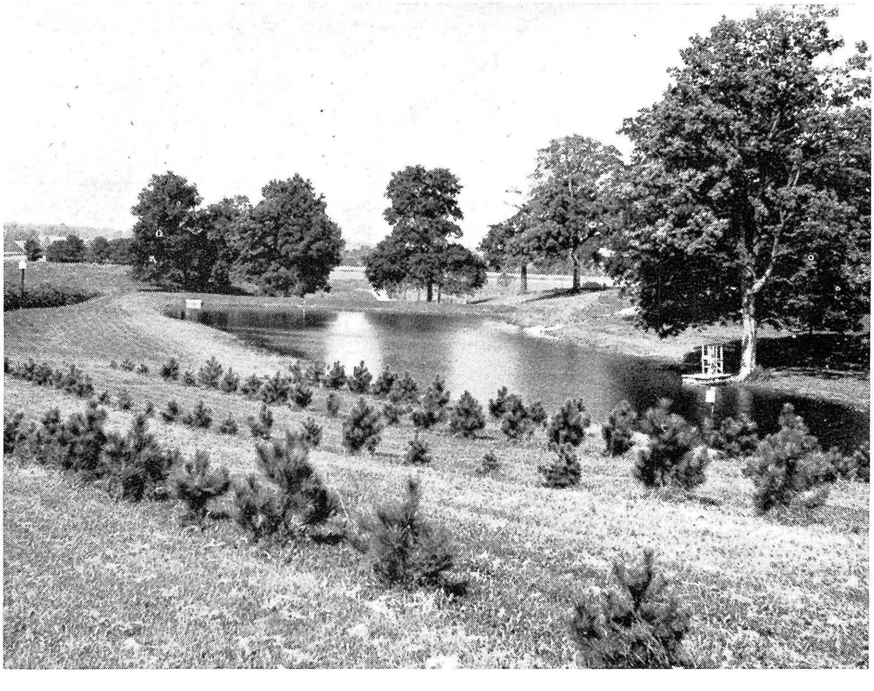
RESEARCH BULLETIN 922 OCTOBER 1962

Quality of Water in
OHIO FARM PONDS

R. D. HILL, G. O. SCHWAB, G. W. MALANEY
H. H. WEISER



OHIO AGRICULTURAL EXPERIMENT
STATION - - - WOOSTER, OHIO

CONTENTS

* * * *

AGDEX $\frac{754}{716}$

10-62-4M

Quality of Water in Ohio Farm Ponds

R. D. HILL, G. O. SCHWAB, G. W. MALANEY and H. H. WEISER*

INTRODUCTION

PURPOSE

The purpose of this study was to determine the physical, chemical, and bacteriological quality of water in farm ponds as affected by physical and cultural features of the watershed, vegetation in or near the water, chemicals applied to the pond, presence of animals in or near the pond, depth of water and seasonal climatic conditions. The overall project included an evaluation and development of various water treatment facilities, but these will be discussed in later reports. The data were obtained during the three-year period, May 1958 through August 1961.

NEED FOR STUDY

In many areas of Ohio and other states, water from wells and cisterns is inadequate in quantity and quality for domestic use. Well water is often unsatisfactory in Ohio because of high mineral content. In some areas of the state ground water is unobtainable. Water supply from cisterns is inadequate to meet the demand on most farms today. Similar problems have been reported in Iowa, Missouri, Indiana, and Oklahoma. The Iowa State Department of Health (1) estimated that 65 to 75 percent of all farm well water was contaminated.

A meeting with farmers in southern Ohio in the fall of 1956 revealed that water supply was one of the important problems in a high percentage of the counties represented.

A survey of county agents in 1956 (44 of 88 counties reporting) showed that 9,000 farmers had a critical water supply problem due to either insufficient quantity or poor quality. This problem is likely to increase in magnitude because of the rapid development of suburban areas and the modernization of rural water facilities. The trend to-

---

*Respectively, Instructor and Professor in Agricultural Engineering; and Assistant Professor and Professor in Microbiology, the Ohio Agricultural Experiment Station and The Ohio State University. This project was carried on under National Institute of Health grants RG7358 and RG895. The authors express their appreciation to the Ohio Department of Health for their cooperation on this project, to E. G. Will and his staff for chemical analyses of water samples, to the thirteen cooperating pond owners, and to R. B. Tompkin of the Microbiology Department, The Ohio State University.

ward bulk milk tanks which require greater amounts of high quality water for cleaning has added to this problem. Picton(3) states that the per capita water requirement of farm homes will approach 116 gallons per day by 1980.

Due to this critical water supply problem, many rural families are turning to farm ponds as a source of water. The 1956 survey of county agents in Ohio showed that 300 farmers were using pond water for domestic or milk room use. Many more than this number are probably using pond water but do not report it for fear of having their water supply condemned.

It is estimated that there were 25,000 ponds in Ohio in 1961. Since 1935 the Soil Conservation Service (S.C.S.) has aided in the construction of 13,611 farm ponds. Approximately 1,000 ponds were constructed under this program in each of the years 1959 and 1960 and it is estimated that an additional 1,000 ponds were constructed each year without S.C.S. assistance. At this rate the number of ponds in Ohio will almost double by 1971.

Farm ponds are useful in many ways including: 1) recreation (swimming, fishing, etc.), 2) livestock water supply, 3) supplemental house supply (water closets, etc., but not for domestic purpose), 4) domestic use (drinking water, cooking, milk house, etc.), 5) irrigation, and 6) spray water for fruits and vegetables. Quality is important for all of these uses. Chemical and bacteriological contamination can make water undesirable for most purposes, particularly for domestic uses. The increased use of pond water for domestic purposes and for food processing places greater importance on the need for information on quality and for the development of more efficient water treatment facilities.

PROCEDURE

LOCATION AND DESCRIPTION OF PONDS

Fourteen ponds in eight counties were selected for study. Figure 1 shows the geographic location of the ponds and the main soil regions involved. Ponds were chosen in three of the four major soil regions. Ponds were not located in the glacial and lacustrine soils region as less than one percent of the ponds in the state are found in this area. Appendix A presents soil information for each pond. The eight counties in which ponds were selected had 19 percent of the ponds in the state.

The fourteen ponds varied in size from 0.14 to 3.2 acres (surface area) with a mean of 0.75 acres. Watersheds contributing to these ponds ranged from 0.9 to 81 acres with a mean of 19.4 acres. Three ponds were spring fed, and two others were fed by field tile. Appendix B gives pertinent information on each pond and watershed. Photographs of the ponds are shown in Appendix C.

FIELD SAMPLING PROCEDURE

During the period from May 1958 to October 1959, each of the fourteen ponds was sampled at least 10 times. After October 1959 the sampling frequency was increased to monthly on 6 ponds and bimonthly on the other 8 ponds during 1960. In 1961 all ponds were sampled monthly except pond 60 which was sampled three or more times per month.

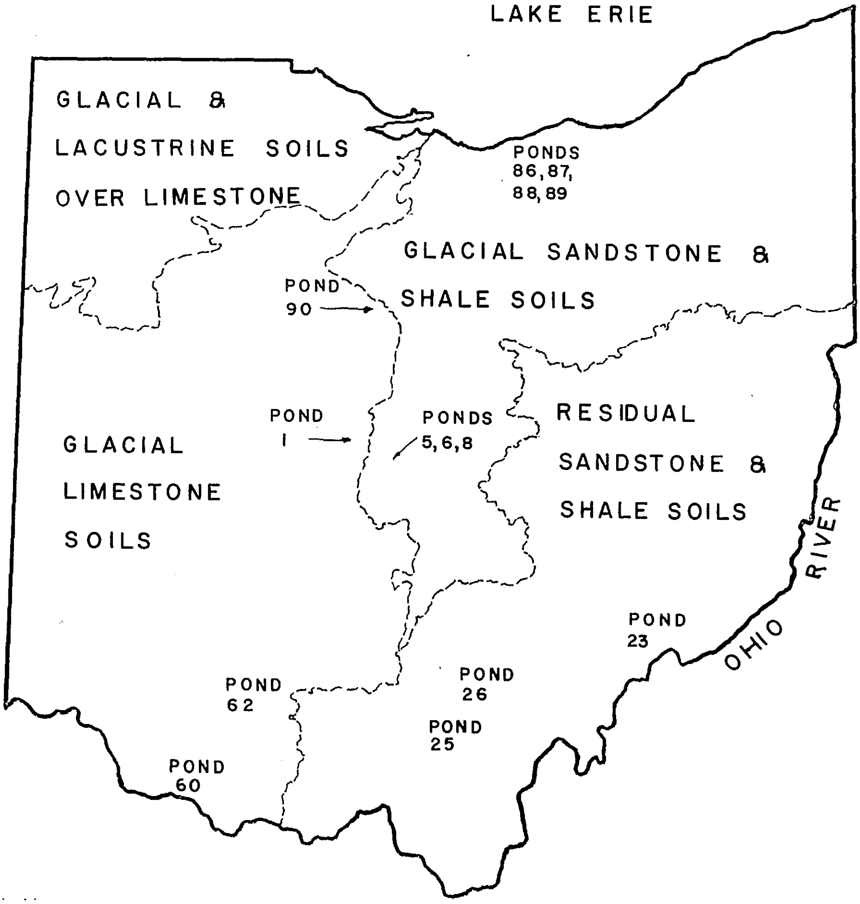


Fig. 1.—Location of Ponds by Soil Regions

From May 1958 to October 1959 samples were taken one foot below the surface and one foot above the bottom (these will be called top and bottom samples, respectively, throughout this report). After this period samples were taken at intervals of one-foot depth. Samples were taken either at the deepest point of the pond or near the inlet into the water effluent pipe.

Samples for chemical analyses, unless otherwise noted, were taken one foot below the surface. These tests were performed by the Ohio Department of Health Laboratory. Samples for bacterial analysis were placed on ice within a few minutes after being taken and remained under refrigeration until tests were performed. Analyses were begun on all samples within 24 hours.

WATER QUALITY TEST DEFINITIONS AND PROCEDURES

A description of the more important phyical, chemical, and bacteriological tests is as follows:

PHYSICAL

Turbidity—The turbidity of water is caused by the presence of suspended matter, such as clay, silt, finely divided organic matter, plankton, and other microscopic organisms. Turbidity is an expression of the optical property of a sample which causes light rays to be scattered and absorbed rather than transmitted in straight lines through a sample. A Hellige turbidimeter precalibrated by the Jackson candle method was used for making these determinations.

Color (apparent)—When color is mentioned in this report, apparent color is implied. The apparent color includes not only the color due to substances in the solution, but also to suspended matter. Apparent color was determined on the raw water sample without filtration or centrifugation. The color was determined by comparing the sample with precalibrated colored glass disc standards in a Hellige Aqua Tester.

Odor—During the first seventeen months (May 1958 to October 1959) of this study, odor was detected by smell and was classified as follows: 1) no odor, 2) perceptible, and 3) objectionable. A sample having a faint odor, but not considered objectionable, was classified as perceptible. Any sample having a strong odor or an objectionable odor was classified as objectionable. Starting in 1960, the threshold odor method was used. The procedure for this test is given in Standard Methods for the Examination of Water and Wastewater (5). High threshold numbers indicate strong odors.

Solids—Three types of solids were evaluated: 1) total solids, 2) suspended solids, and 3) volatile solids. Total solids were measured by evaporating a sample of water and weighing the remaining residue. Suspended solids were found by filtering a sample and then drying the suspended matter obtained by filtration. The residue from the total solids determination was ignited for 1 hour at 500° C. to obtain the volatile solids. The loss of weight of the residue was the amount of volatile solids. All of these measurements gave an indication of the amount of foreign matter in the sample. Volatile solids gave an indication of the amount of organic matter.

BACTERIOLOGICAL

Thermophilic bacteria—As the term is used by the dairy industry, the thermophiles are those bacteria which are able to grow at 55° C. The population of thermophiles was estimated by the standard plate count (SPC) technique as outlined in Standard Methods for the Examination of Dairy Products (6), with incubation at 55° C.

Thermoduric bacteria—As used by the dairy industry, the term thermoduric bacteria includes those bacterial species able to survive conventional pasteurization exposures. The density of thermodurics was estimated by the laboratory pasteurization test as described in Standard Methods (6), i.e., the water sample was heated at 145° F. for 30 minutes in a David Bradley Home Milk Pasteurizer, then the surviving bacterial population was determined by the SPC technique with incubation at 35° C.

Psychrophilic bacteria—The term psychrophilic refers to those bacterial species which are capable of growth and multiplication at refrigerator temperatures. The psychrophilic density was estimated by the SPC method with incubation at 0-10° C.

Total bacterial population—The total bacterial count of pond water samples was estimated by the SPC technique with incubation at 35° C.

Coliform bacteria—By definition the coliform group includes all aerobic and facultative anaerobic, Gram-negative, non-spore-forming bacilli which ferment lactose within 48 hours at 35° C. with gas formation. The coliform population was estimated by the conventional, multiple-tube MPN method recommended in Standard Methods for the Examination of Water and Wastewater (5). The specific procedure employed five tubes of lactose broth per dilution and three dilutions per sample. Positive presumptive tubes were confirmed in brilliant green lactose bile (BGB) broth. All positive BGB tubes were transferred to EMB agar, then significant colonies to lactose broth and agar slants.

Enterococci—The enterococci group consists of a number of species of gram-positive streptococci found almost universally in the intestinal contents of man and animals. The enterococci density was estimated by the conventional MPN method, using Winter-Sandholzer media and three tubes per dilution.

Salmonella and Shigella organisms—This group of bacteria encompasses a large number of common enteric pathogens which cause intestinal infections ranging from mild gastroenteritis to fatal typhoid fever. Detection of these organisms involves a lengthy cultural procedure. In this study a quart sample of pond water was passed through a sterile membrane filter in order to trap all the bacteria in the sample on the surface of the membrane filter. This filter was transferred to selenite broth and incubated for 18-24 hours. The selenite broth was streaked on various selective media, including MacConkey's agar, Brilliant Green agar, SS agar, and Bismuth Sulfite agar. Suspicious colonies were transferred to Triple Sugar Iron (TSI) agar. Cultures which showed glucose, but not lactose or sucrose fermentation on TSI agar were examined further, following the protocol of biochemical and serological tests recommended by Edwards and Ewing (2).

Chemical—Chemical tests were made annually on at least one sample from each pond. More frequent chemical tests were taken at pond 60 and at others when special conditions warranted, such as when ponds were chemically treated. The following tests were run: 1) alkalinity, 2) hardness, 3) pH, 4) iron, 5) chloride, 6) fluoride, 7) nitrate nitrogen, 8) sulfate, and 9) manganese. Arsenic, copper, and radiation were determined in special cases. For comparison the Drinking Water Standards of the U. S. Public Health Service are presented in Table I.

The recreational use of pond water may be effected by the alkalinity and pH levels of the water. Water with extremely high or low pH may cause fish kills, and eye and skin irritation to swimmers.

