout the PWS and few problems arose between the cooperators and the study.

- When compared to the cooperator commitment created through the project implementation process the agreement was much less useful in this regard. The agreement did serve to involve spouses and offset liability concerns.

Conservation Farm Planning

- Using a conservation farm planning approach which considered both on-site (farm level) and off-site (watershed level) erosion and sedimentation impacts was a unique feature of the approach used in the PWS.

- GAMES, through its use of the USLE, could model sheet and rill erosion losses only. Modelling gully erosion was not possible with GAMES. Neither was it capable of modelling erosion by tillage displacement of soil, which research in Ontario has shown to be a significant factor in affecting soil productivity.

  This weakness in GAMES was overcome somewhat by making crude assumptions in the effectiveness of a structure and adjusting sediment delivery pathways to reflect this assumption. For example, terraces were assumed to be 100 percent effective in settling out sediment. Catchbasins were assumed to have no settling affect and would actually improve delivery once the water entered the tile system.

- As a result of using the USLE factors it was difficult to model subtle changes landowners made in cropping/management practices. For example, converting from a fall moldboard plough system to a full modified moldboard plough (cut-offs) system was a positive measure taken by cooperators to increase soil residue cover. It was difficult, however, to model this change in residue management simply through the C-Factor.

  A series of tables were prepared for determining C factors for a variety of crops and residue levels to better model the small changes in residue level remaining on the fields following planting. If residue levels were between the levels provided on the C factor sheets, an interpolated C factor was used.

- Only erosion and sedimentation components of the planning process were considered by the analysis model. The economic and other aspects were left to the planners to evaluate using other tools and/or their own experience.

- Defining the target erosion and sediment delivery rates proved difficult. Target erosion rates were better defined once the 1989 water quality data became available. The exercise of selecting applicable targets for all watersheds illustrated the inappropriateness of a single rule-of-thumb target for erosion and sediment delivery in consideration of the variety of landscapes in Ontario.

- The GAMES analysis gave planners important background data with which to initiate farm planning discussions. Because of the capacity to model on a specific polygon basis, it was possible for planners to address erosion sensitive areas as well to plan on a field-by-field basis.

- The Lotus spreadsheet derived from GAMES and the Farm Planning Module (FPM) output allowed quick comparisons of alternative conservation solutions so that cooperators could test their preferences and more easily adjust the effect of practices. For example, chisel points versus chisel sweeps could be compared by simply adjusting the residue levels which could be expected.

- The GAMES analysis allowed users to test the effect field management decisions would have on water quality at the watershed outlet. The presentation of the data, however, remained at the field scale - the management unit.

- The 1990 and 1991 Lotus spreadsheet approach provided an efficient means of recording conservation plans for the next crop year.

- The approach used computer analysis tools but left it with one-to-one contact between the cooperator and PWS field staff to make experienced decisions. This avoided cookbook solutions and encouraged innovation.

- The primary weakness at the field discussion level of planning was the sensitivity gap between knowing precisely what field situations were versus what was reported in the GAMES information. The field staff who were making recommendations to the farmer cooperator had been provided with a great deal of helpful information but lacked the familiarity and experience with the land that the cooperator possessed. It was, therefore occasionally difficult to answer questions raised by cooperators and sometimes required time consuming (but necessary) additional site visits to the area (polygon) of concern.

- Field discussions in conservation farm planning were an obvious necessity. In this project they had some additional peripheral benefits as well:
    1. They provided an opportunity for cooperators to raise, and often resolve, concerns about the use of new practices.
    2. They provided an opportunity for PWS field staff to establish a common identity with cooperators in addressing the objectives of the project.
    3. They provided an opportunity for cooperators to discuss or suggest ways to make the project more acceptable, a necessary first step if an effective plan was to follow, and an opportunity for cooperators to gain ownership in the project.

Indicators of Adoption

- In the PWS the social indicators of adoption were monitored by documenting the attitudinal change experienced by the cooperators. The reader is referred to the PWS report Evaluation of Conservation Systems: Cooperator Attitude Change for more information.

- The short term economic indicators of adoption in the PWS were embodied in the planning and adoption decisions of the cooperators. It may be assumed that continued adoption of a given practice meant that in the short term the cooperator did not experience a large enough negative impact, including economic, to cause him to change his mind about proceeding.
- An inventory of physical change does not indicate how effectively the changes were implemented with resulting impacts on soil movement and water quality.
- Across all test watersheds the number of potential conservation actions identified during the planning sessions each year ranged from 51 to 72 discrete actions. Over the three years documented, on average approximately half of the identified actions were planned for at the beginning of each crop year (August/September). The high degree of uncertainty in making plans reflected mainly the impacts of weather and the effect this had on farming activities. Many producers were unwilling to make a commitment they were unsure of keeping. Without exception across all years and watersheds the percentage of completed conservation actions was greater than what was planned for.
- Future program planners may anticipate an increase in actual adoption when compared with initial indications obtained through the planning process.
- In Essex and Kettle there was a definite general shift during the project toward the use of conservation tillage systems. In the Pittock watershed the nature of the adoption trends for conservation tillage systems were less clear. There was little doubt, however, that a positive shift occurred in the adoption of conservation tillage systems.
- In most cases the PWS acted as the catalyst and/or means by which cooperators were able to implement conservation buffers, seed critical areas and build structures. The continued presence of these control practices to the end of the project and beyond (especially with regard to the structures) served as a useful indicator of adoption.

- In general those buffers and critical areas considered important to achieving PWS objectives were implemented by cooperators. The prioritization of the structures for project purposes meant that cooperators were more likely to install high priority structures first. The greatest adoption in this regard was achieved in the Kettle watershed. In Essex and Pittock, where the visual impact of the problems was less striking, the cooperators implemented less than half of the structures suggested.

3.5 Recommendations

- Future proactive and targeted programs should incorporate all of the elements of the incentive package described herein.
- Future proactive and targeted programs should ensure that staff working directly with producers are knowledgeable and experienced in the adoption of conservation farming systems.

