FINAL REPORT AAFC-6

Indicators of Risk of Water Contamination: Local Scale Implementation and Testing

September 1995

SSC Contract No. 01950-4-1313/01-XSE

Compilation of a Computerized Database using Data Assembled under the Pilot Watershed Study of the Soil and Water Environmental Enhancement Program (SWEEP)

Prepared by:
Andrew Couturier
358 Metcalfe St., Guelph, Ontario
N1E 4Z7

On behalf of:
Agriculture and Agri-Food Canada
Centre for Land and Biological Resources Research
Land Resource Division
70 Fountain St., Guelph, Ontario
N1H 3N6

EXECUTIVE SUMMARY

This report assesses the feasibility of implementing the Indicators of Risk of Water Contamination (IROWC) at level 2/3 of the hierarchy proposed by MacDonald and Spaling (1995a). In particular, the paper assesses the utility of the Erosion Productivity - Impact Calculator (EPIC) as an analytical tool to address water contamination risk at this scale. A description of the broad approach is followed by an evaluation of the EPIC model's ability to simulate surface runoff and an example calculation of Nitrogen concentration in surface runoff. The paper concludes that EPIC represents a viable means for calculating the various components of IROWC, but that some fine tuning of the model is required to improve the accuracy and reliability of such calculations.

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1. INTRODUCTION AND OBJECTIVES

This paper continues a series of reports pertaining to digital data gathered during the course of the Pilot Watershed Study (PWS) and to the Indicators of Risk of Water Contamination (IROWC) Project at the Ontario Land Resource Unit (OLRU) (MacDonald and Spaling 1995a,b). Earlier papers (Couturier 1995 a,b,c,d,e) have (i) assessed and documented the types of digital data available from the PWS, (ii) illustrated the organization of the digital database, and (iii) have described the structure of the individual data files associated with the test and control watersheds. The primary goal of these activities was to prepare the PWS data for application to the Indicators of Risk of Water Contamination (IROWC) Project (MacDonald and Spaling 1995a,b).

The purpose of this report is to assess the feasibility of implementing the Indicators of Risk of Water Contamination at the scale of micro drainage basins (5-28 ha) nested within the test and control watersheds. A model which simulates a variety of agriculture-related physical and biological processes (Erosion Productivity - Impact Calculator [EPIC]) has been selected to aid in the implementation of IROWC at this scale. The report begins by summarizing the basic principles of IROWC and by outlining the broad approach used to calculate water contamination. Subsequent sections evaluate the degree of agreement between the surface runoff values predicted by EPIC and the surface runoff values observed at a selected micro-basin for sample runoff events in 1989 and 1990. The concentration of nitrogen in surface runoff is documented for the sample runoff events as an example calculation of IROWC. Finally, an appendix is included which documents the input file format and various procedures required to run the EPIC model.

1.1 Background

Calculation of the **Potential Contaminant Concentration (PCC)**, which is used to determine IROWC, involves two primary components (MacDonald and Spaling 1995b): i) determination of the **Potential Contaminant Present (PCP)** in mg/ha, and ii) calculation of **Excess Water (EW)** in l/ha, which represents the quantity of surplus water available for transport and dilution of contaminants present. The PCP is sensitive to such factors as the type of crop grown (and associated pesticide and fertilizer inputs), soil conditions and management factors, e.g. tillage. Determination of excess water requires climatic data such as precipitation and evaporation and, when possible, information on partitioning of water between surface and sub-surface flow. Of course, the appropriateness of these factors will vary according to the spatial and temporal resolution selected for calculation of IROWC.

MacDonald and Spaling (1995a) proposed that risk of water contamination from agricultural activities could be assessed at a variety of spatial and temporal scales. They proposed a seven-level hierarchical framework for investigating IROWC, beginning with the national level (macro) and moving down to the regional (meso), local and micro plot scales. Inherent in this transition is an increasing level of detail and complexity, accuracy, data requirements and difficulty. Whereas average annual data may be appropriate for calculating PCC at the meso to macro levels of the hierarchy, monthly to daily (and in some cases even finer) data is required at lower levels.

