A Comparative Water Quality Study of Man-Made Drainage and Natural Streams

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ABSTRACT—The effects of man-made drainage systems on the water quality of receiving bodies is relatively unknown. During the ice-free season of 1979, thirteen drainage ditches and four rivers were sampled at intervals of three to eight days. With increasing flow, total orthophosphatephosphorous, total Kjeldahl-nitrogen, nitrate-nitrogen and total dissolved solids increased, but not proportionately to flow, with total orthophosphate-phosphorous showing the least proportionality. Variation was observed in each ditch and river when broken down seasonally for each parameter. Generally, when the percentage of flow was greater in one of the three seasons, the percentage of each of the other parameters followed the same trend.

South Central Minnesota is dominated by agriculture, and much of the land has been drained by extensive man-made agricultural ditches. The direction of research at Mankato State University under Dr. Henry Quade and several graduate and undergraduate students has been to qualify and quantify the effect of the man-nade drainage systems on water quality in receiving bodies.

This study attempts to determine the amount of chemical variation in the ditches and rivers in the region.

Scope and characteristics of sampled waters

From March 21, 1979, to November 16, 1979, thirteen ditches and four rivers were studied on a three-to-eight-day interval with an integrating sampler. The sample sites are in four southern Minnesota counties, Brown, Blue Earth, Nicollet, and Le Sueur. The water was sampled at the same time for conductivity with a portable conductivity meter, for temperature in degrees centigrade, and for depth and velocity of flow by the Embody method or by use of a pygmy meter.

Collected samples were stored in one liter glass bottles at four degrees centigrade after two milliliters of concentrated H_2SO_4 were added per liter.

Standard methods for total orthophosphate-phosphorous, total Kjeldahl-nitrogen, and nitrate-nitrogen were used in the laboratory.

Flow was calcualted by velocity measurements multiplied by the square area of each ditch or river which was obtained by plane table mapping during low flow. The instantaneous flow values then were multiplied by the amount of time in the sample intervals.

The values for total flow at each site in 100,000 cubic meters is shown in Table I. The total cumulative value for each chemical parameter is in kilograms for the entire collection season. An estimation of total dissolved solids from the conductivity readings was calculated by generating an equation to describe the relationships of conductivity and temperature, taken from table values, using the Univac 1170/80A computer and running regression analysis using the SPSS language, a statistical package program.

Ditches and rivers have been grouped according to Strahler's scheme of stream order. Ten of the ditches qualify as second order ditches and three as third order ditches. Three of the four rivers are third order rivers, and Shanaska Creek is of second order.

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Load is calculated by multiplying each period flow by the period concentration. Total load is the sum of all period loads. Generally the site in each ditch (river) order which has the maximum flow also was the maximum for all parameters except as mentioned below. By comparing the ratio of maximum to minimum with that of flow, we see it is not only flow dependent.

In the second order ditches, the ratio of maximum to minimum of both nitrate-nitrogen and total dissolved solids is one-half the maximum to minimum ratio of flow. While the maximum to minimum ratio of total Kjeldahl-nitrogen is nearly one and three-fourths times greater than the maximum to minimum ratio of flow. Even more striking is the fact that the maximum to minimuum ratio of total orthophosphate is four times that of flow. Maximum values came from ditch Br-J-30 while minimum values came from ditch Br-C-5.

In the third order ditches the ratio of maximum to minimum for nitrate-nitrogen and total dissolved solids equals the maximum to minimum ratio for flow. The maximum to minimum ratio for total Kjeldahl-nitrogen is one and one half times the maximum to minimum ratio for flow with the maximum to minimum ratio for total orthophosphate slightly higher, approximately one and three fourths greater than the maximum to minimum ratio for flow. Maximum values came from ditch N-J-1A, while minimum values are from ditch BE-J-48.

In the third order rivers, the Cannon River had maximum values for flow, total Kjeldahl-nitrogen and total orthophosphate-phosphorous and also had the minimum value for nitrate-nitrogen, and close to the minimum value for total dissolved solids. The maximum values for nitrate-nitrogen and total dissolved solids were found in Morgan Creek.

For third order rivers, the maximum to minimum ratio of all parameters when compared to the maximum to minimum ratio of flow are all greater than flow, with total dissolved solids and total orthophosphate-phosphorous close to one and one quarter times larger; while the maximum to minimum ratio of nitrate-nitrogen and total Kjeldahl-nitrogen are two and one half times the maximum to minimum ratio of flow.