Information and Education

- Educational material should be provided and/or available from a variety of sources including both the project, the scientific literature and the popular press. This would expose the cooperators to a range of viewpoints and should add supporting evidence to the ideas promoted by the project.
- Information material regarding the project should be current, relevant and frequent enough to maintain the interest of the participants. A clear language writing style is important to enhance communication. A project newsletter can serve this purpose well.
- Technical support must be responsive to cooperator needs especially regarding specific information (e.g. what herbicide to use under certain circumstances) and timeliness (e.g. when a question is raised a response or recommendation is often required immediately). For best results an "on-call" technical support system is desirable.

- Input from project cooperators regarding the content of the information and education component is recommended. Producers will identify those areas of interest and methods of learning that are of most use to them. This input allows the cooperators to guide the project in addressing their changing concerns about adopting conservation practices. It also gives project staff insight into what practices cooperators may initially be most responsive to adopting.

- Whenever possible visits to farm operations practising conservation measures should be encouraged. In contrast experienced conservation farmers should be invited to meet with cooperators on a regular basis to discuss their specific needs. If possible this should be done at least once during a walk over the farm.

- To help ensure adequate attendance at general project meetings the reason and need for the meeting should be well defined. A special interest event or guest speaker in conjunction with the meeting will also encourage attendance.

- If resources allow, social events should be incorporated into those programs where the target group of cooperators is well defined. These events however could be organized in conjunction with other project activities; for example a banquet or barbecue held in conjunction with the annual meeting.

- If a project is visible, community interest will exist. Satisfying requests and even seeking out opportunities to discuss the study can build a sense of achievement in the participants and provide a forum for positive feedback. It is recommended that these opportunities be recognized for their value in aiding the adoption process. If resources permit, a proactive community information component should be incorporated into the project plan. At the very least resources should be allocated to serving community requests when they occur.

- When asking cooperators to give presentations and host visitors on behalf of the project, care should be taken to distribute the requests across a number of cooperators. The tendency is to repeatedly call on the natural leaders in the group instead of giving the less outspoken cooperators an opportunity to participate in this experience.

Benefits Package

- See PWS report Evaluation of Conservation Systems: Cooperator Attitude Change.

- The benefits provided to cooperators should be categorized into those required to meet the projects objectives and those required to meet the cooperators' objectives. Each category should be annually evaluated as to the ongoing usefulness of each. In some cases this would result in project resources being reallocated or decreased if apparent usefulness or effectiveness is low.

  For example the PWS newsletter included conservation article reprints as a way to continue introducing conservation ideas and practices to cooperators. In the final survey however cooperators did not find this service useful. Crop scouting services were provided to help cooperators meet their objective to adopt conservation practices with as little risk as possible. Apparently however few farmers used the information on a frequent basis. Crop scouting services provided on a request basis would have met the needs of those wanting the service and allowed either a reallocation of resources or a decrease in project costs.

- Project staff working directly with the cooperators should possess at least three years experience working as an extension specialist promoting the adoption of conservation farming systems. A farm background would be an asset. The credibility and practicality of the "front line" personnel are key to the success of the project.

- Backup technical assistance should be allowed for to maintain the timeliness of response to cooperator needs.

- Project staff turnover can have a negative effect on project progress from a technical support standpoint. This potential problem should be recognized and efforts made to minimize its occurrence and/or impact.

Cooperator Agreements and Compensation Payments

- Care should be taken to keep formal agreements as simple as possible while ensuring they fulfil the purpose for which they were intended.

- Compensation payments made on an annual basis will save time and resources when compared to payments made on an instalment basis. This saving probably offsets the early financial benefit (or incentive) cooperators receive for participating in the study when the instalment plan is used.

Conservation Farm Planning

- The need for a compendium of C factor tables applicable to Ontario should be examined. Such a document would assist in standardizing the estimates used for modelling and farm planning purposes.

Indicators of Adoption

- Indicators of adoption should be identified at the outset of a program so that appropriate baseline data can be collected.

4.0 EVALUATION OF CONSERVATION SYSTEMS: COOPERATOR ATTITUDE CHANGE

4.1 Introduction

The mandate of the Soil and Water Environmental Enhancement Program (SWEEP) was to reduce phosphorus loadings to the Lake Erie basin and to maintain or improve agricultural productivity by reducing or correcting soil erosion and degradation. Conservation cropping and tillage systems were identified as the best means to achieve these goals over a wide geographic region such as the Lake Erie watershed. The Pilot Watershed Study (PWS) was developed as a means of evaluating the impact on conservation systems on soil erosion and degradation, water quality and crop production when implemented.

Maximizing farm operator participation in soil erosion and sediment control programs is essential to achieving improvements in water quality and sustainable levels of crop production in areas where pollution occurs from agricultural runoff. High participation rates in localized areas were particularly crucial in the Pilot Watershed Study (PWS) where implementation of conservation practices by cooperators in the test sub-watershed was key to discovering whether or not long-term improvements in soil, water and crop production parameters would occur, relative to those in the control sub-watershed.

At the same time that soil and water quality-related benefits were important to demonstrate in the Pilot Watershed Study, it was also necessary to evaluate factors that affected the adoption of soil and water conservation practices and influenced farmer attitudes towards these practices. In the short-term, understanding why a farmer chose to adopt, adapt or reject a particular practice provided the basis for adjusting program delivery on a day-to-day basis. In the post-PWS era, such findings can contribute to the effective design, targeting and implementation of other soil and water conservation initiatives.

4.2 Objectives

The longitudinal nature of the PWS provided the opportunity to explore a number of research objectives relating to conservation attitude change over time. These included:

1. to obtain cooperator perceptions of on-farm soil erosion and local water quality change over the life span of the project;

2. to determine the changes which occurred in cooperator attitude toward the merits of conservation practices and their own willingness to accept risk related to implementing conservation practices;

3. to track the main reasons cooperators decided to continue to work with or discontinue the use of specific conservation practices over time and across types of enterprise;

4. to determine cooperator perceptions of effectiveness of individual conservation practices in controlling erosion, of practice impact on crop yields and farm profitability and the extent to which the practice is accepted in the community;

5. to determine the degree to which the cooperators have "owned" the soil erosion problem and its resolution.