During the course of the Pilot Watershed Study, data on climate, soils, crops, hydrology and water quality were gathered for micro drainage areas ranging in size from 5 to 28 hectares (see Couturier 1995a). These data provide the opportunity to adapt and test the IROWC methodology at level two of the hierarchy identified by MacDonald and Spaling (1995a).

2. MICRO-BASIN SCALE IROWC

2.1 The Approach

A computerized model which simulates a variety of biophysical processes was selected to implement an IROWC at the micro drainage area scale. The Erosion-Productivity Impact Calculator ((EPIC version 4160) USDA, no date) contains 10 modules which render it an excellent choice for calculating water contamination risk at this scale: weather, hydrology, erosion, nutrient cycling, pesticide fate, soil temperature, tillage, crop growth, crop and soil management, and economics. Based on crop type, management practices and the daily uptake of nutrients over the growing season, EPIC can be used to estimate the quantity of inputs in excess of crop requirements (PCP) which are available for water contamination. Climate data are used to produce a daily estimate of the amount of water in excess of the amount held in the soil and used by crops (EW). This excess water will move offsite as surface or sub-surface flow and will dilute the contaminants in question.

Initially, a micro-basin was selected which contains a single type of crop, tillage, land use management, etc., so that relationships between contaminants and excess water can be established. Of the 12 micro-basins identified in the PWS, those found in the Essex test and control watersheds most closely meet these requirements. In fact, Essex test micro-basin 1 (ETB1) is almost entirely comprised of a single field, and has been used to test the EPIC model. An EPIC data file has been created and tested which contains the weather, crop, soil, and management information associated with ETB1 (Appendix A).

Appendix A also documents the steps required to transform the PWS digital climate data into an EPIC compatible weather file. The weather file allows EPIC to simulate actual evapotranspiration on a daily basis, thus allowing an estimate of excess water, and hence PCC, for every day of the year. EPIC also calculates daily surface runoff, which will be used in subsequent sections to produce a crude estimate of Nitrogen PCC.

The model was executed for ETB1 for 1989 and 1990, based on the following assumptions and parameters:

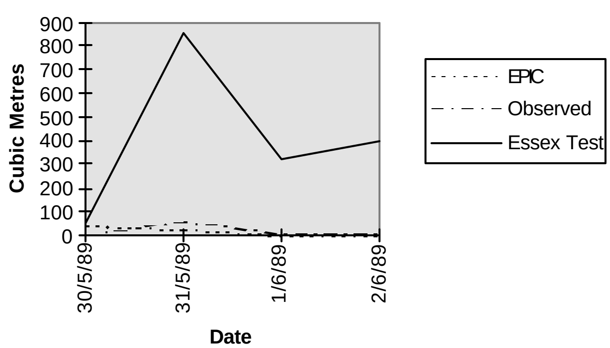
- soybean crop
- 50kg/ha N content of the soil at seeding time
- Sept. 15 harvest date
- Oct. 15 - 100kg/ha N application (to represent N content of crop residue in the soil)

The following pages describe the output of the EPIC model for a series of 5 runoff events. The ability of the model to simulate the observed surface runoff is evaluated and preliminary calculations of Nitrogen PCC are provided.

2.2 Evaluation of Model Performance

In order to ascertain the level of agreement between the surface runoff values predicted by EPIC and the actual runoff values observed at ETB1, 5 runoff events (2 in 1989 and 3 in 1990) were examined and compared. Table 1 displays these runoff values and, in addition, illustrates the relationship between micro-basin flow and overall sub-basin discharge (note that

Figure 1. Event 1 Runoff in ETB1



only surface runoff is computed in the EPIC data and in the observed micro-basin runoff, while total discharge from all sources is included in the values for Essex Test sub-basin flow).