When all ditches are examined together, ditchN-J-1A had the maximum value for all parameters and ditch Br-C-5 had the minimum value for all parameters. The maximum to minimum ratio of total dissolved solids is approximately eight-tenths of the maximum to minimum ratio of flow while the maximum to minimum ratio of nitrate-nitrogen is almost the same, even though slightly higher than the maximum to minimum ratio of flow. The maximum to minimum ratio of total Kjeldahl-nitrogen is almost one and three-fourths times greater than the maximum to minimum ratio of flow. The maximum to minimum ratio of total orthophosphate-phosphorous is greater than two and one fourth times the maximum to minimum ratio of flow.

When all of the rivers are group together the minimum values for all parameters were found at Shanaska Creek, the second order stream; while maximum values were found at the Cannon River for total orthophosphate-phosphorous, total Kjeldahl-nitrogen, and flow. Morgan Creek recorded maximum values for nitrate-nitrogen and total dissolved solids.

In the rivers the maximum to minimum ratio of total Kjeldahl-nitrogen is slightly larger than the maximum to minimum ratio for flow but almost the same, while the maximum to minimum ratio for total dissolved solids is twice as large as for flow. When looking at total orthophosphate-phosphorous the maximum to minimum ratio is five times as large as for flow and the maximum to minimum ratio for nitrate-nitrogen is thirteen times the maximum to minimum ratio for flow.

Observation of the seventeen sites shows a great variability exists in water quality and volume of water flowing through the ditches and rivers. It also can be seen that flow is not the only variable affecting the total chemical load (Table I). In an attempt to discover other variables, the mean value for total orthophosphate in mg/l was arranged by flow from the least to the most, but no predictable relationship was found.

When the same values were arranged according to counties, with an assumption this might bring into play soil types, farming practices, or ditch construction variables, no orderly relationship could be found either.

The second order ditches in this study showed the greatest variability, as indicated by significantly greater maximum to minimum ratios than in any other group for all parameters.

Variables beyond the reach of this study may also influence water quality.

Interparameter relationship noted in seasonal breakdown

The data has further been divided into three seasonal periods. The first season, "Spring Runoff", covers the first fifteen collection dates, March 21, 1979 to June 2, 1979. The second period, "Growing Season", includes the next eighteen sampled dates, June 10, 1979 to October 12, 1979. The third season, "Fall Harvest and Plowing", includes only the last four sample dates before the ditches and rivers began to freeze over, October 24, 1979 to November 16, 1979. The duration of each season was selected to represent the status of vegetation in the fields along the drainage water courses.

The great variability seen in ditches and rivers sampled can be seen when looking at flow in the four second order ditches in Brown County, Br-J-29, Br-C-5, Br-J-30, and Br-J-10. One should keep in mind these ditches are in the same county and yet during "Spring Runoff" we see 28.6 percent, 37.9 percent, 81.3 percent and 20.0 percent of the total flow in the "Spring Runoff" season, respectively.

The year 1979 was an extremely wet year in this area, which not only brought high water levels in the early spring but also a very wet August, with water levels as high as during the traditional snow melt and flooding period of spring. Data from the state climatological office indicates the soils in southern Minnesota were saturated throughout the collection period, resulting in nearly all of the rainfall entering the drainage systems as overland flow.

Generally, when flow has a larger percentage in one of the three seasons, the percentage value of each of the other parameters seems to follow the same trend. For example, in ditch BrJ 30, the "Spring Runoff" season accounted for 81.3 percent of flow, 90.5 percent of total orthophosphate-phosphorous, 86.6 percent of total Kjeldahl-nitrogen, 73.5 percent of nitrate-nitrogen, and 69.3 percent of total dissolved solids.

Ditch Br-J-10, also in Brown County, had a larger percentage of load in the "Growing Season". This ditch had 66.4 percent of flow, 78.4 percent of total orthophosphate-phosphorous, 77.0 percnet of total Kjeldahl-nitrogen, 63.7 percent of nitrate-nitrogen, and 73.8 percent of total dissolved solids in the second season.