4.3 Methodology

Tracking attitudinal change took several different forms throughout the life span of the PWS. The majority of data collection efforts focused on personal interviews of the cooperators. These surveys served to collect baseline data (June 1988), midpoint, equipment use, and end-of-project data (January 1992). Watershed technicians also collected additional ongoing, qualitative attitude change data in their regular contacts with the cooperators.

Data were analyzed at a number of different levels, including: pairs of test and control sub-watersheds; among all three test sub-watersheds, and; grouped test versus grouped control sub-watersheds.

Cross-sectional (point-in-time) and longitudinal (ongoing through time) analyses were conducted for relevant variables in assessing attitude change over time. Where longitudinal analyses were conducted, only those cooperators responding to both the baseline survey and the concluding survey were included in the data set to ensure that the findings reflected accurately and consistently, individual attitude change over the full course of the project.

4.4 Conclusions

The conclusions are grouped as follows: cooperator perception of the problem and the general merits of soil conservation; factors affecting adoption; perception of practice effectiveness; factors inherent to the PWS itself, and; suggestions for future programming.

Cooperator Perception of the Soil Erosion Problem/Merits of Soil Conservation

1. Recognition of soil degradation as a problem on cooperator farms appeared to be an important prerequisite to obtaining consistent farmer interest and response;

2. Implementation of erosion control measures resulted in test cooperators perceiving slightly less erosion on their farms in 1992 relative to 1988. Conversely, control cooperators as a group perceived slightly more erosion happening on their farms over the same time period. Control cooperators probably became sensitized to the erosion problem as a result of the PWS, but did not receive the encouragement to implement measures within the watershed boundaries to alleviate the problem.

3. There is evidence that cooperators in general, affirmed the overall concept of soil and water conservation. In all sub-watersheds, cooperators agreed that "conserving soil and water is a good investment for their area".

   In all three test sub-watersheds in 1992, there was a trend toward disagreement with the statement, "costs to the farmer of soil conservation are greater than the on-farm benefits", relative to how they responded in 1988. This suggested that positive experiences shaped their thinking over the four years, to the point where net returns/farm profitability for virtually all conservation practices were viewed positively.

Factors Affecting Adoption

1. Cooperators' reasoning for choice of conservation practice varied by watershed and over time. In Kettle, where soil erosion was most obvious and where the expressed need for erosion control was the greatest, there remained a continuing desire to do what is right for the land resource (biophysical reasons). Having installed structures, Kettle cooperators demonstrated a growing appreciation for the positive economic benefits of the no-till cropping system in particular, in order to complement the work of the structures. Essex cooperators shifted away from biophysical reasoning to a focus on economic and farm management concerns over the life of the PWS. In Pittock, there appeared to be a growing appreciation of benefits to the land resource, but less consideration of economics as a motivating force.

2. Motivation for practice implementation initially required experimentation with practices farmers were most familiar with and which were most easily incorporated into farming systems. In both Kettle and Essex, initial discussions and experimentation centered around modifications to the moldboard plow. Practice introduction time was reduced by building on practices farmers were familiar with, and by being ready to suggest or respond to requests for technical guidance on the more complicated conservation practices as they arose.

Initial emphasis on structures on long slopes in Kettle seemed an appropriate starting point for some conservation discussions. After the structures were installed, several cooperators noted sediment build-ups in the ponded areas behind the berms. This prompted serious consideration of no-till practices to minimize soil movement off the fields.

3. The time required for practice adoption appears to remain a highly variable and individually-oriented factor. Farm enterprises with livestock manures needing incorporation, or with certain specialty cash crops (e.g. white/coloured beans) were most hesitant to consider conservation cropping systems that included no-till. Very large, diversified farm enterprises with tight crop planting and harvesting schedules did not want to "bother" with scheduling the use of PWS equipment and time to keep field records.

   On the other hand, cooperators who enjoyed modifying and fine-tuning management systems tended to be more patient in working with the more complicated alternative tillage and cropping practices. Timing of technician input was important, particularly where weather was a factor and where the cooperator was open to integrating alternative tillage practices with structural control measures. Access to the PWS equipment was a crucial component in encouraging practice adoption. Farm tours in Ontario and beyond served to stimulate and reinforce adoption behaviour.

   In general, cooperators agreed that five to ten years is a realistic time frame to achieve a satisfactory comfort level with integration of conservation planter equipment into their management systems. Cooperators generally considered three years adequate for the conservation drill.

Perception of Practice Effectiveness

1. Test cooperators had a high regard for the effectiveness of the conservation practices they have implemented for limiting soil loss. For others who perceive they have a problem, this can serve as a strong motivating force.

2. Test cooperators were generally neutral or slightly positive about practice effects on crop yields. They were almost always more positive with respect to "effects on profitability". This bodes well for future adoption as cooperators appeared to be acknowledging the net financial benefits of implementation of even the less familiar practices.

3. Test cooperators in Essex and Kettle had a substantially more positive view of the community acceptance of no-till practices in 1992 relative to 1991. Peer support can contribute to higher adoption rates.

Factors Inherent to the PWS

1. Several cooperators, particularly in Pittock, raised the issue of their own lack of understanding of project design and goals from the outset. It is possible that cooperators who missed one or more of the early orientation meetings were not personally updated on meeting content and therefore developed certain misconceptions about the project (eg. water quality monitoring results to be potentially used against them).

2. The PWS did not provide for designation of a cooperator spokesperson or a small committee to whom project participants could take their concerns and suggestions. This could have served a purpose in providing a "safe place" for cooperators to negotiate disputes and provide a sense of continuity when changes in technical staff occurred.

3. Some interest was expressed in both Essex and Pittock in lowering herbicide use and promoting "ecological" agriculture. Specifically, band spraying combined with inter-row cultivation was mentioned as a technique that the PWS could not provide equipment for, or had few technical or financial resources to use in support of these ideas.

4. Few resources were allocated to dissemination of PWS experience beyond the boundaries of the watersheds. Wider community support for, and understanding of conservation initiatives may have been engendered by such promotion. However, some local organizations gave some profile (conservation/production awards) to selected conservation farmers whose experience was built through the PWS.