All of the chemical properties mentioned above are important when the water is used for domestic purposes or livestock. Iron and manganese cause clogging of pipes, staining of household fixtures, and give food bad color and tastes. High hardness results in scaling of water heaters, increased use of soap and detergents, and unpleasant curd formation in tanks. Sulfate, fluoride, chloride, nitrate, arsenic, and copper in excessive amounts can make water unfit for use.

RESULTS

PHYSICAL PROPERTIES

Turbidity—Four hundred and ninety top and bottom samples were taken from 14 ponds in the period May 1958 through July 1961. The turbidity for all top samples ranged between 1 and 155 units with a mean of 21 units and the bottom samples varied from 2 to 165 units

TABLE 1.–Drinking Water Standards*

Factor	Maximum Allowed
Turbidity	10 units
Color	20 units
Taste	not objectionable
Fluoride	1.5 mg/1
Arsenic	0.05 mg/1
Iron and Manganese (together)	0.3 mg/1
Chloride	250 mg/1
Sulfate	250 mg/1
Total Solids	500 mg/1
pH	10.6 @ 15° C. (6.0 minimum)
Odor	not objectionable
Copper	3.0 mg/1

Total Alkalinity: pH range	Limits for Total Alkalinity (mg/1)
8.0 - 9.6	400
9.7	340
9.8	300
9.9	260
10.0	230
10.1	210
10.2	190
10.3	180
10.4	170
10.5 - 10.6	100

Bacteria: Occasionally all of the (5) equal one hundred milliliter portions constituting a single standard sample may show the presence of organisims of the coliform group, provided that this shall not be allowable if it occurs in consecutive samples or in more than one standard sample when less than five samples have been examined per month.

---

*Information taken from Public Health Service Drinking Water Standards 1946, by U.S. Department of Health, Education and Welfare.

mg/1 – milligram per liter

with a mean of 37 units. Some error can be expected in the bottom samples, due to the disturbance of the bottom of the pond by the sampler. This error would not greatly affect the mean but would be more pronounced in individual sample sets.

As can be seen in Figure 2, the bottom samples had greater turbidity than the top in every month. The difference was greater during the five-month period May through September. The turbidity of the bottom samples was above or near the mean value for all months from February through September. From October through January the turbidity was well below the mean. Only during February, March and April was the turbidity of the top samples above the mean.

In Table II the average monthly and yearly top sample turbidities are presented. As would be expected, the monthly mean values vary from year to year. Runoff was probably the major cause of this difference. Table III presents a summary of the overall Ohio precipitation for the years studied. The long-time normal precipitation shows

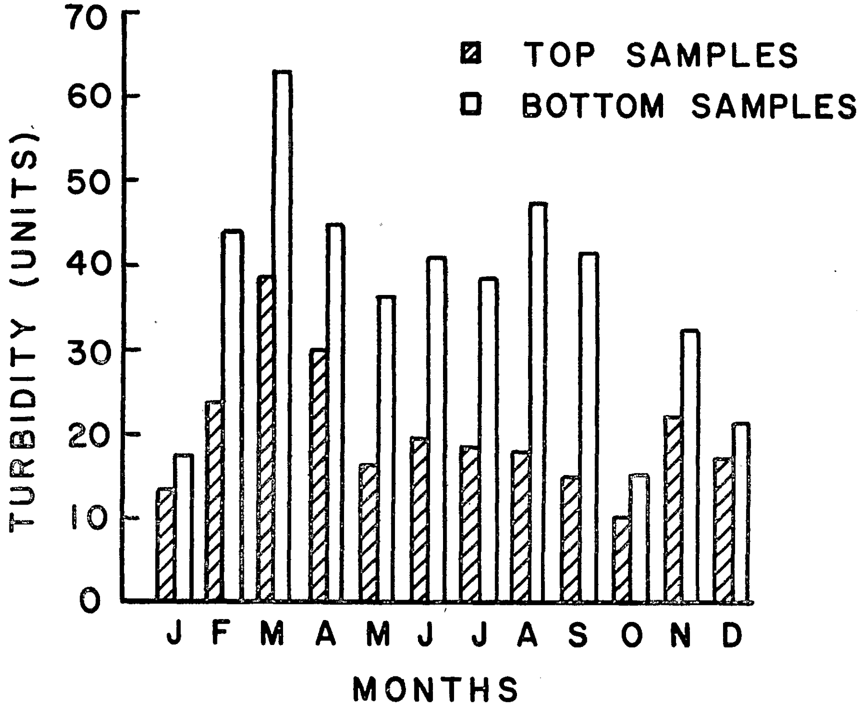


Fig. 2.—Average Turbidity for All Ponds

TABLE II.—Monthly and Yearly Top Sample Turbidities

Month	1958	1959	1960	1961	Mean of Monthly Mean
	Turbidity Mean Values for All Samples (units)				
January	–	14.6	20.2	10.5	15.1
February	–	–	30.8	18.3	24.6
March	–	32.8	28.1	43.4	34.8
April	–	29.2	25.9	45.2	33.4
May	28.8	15.9	11.3	17.9	18.5
June	–	14.3	8.9	35.1	19.4
July	25.7	21.2	10.8	14.1	17.9
August	17.8	28.5	9.5	13.7	17.4
September	15.3	22.2	5.4	–	14.3
October	15.7	17.6	7.1	–	13.5
November	8.5	26.1	18.0	–	17.5
December	11.4	31.5	20.6	–	21.2
Mean	–	23.1	16.4	–	20.6

that the rainfall varied by a little over one inch from month to month during the year. The turbidity varied a great deal more. The maximum precipitation occurred during the summer months of May, June,

TABLE III.—Precipitation for the State of Ohio*

Month	Long-time Normal	1958	1959	1960	1961
	Rainfall (inches)				
January	2.97	1.92	5.70	2.66	1.00
February	2.35	0.83	3.35	2.97	3.17
March	3.40	1.22	2.42	1.41	4.10
April	3.30	3.86	3.71	1.59	5.16
May	3.53	3.30	3.82	3.81	3.15
June	3.85	5.98	2.29	4.14	3.66
July	3.68	7.63	4.43	4.02	5.07
August	3.25	3.65	2.46	3.40	2.98
September	3.10	3.59	2.15	1.32	2.18
October	2.28	1.12	3.72	1.64	2.01
November	2.72	2.79	3.43	1.66	2.93
December	2.61	0.82	2.58	1.55	2.31
Total	37.04	36.71	39.86	30.17	37.72

*Information from Monthly Index of Conditions Affecting Water Supply, Ohio Dept. of Natural Resources, Division of Water, Columbus, Ohio.

and July while the maximum turbidity was during the winter months. From this information it appears that the rainfall had its greatest effect on turbidity during the period December through April. During this time of the year the vegetative cover on the ground was at a minimum, and a large percentage of rainfall occurred as runoff. To substantiate the conclusion that a greater percentage of rainfall occurred as runoff during the winter months, runoff-rainfall data from small watersheds at the Soil and Water Conservation Research Station, Coshocton, Ohio, were studied. In Table IV the data from three watersheds with area and cultivation similar to that found at pond sites is presented. For the larger watersheds the greatest percentage of rainfall occurred as runoff between November through June. On smaller watersheds this was not as pronounced, but the maximum amounts were in the late winter-early spring period. The volume of runoff and the amount of soil loss are related, that is, an increase in runoff generally results in an increase in soil loss.

The effect of rainfall on turbidity for pond 60 at the Southern Substation of the Ohio Agricultural Experiment Station is shown in Figure 3. Located within a few hundred feet of the pond was a rain gauge. A plot of the total monthly rainfall against the mean turbidity of the top sample for each month displays a scatter of points. The data were not significant at the 5 percent level. However, if the data

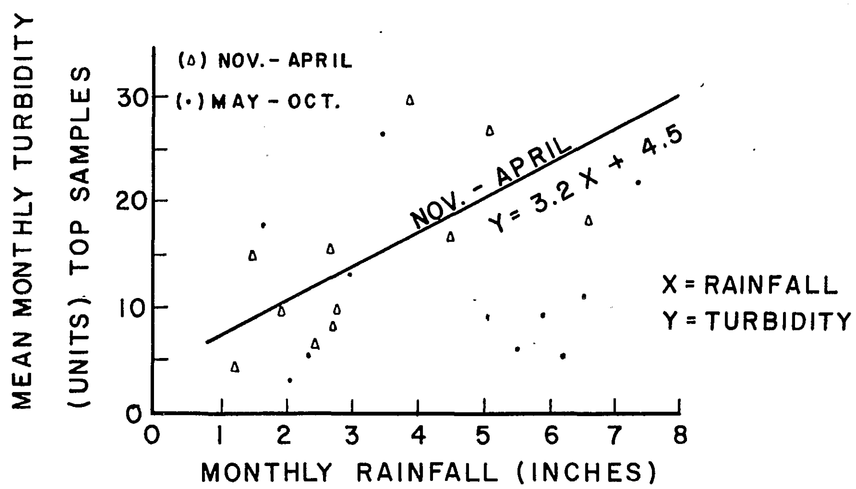


Fig. 3.—Effect of Rainfall on Turbidity (Pond 60)

TABLE IV.—Rainfall-Runoff Relationship for Small Watersheds*

Watershed No.	Watershed Area Acres	Cover	Years of Data 19--	Percent of Rainfall Occurring as Runoff											
				J	F	M	A	M	J	J	A	S	O	N	D
124	2.07	Rotation[1]	39-47	4	13	13	5	4	8	7	7	7	3	2	6
172	43.6	Woods[2]	39-55	51	70	77	70	40	20	6	4	7	8	14	36
169	29.0	Mixed[3]	40-55	36	53	44	31	14	12	6	7	9	2	5	20

*Information from Monthly Precipitation and Runoff for Small Watersheds in the United States, USDA, A.R.S., Soil and Water Conservation Research Division. Watersheds were located at the Soil and Water Conservation Research Station, Coshocton, Ohio

[1] 1939-40 poverty grass pasture; 1941-46 contour strips of corn and meadow on 4-year rotation of corn, wheat, meadow and meadow.

[2] One-third in uneven age stand of hardwoods; two-thirds in poverty grass and brush; reforested to pines in 1938.

[3] 1940, woods 6%; grassland 53%; cultivated 34%; Miscellaneous 7%. In 1957, woods 6%; reforested 6%; grassland 48%; cultivated 34%; miscellaneous 6%.

for the months November through April were chosen, the correlation between rainfall and turbidity was significant at the 5 percent level. The regression coefficient was also significant at the 5 percent level. As shown in Figure 4, pond 6 showed a similar trend. A regression coefficient, significant at the 5 percent level, for the November-April data showed a marked increase in turbidity with increased rainfall. The data for the May-October data was also significant at the 5 percent level. There was a very small increase in turbidity with increased rainfall during this period. Rain gauges were not available near any of the other ponds. Regressions of rainfall at stations some distance from the pond were not significant.

The trend of turbidity increasing with increased rainfall during the high runoff periods, November-April, indicates that runoff is more closely related to turbidity than rainfall. Facilities were not available at any of the ponds to measure runoff. Runoff data from the nearest U. S. Geological Survey stream gauging stations showed no correlation between runoff and pond turbidity. This was probably due to the difference in size of drainage area and the distance of the gauging station from the pond site.

Wind, drainage area (type and size), and presence of livestock in and around the pond were other factors investigated as contributing factors to turbidity. From visual inspection of the roughness of the water an approximation of wind conditions could be obtained. From

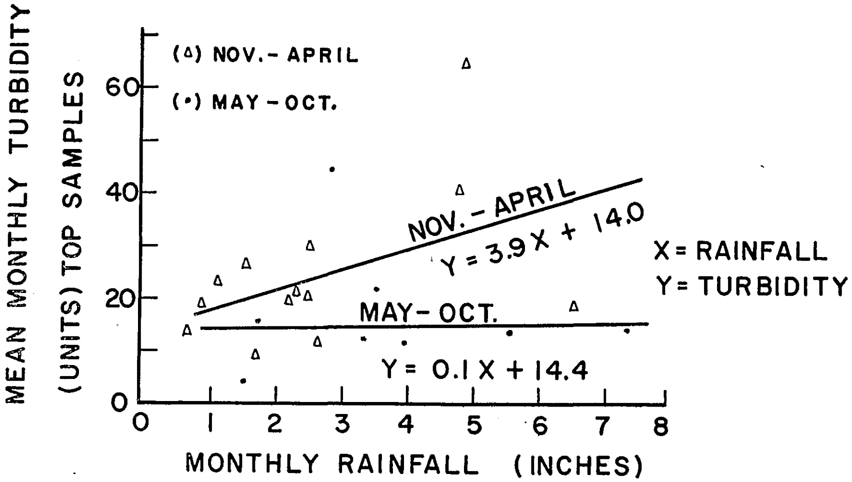


Fig. 4.—Effect of Rainfall on Turbidity (Pond 6)

the information obtained, the wind seemed to have little, if any, effect on turbidity of most ponds. Some increase in turbidity was noted at ponds which had poor cover on the banks. When the wind was strong and the water very rough, an increase in turbidity could be noted along the edge of all ponds.

The correlation between turbidity and size of drainage area was not significant at the 5 percent level. Ponds in the Residual Sandstone and Shale and Glacial Limestone soil regions had lower turbidities (except for pond 23) than those in the Glacial Sandstone and Shale soils. Silt loam was the predominate surface soil at all watersheds. Ponds 25, 26, and 60 which were spring fed had the lowest mean turbidities. This would be expected as spring water is generally very low in turbidity.

Only pond 5 repeatedly had livestock in the pond. This effect is discussed in detail under the section on individual ponds. In general, the turbidity was increased where livestock had access to the pond. Three ponds (5, 6, 87) at one time or another had ducks. On pond 5 and 87 which were relatively small (0.14 and 0.22 acres, respectively) the ducks kept the pond turbid. At the larger pond 6 (1.0 acre), the ducks had very little effect.

In Table V the maximum, minimum, and mean turbidity of top and bottom samples are given for each pond. As in the case of average monthly turbidity, the top mean turbidity was always less than the bottom. The reasons for the difference in the turbidities of each pond are partially explained under the section devoted to individual ponds.

In the foregoing discussion it has been pointed out that the turbidity near the surface is less than that near the bottom. In Figure 5 the turbidity as a function of depth has been plotted for pond depths from four to eleven feet. All of the curves are grouped together except six-foot deep ponds which showed a higher turbidity at all depths. Thirty-three percent of the samples in the six-foot depth class came from pond 5 which had the second highest mean turbidity for top samples and the highest for bottom samples. The influence of this one turbid pond was the cause of the higher turbidities for six-foot deep ponds. A regression of information from all of the different depth ponds, except pond 5, is shown in Figure 6.