Generally, EPIC predicted runoff follows the pattern observed in the **overall sub-basin** during events 1, 2 and 4 (Table 1; Figure 1). In event 4, and more so during event 1, runoff predicted by EPIC and observed at the micro-basin match quite closely. Runoff was not monitored at ETB1 during event 2, so a comparison with the values predicted by EPIC is not possible. However, the predicted values for event 2 do agree with the overall Essex Test discharge. **The patterns observed in these 3 events suggest that EPIC estimates surface runoff quite well during periods of low runoff.**

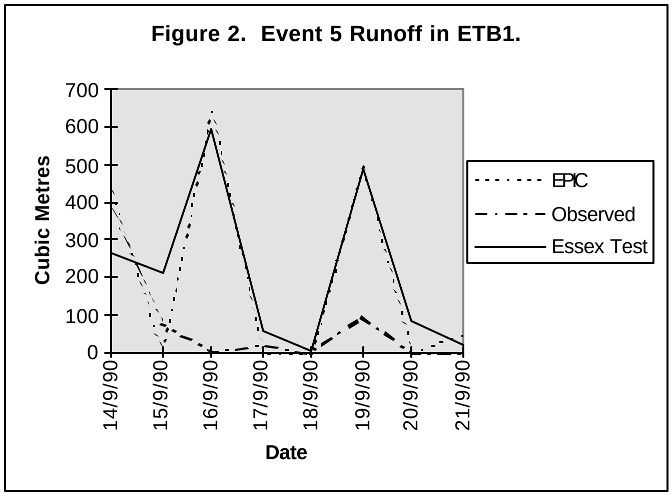
Table 1. **Surface runoff values generated by EPIC, observed surface runoff for ETB1 and total discharge for the Essex Test sub-basin for selected runoff events in 1989 and 1990.**

Date	**EPIC Predicted Surface Runoff (m^3)**	**Observed Surface Runoff (m^3)**	**Observed Total Discharge for Essex Test Sub-basin (m^3)**
Event 1			
30/5/89	35.9	0	55.7
31/5/89	21.6	59.8	852
1/6/89	0	9	314
2/6/89	0	6.1	404
Event Total	**57.5**	**74.9**	**1625.7**
Percent of Total Observed Sub-basin Flow	3.50%	4.60%	100%
Area Flow (m^3 /ha)	10.8	14.1	3.7
Event 2			
19/7/89	25.9	N/A	21.3
20/7/89	49.1	N/A	696
21/7/89	0	N/A	71.1
22/7/89	0	N/A	20.7
23/7/89	0.8	N/A	16.3
Event Total	**75.8**	**N/A**	**825.4**
Percent of Total Observed Sub-basin Flow	9.20%	N/A	100%
Area Flow (m^3 /ha)	14.3	N/A	1.9
Event 3			
13/5/90	601	16.9	168
14/5/90	0	1.44	46
15/5/90	0	0	23.8
16/5/90	254	127	281
17/5/90	3.3	20.2	132
18/5/90	0	0	47.2
Event Total	**858.3**	**165.5**	**697.9**

Date	EPIC Predicted Surface Runoff (m^3)	Observed Surface Runoff (m^3)	Observed Total Discharge for Essex Test Sub-basin (m^3)
Percent of Total Observed Sub-basin Flow	123%	23.70%	100%
Area Flow (m^3 /ha)	161.9	31.2	1.6
Event 4			
15/6/90	0	28.4	0.8
16/6/90	0	4.3	0.2
17/6/90	0	59	0
18/6/90	0	2.16	0
19/6/90	0	0	0
Event Total	**0**	**94**	**1**
Percent of Total Observed Sub-basin Flow	0%	9400.00%	100%
Area Flow (m^3 /ha)	0	17.7	0.002
Event 5			
14/9/90	422	376	262
15/9/90	0	81.4	213
16/9/90	639	3.96	591
17/9/90	0	18.4	57.9
18/9/90	0	0	3.31
19/9/90	490.7	96.1	489
20/9/90	0	0	86.7
21/9/90	45	0	18
Event Total	**1596.7**	**575.9**	**1720.9**
Percent of Total Observed Sub-basin Flow	93%	33.50%	100%
Area Flow (m^3 /ha)	301.3	108.7	4

