UPPER HUDSON RIVER SURVEY

1954

INTERSTATE SANITATION COMMISSION

New York • New Jersey • Connecticut

REPORT

1954 UPPER HUDSON RIVER SURVEY

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Interstate Sanitation Commission

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INTRODUCTION

Article VIII of the Tri-State Compact states that:

> "Each of the signatory states agrees, that insofar as waters within its jurisdiction may flow into any portion of the District, all sewage discharged or permitted to flow into any stream tributary to the tidal waters of the District shall be treated to that extent, if any which may be necessary to maintain such tributary immediately above its confluence with the tidal waters of the District in a sanitary condition at least equal to the classification of requirements determined by the Commission for the tidal waters of the District into which it discharges. . . . ."

The Hudson River enters the waters of the Interstate Sanitation District at the northerly bound of the District. As a tributary to District waters, the Hudson River waters at Bear Mountain Bridge must be maintained in a condition at least equal to the District waters. The Tri-State Compact also specifies that the waters of the Hudson River, immediately above the mouth of the Sparkhill Creek on the westerly side and the New York-New Jersey boundary on the easterly side shall be maintained in a sanitary quality at ebb tide at least equal to the sanitary condition prevailing in the waters of the river immediately below this line at flood tide. It was deemed adviseable to first survey the Hudson River waters in the vicinity of Bear Mountain Bridge.

There are two other Commissionswhich have an interest in the quality of the Hudson River waters in the vicinity of Bear Mountain, namely the Water Pollution Control Board of the New York State Department of Health, whose interest is obvious, and the Palisades Interstate Park Commission which operated bathing beaches in this part of the Hudson River for a number of years.

It is the intent of this report to present the results of the Interstate Sanitation Commission survey conducted during 1954, and to interpret the results of this survey.

DESCRIPTION OF SURVEY

The survey was conducted in two sections, the first during June 21, 22, 23, 28, 29, 30 and later during October 4, 5, 6, 1954. Previous survey conducted by the Commission in the New York Harbor area had indicated that surveys conducted during these weeks would give an approximation of the general conditions prevalent during the entire summer. Twenty-five samples were obtained routinely during each day the survey was conducted which amounted to a total of 235 separate samples.

All samples were obtained by means of a "Foerst" water sampler. Immediately after securing a sample by the appropriate use of the Foerst sampler, two standard B.O.D. bottles of 300 ml. capacity, properly labelled, were filled from the sampler avoiding the entrainment of air into the sample and permitting a three fold displacement of the liquid in each of the sample bottles. The B.O.D. sample bottle was set into a stand equipped with a funnel and the overflow from the B.O.D. bottle was allowed to empty into a quart sample jar. The temperature of the sample was obtained immediately on securing the sample by placing the thermometer directly in the quart jar. Dissolved oxygen determinations were made on shipboard in accordance with "Standard Methods".

Lactose tubes for the determination of MPN coliform concentrations were inocculated after a sample had been obtained from the Foerst sampler. The inocculation of the lactose tubes was conducted on shipboard. Three tubes in each of three decimal dilutions were used. "Standard Methods" were followed throughout with only the 48 hour presumptive positives being confirmed in brilliant green bile.

The sampling stations were selected in order to obtain the quality of the water entering the District. Since, in the area of the District boundary the Hudson is a tidal river, it is theoretically possible to obtain some concept of the waters entering the District by sampling on an ebb tide, at which time the waters are flowing in a southerly direction. Accordingly, it would then be possible to obtain some idea of the quality of the waters in the District by sampling on a flood tide at which time the waters in the Hudson are flowing in a generally northerly direction. However, since it was felt that the waters might be so well mixed in the general vicinity of Bear Mountain Bridge so as to afford little differentiation between the waters on the flood or the ebb tides, two other sampling sections were chosen, one at West Point near Constitution Island approximately 3 miles north of the District boundary, and at Verplanck, which is approximately 3 miles south of the District boundary. The accompanying map indicates the location of the sampling stations.

RESULTS

The data obtained from the survey may be analyzed in any of a considerable number of ways. However, the ultimate purpose of all these analyses are to present a physical description of the state of the Hudson River in the vicinity of Bear Mountain Bridge.