The turbidity increased with increasing depth at a slow rate until 75 to 80 percent of total depth. At this point it increased at a much higher rate. In a few ponds a slight decrease in turbidity with depth was noted for samples two to three feet below the surface. An increase

TABLE V.–Maximum, Minimum, and Mean Turbidity for Each Pond

	Turbidity of Top Samples one foot below surface (unit)			Turbidity of Bottom Samples one foot above bottom (unit)		
Pond	Maximum	Minimum	Average	Maximum	Minimum	Average
1	47	2.9	18.7	150	3.3	28.8
5	155	4.9	35.3	165	8.0	54.8
6	115	3.3	21.9	113	4.5	33.6
8	99	1.0	20.0	150	1.8	38.8
23	76	8.0	38.6	151	18.0	58.3
25	19	3.3	10.0	155	2.5	33.0
26	27	4.0	12.6	151	4.5	38.6
60	37	2.2	13.6	155	2.5	31.4
62	55	1.0	14.7	134	2.6	23.4
86	50	3.8	16.8	145	6.1	46.7
87	78	3.3	26.6	153	3.3	36.8
88	102	4.8	23.2	131	4.4	37.2
89	61	12.3	30.2	99	10.0	37.8
90	37	4.0	16.6	93	6.1	39.1
Average			20.9			37.3

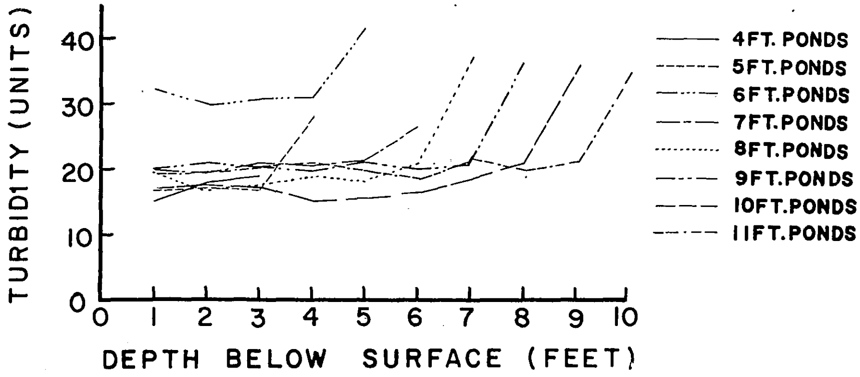


Fig. 5.—Effect of Depth on Turbidity

in turbidity then occurred for deeper depths. This decrease was probably due to less microbial life at this level than nearer the surface.

Total solids, suspended solids, and volatile solids are a quantitative measure of the foreign matter in a sample. Table VI presents the maximum, minimum, and mean values for each pond. No correlation existed between turbidity and total solids. According to the Public Health Service Drinking Water Standards, the maximum allowable total solids is 500 parts per million. The maximum value found in these ponds was 464 and the mean was 183 ppm. According to this standard, these ponds were relatively low in total solids.

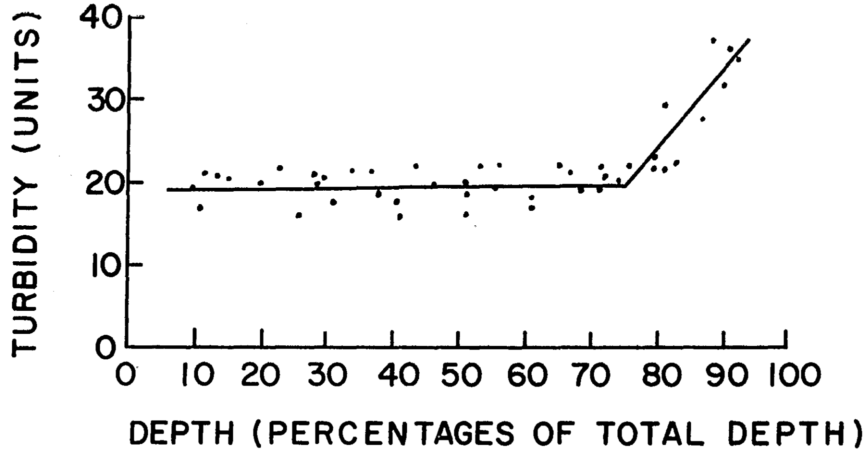


Fig. 6.—Effect of Depth on Turbidity

TABLE VI.–Maximum, Minimum and Mean Solids for Each Pond (samples taken one foot below surface)

Pond No.	Total Solids, ppm*			Suspended Solids, ppm			Volatile Solids, ppm		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean
1	464	285	363			2[1]	121	39	82
5	176	141	162			10[1]	57	11	37
6	320	219	280			13[1]	87	20	57
8	280	172	227				51	18	35
23	329[2]	60	161	57	17	39	49	27	43
25	97	83	91			17[1]	49	6	28
26	69	43	57			26[1]	24	17	20
60	166	98	137	27	1	15	64	11	35
62	129	117	123			0[1]	65	34	47
86	329	238	292	35	14	25	110	43	67
87	258	160	211	14	13	14	79	31	47
88	201	158	176			5[1]	71	46	59
89	79	25	52				200	169	185
90	263	206	228			20[1]	106	32	77
All ponds	464	25	183	57	1	16	200	6	59

*ppm--parts per million

[1] only one sample was taken for suspended solids

[2] maximum value was found when pond was treated with soda ash. See discussion on individual pond.

A linear regression of turbidity versus suspended solids was significant at the one percent level. A plot of this data is shown in Figure 7. Suspended solids increased with increased turbidity.

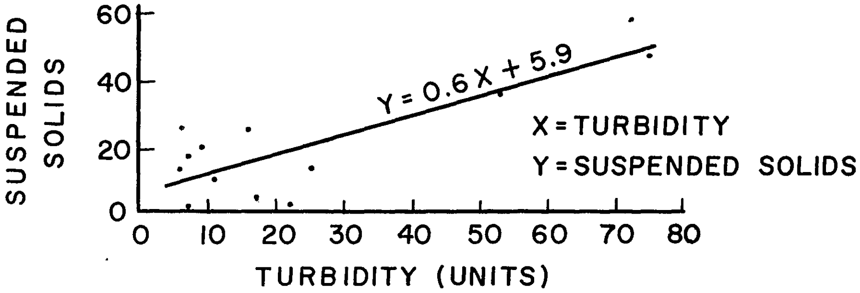


Fig. 7.—Relationship Between Turbidity and Suspended Solids

The correlation of volatile solids and turbidity was not significant at the five percent level. Measurements of volatile solids give some indication as to the amount of organic material in the water. On an average 32 percent of total solids were volatile. Volatile solids are discussed further under color and odor.

A detailed study was carried on at pond 60 to determine the seasonal variations of solids and the difference between top and bottom samples. Table VII presents this information. The total solids in the samples were relatively constant for the period January through April and then decreased during the remainder of the year with a minimum occurring in July. The bottom samples were erratic and showed no trend, but were always greater than the top. The top volatile solids varied little throughout the year except during the high month of January and the low of September. Bottom samples in some cases had lower volatile solids than top. In June this was probably due to the larger microbial life near the surface than near the bottom, but as this material (algae especially) died and settled to the bottom the organic material increased in the lower levels, as seen in the July data.

Color (Apparent)—Apparent color and not true color was measured in this study. To gain some idea of the amount of color that was in suspension, color determination of samples of pond water before and after passing through a 5-micron (± 1.2-micron) filter was made. Some error can be expected in these results because as sediment built up on the filter the effective pore size decreased. True color would not be affected greatly by mechanical filtration, but would be partially absorbed by the filter.

TABLE VII.—Monthly Variation of Solids in Pond 60

Month	Total Solids, ppm Top	Total Solids, ppm Bottom	Volatile Solids, ppm Top	Volatile Solids, ppm Bottom	Suspended Solids, ppm Top	Suspended Solids, ppm Bottom
January	159	190	61	58	27	16
March	156	165	29	37	14	20
April	160	243	37	39	14	120
May	121	194	32	36	9	–
June	128	134	23	9	18	–
July	106	212	40	61	26	95
August	137	246	38	46	24	110
September	126	252	15	18	1	113
December	125	–	21	–	–	–

The results from these tests are given in Table VIII. Anywhere from 0 to 100 percent of color was removed by a 5-micron filter. When the apparent color was 10 or less, 3 of 4 samples indicated that the majority of the color was in solution. Apparent colors greater than 10 units contained 50 to 100 percent suspended matter in the form of turbidity. One exception can be noted in the data. Pond 89 bottom sample on July 18, 1961, had only a 29 percent decrease in color after the filter even though it had an apparent color of 140 units. This

TABLE VIII.—Effect of Filtering on Turbidity and Color

		Turbidity			Color		
Pond	Date	Before Filter	After Filter[2]	% Decrease in Turbidity	Before Filter	After Filter	% Decrease in Color
60-t*	8/24/60	6.1	0.69	89	20	5	75
60-b**	8/24/60	29[1]	0.84	97	160	20	88
60-t	9/20/60	5.7	1.39	92	15	5	67
60-b	9/20/60	6.1	0.84	86	20	2.5	88
60-t	9/27/60	4.8	0.47	90	15	5	67
60-b	9/27/60	5.2	0.69	87	25	5	80
60-t	10/4/60	2.5	0.75	70	10	0	100
60-b	10/4/60	3.6	0.92	74	15	5	67
23-t	8/19/60	15[1]	5.70	62	45	17.5	61
23-b	8/19/60	40[1]	0.47	99	90	0	100
23-t	10/5/60	24	0.92	96	80	5	94
23-b	10/5/60	16.5	0.92	94	80	5	94
25-t	8/18/60	7	0.23	97	20	5	75
25-b	8/18/60	33	2.20	63	140	35	75
25-t	10/6/60	3.6	0.69	81	7.5	5	33
25-b	10/6/60	6.5	0.92	86	20	5	75
26-t	10/6/61	4.0	0.75	81	5	5	0
26-b	10/6/61	5.7	0.92	84	10	10	0
88-t	8/22/60	5.7	0.84	85	20	10	50
88-b	8/22/60	8.9	0.92	90	20	10	50
89-t	8/22/60	12	0.92	92	70	20	71
89-b	8/22/60	14	1.19	92	80	20	75
89-t	7/18/61	16.5	4.50	75	130	60	54
89-b	7/18/61	54.4	19.50	64	140	100	29
Mean		13.75	2.01	85	51.56	5.25	90

[1] microscopic algae in sample

[2] 5-micron ± 1.2-micron pore size as rated by Millipore Filter Corp., Bedford, Mass.

*top **bottom

pond had a high fish kill during the 1960-61 winter due to prolonged ice and snow cover on the pond. The decaying fish resulted in the water having a blackish color.

Four hundred and eighty-eight top and bottom samples were tested for color. The color of the top samples ranged between 300 and 0 with a mean of 40 units, and the bottom samples between 1120 and 0 with a mean of 81 units. The bottom color was greater than the top color in every month (Figure 8). Starting in October the top sample color was a minimum and increased until it reached a peak in March. A decrease in color was found in April and May with a second peak in June. July, August, and September were approximately constant, well below the June value and higher than October. In Table IX the monthly and yearly top sample color results are presented.

A relationship existed between color and turbidity. A correlation of turbidity and color was significant at the one percent level for both top and bottom samples. If the October-May and June-September periods, which were important in the turbidity-rainfall relationship, are studied, it is found that the color increased at a higher rate with an increase in turbidity during the June-September period. To illustrate this point, the turbidity versus color for pond 60 top and bottom sam-

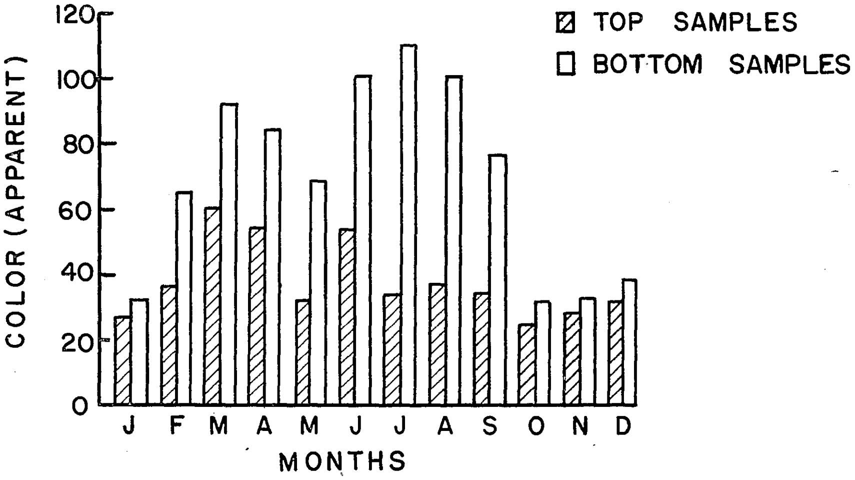


Fig. 8.—Average Color for All Ponds

TABLE IX.—Mean Monthly and Yearly Top Sample Color (Apparent)

Month	1958	1959	1960	1961	Average
January		35	40	17	31
February			53	22	37
March		76	49	62	62
April		98	43	63	68
May		51	27	27	35
June		24	32	90	48
July	60	18	33	40	38
August	48	31	34	35	37
September	42	30	18		30
October	40	20	25		28
November	38	14	33		28
December	40	30	23		31

ples are plotted in Figures 9 and 10. This same relationship was found at the other ponds with slope of the curves different for each pond.

It appears from this information that there are other factors besides turbidity accounting for a large portion of the color during June

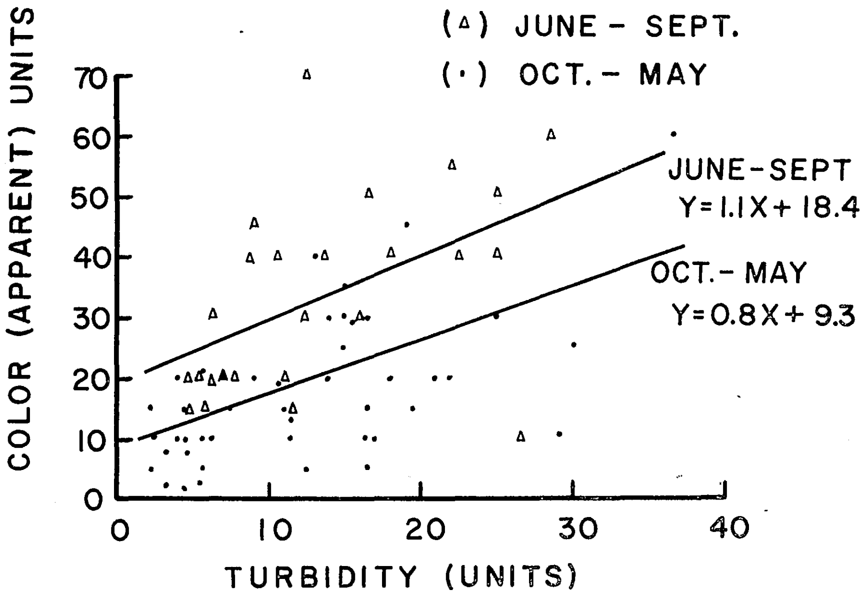


Fig. 9.—Relationship Between Color and Turbidity for Top Samples, Pond 60

through September. On the other hand with rainfall having a noticeable affect on turbidity during the October-May period, it would be expected to have a similar effect on apparent color. Water temperature and aquatic vegetation were considered as possible causes of the higher color during the June through September period. Regression of temperature and color was not significant at the five percent level. Plankton and weed counts were not taken, so no accurate data on the effect of aquatic vegetation on color was obtained. From observations throughout the study, it appeared that weeds had little effect on color while algae had considerable effect. Ponds that had bad infestation of algae almost always had higher color. The color appeared to come from the dead decayed algae for bottom samples and not from the live algae. In top samples live microscopic algae were the primary cause of color. The effect of algae in ponds is discussed further under individual ponds.