Cooperator Perspectives on Post-PWS Conservation Intentions and Future Programming

1. There appeared to be interest in maintaining or increasing acreage of crops under selected conservation practices in each of the watersheds. The focus is expected to be on no-till in Kettle and Essex, along with some increase in cropping systems practices (e.g. winter cover crop grown for crop or tilled in spring). Fewer cooperators in the Pittock watershed were choosing to expand no-till practices; rather, there appeared to be a reliance on cropping systems practices.

2. The most frequently cited kinds of support required to enable continuation of cooperator conservation goals post-PWS included:

   - money from better crop prices and through financial assistance programs;
   - availability of equipment at low cost, as it is too expensive to buy; and
   - continued technical support.

3. In future programming, cooperators suggested the following approaches:

- a low key, non-threatening approach where the farmers help set the agenda, similar to the PWS approach;
- take prospective cooperators on tours to see first hand how other people are
- working with the specific techniques, and thus provide motivation;
- keep cooperators up-to-date with project findings along the way;
- ensure technical support is based in the local community; and
- where possible, involve cooperators in environmental monitoring or other field testing exercises.

Recommendations

Recommendations applicable to other conservation programming initiatives where accelerated adoption rates are sought, are noted below:

1. determine from potential cooperators, whether they perceive a soil erosion problem, and whether they are willing to try to correct it. Also, ensure that they are presented with current information about the soil conserving attributes and economic benefits of the conservation measures they are being asked to consider to alleviate the problem;

2. whenever cooperators are unable to attend project information sessions particularly at project start-up, contact each cooperator to ensure they get the same information as everyone else. This will minimize the possibilities of misunderstandings arising related to project intentions and objectives;

3. wherever possible, include peer support mechanisms for promoting newer practices such as no-till. These may include visits to other conservation farms of similar

enterprise types where exposure to proven techniques can occur, or participation in technical workshops, seminars or demonstration sites;

4. ensure that adequate technical support is available locally, and that access to equipment at critical cropping phases does not pose a constraint to experimentation with alternative practices;

5. ensure that cooperators have a "safe place" where they feel comfortable taking their project-specific concerns. This may require setting up a cooperator committee as a sounding board where potential disputes can be resolved and where continuity can be maintained should change in technical staff occur;

6. in future programming, use a low-key, non-threatening approach to project design and implementation where farmers help set the agenda. The farm management system and enterprise-specific conservation needs and constraints must be addressed with each cooperator.

5.0 EVALUATION OF CONSERVATION SYSTEMS: SOILS AND CROPS

5.1 Introduction

The mandate of the Soil and Water Environmental Enhancement Program (SWEEP) was to reduce phosphorus loadings to the Lake Erie basin and to maintain or improve agricultural productivity by reducing or correcting soil erosion and degradation. Conservation cropping and tillage systems were identified as the best means to achieve these goals over such a wide geographic region as the Lake Erie watershed. The Pilot Watershed Study (PWS) was developed as a means of evaluating the impact of conservation systems on soil erosion and degradation, water quality and crop production when implemented on a watershed basis.

The erodibility of soil is a major factor which determines the extent of soil erosion occurring on a landscape. Soil erodibility potential depends on such properties as soil particle size distribution, organic matter content, aggregate stability, bulk density and soil structure. The removal of topsoil by erosion results in changes in these soil properties. The major cause of these changes has been attributed to shifts in land management practices or cultural practices. Prominent among the factors which change soil quality are tillage practices, cropping systems or crop sequences, manure and fertilizer applications and crop residue management. Identifying the components of these systems that improve soil quality has been the focus of numerous research undertakings.

At the watershed level in the PWS the evaluation of conservation systems focused on changes in soil cover. This was the one factor affected by crop production practices that most directly influenced soil erosion control, sediment delivery and ultimately water quality as evidenced by sediment and phosphorus loadings. Target soil cover levels were set in order to provide a tangible and achievable goal for the cooperators to strive for. It was anticipated that these targets, when met, would reduce soil loss on average by at least 50%.

In the PWS the impact of conservation systems on crop production at the farm and field level were left to the cooperators to evaluate in the context of their own operations, their previous experience and their personal production goals. Since the indicators of adoption were strong and favourable it was concluded that during the study, cooperator evaluations of the conservation systems were positive.

For comparative purposes, however, information related to two crop production parameters, use of commercial phosphorus fertilizer and crop yields, is also reported on a watershed basis.

5.2 Methodology

Soil quality monitoring was implemented on a series of soil benchmark sites located within the study watersheds. Using the results of a literature search, a sampling scheme was designed to monitor a broad range of soil properties on an annual basis over the duration of the program. During the spring of 1990, the client directed that the soil monitoring component be expanded to include measurements of seasonal variability in soil physical properties. Of the 38 original soil benchmark sites, 18 were selected (3 in each of the 6 watersheds) for this additional work.

Soil cover within the cropped areas of the watersheds was estimated using either the knotted rope method or a series of assumptions based on previous knowledge or experience. Factors affecting crop production were tracked on a field basis by monitoring cooperator management decisions, weather, soil fertility and crop pests.

5.3 Objectives

The components of the study documented in this report apply specifically to the following PWS objective:

- To determine the nature and degree of changes in relevant soil and water quality parameters and crop yields as influenced by "basin-wide" soil and water conservation practices.

  Strategy: Establish soil, water and crop yield baseline conditions and monitor changes in relevant parameters throughout the life of the program;

  Correlate changes in soil, water and crop yield parameters to soil and water conservation practices and systems.

Soil Quality Monitoring Program

The specific objective of the soil quality monitoring component of the PWS was to measure changes in selected soil parameters over the life of the project at benchmark sites in the **test** watershed and to compare these with changes at comparable sites in the **control** watershed. Sites were selected on the principle soils in the watersheds on landscape positions representative of the selected soil types.