Two primary variations can be expected in the data obtained from any survey; those due to variation in distance, and those due to a variation in time. The variations in samples because of distance are self-explanatory, i.e. one intuitively accepts the fact that samples taken at different places are not necessarily the same. Since there are no major sources of fresh water available for dilution in the stretch of the Hudson River under consideration, variations in distance are to be expected because of the discharge of polluting materials and the purifying capacity of the river itself. Thus, at a point immediately below a pollution source, one expects worse conditions than at a point above this source. Further downstream, due to the recuperative powers of the river, one expects an improvement in the quality of the river.

Variations at a fixed point will occur with respect to time due to the influence of the tide, weather, river flow, temperature of the water, and any other variables which describe either the river or the waste discharged to the river.

Some concept of the relative size of the primary variations due to time and place may be obtained from Table I which presents an analysis of coliform data at the Bear Mountain section for June 21, 1954. Data are presented for each of the three trips conducted during that day. The figures in the primary table are the values of the MPN of coliform organisms per ml. The analysis indicates that there is a considerable difference between the different sampling points, insofar as coliform concentrations are concerned, and further that there is also a considerable difference between the values at a given station for the different sampling times. These results make further analysis difficult since, inasmuch as a difference exists between the sampling points, the use of an average value for all of the sampling points at a station is not especially valid.

Although to some extent, as indicated previously, tidal actions introduce a complicating factor in the interpretation of any survey results, in some respects they afford a clear and simple interpretation of the survey data. This simple interpretation of the survey data is possible because of the fact that at the Bear Mountain station, waters enter the District on ebb currents whereas the flow is reversed and waters flow out of the District northward during periods of flood current. Therefore, by a comparison of values on

TABLE I

ANALYSIS OF MPN DATA
June 21, 1954
Bear Mountain Survey

Station	TRIP A	TRIP B	TRIP C	Total
IE	15.0	23.0	23.0	61.0
ICT	3.6	9.1	9.1	21.8
ICM	15.0	23.0	9.1	47.1
ICB	9.1	15.0	3.6	27.7
IW	9.1	23.0	9.1	41.1
Totals	51.8	93.1	53.9	198.8

$$(1) = 15^2 + 23^2 + 23^2 + - - - + 23^2 + 9.1^2 = 3{,}313.78$$

$$(2) = (61.0^2 + 21.8^2 + 47.1^2 + 27.7^2 + 41.1^2) \;/3 = \frac{8{,}871.15}{3} = 2{,}957.05$$

$$(3) = (51.8^2 + 93.1^2 + 53.9^2)\;/5 = \frac{14{,}256.06}{5} = 2{,}851.212$$

$$(4) = 198.8^2/15 = \frac{39{,}521.44}{15} = 2{,}634.7627$$

ANALYSIS OF VARIANCE

Source of Variation	Sum of Square	DF	Mean Squares
Between Rows	322.29	4	80.57
Between Columns	216.45	2	108.22
Residual	140.28	8	17.54
Total	679.02	14	

$F_R = \frac{80.57}{17.54} = 4.59$ 0.04 _ P

$F_C = \frac{108.22}{17.54} = 6.17$ 0.04 _ P flood and ebb currents some estimate can be obtained of the waters immediately above the District boundary and immediately below the District boundary.

The method used in order to determine the change in a variable due to the tidal influence is presented in detail in a technical memorandum of the Interstate Sanitation Commission entitled, "Analysis of MPN Data". However, some concept of the method can be obtained from the data of Table II which are plotted in the accompanying graph of variation of salinity with tidal current. Inasmuch as the time of zero degrees current was taken at the start of the flooding current, it is apparent that as soon as the flood current starts, the salinity begins to increase and reaches a maximum at the Bear Mountain sampling point 1-CT at the end of the flood period. Of course, this is exactly in accord with what we would expect, i.e. waters of greater salinities lie to the south of Bear Mountain Bridge rather than to the north of the Bridge because of the gradual increase in chlorides as one proceeds seaward. However, the mathematical methods used point out that a fairly simple determination can be made with a tidal river if one desires to know the water qualities on both sides of a given section. The values of the lag angle in general indicate whether values tend to increase or decrease with a flooding current. As can be seen from the graph if values of the lag angle lie