As mentioned earlier, the bottom color was greater than the top. In Figure 11 the variation in color with depth is plotted. All of the curves are grouped together except for six-foot depth ponds. The six-foot pond color was higher at all depths due to a large portion of the

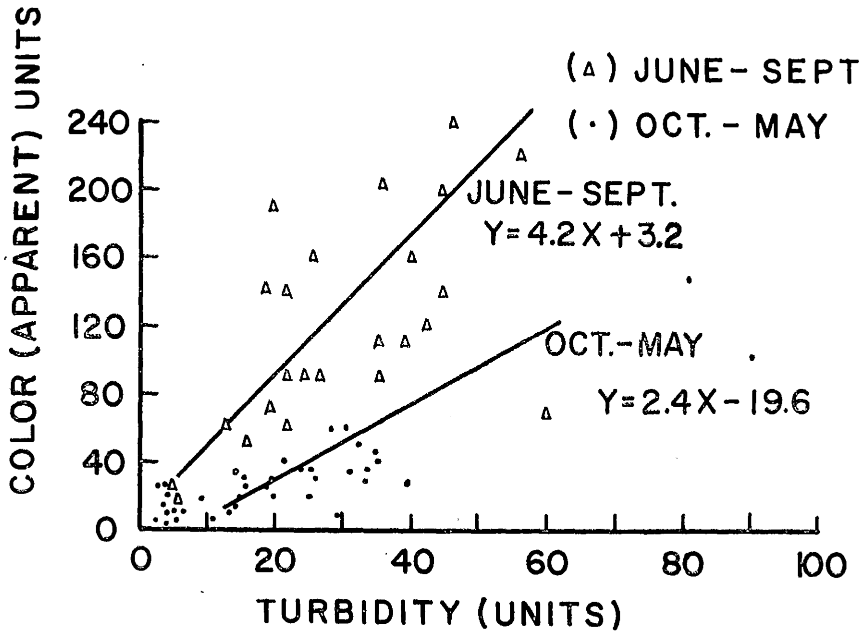


Fig. 10.—Relationship Between Color and Turbidity for Bottom Samples, Pond 60

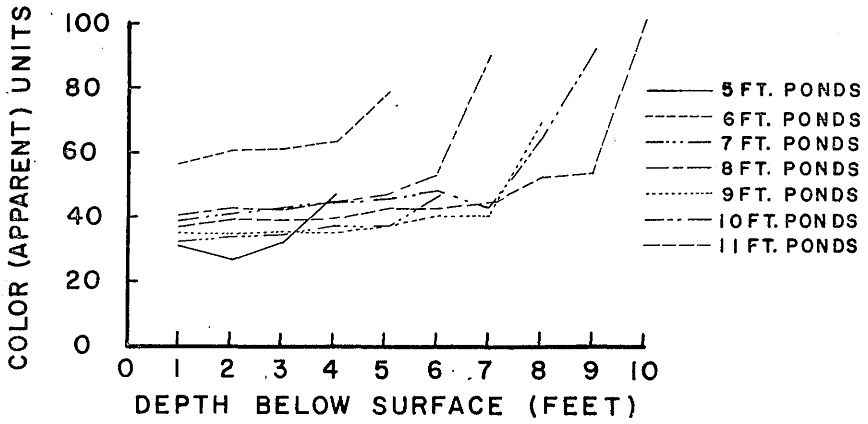


Fig. 11.—Effect of Depth on Color

data for this curve coming from highly turbid and colored water from pond 5. A regression for all the data except from six-foot depth ponds is plotted in Figure 12. The color increased at a slow rate with depth down to 75 to 80 percent of total depth; below this level the color increased at a much higher rate.

In Table X the maximum, minimum, and mean apparent color

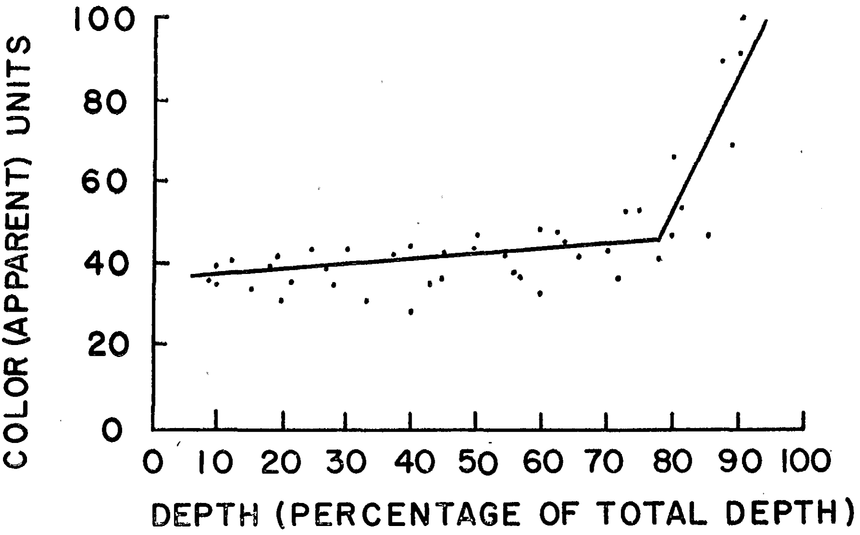


Fig. 12.—Effect on Depth on Color

TABLE X.—Maximum, Minimum and Mean Color (Apparent) by Ponds

Pond No.	Top Samples Maximum	Minimum	Average	Bottom Samples Maximum	Minimum	Average
1	130	5	27.8	165	5	58.4
5	300	0	77.1	350	10	101.4
6	130	10	44.1	200	20	81.7
8	180	0	40.0	600	7.5	75.6
23	280	10	86.0	1120	20	168.0
25	60	0	24.3	400	0	145.0
26	40	0	19.3	600	0	69.8
60	60	25	22.4	520	2.5	78.6
62	80	0	23.9	120	0	33.5
86	70	0	29.3	800	0	106.6
87	110	0	32.3	150	0	44.8
88	120	0	29.4	210	0	55.7
89	210	20	82.4	360	30	130.0
90	210	0	37.2	200	0	65.0
Average			39.6			81.3

for each pond is presented. The variation from pond to pond is discussed in the section devoted to individual ponds.

No relationship was found between total solids or volatile solids and color. A correlation between suspended solids and color was significant at the one percent level. This would be expected due to the relationships between color-turbidity and turbidity-suspended solids. The regression of suspended solids and color resulted in the formula, $Y=.09X + 13.2$, where Y was apparent color and X was turbidity.

Odor—Four hundred and ninety-five top and bottom samples were tested for odor. Odor was found in 4.8 percent of the top and 21.2 percent of the bottom samples. The presence of odor in pond water depended largely on the season of the year. As seen in Figure 13, the top samples had no odor from November through February or in April and September. A peak in odor was reached during March and July. The bottom samples had odors in all months except February. Samples with odor were most numerous between May and September. The peak was reached in September when 47.8 percent of the bottom samples had an odor. The monthly variation of odor is presented in Table XI.

As many as 19 percent of the top samples and 44 percent of the

TABLE XI.—Monthly Percentages of Samples with Odor

	Top Samples				Bottom Samples			
Month	1958	1959	1960	1961	1958	1959	1960	1961
January		0	0	0		0	10	0
February			0	0			6.3	0
March		40	0	4.3		40	0	4.2
April			0	0		7.5	5.9	0
May		20	13.3	0		60	20	0
June		15.4	6.7	0		53.8	13.3	45
July	5.9	33	0	8.6	5.9	71.4	19.2	52.1
August	4	6.7	0		32	46.6	13.2	
September	0	0	0		46.2	60	0	
October	0	0	4.8		25	0	14.3	
November	0	0	0		0	0	7.2	
December	0	0	0		0	25	0	

bottom samples of individual ponds contained odors (Table XII). In three ponds (26, 60, and 87) odor was never present in the top samples while all of the ponds had some odors in the bottom samples. Reasons for the variations in odor are discussed under individual ponds.

The threshold odor is a measure of the intensity of an odor. It was found to vary between 0 and 64. In the period January 1960 through July 1961, 45 sample sets had at least one sample with a threshold odor. The months of June, July, and August had 10, 17, and 8 of the 45 sample sets containing threshold odors. In Table XIII the

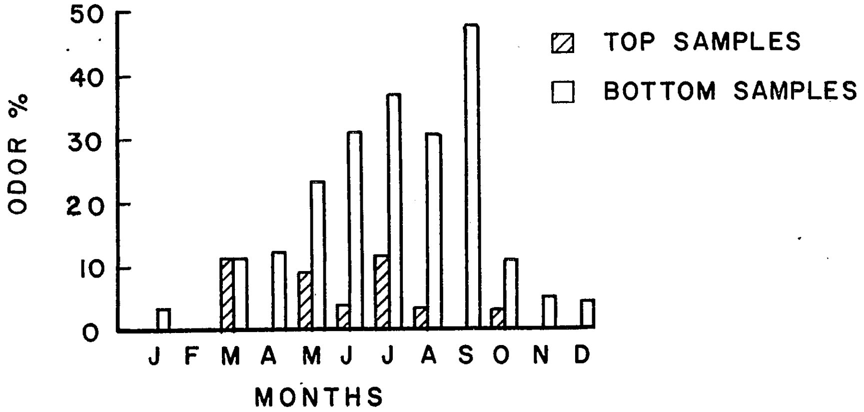


Fig. 13.—Percent of Samples with an Odor for All Ponds

TABLE XII.–Percent of Top and Bottom Samples Having an Odor by Ponds

Pond No.	Percent Top Samples	Percent Bottom Samples
1	2.0	8.2
5	9.5	19.0
6	2.6	35.8
8	6.0	18.0
23	8.0	44.0
25	4.6	41.0
26	0	4.6
60	0	13.1
62	4.7	4.7
86	4.4	39.2
87	0	9.1
88	9.1	18.2
89	19.0	42.8
90	9.1	36.4

threshold odor as a function of depth is presented. The general trend seen here was that odor intensity increases with increased depth. Maximum threshold odors were found in five ponds during July and in two ponds during June, August, and November. The odor types were classified as fishy, musty, and grassy based on descriptions in Standard Methods (5).

Ponds that had large masses of algae always produced some odor. The odor was more noticeable and of higher intensity after the algae had died. In a deep pond (pond 86) odor was found only at the deeper depths. This was probably due to anaerobic decomposition. Weeds did not seem to have any effect on odor.

Temperature—The temperature of pond water varied between 88° and 34° F. with the average of top and bottom samples being 60.9° F. The maximum difference in temperature between top and bottom samples was 16° occurring in June. The top samples were warmer than the bottom. Maximum differential temperatures always occurred during the summer months. During January and February the bottom was usually warmer than the top. During most of the year the differential temperature between top and bottom was only 2 or 3 degrees.

TABLE XIII.—Threshold Odor for Individual Ponds

Pond No.	No. Sample Sets with Threshold Odor	Pond Mean Depth	Highest Threshold Value Recorded	Month Highest Value Recorded	Mean Threshold Odors Depth Below Surface (ft.) 1	2	3	4	5	6	7	8	9	10	11	12	One Foot Above Bottom
1	0																
5	6	6'	64	June	1.1	1.1	1.7	3.5									14.2
6	9	8'2"	64	August	0	0.4	0.4	0.4	0.5	5.0	10.9						8.9
8	7	10'2"	2	July	0.2	0	0	0	0.2	0.2	0	0.4	1.4				1.1
23	3	8'3"	32	July	0	0	0	0	0.7	2.0	4	8					16.7
25	3	9'2"	8	July	0	0	0	0	0	0	0.5	0	0				4.0
26	1	10'7"	1.4	June	0	0	1.4	0	0	0	0	1.4					0
60	9		8	August	0	0	0.3	0.3	0.3	0.8	0.6	0.7	2.2				2.3
62	0																
86	4	13'7"	16	July	0	0	0	0	0	0	0	0	0.3	0	5.0	5.3	3.6
87	0																
88	1	4'	4	November	0	0											4
89	1	6'	4	July	2	0	4	4									4
90	1	7'3"	1.4	November	1.4	0	1.4	0	0	1.4							1.4

BACTERIOLOGICAL PROPERTIES

Coliform bacteria—Two hundred and eighty-six top samples and 220 bottom samples were examined for density of coliform bacteria. The median count for top samples was 100 per 100 ml, and for the bottom samples was 170 (Table XIV). Medians instead of arithmetic means were used in the analysis of bacteriological data to eliminate the effects of extreme or indeterminate values. All farm pond waters were polluted, but the degree of pollution was slight.

The seasonal variation in coliform density is presented in Figure 14. The highest median counts occurred in the summer months of July, August, and September for bottom samples, and during August, July, and September for top samples. From the monthly data, it appeared that temperature was a factor in the coliform count. The correlation coefficient between 277 temperature and top sample coliform counts was 0.546. This was significant at the 1 percent level (4). The correlation coefficient for 210 bottom samples was 0.209, which was significant at the 1 percent level. There appears to be a definite relationship between temperature and coliform density, i.e. as the temperature increases, the coliform density can be expected to increase. This probably represents growth of certain species of coliforms in pond water.