Note: ETB1=5.3ha Essex Test= 435ha

During event 3, the runoff predicted by EPIC exceeds the amount observed for the overall sub-basin, and is only slightly less than the observed Essex Test discharge for event 5 (Table 1; Figure 2). The accuracy of both observed micro-basin and sub-basin values is



unknown, and it is acknowledged in BEAK (1994) that micro-basin monitoring was interrupted periodically by blockages in the measuring devices. This raises some doubt as to the reliability of the observed values at the micro-basin level. Nevertheless, even if the observed discharge for the overall sub-basin has been underestimated, the values predicted by EPIC are substantially overestimated and are not indicative of the true situation. **Moreover, these 5 sample events indicate that EPIC tends to track low runoff events quite accurately, but that the model tends to overestimate during high runoff events.**

On an annual basis, EPIC is consistent with trends observed in the sub-basin as a whole (Table 2), however, it clearly overestimates the total amount of runoff. The total yearly runoff observed in ETB1 cannot be used as a comparison because it was only monitored on an event basis and not continuously throughout the year. Moreover, with some adjustments and tuning, the EPIC model can provide daily estimates of surface runoff which are more representative of a micro drainage area nested within the Essex Test sub-basin.

Table 2. **Yearly surface runoff totals predicted by EPIC and yearly totals observed at the micro-basin and sub-basin levels.**

Year	EPIC	ETB1 Observed	Essex Test Observed
1989 Total Surface Runoff (m^3)	1708	74.9#	7820*
% of total	21	1	100
area flow (m^3/ha)	322.3	14.1	18
1990 Total Surface Runoff (m^3)	9699	1458#	25910*
% of total	37	5.6	100
area flow (m^3/ha)	1830	275.1	59.6

#incomplete total
*comprises total runoff from all sources

2.3 Estimation of Nitrogen Concentration in Surface Runoff

This section utilizes the 5 sample events discussed above to calculate a preliminary estimate of surface water contamination by Nitrogen. The results from the EPIC model indicate that no movement of water below the rooting zone occurred during the two year period, and so contamination of groundwater by Nitrogen has not been addressed here. Table 3 illustrates the concentration of Nitrogen present in surface runoff, as predicted by EPIC, for the five sample runoff events. As indicated earlier, these estimates of Nitrogen concentration are only as accurate as the surface runoff values from which (in part) they were derived. Since, at this stage, the surface runoff values are rough estimates, so too are the Nitrogen PCC values. Once the model has been properly configured, more accurate estimates of Nitrogen PCC are possible.

3. SUMMARY AND CONCLUSIONS

This report assesses the feasibility of implementing IROWC at level 2/3 of the hierarchy proposed by MacDonald and Spaling (1995a) and, in particular, assesses the EPIC model as a tool for accomplishing this task. This report has demonstrated that It is possible (via EPIC) to produce a daily estimate of PCC by calculating the daily quantity of nitrogen in excess of crop requirements (PCP) relative to the daily quantity of water in excess of crop requirements (EW-surface). The activities discussed in this report represent a significant step in analyzing water contamination risk at the micro-basin level. Future tasks involve fine tuning the EPIC model so as to produce a more accurate estimate of water contamination risk.

Table 3. Nitrogen Potential Contaminant Concentration (PCC) calculation for ETB1 for selected runoff events in 1989 and 1990.