TABLE II

SALINITY AND CURRENT DATA
SAMPLING POINT 1-CT

DATE	TIME	CURRENT (DEGREES)*	SALINITY - PPM (AS CHLORIDES)
6-22-54	08:23	249.	39.
	10:00	295.	12.
	12:35	9.	17.
	14:10	56.	19.
6-23-54	08:40	232.	37.
	10:15	277.	13.
	12:48	351.	6.
	14:13	31.	8.
6-28-54	08:10	74.	14.
	09:42	121.	28.
	12:32	207.	33.
	14:00	251.	20.
6-29-54	08:33	58.	10.
	10:10	107.	25.
	13:03	194.	33.
	14:38	243.	38.
6-30-54	08:33	33.	11.
	09:58	76.	10.
	13:10	174.	38.
	13:16	176.	36.
			306.

N = 20

* A current of zero degrees corresponds to the time of flood beginning.

between 0° and 180°, the parameters that are being analyzed will tend to increase with a flood current, that is to say, the values of these parameters are greater to the south of the District rather than to the north of the District.

In recapitulation, if the values of the lag angle are in phase with the current (if they lie between 0 - 180°) then the water quality under consideration is greater in the District waters themselves as compared to the waters entering the District.

The general variations of the MPN of coliform organisms per ml., the percent of dissolved oxygen saturation, and the bio-chemical oxygen demand have been plotted in the accompanying figure. It is apparent that the only appreciable variation in any of these parameters occurs in the MPN. The average values indicate that as one proceeds southward from West Point there is a gradual decrease in the MPN to a minimum value somewhere in the vicinity of the Bear Mountain Bridge station, and then as one proceeds further southward towards Verplanck, there is an increase in the MPN.

The increase in the geometric average of the MPN of coliform organisms per ml. from Bear Mountain Bridge to the Verplanck station is, in all likelihood due to the discharge of raw sewage from the Peekskill area. Although the City of Peekskill has a sewage treatment plant for the treatment of its wastes, the interceptors necessary to divert the raw sewage to the treatment plant were not completed at the time of the Bear Mountain Survey. The total amount of sewage emanating from the Peekskill area is approximately 2.8 million gallons per day. Of this total, approximately 25% was treated during the summer of 1954. Although the United States Military Academy has a population of approximately 4500, not all of the sanitary sewage emanating from the Academy is discharged to the Hudson River. Regardless of the amount discharged, it does not appear from the data obtained (there is no marked change between the West Point and Bear Mountain stations) that the increase at Verplanck is due to the discharge from the Academy.

Table III presents the results of the tidal analyses at the Bear Mountain station. From the values of the lag angle given in the table, it is evident that the MPN of coliform organisms are greater in the District waters than they are immediately to the north of the District waters in the Upper Hudson River. This can be seen from the fact that all of the values for the lag angle are between 0 and 180°.

It is extremely important to note that the conclusions that can be drawn concerning these tidal analyses are approximate at best. This is indicated clearly in Table IV, which is an analysis of the variances of the tidal analyses. In many respects this can be regarded as an analysis of the reliability

TABLE III

TIDAL ANALYSES
BEAR MOUNTAIN STATION

CURRENT VS. WEEKS	SALINITY 1	SALINITY 2	SALINITY 3	B. O. D. 1	B. O. D. 2	B. O. D. 3
K*	+37.5050	+21.0503	+4,230.3542	+1.1011	+1.0031	+ 0.3921
A_1	+ 1.7792	+ 0.2918	+ 8.7270	+0.1220	-0.2179	- 0.1131
A_2	-25.6040	-15.6755	- 95.3215	-0.0627	-0.0139	+ 0.0020
Quadrant	1	1	1	1	2	3
$Cot(A_1/A_2)$	+ 0.0695	+ 0.0186	+ 0.0916	+1.9458	-15.6763	+56.5500
Lag. Angle (t_0/P)	86.0	89.0	84.8	27.2	176.4	181.0
Sin $t_0/P°$	+ 0.9976	+ 0.9999	+ 0.9959	+0.4571	+0.0628	- 0.0175
K_1	+25.6656	+15.6771	+ 95.7139	+0.1372	+0.2213	+ 0.1143
K_1/K	+ 0.6843	+ 0.7447	+ 0.0226	+0.1246	+0.2206	+ 0.2915

* Values of these parameters refer to the methods discussed in Interstate Sanitation Commission Report on MPN Analyses.