No definite relationship was evident between the coliform count of corresponding top and bottom samples. During 10 months of the year, the bottom sample median was higher than the top sample, while in March the top sample median was higher and in May the medians

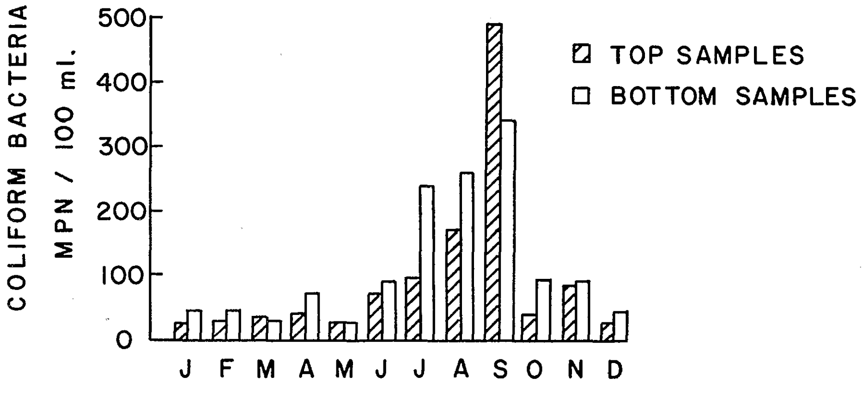


Fig. 14.—Median Coliform Bacteria for All Ponds

TABLE XIV.—Coliform Population in Pond Water
(MPN per 100 ml)

Pond	Top Samples			No.	Bottom Samples			No.
No.	Maximum	Minimum	Median	Samples	Maximum	Minimum	Median	Samples
1	2,400	< 3	43	29	930	< 3	43	22
5	5,400	3.6	97	17	9,200	3.6	130	18
6	> 2,400	3.6	33	12	> 24,000	23	240	12
8	> 2,400	3.6	93	33	> 2,400	3.5	140	26
23	11,000	< 3	93	17	1,700	< 3	170	13
25	> 11,000	15	210	18	1,100	9.1	220	13
26	790	9.1	93	19	490	3.6	78	15
60	11,000	< 3	36	53	1,100	< 3	43	34
62	1,400	< 3	35	28	9,200	9.1	93	17
86	> 2,400	3.6	230	16	9,200	23	350	14
87	4,900	21	780	12	> 24,000	29	240	9
88	1,700	23	170	11	2,400	36	240	8
89	5,400	23	350	7	5,400	93	460	7
90	> 24,000	9.1	111	14	16,000	7.3	180	12
Total				286				220
Median of medians			100				170	

were the same. However, in most cases the difference between the top and bottom monthly medians was very small. The variations in coliform population among ponds is shown in Table XIV. Eleven ponds had higher median coliform counts for bottom samples, two had higher for top samples, and one was the same. Although these data show a trend for the bottom samples to have higher counts, results for a specific pond showed that either the top or bottom count might be higher on a given day. Caution is necessary in the interpretation of the bottom sample results. In collecting bottom samples, it was inevitable that occasionally the sampler would strike the bottom sediment, with resulting agitation of the mud. Such accidents would probably increase the bacterial count of these samples.

Enterococci—The enterococci MPN ranged between 1600 and less than 3 per 100 ml for top samples and between 460 and less than 3 for bottom samples (Table XVI). The median of all top and bottom samples was 2 and the median for bottom samples 3.6. The median of all top and bottom samples was less than 3 colonies per 100 ml. These results show that the ponds were lightly contaminated and confirm the coliform results. Considering top samples, ponds 86, 87, and 88 had the highest median enterococci counts, as they had for coliform counts. (Pond 89 had the highest median coliform counts, but no tests for enterococci were made on this pond.) Ponds 23 and 6 had the highest median bottom enterococci count. The median enterococci counts per month remained generally at 3 from September through January with a tendency toward slightly higher counts during the summer (Table XV). The maximum median top enterococci counts occurred in June and August.

Salmonella and Shigella—The bacteriological examination of 152 farm pond samples over a period of approximately ten months failed to demonstrate the presence of typical Salmonella or Shigella organisms. Many cultures were isolated which resembled Salmonella or Shigella organisms as far as the TSI agar step but failed to conform either biochemically or serologically to all the conventional reactions of a typical enteric pathogen in these genera.

Total Bacteria—The SPC with incubation at 35° C. gives some indication of the total heterogeneous bacterial population. Even though the pond water might consist principally of runoff from well-grassed meadow land, it would still be expected to contain large numbers of soil bacteria. When compared with plate counts of various types of natural waters, the SPC values indicate that farm ponds have a relatively low microbial population (Table XVII).

TABLE XV.–Bacterial Populations for All Ponds by Months

(Median Values)

	January	February	March	April	May	June	July	August	September	October	November	December
ENTEROCOCCI (MPN per 100 ml.)												
Top	< 3	3.6	< 3	1.9	4.5	8.4	2	8.4	< 3	< 3	< 3	< 3
Bottom	3.6	3.6	< 3	< 3	< 3	4.5	< 3	12.5	< 3	3.6	< 3	< 3
THERMODURICS (per ml)												
Top	55	20	75	70	55	27	55	20	82	39	24	18
Bottom	47	25	85	210	160	80	400	110	44	39	38	27
THERMOPHILES (per ml)												
Top	2	4	4	5	1.5	3	3	1	< 1	1	13	10
Bottom	5	9	2	4	2	7	15	9.5	2	1	18	12
PSYCHROPHILES (per ml)												
Top	70	2300	100	10	2	34	12	4.5	2	4	38	30
Bottom	600	2200	100	20	5	12	75	45	16	29	43	50
TOTAL BACTERIAL COUNT (SPC per ml)												
Top	900	240	460	150	210	190	890	510	260	360	500	200
Bottom	400	380	600	300	190	210	760	600	460	400	400	440

TABLE XVI.—Enterococci Populations in Pond Water
(MPN per 100 ml)

Pond No.	Top Samples				Bottom Samples			
	Maximum	Minimum	Median	No. Samples	Maximum	Minimum	Median	No. Samples
1	110	< 3	< 3	23	3.6	< 3	< 3	14
5	150	< 3	< 3	13	460	< 3	9.1	13
6	9.1	< 3	< 3	7	43	< 3	14	6
8	1600	< 3	2	25	240	< 3	< 3	18
23	93	< 1.8	16	8	240	< 3	15	3
25	93	< 1.8	7.8	9	460	< 3	3.6	4
26	49	< 1.8	< 3	10	26	< 3	< 3	5
60	110	< 1.8	< 3	40	43	< 3	< 3	21
62	240	< 3	3.6	20	39	< 3	9.1	10
86	49	< 3	22	8	3.6	< 3	3.6	3
87	280	2	28	6	9	9	9	1
88	350	7.8	130	3	---	---	---	0
90	7.8	< 3	< 3	4	91	1.8	3.6	3
Total				176				101
Median of medians			2				3.6	

TABLE XVII.—Total Bacterial Populations in Pond Water (SPC per ml)

Pond		Top Samples		No.		Bottom Samples		No.
No.	Maximum	Minimum	Median	Samples	Maximum	Minimum	Median	Samples
1	29,000	20	400	28	11,000	60	380	16
5	6,800	200	830	15	2,800	56	960	14
6	2,500	210	440	7	670	250	490	3
8	30,000	50	550	29	22,000	30	600	25
23	2,400	41	570	9	5,000	440	830	4
25	1,500	40	390	10	350	250	260	4
26	1,100	10	320	11	1,300	180	410	6
60	5,400	12	320	44	8,700	30	290	24
62	1,700	40	350	22	1,300	75	380	12
86	2,000	120	500	9	2,500	200	670	4
87	1,200	80	210	6	580	580	580	1
88	320	115	300	3	--	--	0--	—
90	3,000	700	770	3	2,900	620	660	5
Total				196				118
Median of medians			400				600	

The maximum SPC for all top samples was 30,000; the minimum was 10 and the median 400 bacteria per ml. Maximum SPC for bottom samples was 11,000, minimum was 30, and the median 600 bacteria per ml.

The medians of the top SPC's for individual ponds fell between 210 and 570 for 11 of 13 ponds, a relatively narrow range. Ponds 5 and 90 had peak medians of 830 and 770 for the top samples, while the peak bottom medians of 960 and 830 were found in ponds 5 and 23, respectively.

Thermophiles—Presented in Table XVIII are the maximum, minimum, and median thermophilic counts for each pond. The maximum top sample thermophilic count was 7200, the minimum was 1, and the median was 3 per ml. The maximum bottom sample thermophilic count 370 and minimum 1 with a median count of 8 per ml. A total of 306 top and bottom samples were analyzed with an overall median of 3 per ml.

The top sample median thermophilic count was relatively constant, ranging between one and five for the period January through October. Peak counts of 13 and 10 were reached in November and December, respectively (Table XV). The bottom sample median showed a peak during the same months, as well as during July. Ponds 6, 87, and 88 had the highest median top sample counts and ponds 5, 6, and 25 the highest median bottom sample counts. The ponds in general were only lightly polluted with thermophilic bacteria.

Thermoduric Bacteria—Maximum top thermoduric count was 10,000 with minimum 2 and median 65 per ml (Table XIX). The maximum bottom thermoduric was 8400, with minimum 3 and median 60 per ml. The median of 291 top and bottom samples was 60 per ml.

Ponds 23 and 87 showed the highest medians for top samples with 88 and 94 per ml, respectively. Ponds 5 and 6 had the highest counts for bottom samples, with median counts of 240 and 170 thermodurics, respectively.

Psychrophiles—The maximum, minimum, and median psychrophile populations for top samples were 3200, 1, and 14 per ml, respectively (Table XX). The values for the bottom samples were 2300 maximum, 1 minimum and 35 median per ml. The overall median of 276 top and bottom samples was 18 psychrophiles per ml. Ponds 23 and 86 had the highest median top and bottom psychrophilic populations.

TABLE XVIII.–Thermophilic Populations in Pond Water
(per ml)

Pond		Top Samples		No.		Bottom Samples		No.
No.	Maximum	Minimum	Median	Samples	Maximum	Minimum	Median	Samples
1	7,200	<1	2	29	210	0	3	16
5	100	0	9	15	370	<1	25	14
6	50	1	14	6	64	4	16	4
8	130	<1	2	28	260	<1	5	21
23	30	<1	3	7	30	5	6	3
25	10	<1	3	8	27	1	12	4
26	40	<1	5	9	10	<1	2	6
60	38	<1	2	44	60	<1	8	24
62	51	<1	1	21	57	<1	2	11
86	13	<1	1	9	32	<1	8	4
87	160	2	23	6	9	9	9	1
88	31	1	12	3	7	<1	2	3
90	130	<1	10	4	19	<1	10	4
Total				189				115
Median of medians			3				8	

TABLE XIX.–Thermoduric Populations in Pond Water
(per ml)

Pond	Top Samples			No.	Bottom Samples			No.
No.	Maximum	Minimum	Median	Samples	Maximum	Minimum	Median	Samples
1	4,100	4	20	19	80	12	40	12
5	330	< 100	75	11	1,400	< 100	240	12
6	690	78	82	4	320	56	170	5
8	4,900	2	73	18	3,000	3	90	17
23	660	16	88	4	1,000	8	66	9
25	240	3	30	9	390	10	39	5
26	910	8	24	11	930	15	58	6
60	10,000	40	34	42	8,400	16	60	23
62	550	6	23	21	1,300	23	110	11
86	80	8	41	9	60	20	50	3
87	680	20	94	6	50	50	50	1
88	140	49	75	3	--	--	--	--
90	100	40	65	4	110	30	40	4
Total				161				108
Median of medians			65				60	

TABLE XX.–Psychrophilic Populations in Pond Water
(per ml)

Pond No.	Top Samples Maximum	Minimum	Median	No. Samples	Bottom Samples Maximum	Minimum	Median	No. Samples
1	2,100	< 1	43	25	2,300	< 10	32	14
5	150	< 1	10	14	2,300	< 1	52	14
6	13	< 1	7	6	100	< 1	79	4
8	330	< 1	24	25	670	< 1	45	18
23	1,500	< 1	98	8	1,100	8	470	4
25	1,800	< 1	5	10	1,500	3	25	5
26	73	< 1	14	11	70	< 1	35	6
60	3,200	< 1	5	42	1,800	< 1	30	25
62	2,600	< 1	4	18	2,100	< 1	20	13
86	840	1	78	8	130	< 1	120	3
87	980	< 1	18	5	--	--	--	--
88	1,600	< 1	14	3	12	< 1	1	3
90	110	< 1	17	4	95	< 1	18	3
Total				179				112
Median of medians			14				35	

Between November and March the psychrophile count was relatively high for both top and bottom samples (Table XV). The peak was reached for both top (2100) and bottom (2200) during February. During the summer months (April-October) the psychrophiles population was low, although a notable exception was June for the top sample and July for the bottom. In both of these cases the population was much higher than the preceding or the succeeding month. The higher counts during the colder months of the year is not unexpected since psychrophiles are by definition bacterial species able to multiply at lower temperatures. In general, the ponds showed only slight pollution with psychrophiles.

CHEMICAL PROPERTIES

Samples for chemical analysis were taken once a year from each pond. These samples were collected in the late summer, because it was felt that the water level in the ponds would be low, and therefore, the chemical content would be at a maximum. In order to test this hypothesis, pond 60 was sampled 9 times in 1960 and 7 times in the first 8 months in 1961. The results of these tests are given in Appendix E. The general trend shows that maximum values for the different chemical entities occurred during January and not in late summer. Actually, minimum values were found during the summer. The pH, however, fluctuated throughout the year.

The regular sampling procedure was to take chemical samples one foot below the surface near the deepest part of the pond. At pond 60 samples were also taken one foot above the bottom. The results from this one pond showed that bottom samples had slightly higher values than top samples for most chemicals tested. One exception to this was pH which usually had a lower value at the bottom.

Table XXI presents the maximum, minimum, and mean values. Appendix D gives the values for individual ponds. A discussion of each of these properties follows:

Hardness (Total)—In general, water which has less than 50 ppm hardness is considered "soft", but may be corrosive. Water with greater than 100 ppm hardness is "hard" and results in excessive consumption of soap and scaling of water heaters. Water above 100 ppm should probably be "softened" before use in the home. The average value of 100 ppm of hardness for the 13 ponds was at the lower limit of "hard" water. Seven of the ponds had average hardness values above 100 ppm. In general, the ponds in the Residual Sandstone and Shale

TABLE XXI.—Chemical Properties of Pond Water[1]

	Maximum	Minimum	Mean
Alkalinity, total, ppm[2]	195	5	79.0
Hardness, total, ppm	190	0	100.0
Iron, total, ppm	1.55	0.05	0.35
Manganese, ppm	0.45	0	0.12
Sulfate, ppm	120	4	36.3
Chloride, ppm	120	0	14.3
Fluoride, ppm	0.5	0	0.27
Nitrate Nitrogen, ppm	3.1	0	0.17
Copper, ppm[3]	0.58	0	0.34
Arsenic, ppm[4]	7.0	0	1.42
pH	9.75	5.4	7.9
Radiation (Alpha and Beta) (microcuries per ml x 10^{-7})			
Suspension	3.95	0	0.47
Filtrate	0.64	0	0.24

[1] Analysis performed by Ohio Department of Health.

[2] ppm — parts per million.

[3] Copper level was zero except in ponds that had been treated with copper sulfate to control algae (4 ponds).

[4] Arsenic level was zero except in ponds that had been treated with sodium arsenite to control algae and weeds (3 ponds).

Soils Region (Ponds 23, 25, 26) had low hardness. Pond 86 had the highest hardness with an average of 205 ppm (Appendix D).

Iron (Total)—Water having an iron content over 0.3 ppm causes staining of laundry and plumbing fixtures, The average iron content in these ponds was 0.35 ppm. Six ponds had iron levels such that staining would probably take place (Appendix D). Geographical location had little, if any, affect on the iron content of the water.

Manganese—Manganese like iron causes staining above 0.3 ppm. The manganese average for the 13 ponds was 0.12 ppm. None of the ponds showed an average manganese greater than 0.3 ppm. Manganese at most ponds would tend to intensify an iron problem.

pH—The average pH was 7.9 or in the alkaline range. All of the ponds had an average pH near 8.0 except those in the Residual Sandstone and Shale Soils (Ponds 23, 25, 26). Ponds 25 and 26 had pH's which were essentially neutral. The average pH of pond 23 was below 7.0 until the pond was treated with soda ash (See discussion on pond 23).