Date	Precipitation (P) (mm)	Actual Evapotranspiration (AE) (mm)	Available Water (P-AE) (mm)	Surface Runoff (l/ha) EW	NO_3 in Surface Runoff (mg/ha) PCP	Potential Contaminant Concentration (PCP/EW) (mg/l)
Event 1						
30/5/89	29.3	4.78	24.52	6784	474200	**69.90**
31/5/89	25.0	2.89	22.11	4072	280700	**68.93**
1/6/89	4.8	3.68	1.12	0	0	**0.00**
2/6/89	6.5	6.48	0.02	0	0	**0.00**
Event 2						
19/7/89	44.8	1.81	42.99	4889	495600	**101.37**
20/7/89	30.3	1.03	29.27	9271	203200	**21.92**
21/7/89	0.0	3.42	-3.42	0	0	**0.00**
22/7/89	0.0	3.55	-3.55	0	0	**0.00**
23/7/89	6.7	4.15	2.55	144	800	**5.56**
Event 3						
13/5/90	27.1	3.02	24.08	113528	2905800	**25.60**
14/5/90	0.6	2.62	-2.02	0	0	**0.00**
15/5/90	4.7	2.88	1.82	0	0	**0.00**
16/5/90	17.4	2.21	15.19	47943	361500	**7.54**
17/5/90	5.7	4.94	0.76	621	3600	**5.80**
18/5/90	0.0	2.46	-2.46	0	0	**0.00**
Event 4						
15/6/90	0.0	3.43	-3.43	0	0	**0.00**
16/6/90	0.0	2.57	-2.57	0	0	**0.00**
17/6/90	0.0	1.60	-1.60	0	0	**0.00**
18/6/90	0.0	1.51	-1.51	0	0	**0.00**
19/6/90	0.0	1.65	-1.65	0	0	**0.00**

Date	Precipitation (P) (mm)	Actual Evapotranspiration (AE) (mm)	Available Water (P-AE) (mm)	Surface Runoff (l/ha) EW	NO_3 in Surface Runoff (mg/ha) PCP	Potential Contaminant Concentration (PCP/EW) (mg/l)
Event 5						
14/9/90	24.0	1.44	22.56	79693	69900	**0.88**
15/9/90	0.3	1.61	-1.31	0	0	**0.00**
16/9/90	19.1	3.03	16.07	120542	96900	**0.80**
17/9/90	0.0	0.89	-0.89	0	0	**0.00**
18/9/90	0.6	2.10	-1.50	0	0	**0.00**
19/9/90	20.9	1.02	19.88	92591	76600	**0.83**
20/9/90	0.0	2.61	-2.61	0	0	**0.00**
21/9/90	8.9	1.36	7.54	8508	6300	**0.74**

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APPENDIX A

Notes on EPIC

-EPIC version 4160 was used to conduct the analysis (with a manual from a previous version).

-while attempting to match the surface runoff predicted by EPIC with the observed runoff, several input parameters were adjusted and tested. While changing the values for field width, field length, and slope length had no effect on predicted runoff, altering the **runoff curve number** had a very significant impact.

-if an error message (e.g. run-time, invalid floating point error) halts a simulation run, check the data file for values of “0" in cells. Even though a value of 0 may fall within the acceptable range, it still causes this error. Replace any values of 0 with another value as close to 0 as possible.

-conflicting instructions on how to set up a daily weather file are given in the EPIC User’s Guide and in the on-line help. Since the format used for ETB1 has been tested and works well, it may be wise to use this format in future weather files (a portion of the daily weather file is provided on the following pages). There may be a more straight forward way of creating a weather file -- a combination of Quattro and Excel was used to create the desired column widths and add decimals in the appropriate places. The name of the weather file (ess89.wth) was added to the end of the EPIC data file in MS-DOS Editor (any text editor would suffice).

EPIC DATA FILE FOR ESSEX TEST MICRO-BASIN 1

DAILY WEATHER FILE FOR ESSEX