The scope of this component was:

1. To assess the effect of conservation farming practices and systems on soil properties which are known to affect crop productivity and/or the magnitude of soil erosion, sediment yield and runoff;

2. To provide soils information needed for comparing crop performance between conservation farming systems and conventional systems; and

3. To provide soils data from refining preliminary estimates of soil loss using the Universal Soil Loss Equation (USLE) and to determine the extent of any changes in the soil related values of parameters in the USLE during the life of the project.

The literature review suggested that improvements would be seen in those soil parameters monitored at the soil benchmark sites managed under conservation systems relative to those managed conventionally.

Crop Monitoring Program

The specific objectives of the crop monitoring program were as follows:

- to determine the proportion of the soil surface covered with live crop or dead crop residue at critical times in the cropping season;
- to monitor pests, soil fertility, weather, and other factors that influence crop performance during the crop production season; and
- to monitor whole plant grain yields of crops.

5.4 Conclusions

- In general there appeared to be more measurable and contrasting change occurring amongst the soil quality parameters in the three test watersheds than in the three control watersheds although the change was not consistent amongst parameters or slope position.

- Uncontrolled differences and/or similarities in tillage and cropping practices between and amongst soil benchmark pairs made it difficult to monitor significant changes in soil quality parameters in the short term (3 years) of the PWS.

- In general the amount of soil cover and area affected increased in the test watersheds during the study and relative to the control watersheds.

- Approximately one half to three quarters of the monitored agricultural areas within the test watersheds that were affected by elevated soil cover levels (20% +) during spring runoff, continued to be affected by soil cover levels greater than 20% after planting (during late May and early June).

- The adoption of conservation systems during the PWS impacted to a greater degree on the soil cover remaining after spring runoff when compared to the soil cover remaining after planting.

- Understanding the influence of the adoption of conservation measures on soil cover within the Pittock watersheds was complicated by the presence of hay-based rotations.

- At the beginning of the PWS the actual application of phosphorus fertilizer on a watershed basis was approximately 1.4 to 3.6 times greater than recommended amounts and at the end of the PWS the actual application of phosphorus fertilizer on a watershed basis fell to approximately .8 to 1.3 times the recommended rates.

- Over application of phosphorus fertilizers can be significantly reduced on a watershed basis if information about soil fertility levels and phosphorus loading of water courses is provided to the producers.

- No difference in crop production potential was detected between each pair of test and control watersheds based on yield data (or any other data) collected during the PWS.

5.5 Recommendations

- In future projects, consideration should be given to holding soil samples, or perhaps splitting each soil sample and holding one of the resulting samples, through the life of the project (or for a suitable timespan) and having all of the samples analyzed by the same laboratory at the same time. This would avoid potential problems with changes in laboratory and analytical techniques that may impact on the study results.

- In short term projects (less than five years) it is critical that paired sites are similar not only in soil character but in soil management as well. Current management practices can influence yearly results and where long term trends are not an objective of the study, short term soil management practices should be similar between pairs and if possible groups of pairs.

- To obtain long term trends of change the monitoring period of soil benchmark sites should be carried out over five years or more. This would allow for the adoption and incorporation of conservation practices as part of the normal farming system.

- The soil benchmark data collected during the PWS could serve as a baseline data set from which future changes in soil quality could be monitored. In the Essex and Kettle watersheds in particular it is likely that the adoption of conservation systems will continue in the future. It is recommended that these soil benchmark sites be monitored every three to five years where adoption of conservation measures has occurred and alternatively where conventional practices have been maintained. This approach should document the long term effects of both systems on soil quality.

- The use of conservation practices should be promoted to sustain increased levels of residue cover on a field or watershed basis.

- Additional clarification regarding the potential contribution of commercial fertilizer to phosphorus loadings should be published.

- Producers should be encouraged to examine their phosphorus fertilizer programs to ensure maximum efficiency.

- The methods and equipment for calibrating fertilizer application rates should be improved.

6.0 EVALUATION OF CONSERVATION SYSTEMS, HYDROLOGY

6.1 Objectives

The purpose of the of the hydrology component of PWS was to monitor runoff and stream flow to determine if the implementation of conservation farm systems had an affect on the overall basin hydrology. The specific objectives relating to the hydrology component of the PWS were:

- through environmental monitoring, establish continuous records of watershed water balance in order to investigate hydrologic process;
- determine the flow component of runoff necessary for estimating mass flux of water quality parameters; and
- investigate the relationships between soil conservation systems and hydrologic response at the plot, field and watershed scales.

6.2 Methods

Water Quantity Monitoring

Watershed Scale

Watersheds and microbasins were instrumented with flow monitoring and water quality sampling devices to facilitate the accurate estimation of mass loadings of water quality parameters. In-stream water control devices (v-notch and rectangular weirs) were installed to better define low flow estimates. Water quality shelters were installed at each watershed outlet (two per study area, six in total) to house automated water level monitoring, meteorological, and water quality sampling equipment. Continuous water level data was used in conjunction with flow velocity determination to derive flow-discharge curves for each watershed outlet. The resultant continuous flow record was ultimately used for calculating relationships between flow and water quality concentrations for water quality loading determination.

Microbasin Scale

A total of twelve microbasins (four per study area) were instrumented with automated water level monitoring equipment and manual water quality sampling which were operated during non-winter months. Hydrologic control structures (v-notch weirs and Parshall flume) were installed at each microbasin along with a stilling well for water level-flow estimation purposes.

Plot Scale

Rainfall simulation techniques were employed to evaluate water quality at the plot scale at critical times of the year when soil conditions may vary due to farm management or seasonal influences (ie. post-fall tillage 1990-91; spring pre-plant 1991-92; and post harvest 1991). Water quality samples were collected in triplicate from three field plots at benchmark sites in both the test and control watersheds to determine water quality loads.

Groundwater Monitoring

One pathway for phosphorus loss is through subsurface soils and groundwater transport. To define the magnitude of this pathway, groundwater monitoring wells were installed in each watershed to determine the amount of phosphorus transported through the subsurface in the soluble phase. One groundwater monitoring well was installed near each microbasin of each study area. Groundwater samples were collected approximately monthly through the monitoring phase of the study.