Arsenic—Sodium arsenite is commonly used in farm ponds to control weeds and algae. The maximum allowable arsenic in drinking water has been set at 0.05 ppm (Table I). The safe level of arsenic for livestock consumption has not been established. Three ponds in

TABLE XXII.—Arsenic Content in Ponds After Being Treated with Sodium Arsenite

Date of Sample	Top Pond	Bottom Pond	Remarks
Pond 88			
6- 5-59	---	-----	Pond sprayed with 40% sodium arsenite at rate of 3 gal/acre ft.
6-10-59	1.00	-----	
7-12-59	0.60	-----	
8-14-59	0.60	-----	
9- 1-59	1.00	-----	
2-20-60	---	0.2	
7-16-60	0.4	0.4	
8-22-60	0.4	0.4	
10-19-60	0.2	-----	
1-18-61	0.0	0.0	
5-17-61	0.0	-----	
Pond 86			
6-16-60	---	-----	2½ gal. 40% sodium arsenite on 0.3 acre pond.
7- 7-60	1.4	1.4	
8-22-60	1.4	-----	
10-20-60	1.0	-----	
11-29-60	0.8	-----	
1-18-61	0.6	0.8	
4-19-61	trace	-----	
5-17-61	0.4	-----	
7-18-61	0.4	-----	
Pond 6			
7-11-60	---	-----	3 gal. 40% sodium arsenite on 1 acre pond.
7-28-60	1.4	1.4	
8- 8-60	1.0	1.0	
10-13-60	7.0	-----	Pond treated day before with unknown amount of sodium arsenite.
11-14-60	0.1	-----	
1-12-61	0.0	0.0	

this study were treated with sodium arsenite. The arsenic levels found in these ponds are given in Table XXII.

The stability of arsenic is evident from the results obtained. It took over 16 months for the arsenic in pond 88 to be reduced to a low level. The summer of 1960 was very dry, resulting in most of the water in pond 88 being used. Refilling the pond diluted the arsenic to an undetectable level. Pond 86 had an undesirable arsenic level 13 months after being treated. Pond 6 differed from the others in that a fairly rapid removal of arsenic took place. The reason for the rapid decrease in one pond and not in another is not known.

From these results it is evident that great care should be exercised in using sodium arsenite to control algae and weeds in ponds. This chemical is certainly not a wise choice when the water is to be used for domestic purposes.

Copper—Copper sulfate is widely used to control algal growth in farm ponds. The maximum copper concentration allowed by the U. S. Public Health Service Drinking Water Standards is 3.0 ppm. None of the treated ponds showed a copper concentration approaching this limit. The copper level in pond water decreased at a fairly rapid rate following treatment

Other Chemicals—Alkalinity (total), sulfates, chlorides, fluorides, and nitrate nitrogen levels were satisfactory and should not be of concern (Table XXI).

Alpha Beta radiation readings were made on the suspended material and the filtrate. Although no definite standard has been set for maximum radiation, authorities feel that a radiation count of 1.00×10^{-7} microcuries per ml should be the maximum allowable for drinking water. Only in two samples did the radiation count exceed this amount. These high counts occurred on suspended solids samples in both cases. Samples tested before and after these samples were well below the 1.00×10^{-7} microcuries level. Radiation levels in farm ponds are relatively low.

INDIVIDUAL PONDS

Pond 1—Pond 1 differed from the other ponds in that it was an upground pond into which water had to be pumped from a small intermittent stream, usually during the spring of the year and during heavy periods of runoff in the summer.

Septic tank effluent from a tile field was noted to seep into the channel of the stream used as a source of water for the pond. In order to flush out this material the owner usually allowed the stream to flow for a short period before pumping water into the pond. Even though this precaution was taken, it seemed probable that some sewage effluent would enter the pond; however, the bacterial results did not confirm this suspicion. Of all the ponds, Pond 1 had one of the lowest coliform and enterococci population, indicating very light pollution. The chloride level, a chemical index of pollution, was 83 ppm, 45 ppm higher than the pond with the next highest chloride content. This high level may have been caused by the influx of sewage material.

Pond 5—Pond 5 was the smallest pond studied (0.14 acres). Animals, such as ducks and horses, were often found on the watershed and even in this pond. Their presence was probably the major factor causing this pond to be one of the highest in turbidity, color, and coliform density. Infestation by the weed, Potamogeton, occurred each summer but with no apparent effect on the quality of the water. A black layer of organic material was found on the bottom of the pond after the weeds had died and decayed.

Pond 6—Pond 6 may be considered a typical pond in that the quality of its water was relatively near the average values. This pond was stocked with a few ducks which seemed to have little effect on the pond, except to keep the shallow water stirred up. Growth of the algae Cladophora and Spirogyra was abundant during the summer months. This algal growth may have been responsible for the high odor level at the bottom of this pond.

Pond 8—Pond 8 had water that may be considered to be about average. This pond showed Chara algae during the summers of 1959, 1960, and 1961, but this growth had little effect on the water quality. The odors found in the water at lower levels may have been partly due to the Chara, but was more likely due to the small infestations of Cladophora that appeared each summer. A great deal of swimming took place in this pond, but samples taken near the swimming area failed to show an increase in coliforms or enterococci.

Pond 23—Pond 23 had the highest turbidity and apparent color (due to turbidity) of any of the ponds. The banks of the pond had poor vegetative cover and the soil continuously eroded into the pond. The suspended material settled out very slowly or not at all. The pH was the lowest of any of the ponds, ranging between 7.1 and 5.4 between 1958 to 1960, respectively, decreasing each year. The total alkalinity was also low, being only 10 and 7 in 1959 and 1960, respectively. Water with low pH and alkalinity are known to have poor coagulation and settling characteristics. This coupled with a highly collidal clay suspension in the water may have been the cause of the high turbidity.

An attempt was made to remove the turbidity by coagulation and settling. Based on laboratory tests, 600 lbs. of soda ash and 280 lbs. of alum were added to the pond in June 1961. The soda ash was fed in a dry form along the edge and in the middle of the pond by boat. A half hour after treating with soda ash the alum was added in the same manner as the soda ash. The formation of floc near the surface occurred almost immediately after addition of the alum. This floc moved to the surface instead of settling. The results of this experiment are given in Table XXIII. The failure of the turbidity to settle in the first 20 hours was probably due to poor mixing between alum and water and insufficient alum. There is no way of knowing if the lower turbidity found 46 days later was due to this treatment. Better results would have been achieved if the alum had been added as a slurry instead of a powder.

TABLE XXIII.—Farm Pond Coagulation Experiment Results (Pond 23)

	Turbidity	Suspended Solids	Total Solids	Total Alkalinity	pH	Sulphate
Before treatment	53	36	107	5	5.85	24
After Soda Ash (600 lbs.)	75	47	329	195	9.75	23
After Alum (280 lbs.)						
20 hours later	72	57	290	120	8.30	76
46 Days later	7	9	195	94	7.45	42

Pond 25—Pond 25 was one of the spring fed ponds. Its drainage area was relatively small and fenced in by multiflora rose bushes. Turbidity and color levels were very low. Odor was common in the summer months at the deeper levels. Little algae growth occurred in this pond, but an abundant number of cattails grew along most of the shore line. It could not be determined if these weeds caused the odor.

The coliform and enterococci populations in this pond were above average, even though humans and animals were very seldom near the pond or on its watershed. The chemical content of this pond water was relatively low.

Pond 26—Pond 26 had one of the best watersheds, having a good grass cover and a wooded wildlife area at its upper extremity. It was fenced from livestock by multiflora rose bushes and a wire fence. This pond was fed partly by a small spring. The physical, bacterial, and chemical properties indicate that the water had, in general, the best quality of the 14 ponds studied.

Pond 60—The greatest number of samples was taken from pond 60, which is located at the Southern Substation of the Ohio Agricultural Experiment Station. In conjunction with this pond is a water treatment laboratory. The physical, chemical, and bacterial properties of this water were either average or better in all cases.

Algae growths were a constant problem during the summer. Cladophora was the predominant type, but Spirogyra was also common. The pond was treated one to three times each summer with copper sulfate. The copper sulfate killed the algae, but it was only a temporary control. The dead organisms settled to the bottom and decayed, producing odor and color.

Pond 62—Pond 62 had the highest percentage of cultivated acreage in its watershed. One year corn was planted within 20 feet of the pond, although a buffer strip of grass was established between the pond and corn. Even with this potentially erodible land near the pond, the water was nearly the lowest in turbidity. The buffer strip seemed to remove most of the sediment from the runoff.

Color and odor were low in this pond, even though Cladophora and Spirogyra were common during the summer. This pond was the only one without fish. The bacterial population was relatively low. This low level may be attributed partly to the absence of livestock on the farm and to the fact that no recreational use was made of the pond.

Pond 86—Pond 86 was the deepest pond studied. Water samples from the upper level were high in physical quality while those from the lower levels were of poorer quality. Odor and color were common at the lower levels, and it appeared that anaerobic decomposition of the algae and weeds was taking place. Bacterial quality was relatively poor as compared to other ponds. The alkalinity, hardness, and sulfate levels were very high. The cause of these high values was not readily apparent.

Pond 87—Pond 87 had just been constructed when this study began. During the first two years of the study the banks of the pond were bare and erosion was evident. During this period the turbidity was very high. Ducks were also present and they aggravated the turbidity problem. Coliform bacteria counts were high, probably due to the ducks.

By 1960 the pond had filled with water and vegetative cover was established on the banks. The ducks had been removed. The turbidity, color, and bacteria levels dropped appreciably. During 1958 and 1959 there were no algae or weeds, but in 1960 with low turbidity water a few cattails and small clumps of algae began to appear. In 1961 these aquatic plants were much more apparent.

The chemical quality of the water changed little during the four years after construction. A slight decrease was noted in total hardness, total iron, and sulfates. An increase in pH occurred during the first three years, but leveled off the fourth year.

Ponds 88 and 90—Ponds 88 and 90 were average in most respects. They both had above average odor, probably due to algae.

Pond 89—Pond 89 had poor quality water with respect to physical properties and coliform bacteria. Turbidity, color, and odor were above normal in most cases. Algae were a primary reason for the color and odor being high during 1958 and 1959. The algae were kept under control in 1960 and the quality improved. During the 1960-61 winter a prolonged ice and snow cover on the pond resulted in a heavy fish kill. The effect of this kill was noted in the June sampling when the turbidity and color almost doubled. The water had a blackish cast. Odor appeared in July in the samples near the bottom.

DISCUSSION OF RESULTS

In general the physical characteristics of pond water were reasonably good, but not as satisfactory as most well water. Two critical periods occurred during the year. During February, March, and April the water was high in turbidity and color; and during June, July, and August odor and color were high. There was no indication that "turn over", in which water moves from one level to another due to differences in density causing the pond to be stirred up, occurred in these ponds either in the spring or fall. Good grass cover in the watershed, especially around the water edge, reduced the turbidity of the runoff.

The physical characteristics indicated that the water was suitable for livestock water supply, recreational uses, irrigation water, and spray water without further treatment. Turbidity and color were low enough in most ponds that simple filtration would reduce them to an acceptable level for milk house and domestic use. At a few ponds more complex treatment would be needed.

The results definitely showed that water near the surface had better physical properties than that near the bottom. Odor would not be a problem in most cases where the water was removed from near the surface. An inlet in the pond that removes water from near the surface would be highly desirable because less additional treatment would be needed to render it suitable for domestic use. This type of inlet is much better than the gravel barrel and other fixed depth inlets in common use.

Based upon its chemical properties, pond water was suitable for most uses. The only exceptions were a few ponds which had water that was "hard" and "softening" would be recommended for domestic use. Ponds that are sprayed for algae and weed control should be carefully checked as chemical residues might build up to a dangerous level for both humans and livestock.

Certain of the bacterial groups found in pond water have public health significance, either as etiological agents of disease or as indicators of the possible presence of enteric pathogens. Their presence or absence determine the safety or potential hazard of pond water as a source of domestic water supply.

The presence of recognized pathogens such as the Salmonellae and the Shigellae would greatly increase the danger in the use of such water. Since Salmonella species have been isolated from virtually every farm animal, and since farm animals had access to many of the ponds sampled, it seemed quite likely that these organisms would be readily found in ponds. In addition, the exposed nature of any farm pond watershed makes it highly susceptible to fecal contamination by birds and other kinds of wildlife. Consequently, it was rather surprising when no typical Salmonella or Shigella organisms were isolated from the rather large number of pond samples examined. There are several possible explanations for this: (1) no pathogens gained entrance into the ponds, (2) pathogens gained entrance but died out in the pond water, or (3) pathogens gained entrance but altered in biochemical or serological properties, so as to no longer conform to the accepted description of these two genera. However, on the basis of the experimental evidence, it must be tentatively concluded that enteric pathogens in the genera Salmonella and Shigella were absent from the farm ponds examined.

The use of the coliform group of bacteria as an indicator of fecal pollution in raw water supplies and in domestic drinking water is well known. The experimental results reported here show that, using coliform density as the criterion, the pond waters examined were only lightly polluted and constitute a good raw water supply. Of course, the water supply requires further treatment to be safe bactriologically. The low level of coliform population is corroborating evidence as to the validity of the results on Salmonella and Shigella isolation.

Enumeration of the enterococci as an indicator of fecal pollution has gained status in recent years, but it is still not widely used. The MPN data show the enterococci population in farm pond waters to be very small. The enterococci counts, therefore, substantiate the results obtained in the coliform analyses.

Although a water may be of high sanitary quality, it may still act as a source of nuisance organisms in milk production, or as a source of spoilage organisms in food-packing operations in the home or in commercial food-processing plants. Thermoduric, thermophilic, psychrophilic, and coliform bacteria fall into the category of nuisance organisms.

Thermoduric bacteria have proved especially troublesome to the market milk industry in its efforts to produce pasteurized milk with a low bacterial count. A major factor in high total counts in pasteurized milk is the presence of excessive numbers of thermoduric bacteria in the raw milk from the dairy farm. A water supply containing thermoduric organisms which is used in cleaning operations would act as a source of these nuisance organisms. This factor must be considered and controlled, although the small numbers of thermodurics in most samples of farm pond water suggest that no serious problem is involved.

Home-canned foods are subject to spoilage by thermophilic bacteria. Inadequately treated pond water used in home-packing operations may serve as source of such spoilage bacteria, although here again the low thermophilic population does not seem to warrant any great concern.

The thermophilic problem in the dairy industry centers about the growth of bacteria during the pasteurization of milk. Since thermophiles may reproduce at very near conventional pasteurization temperatures, excessive numbers may develop and be counted in the mesophilic SPC. This makes it difficult to meet the established public health standards for pasteurized milk. In addition, thermophiles in milk are objectionable because their metabolic activities cause off-flavors, high acidity, and a tendency for the milk to curdle upon heating.