A few exceptions were observed in the trend of the largest percentage load to follow the largest percentage flow by season, as seen in Shanaska Creek. The second season, "Growing Season", accounts for 61.8 percent of flow, and every other parameter except nitrate-nitrogen is very close. Nitrate-nitrogen in this season is only 28.9 percent, while it is 64.1 percnet in the first season which had a corresponding

Table I Cumulative total load by study site in kilograms.

	Site	Total PO_4	TKN	NO_3	Total Dissolved Solid	Total Flow**
Second Order Ditches	N-C-40A	No Flow	No Flow	No Flow	No Flow	0.0
	N-C-38A	1599.0	19250.6	193882.2	6614791.7	93.9
	Br-J-29	1200.3	11743.4	116137.1	3973388.3	75.7
	Br-C-5	51.5	634.9	12190.7	481305.0	5.8
	Br-J-30	8711.4	46608.8	302405.5	9988864.5	242.0
	Br-J-10	1009.3	9437.3	185116.1	5822894.3	70.0
	BE-C-56	2154.8	18666.5	158199.1	5947185.2	107.0
	BE-C-5	1275.4	17730.9	76149.5	4478515.6	78.3
	LS-C-59	795.4	14626.1	80262.4	2629249.8	58.9
	LS-C-58	326.0	4448.4	50935.3	1093212.5	17.7
Third Order Ditches	BE-J-48	2980.3	29922.3	588588.9	16935025.5	260.8
	N-J-1A	10973.2	100510.0	1176561.5	35325877.5	535.3
	N-J-1A*	5533.5	37361.1	658465.7	21576960.0	280.8
Third Order Rivers	Br-BE Morgan Creek	8299.9	63328.5	1033460.4	38010640.0	482.5
	BE-Little Cobb River	5985.9	30630.5	576006.7	16288744.1	303.4
	LS-Cannon River	12394.6	132032.0	254467.2	20767024.7	528.7
Second Order River	LS-Shanaska Creek	219.3	9961.4	6753.3	1535491.0	45.2

**in 100,000 m^3

flow of only 32.0 percent.

The Cannon River shows a few interesting variations. The first season has 49.8 percent of total flow, the second season has 42.7 percent of flow with the third season having 7.4 percent. Total Kjeldahl-nitrogen and total dissolved solids mirror these percentages closely, with 53.1 percent, 41.2 percent, and 5.7 percent for total Kjeldahl-nitrogen and 50.9 percnet, 42.6 percent and 6.5 percent for total dissolved solids. Total orthophosphate-phosphorous doesn't follow this trend as the first season is 36.1 percent, second is 59.6 percent, and the third is 4.3 percnet. The values for nitrate-nitrogen are even more one sided, with 84.9 percent in the first season, 12.6 percent in the second season, and 2.5 percent in the last season.

Ditch LS-C-59, with flow values of 64.4 percent for the first season, 35.6 percent for the second and .0 percent for the third shows a few exceptions as well. Total orthophosphate-phosphorous doesn't follow the percentages of flow as only 40.1 percent of the total is in the first season with 59.9 percent in the second, and .0 percent in the third season. The values for total Kjeldahl-nitrogen closely follow that of flow, but nitrate-nitrogen interestingly is very high, 78.0 percent in the first season, 22.0 percent in the second and .0 percent in the third. The values for total dissolved solids are nearly equal for season one and two at 50.2 percent and 49.8 percent respectively. The third season is .0 percent. Ditch LS-C-59 had an ice covering the last three sample days of the "Fall Harvest and Plowing" season.

The last ditch to be discussed is Br-J-29 which is the only ditch with any significant values over 15.0 percent in the third season, "Fall Harvest and Plowing". The value for flow at 32.5 percent and for the other parameters close to one third of the total is different than any other ditch or river. Total Kjeldahl-nitrogen is low at 24.3 percent in the third season and total dissolved solids is the lowest at 14.4 percent. But many of the ditches have values close to zero and most below 10.0 percent.

This study shows the great variability and unique water quality of each ditch and river sampled and indicates that each must be examined separately.

REFERENCES

American Public Health Association, American Water Works Association, Water Pollution Control Federation, Standard Methods for the Examination of Water and Wastewater, 14th Edition, 1975.

HYNES, H.B.N. The Ecology of Running Waters, 1970, University of Toronto Press.

QUADE, COLAKOVIC, HILL, LARSON, et. al. Limnological Investigation of the Cannon River-County Ditch 59 Watershed of Lake Tetonka. Department of Biology, Mankato State University, 1979.

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