6.3 Results

Watershed Scale

Runoff

- Essex **control** unit area runoff slightly exceeded **test** runoff over the period of study;
- Kettle Creek **test** unit area runoff exceeded **control** runoff during the wettest seasons; and
- Pittock **test** unit area runoff was significantly greater (nearly 50%) than that of the **control** throughout the study period.
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Hydraulic Yield

- Essex and Kettle Creek **test** and **control** watersheds compare closely with respect to hydraulic yield throughout the period of study; and
- Pittock **test** had generally higher hydraulic yields than **control.**
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Microbasin Scale

Runoff

- Frequency and extent of microbasin flow was quite variable in all microbasins; and
- Generally **control** microbasins produced less runoff than test microbasins, especially during periods of tillage.

Plot Scale

Rainfall Simulation Results

- Time to ponding (TTP) values, indicating soil porosity, showed no distinct trends when comparing test and **control** sites, possibly due to spatial variability of infiltration rates of soils;
- Time to runoff (TTR) values, reflecting soil storage capacity, were not significantly different for **test** or **control** sites, again possibly due to high spatial variability of soil properties;
- Total runoff volume was generally higher for test sites than for **control;**
- Runoff volume was lowest for control sites following tillage, likely due to increased surface roughness; and
- The difference between test and **control** runoff volume is most pronounced during pre-plant and post-tillage, when the difference in surface cover is most pronounced.

6.4 Conclusions

The following are general conclusions drawn from the PWS concerning hydrology.

- At the watershed scale, the effects of conservation tillage on runoff volume are site specific:
  - Essex: runoff is higher from the test watershed due to higher resultant cover in the last 2 years of the study.
  - Kettle Creek: runoff is higher from the test watershed during the periods of high annual rainfall.
  - Pittock: the test watershed produced significantly higher unit area runoff volumes throughout most of the study period.

- At the microbasin (field) scale, there is no clear pattern of dependency between unit area runoff and conservation farm management in Kettle or Pittock. In Essex, microbasins generally indicate that increased cover resulting from conservation systems correlates with increased runoff.

- At the plot scale, responses of runoff to the presence of conservation tillage increased cover corresponds to increased runoff in Kettle and Pittock, but in Essex the reverse is true.

- During rainfall simulation, test runoff exceeded **control** when all data where analyzed together.

- During rainfall simulation, **control** runoff was lowest during the post-tillage period, most likely due to high surface storage.

- More replication is recommended for plot scale studies, such as rainfall simulation experiments, to reduce the effects of spatial heterogeneity of soil characteristics.

- At the microbasin scale, greater duration of study is required so that more events are available to be used in time trend analysis on individual microbasins. Currently, direct comparisons between different microbasins are confounded by differences in physical and agronomic factors, despite all efforts to avoid such differences when choosing microbasins.

- At the watershed scale, extension of the duration of study to create a larger database would help to more clearly define the effects of tillage and residue on runoff.

7.0 EVALUATION OF CONSERVATION SYSTEMS, WATER QUALITY

7.1 Objectives

The overall purpose of the of the water quality component of PWS was to, define water quality concentrations and mass loadings between conventional and conservation farm systems. The specific objective relating to the water quality evaluation component of the PWS were:

- through water quality monitoring, quantify loading rates of phosphorus and soil loss at three scales (plot, microbasin and watershed) in the short-term (single rain event) and long-term (seasonally and annually); and
- quantify the benefits to receiving waters of conservation system adoption at the watershed scale.

7.2 Methods

Surface Water Quality Monitoring

Watershed Scale

Watersheds and microbasins were instrumented with flow monitoring and water quality sampling devices to facilitate the accurate estimation of mass loadings of water quality parameters. In-stream water control devices (v-notch and rectangular weirs) were installed to better define low flow estimates. Water quality shelters were installed at each watershed outlet (two per study area, six in total) to house automated water level monitoring, meteorological, and water quality sampling equipment. Continuous water level data was used in conjunction with flow velocity determination to derive flow-discharge curves for each watershed outlet. The resultant continuous flow record was ultimately used for calculating relationships between flow and water quality concentrations for water quality loading determination.

Microbasin Scale

A total of twelve microbasins (four in each of Essex, Kettle Creek and Pittock Watersheds) were instrumented with automated water level monitoring equipment and manual water quality sampling which were operated during non-winter months. Hydrologic control structures (v-notch weirs and Parshall flume) were installed at each microbasin along with a stilling well for water level-flow estimation purposes. Water quality samples were collected during rainfall events.

Plot Scale

Rainfall simulation techniques were employed to evaluate water quality at the plot scale at critical times of the year when soil conditions may vary due to farm management or seasonal influences (ie. post-fall tillage 1990-91; spring pre-plant 1991-92; and post harvest 1991). Water quality samples were collected in triplicate from three field plots at benchmark sites in both the test and **control** watersheds to determine water quality loads.

Groundwater Monitoring

One pathway for phosphorus loss is through subsurface soils and groundwater transport. To define the magnitude of this pathway, groundwater monitoring wells were installed in each watershed to determine the amount of phosphorus was transported through the subsurface in the soluble phase. One groundwater monitoring well was installed near each microbasin of each study area. Groundwater samples were collected approximately monthly through the monitoring phase of the study.

Water Quality Loading Estimation

Water quality loads were determined from continuous water level/flow data and discrete water quality sample concentrations. A least squares technique was employed to determine the best fit method or relationship between water quality parameters and streamflow. From the least squares best fit equations, continuous water quality loading estimates were determined for all stations throughout the study period.

7.3 Results

Parameter Concentrations

Watershed Scale

In-stream total suspended solids (TSS) and total phosphorus (TP) concentrations at the six watershed outlets are quite variable both temporally and with respect to location (i.e. test or **control** sub-watershed). TP concentration at the watershed outlets follows similar patterns to TSS, since a large proportion of the total phosphorous content is sediment bound. In the Essex watershed, the test sub-watershed exhibits higher TSS concentrations than the **control** throughout the study period except for the first six months of 1992. In general however, TSS concentrations consistently decreased in the test sub-watershed over the time conservation practices had been phased in. The **control** sub-watershed did not exhibit this trend. In the Kettle Creek watershed, TSS concentrations were again higher in the test than in the **control** except in 1991 when average annual TSS concentration was higher in the **control.** Neither the test nor the **control** sub-watershed exhibited a consistent increase or decrease in TSS over the study period. TSS concentrations at the Pittock watershed were lower at the **test** outlet than at the **control** except for during the first six months of 1992, when both the test and **control** TSS concentrations were very low. Overall, the lower Pittock **test** TSS concentrations are positive evidence of the potential water quality enhancement of conservation practices.