Since storage at low temperatures is the most common method for preserving milk and milk products, the presence of psychrophiles, which are able to grow even at temperatures near 0° C., has been a matter of concern in the transportation, processing, and keeping quality of fluid milk products. Since certain members of this group of organisms are capable of producing flavor and aroma defects in milk, initial contamination must be kept at a minimum. While pond waters show the presence of psychrophiles, their level is very low and should constitute no problem, provided the water is adequately treated before use.

The concentration of coliform organisms in any milk or milk derivative reflects the care taken in the production and processing of the product. Therefore, careful control of all sources of coliforms, including the water supply, is essential to the production of acceptable milk products. Of course, coliform organisms in raw milk are readily killed by proper pasteurization methods. The level of coliforms in the farm pond waters tested does not appear to present any serious problem to the dairy industry.

CONCLUSION

Water from fourteen farm ponds in eight Ohio counties was sampled to determine the physical, bacterial, and chemical characteristics of the water for the period May 1958 through August 1961. The major conclusions from this study are as follows:

1) Turbidity ranged between 1 and 155 units with a mean of 30 units. Maximum turbidities occurred during March and these high values appeared to be associated with high runoff.

2) Apparent color ranged between 0 and 800 units with an average of 60 units. Turbidity was the major cause of color.

3) Odor was found in 4.8 percent of the samples taken near the water surface and in 21.2 percent of the samples taken near the bottom. Maximum odor occurred during the summer months. Maximum threshold odor was 64.

4) As depth of water increased, turbidity, color, and odor increased. The greatest increase occurred in the lowest two-foot layer.

5) All pond waters contained coliform bacteria, but the degree of contamination was slight. The waters were of good sanitary quality. Highest coliform populations occurred during the summer months.

6) The populations of thermophilic, thermoduric, and psychrophilic bacteria, as well as counts of entercocci and total bacteria were relatively low, indicating a generally low level of microbial contamination.

7) Chemical quality of pond water was good except for hardness, which averaged 100 ppm. Fifty percent of the ponds had hard water which might have to be softened for domestic use.

8) Pond water treated with sodium arsenite for weed control had dangerous arsenic levels for human consumption as long as 16 months after treatment.

REFERENCES

1. Baumann, E. R., A Preliminary Survey of Farm Water Supplies in Southern Iowa. Engineering Experiment Station, Iowa State College, Ames, Iowa. 1956.

2. Edwards, P. R. and Ewing, W. H., Identification of Enterobacteriaceae. Burgess Publishing Co., Minneapolis. 1957.

3. Picton, W. L., Water Use in the United States 1900-1980, U. S. Department of Commerce Water and Sewerage Industry and Utilities Division, Washington, D. C. March 1960.

4. Snedecor, G. W., Statistical Methods, Iowa State College Press, Ames, Iowa, 1946.

5. Standard Methods for the Examination of Water and Wastewater, 11th Ed., American Public Health Assoc., New York, 1960.

6. Standard Methods for the Examination of Dairy Products, 11th Edition, American Public Health Assoc., New York, 1961.

APPENDIX TABLE A.–Location of Ponds by County, Soil Region, and Soil Description

Pond No.	County	Soil Region	Soil No.	Soil Name	Description of Soil[1]
1	Delaware	Glacial limestone	6B2	Blount	Grayish-brown, medium to strongly acid, imperfectly drained, moderately productively, and developed from highly calcareous silty clay loam or clay loam glacial till.
			6B3	Morley	Grayish-brown, medium acid, moderately to well drained.
			6B8	Plwamo	Very dark gray, very poorly drained, high productive, good moisture holding capacity.
5	Delaware	Glacial sandstone and shale	692	Bennington	Brownish-gray, strongly acid, imperfectly drained and moderately productive, developed from calcareous clay loam glacial till,
6	Delaware	Glacial sandstone and shale	693	Cardington	Yellowish-brown, medium acid, moderately well drained, moderately productive, moderately good water holding capacity.
			694	Alexandria	Light colored, well drained, medium acid, moderately productive, fair to good holding capacity.
8	Delaware	Glacial sandstone and shale	692	Bennington	(see pond 5)
			693	Cardington	(see pond 6)
23	Washington	Residual sandstone and shale	374	Vincent silt loam	
25	Jackson	Residual sandstone and shale	423	Coolville	Light brown, strongly acid, moderately well-drained, moderately low in productivity, low organic matter, good water holding capacity.
26	Vinton	Residual sandstone and shale	406	Muskingham	Light colored, drouthy, shallow, moderately productive, low in organic matter, medium to strongly acid.
60	Brown	Glacial limestone	752	Avonburg	Brownish-gray, imperfectly drained, medium to strongly acid, moderately low in productivity.

APPENDIX TABLE A.—Continued—Location of Ponds by County, Soil Region, and Soil Description

Pond No.	County	Soil Region	Soil No.	Soil Name	Description of Soil[1]
			753	Rossmoyne	Grayish-brown, highly erosive, strongly to very strongly acid, moderately well drained, moderately productive.
62	Highland	Glacial limestone	753	Rossmoyne	(see pond 60)
			754	Cincinnati	Grayish-brown, erosive, well drained, strongly acid, moderately productive, good moisture holding capacity.
86	Lorain	Glacial sandstone and shale	703	Ellsworth	Grayish-brown, medium to strongly acid, moderately well drained, moderately productive, fair moisture holding capacity.
87	Lorain	Glacial sandstone and shale	703	Ellsworth	(see pond 86)
88	Lorain	Glacial sandstone and shale	702	Mahoning	Brownish-gray, strongly acid, imperfectly drained, moderately low in productivity.
89	Lorain	Glacial sandstone and shale	702	Mahoning	(see pond 88)
			703	Ellsworth	(see pond 86)
90	Crawford	Glacial limestone	103	Eel	Light colored, moderately well drained, moderately high in productivity, high moisture holding capacity.
			602	Crosby	Brownish-gray, slightly to strongly acid, imperfectly drained, moderately productive, good moisture holding capacity.
			603	Celina	Grayish-brown, slightly to medium acid, moderately well drained, moderately productive, good moisture holding capacity.

---

[1] Information from OUR OHIO SOILS, Ohio Department of Natural Resources, Division of Lands and Soil, Columbus, Ohio, 1958.

APPENDIX TABLE B.—Pond and Watershed Description

Pond No.	Size Pond* Acres	Max. (5) Measured Depth-ft.	Max. Vol. Estimated Acre-ft.	Source of Water	Size Watershed Acres	Normal Watershed Use %	Slope Watershed %	Type Overflow	Use
1[1]	0.5	8.0	2.5	surface	81	crops-25 pasture-75	0-5:100	none	house-domestic livestock milk house recreation
5	0.14	6.0	0.42	surface field tile	0.9	pasture-100	0-5:100	4'' tile	house-non-domestic livestock[4] recreation
6	1.0	9.0	4.5	surface	31.	crops-10 pasture-50 woods-40	0-5:60 5-10:40	drop inlet grass waterway	livestock recreation
8	1.75	10.8	12.0	surface	51.	crops-50 grass-30 woods-20	0-5:80 5-10:20	8'' tile drop inlet, grass waterway	house-domestic livestock recreation
23	0.3	9.75	1.8	surface	1.7	grass-100	5-10:100	grass waterway	house-domestic livestock recreation
25	1.14	12.5	5.7	surface spring	2.74	grass and brush-100	0-5:100	12'' drop inlet	3 houses-domestic milk house livestock recreation
26	0.7	11	4.2	surface spring	9.3	grass and trees-100	10-20:100	8'' tile[2] grass waterway	house-domestic livestock recreation

APPENDIX TABLE B.–Continued–Pond and Watershed Description

Pond No.	Size Pond* Acres	Max.(5) Measured Depth-ft.	Max. Vol. Estimated Acre-ft.	Source of Water	Size Watershed Acres	Normal Watershed Use %	Slope Watershed %	Type Overflow	Use
60[3]	3.2	12	17.1	surface spring	31	crops-25 grass-70 orchard-5	0-5:100	10" mech. spillway, grass waterway	livestock[3] irrigation exp. water treatment recreation
62	1.1	6.5	3.3	surface	50	crops-50 hay-50	0-5:80 0-10:20	grass waterway	house-domestic
86	0.28	14	2.8	surface	2	grass-100	0-6:100	6" tile grass waterway	house-domestic livestock recreation
87	0.22	9	1.3	surface roof of barn	0.86	grass-90 yard-10	0-5:100	grass waterway	house-domestic livestock recreation
88	0.26	8.7	1.2	surface	1.76	pasture-90 yard-10	0-5:100	grass waterway	house-domestic milk house livestock recreation
89	0.18	8.3	0.7	surface tile[6]	6	pasture-80 yard-20	0-5:100	grass waterway	house-non-domestic livestock recreation
90	0.64	10	3.2	surface	3	yard hay-100	0-5:100	grass waterway	house-domestic livestock recreation

*At spillway level.

[1] Upground pond, water pumped into pond from small wet-weather stream.

[2] Washed out in 1960.

[3] Pond located on Ohio Agr. Exp. Sta. farm and used for experimental purposes.

[4] Livestock and ducks often found in pond.

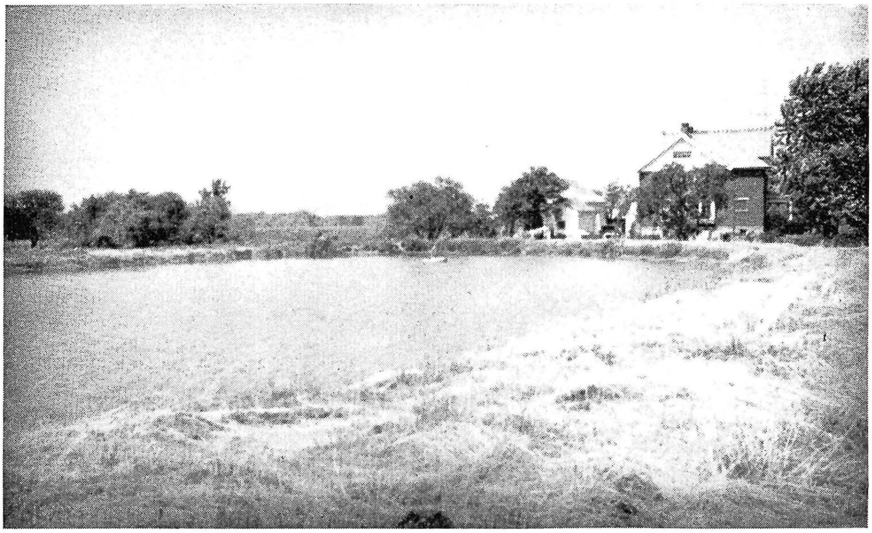
[5] Maximum measured depth, pond could be deeper at certain points.

[6] Tile flow added. Jan. 1961.

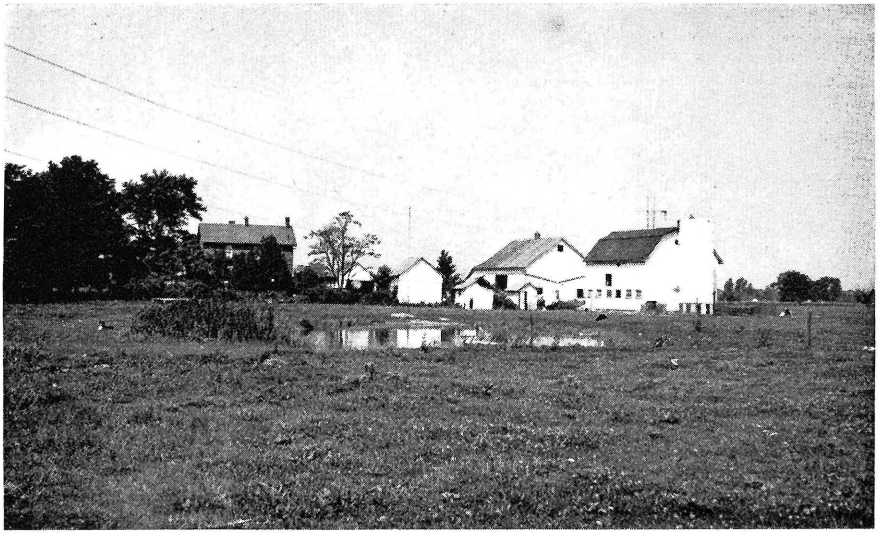
Example of Slope Watershed Percent: 0-5:100 means 0-5% slope on 100% of watershed.

APPENDIX C

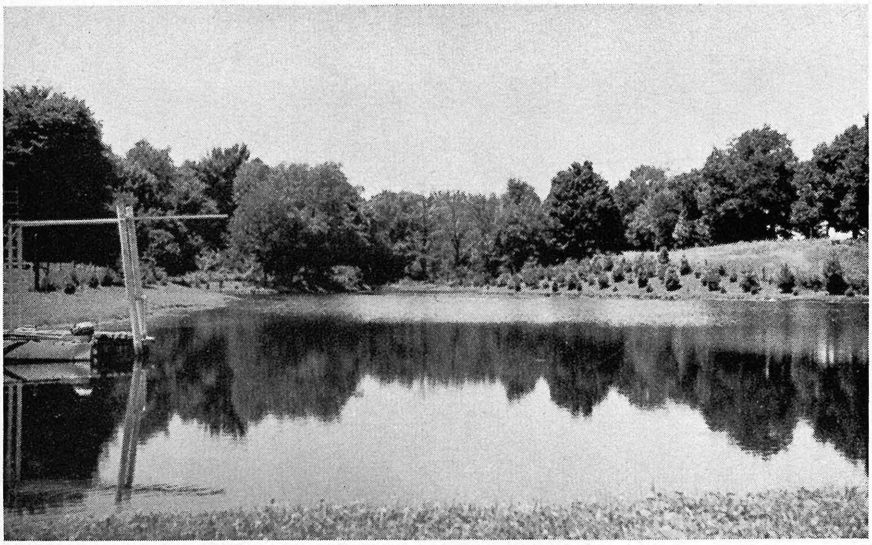
Photographs of Each Pond



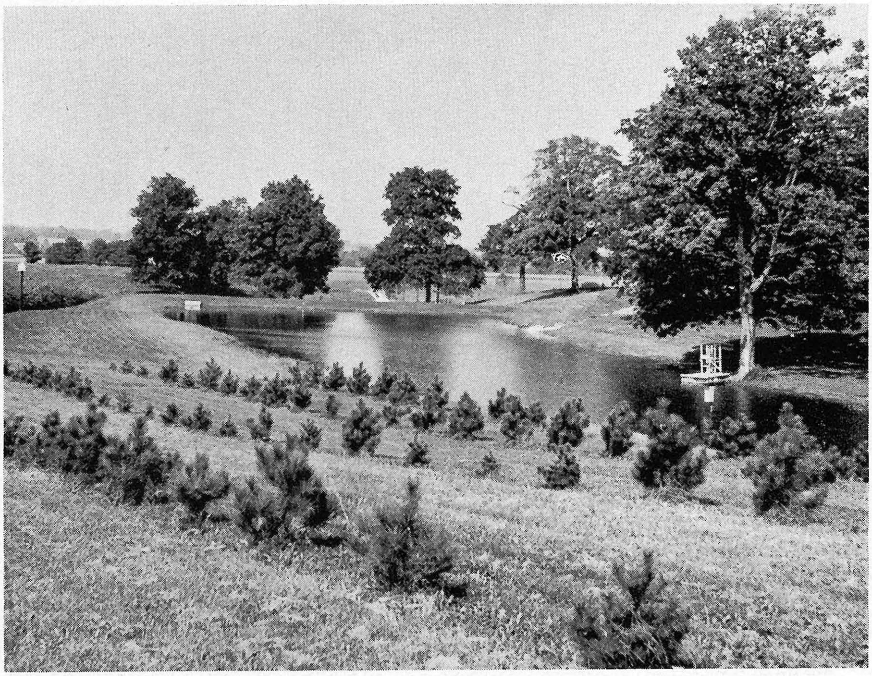
Pond 1.—Upground pond into Which Water was Pumped from a Small Intermittent Stream.



Pond 5.—Smallest Pond Studied.

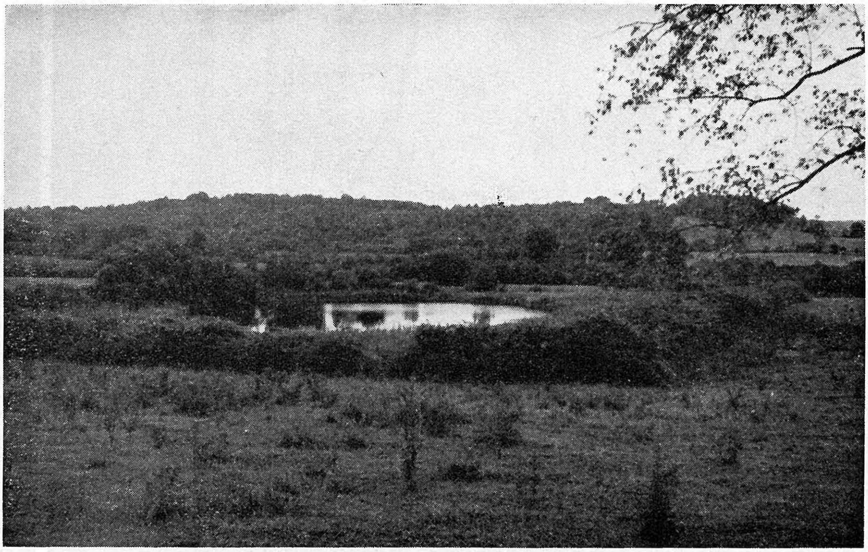


Pond 6.—Note Well Grassed Drainage Area.

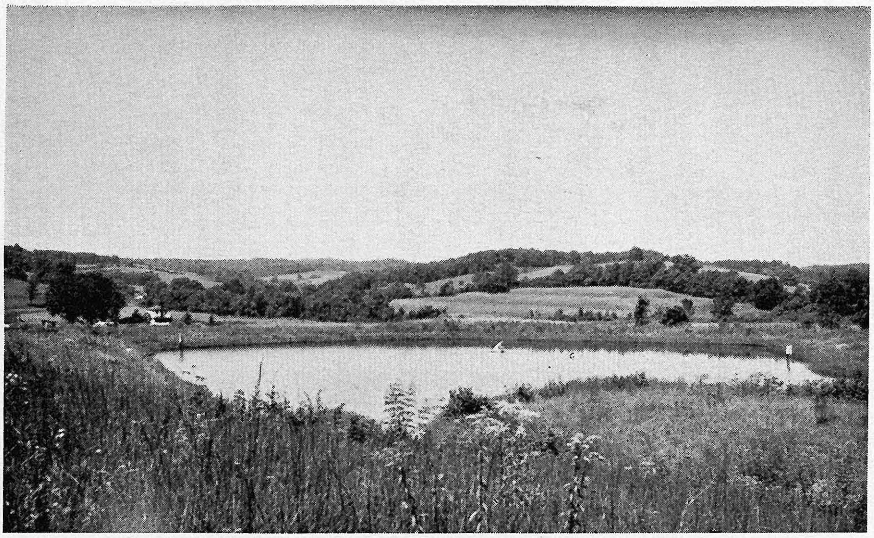


Pond 8.—Note Recreational Area.

Pond 23.—This Pond, Even with the Good Vegetative Cover in the Watershed, had Some of the Highest Turbidities.



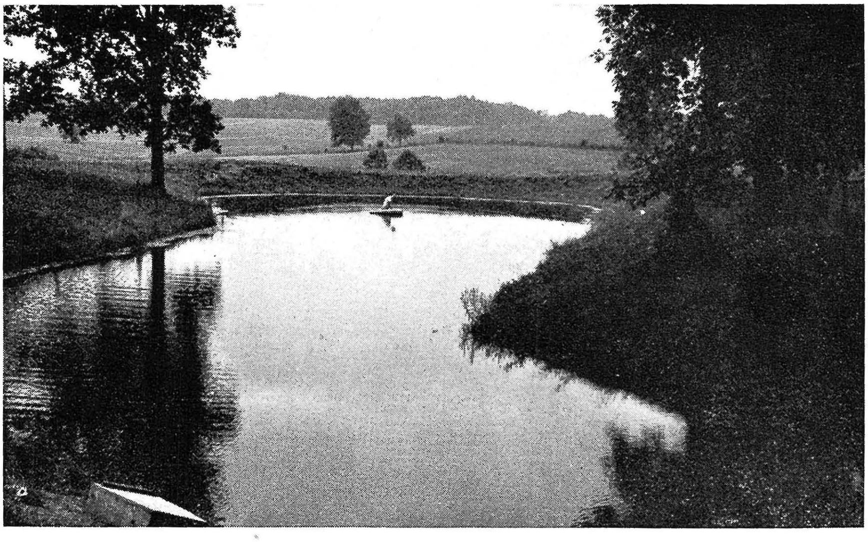
Pond 25.—Pond was Completely Surrounded by Multiflora Rose Bushes. Cattails were a Major Problem.



Pond 26.—One of the Best Ponds Studied with Respect to the Physical and Chemical Properties of its Water.

Pond 60.—Larger Pond was Studied. This Pond was Located on the Southern Substation, Ohio Agricultural Experiment Station, and is Used in a Number of Studies Dealing with the Uses of Pond Water.

Pond 62.—Note Bad Infestation of Algae.

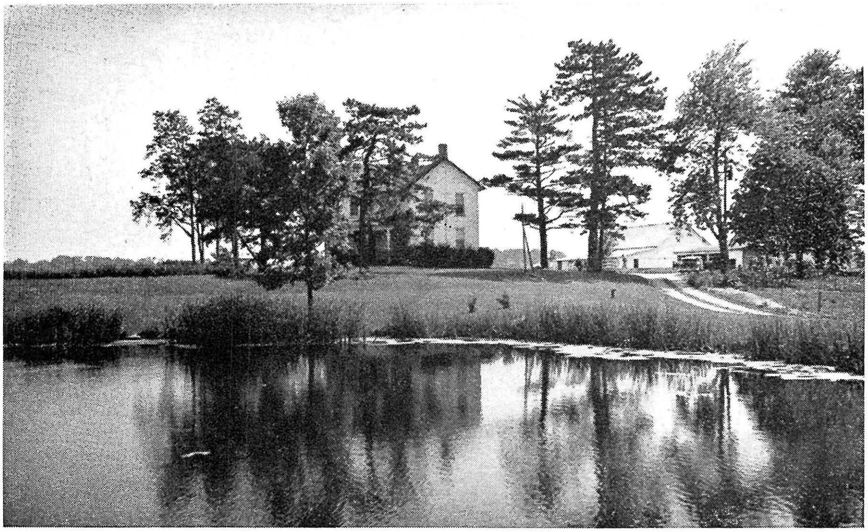


Pond 86.—Deepest Pond Studied.

Pond 87.—Note Erosion on Banks of Pond and Ducks. Boat Pictured was Used in Taking Samples.

Pond 88.—Note Swimming Area.

Pond 89.—A Pond Normally High in Turbidity, Color, and Odor.



Pond 90.—Note Algae and Cattails.

APPENDIX TABLE D.—Chemical Properties of Individual Ponds

	Alkalinity Total (ppm)	Hardness Total (ppm)	Hardness Non-carbonate (ppm)	pH	Iron (ppm)	Manganese (ppm)	Sulfate (ppm)	Chloride (ppm)	Fluoride (ppm)	Nitrate Nitrogen (ppm)
Pond 1										
Maximum	145	190	116[1]	8.8	1.1	.05	120	120	0.33	3.1
Minimum	54	120	116	7.3	0.2	0	48	54	0	0
Mean	79.7	151.3	116	7.9	0.54	.025	73.8	82.7	0.24	0.72
Pond 5										
Maximum	82	108	40[1]	9.4	0.6	0.1	29	9	0.45	0.2
Minimum	68	64	40	7.4	0.4	0.05	9	4	0.35	0
Mean	73.7	89.5	40	8.7	0.49	.075	19.5	7.2	0.4	0.1
Pond 6										
Maximum	127	168	56[1]	8.85	0.4	0.25	46	52	.35	0.1
Minimum	90	114	56	8.4	0.3	0.25	46	18	.30	0
Mean	112	133	56	8.6	0.36	0.25	46	37.6	.33	.05
Pond 8										
Maximum	97	132	---	8.8	.10	----	110	4	0.25	0.2
Minimum	51	96	---	7.5	.10	----	51	2	0.25	0
Mean	81	114	---	8.2	.10	----	71.1	3	0.25	0.1
Pond 23										
Maximum	195	50	31	9.75[2]	0.6	0.45	76[2]	15	0.3	0.1
Minimum	5	20	23	5.4	0.25	0	14	0	.05	0
Mean	69	32	27	7.2	0.43	0.2	31.7	1.7	0.17	.025

APPENDIX TABLE D.–Continued–Chemical Properties of Individual Ponds

	Alkalinity Total (ppm)	Hardness Total (ppm)	Hardness Non-carbonate (ppm)	pH	Iron (ppm)	Manganese (ppm)	Sulfate (ppm)	Chloride (ppm)	Fluoride (ppm)	Nitrate Nitrogen (ppm)
Pond 25										
Maximum	52	50	18[1]	7.2	0.4	0.25	21.2	7	0.3	0
Minimum	26	38	18	6.75	0.25	0.2	10	2	0.1	0
Mean	39	44.5	18	7.04	0.3	0.22	15.3	4.5	0.2	0
Pond 26										
Maximum	22	34	---	7.1	0.1	0.2	16.7	0	0.2	0
Minimum	18	0	---	6.6	0.45	0.1	7	0	0.1	0
Mean	21	17.5	---	6.9	0.26	0.15	11.8	0	0.15	0
Pond 60										
Maximum	105	124	28	8.5	0.5	0.3	30.6	7	3	5.9
Minimum	59	66	5	7.2	0.05	0.5	7	0	0.15	0
Mean	82.7	100.3	16.3	7.9	0.16	0.16	15.8	2.8	0.23	0.89
Pond 62										
Maximum	103	100	32[1]	9.0	0.4	0.1	15	3	0.25	0.4
Minimum	66	72	32	7.45	0.1	0.05	4	2	0.15	0
Mean	83	91.5	32	8.1	0.24	0.07	8.7	2.8	0.2	0.15
Pond 86										
Maximum	159	226	59[1]	9.25	0.4	0.25	97	17	0.3	0.5
Minimum	72	156	59	7.4	0.05	0.10	50	12	0.2	0
Mean	135.8	205.6	59	7.93	0.17	0.16	77.6	14.8	0.25	0.14

APPENDIX TABLE D.–Continued–Chemical Properties of Individual Ponds

	Alkalinity Total (ppm)	Hardness Total (ppm)	Hardness Non-carbonate (ppm)	pH	Iron (ppm)	Manganese (ppm)	Sulfate (ppm)	Chloride (ppm)	Fluoride (ppm)	Nitrate Nitrogen (ppm)
Pond 87										
Maximum	105	122	37[1]	8.2	1.5	0.05[1]	76	16	0.5	0.1
Minimum	68	90	37	7.9	0.1	0.05	31	12	0.3	0
Mean	77.5	110	37	8.1	0.62	0.05	47.7	13	0.36	.05
Pond 88										
Maximum	89	126	43[1]	9	0.3	0.25	41.7	13	0.4	0.2
Minimum	66	100	43	7.5	0.05	0.03	6.9	6	0.25	0
Mean	78.2	108	43	8.1	0.21	0.14	22.1	10	0.32	.08
Pond 89										
Maximum	95	82	---	7.6	1.55	---	14.4	13	0.4	0.1
Minimum	93	70	---	7.5	0.7	---	8	9	0.4	0.1
Mean	94	76	---	7.55	1.12	---	11.2	11	0.4	0.1
Pond 90										
Maximum	99	138	77[1]	8.6	0.2	.01[1]	74	16	0.4	0.12
Minimum	57	130	77	8.2	0.1	.01	45.1	3	0.25	0
Mean	80	134	77	8.4	0.13	.01	56	9.6	0.3	0.04
Summary										
Maximum	195	190	116	9.75	1.55	0.45	120	120	0.5	3.1
Minimum	5	0	5	5.4	0.05	0	4	0	0	0
Mean	79	100.5	47.4	7.9	0.35	0.12	36.3	14.3	0.27	0.17

[1] Only one sample.

[2] Maximum occurred after pond had been treated with soda ash and alum.

APPENDIX TABLE E.—Seasonal Variation in Chemical Content – Pond 60

	Jan. 1960	Mar. 1960	Apr. 1960	May 1960	June 1960	July 1960	Aug. 1960	Sept. 1960	Dec. 1960	Jan. 1961	Mar. 1961	Apr. 1961	May 1961	June 1961	July 1961	Aug. 1961	Average
Alkalinity Total	105	87	93	70	71	72	82	93	92	102	92	83	66	59	61	81	81.8
Hardness Total	121	118	124	98	96	90	90	104	114	124	116	114	85	80	66	90	101.9
Iron Total	0.4	0.2	0.3	0.2	0.2	0.1	.15	.05	0.1	0.2	0.3	0.4	0.5	.45	.15	0.1	0.24
Manganese	-----	-----	-----	-----	0.2	0.1	0.2	-----	.05	.05	0.1	0.1	.15	0.6	-----	.05	0.15
Sulfate	30.6	22	12	7	11	-----	10	10	12	17	20	21	27	30	13	7	16.6
Chloride	7	4	4	4	-----	-----	3	-----	2	3	1	0	1	1	0	0	2.3
Fluoride	0.3	0.2	.15	0.2	-----	-----	.25	-----	0.1	---	---	---	---	---	---	---	0.2
Nitrate Nitrogen	0.8	1.1	0.5	0	0	0.1	0	0.1	0.2	0.3	0.6	0.9	0.8	0.8	0.1	0.5	0.43
pH	7.95	8.5	8.45	8.4	7.3	7.9	8.1	7.7	7.25	7.2	7.95	8.2	8.5	7.55	8.3	7.4	7.91