Parameter Loads

As with concentrations of water quality parameter concentrations, loads are quite variable in time, especially in the fall season, and with respect to location. In the Essex watershed, **annual** unit area TSS loads where similar for the **test** and **control** sub-watersheds in every year of the study. In Kettle Creek, the **test** sub-watershed outlet had higher unit area TSS loads than the **control** except during 1991 - a very dry year. A partial explanation for low Kettle Creek **control** TSS loads is the sediment trap in the low lying, wetland area situated in the **control** sub-watershed. In the Pittock watershed, TSS loads were not consistently higher in either of the sub-watersheds and therefore inconclusive.

Loadings of TP were similar in pattern to TSS loads, since a large portion of the TP is delivered in a sediment bound form.

Parameter Concentrations

Microbasin Scale

General trends between water quality and conservation farm benefits were more apparent at the microbasin scale as confounding spatial factors tended to decrease with a corresponding decrease in size or scale of monitoring.

In Essex, TSS concentrations consistently decreased in the **test** microbasins while showing no trends in the control **microbasins.** The same decreasing trend was observed for one of the **test** microbasins in Kettle Creek while the other microbasins **(test and control)** data were inconsistent. This decrease in TSS in test microbasins is evidence of potential positive effects of land conservation practices on water quality. The lack of flow events in the Pittock **control** microbasins makes comparisons less conclusive. Microbasin TP concentrations follow a very similar pattern to TSS concentrations.

Parameter Loads

Overall, unit area microbasin loads show no distinct trends with respect to time or location (test or **control).** Again, the rarity of significant microbasin flow events makes it difficult to make firm conclusions and underscores the need for further study.

Correlation analysis of lumped microbasin loading data did however, provide for a comparison of test and **control** loads for both Essex and Kettle Creek watersheds. In both cases, TSS and TP loads were higher in the test at low flows but were higher in the **control** at moderate to high flows. This indicates a possible advantage to land conservation practices in the enhancement of water quality during critical large rainfall/flow events when a very large proportion of the total annual soil loss usually occurs.

Plot Scale

The rainfall simulation component of the PWS water quality evaluation produced the most obvious and predictable results. This is due to the controlled nature of these tests in terms of area, land management, rainfall intensity and time, and precise measurement of runoff, soil moisture, slope and residue.

Test plots had significantly lower loads of TSS and TP, often due to lower TSS and TP concentrations in test plot runoff particularly in Essex. This was particularly true for the Pre-Plant period which generated the highest unit area loads by far and for the Post-Tillage period which generally produced the next highest loads of the three time periods examined.

The Post-Tillage and Pre-Plant periods bracket a significant period of the year usually from early fall to early summer and represent an erosion prone period with minimal live plant cover. Results show that during this period conservation tillage reduces TSS and TP loadings.

7.4 Conclusions

Watershed Scale

- The watershed scale proved to be the most complex in terms of inherent variability, of climatic, soil, runoff and erosion process factors. However, even with the inherent variability at this monitoring scale, at four of the six subwatersheds there was an indication that an increase in percent cover decreased water quality loads.

- The positive effects of conservation practices in the test watersheds were most evident during the November through April period when the percent cover was much higher than the **control** watersheds.

- In Essex test sub-watershed, average and median yearly TSS concentration decreased consistently since the onset of the project. In contrast, Essex **control** sub-watershed average and median concentrations were variable. Other watersheds did not show this trend but may with time.

- Dry weather of the study period has not provided for a comparison of **test** versus **control** during years with higher than normal precipitation.

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Microbasin Scale

- During high flows (in the November to April periods) the high percent cover in the test microbasins of Essex and Kettle Creek proved to be effective in reducing TSS loads when compared to **control** microbasins (low percent cover).

- Pittock microbasin loads were very low in both **test** and **control.** Due to the lack of moderate to high flow events, conclusions could not be drawn from the Pittock microbasins.

Plot Scale

- Conservation tillage resulted in significantly reduced loadings of TSS and TP in general with some exceptions. These exceptions include Post-Tillage periods wherein some cases, test plots produced significantly more runoff due to soil surface differences between test and **control** plots.

- Pre-Plant periods produced the highest loadings in all areas due to much higher TSS and TP concentrations and generally higher runoff volumes. Post-Harvest measurements are of little value since in conventional systems the condition is short lived and crop residue levels are similar in test and **control** plots.

- Crop live and dead cover is an effective level of protection against interrill (sheet) erosion as determined in intense simulated rainfall measurements.

- Rainfall simulation measurements are an effective means of evaluating conservation farming systems and identifying the effect of various independent factors (i.e. cover, soil moisture, tillage practices).

8.0 WATERSHED MODELLING

8.1 Objectives

The objectives of the modelling component of the Pilot Watershed Study (PWS) were as follows:

- develop spatially descriptive erosion and runoff models of the study sub-watersheds;
- apply the site specific models to the evaluation of future soil and environmental benefits relating to various agricultural land management practices; and
- use the models as tools to aid in the assessment of the erosion and phosphorus runoff processes and the effects of land management upon the runoff processes.

8.2 Watershed Models

Two different watershed models were used in the PWS. The Guelph model for evaluating efforts of Agricultural Management systems on Erosion and Sedimentation (GAMES) with the Phosphorus component (GAMESP) was set up and calibrated for the purpose of acting as a planning and communication aid. In fact, a modified version of GAMES was taken to farm level planning meetings to assist in illustrating to farm managers the long term benefit of various localized and field level changes to farming practice. GAMES also was used to highlight problematic areas in the sub-watersheds, that is, where erosion prone factors combined to increase the potential for high erosion. Further, GAMES was applied to estimating losses from hypothetical land management systems across entire sub-watersheds. These predictions represent potential long term benefit, in terms of soil conservation and improved runoff water quality, in the long term.

A second more complex model was set up and applied to a different set of tasks. The Hydrolo gical Simulation Program-Fortran (HSPF) is a dynamic predictive model with runoff and erosion prediction capabilities as well as instream flow and material transport and transformation capabilities. This model predicts and accounts for the complete hydrological cycle and various storage compartments within the watershed (i.e., groundwater, instream, interception etc.). This model was applied to aiding in the assessment of watershed processes which affect runoff and erosion. In effect, this model was used to provide estimates of rates and fluxes within the sub-watersheds for processes which can be easily measured as well as for those that cannot. HSPF was rigorously calibrated using the continuous runoff and loading information documented in Reports #5, Hydrology and #6, Water Quality.

Both models have excellent documentation (Cook *et al* 1985, Johanson, 1980). Some of the more relevant components of the models are described in more detail along with model input requirements, data sources and the set up process.

8.3 Model Set up

In terms of set up, both models require that land areas and their characteristics be represented as model input. Both models use a system of irregular polygons with homogenous attributes. That is, each polygon has one characteristic associated with soil type, land use and slope and differs from its neighbouring polygons in at least one of the attributes. Polygons were determined using a SPANS Geographical Information System and digital information on sub-watershed soils, land use and slopes. Other model input information was determined from PWS surveys and monitoring programs.

8.4 Model Testing

HSPF was calibrated using PWS sub-watershed outflow and loading estimates for 1989. Verification was achieved by comparing predicted and observed results through 1990.

GAMESP was calibrated using 1989 to 1991 PWS soil and phosphorus losses at the sub-watershed mouths.

HSPF was shown to be capable of accurately predicting outflow rates, soil loss and total phosphorus loss on a sub-watershed scale over monthly and annual periods. Daily total flows and loads were generally reliable although snowmelt periods were not modelled accurately in the time frame of days. The model was able to respond to very short term changes in moisture conditions in the sub-watersheds which could result in increases in runoff of several orders of magnitude. The small headwater PWS study areas are very responsive to rainfall or snowmelt events. In general, annual flows and loads were predicted to within +5% of the observed flows and loads while daily predicted values were accurate to within +50%.

GAMESP is calibrated by adjusting two parameters which affect soil delivery until correspondence is achieved at the sub-watershed mouth. A similar process is followed for phosphorus. Actual erosion is determined using a derivation of the Universal Soil Loss Equation and is based upon long term conditions for rainfall. Soil delivery to drains is based upon overland flow path hydraulic parameters which relate to the transport capacity of overland flow.

8.5 Model Applications

HSPF and GAMESP inputs were adjusted to reflect two extreme land management schemes. A continuous fallow system was chosen to represent the worst case wherein no soil cover protection is provided throughout the year. A no till case was used to reflect a best case in which all tilled fields would be managed for high crop and plant residue levels.

GAMESP predicted that fallow conditions would result in up to ten times more soil delivery to the Essex sub-watershed mouths depending upon the simulation year rainfall, over the existing conditions (1989 to 1991 were used).

No till conditions were predicted to result in a reduction in soil loss of up to 85%, with the highest value in the wettest year.

A similar range of relative increases and decreases were predicted for Kettle Creek and Pittock.

GAMESP predicts the changes in soil delivery are primarily due to increased crop cover and reduced overland delivery.

HSPF predictions were somewhat less optimistic. HSPF predicted affects of land management upon runoff and water balance as well as soil and phosphorus losses. Land management practice adjustments had an overall affect on runoff due to modified land surface conditions. These changes in runoff over a two-year period ranged up to 19%. Soil loss increases due to fallow conditions were predicted to range up to 87 % or about double from the existing while no till was predicted to save 60% of the soil at best. Phosphorus losses under fallow and no till were predicted to be slightly reduced from the soil loss figures since phosphorus pathways include subsurface and other soluble and non soil attached forms. HSPF predicts that phosphorus transport is not as controllable as soil loss.

8.6 Conclusions

The following conclusions have been presented from the modelling activities undertaken during the PWS:

- GAMESP is an effective screening level soil and phosphorus management tool. It lends itself to interactive planning at the farm field level up to the small watershed scale. The model is easy to apply and interpret using readily available information.

- HSPF is suited to assessment as it clearly links cause and effect at the primary process level. Provided with detailed input regarding watershed characteristics, management practices and watershed runoff; the model can assist researchers and planners to identify the effects of conservation tillage in the short and long term through runoff and erosion process alteration. HSPF provides real time estimates of runoff as well as erosion and can simulate subsurface as well as surface transport processes for phosphorus. In this regard, HSPF is more complete than GAMES and can be used to more fully assess and plan farm management at field and watershed scales.

- Both models predict that significant benefit can be realized through the implementation of farm conservation management systems. The GAMES predictions are somewhat optimistic and do not account for the complex interaction of processes governing runoff. The HSPF predictions indicate that factors of two to five may be relevant between worst case and best case erosion and phosphorus delivery rates. These benefits are significant in light of water quality targets for the Great Lakes and on-farm conservation expectations.

8.7 Recommendations

Recommendations regarding the use of models are noted below.

- Screening level models such as GAMESP should be an integral part of the farm level planning process to achieve full implementation of conservation farming.

- Detailed deterministic models such as **HSPF** should be used to improve the estimation of conservation system benefits in the short and long term and as an aid to researchers in accounting for the complex system of processes governing runoff and erosion.

- More research is required to define the cause and effect relationships involved in erosion and runoff from farm fields. The currently available models are only as accurate in predicting benefit as the accuracy of input parameter adjustments. At present, several processes are poorly quantified in this regard.

- Pilot watershed studies must be continued over longer periods of time to allow for effective adoption followed by acclimatization. The PWS had achieved a reasonable level of adoption after five years. However the program did not allow for a new equilibrium to be achieved with respect to soil structure and quality, farmer practices, and crop performance. Model predictions of conservation system benefits cannot be verified since the watershed was not monitored following establishment of new systems.