TABLE III

TIDAL ANALYSES
BEAR MOUNTAIN STATION

CURRENT VS. WEEKS	LOG. M.P.N. 1	2	3	ARITH. M.P.N. 1	2	3
K*	+0.9501	+1.2090	+1.7908	+16.3605	+24.3253	+175.8970
A_1	+0.0286	+0.1402	+0.2131	+ 0.7682	+ 0.1746	+146.0246
A_2	-0.0531	-0.0738	-0.1631	-10.2505	- 3.7555	- 70.6106
Quadrant	1	1	1	1	1	1
$Cot(A_1/A_2)$	+0.5386	+1.8997	+1.3066	+ 0.0749	+ 0.0465	+ 2.0680
Lag. Angle (t_0/P)	61.7	27.8°	37.6	85.8	87.3	25.8
Sin $t_0/P°$	+0.8805	+0.4664	+0.6102	+ 0.9973	+ 0.9989	+ 0.4352
K_1	+0.0603	+0.1582	+0.2673	+10.2783	+ 3.7596	+162.2486
K_1/K	+0.0635	+0.1309	+0.1493	+0.6282	+ 0.1546	+ 0.9224

* Values of these parameters refer to the methods discussed in Interstate Sanitation Commission Report on MPN Analyses.

TABLE IV

ANALYSES OF VARIANCES OF TIDAL ANALYSES

		SALINITY			B. O. D.		
	1st Week						
1	Variance due to Current	2140.9566	2	1070.4783	0.0805	2	0.0403
2	Residual Variance	1853.9184	6	308.9864	0.2166	9	0.0241
3	Total Variance	3994.8750	8		0.2971	11	
		ratio = 3.5	significance = 0.10		ratio = 1.7	significance = .20+	
	2nd Week						
1	Variance due to Current	929.5410	2	464.7705	0.2880	2	0.1440
2	Residual Variance	13.0045	9	1.4449	1.2918	9	0.1435
3	Total Variance	942.5455	11		1.5798	11	
		ratio = 321.7	significance = 0.001-		ratio = 1.00	No significance	
	3rd Week						
1	Variance due to Current	30,387.8276	2	15,193.9138	0.0520	2	0.0260
2	Residual Variance	105,953.1724	10	10,595.3172	0.0866	10	0.0087
3	Total Variance	136,341.0000	12		0.1386	12	
		ratio = 1.4	significance = 0.20+		ratio = 3.00	significance = 0.10	

TABLE IV

ANALYSES OF VARIANCES OF TIDAL ANALYSES

		LOG MPN			ARITH. MPN		
1st Week							
1	Variance due to Current	0.0091	2	0.0046	53.9063	2	26.9532
2	Residual Variance	0.2508	9	0.0279	234.7039	9	26.0782
3	Total Variance	0.2597	11		288.6102	11	
		ratio = less than 1.0		No significance	ratio = 1.0		No significance
2nd Week							
1	Variance due to Current	0.0812	2	0.0406	5.1791	2	2.5896
2	Residual Variance	0.5179	9	0.0575	2,242.3780	9	249.1531
3	Total Variance	0.5991	11		2,247.5571	11	
		ratio = less than 1.0		No significance	ratio = less than 1.0 No significance		
3rd Week							
1	Variance due to Current	0.1552	2	0.0776	81,533.0731	2	40,766.5366
2	Residual Variance	0.3863	10	0.0386	84,015.3467	10	8,401.5357
		ratio = 2.0		Significance = 0.20-	ratio = 4.9		Significance = .05

of the constants for the values of the lag angles which were used previously. Values of P are significant if they are 0.05 or less. It can be seen that none of the values in this table are of this order. To some extent, the reasons for this poor degree of reliability are evident because of the use of averages for the station values for salinity, MPN, and B.O.D. It will be recalled that the analysis presented in Table I and the conclusions drawn from this analysis were to the effect that the grouping of values at a given sampling station in order to obtain an average value was of doubtful validity. In general, it appears that values of the lag angle for salinities are much more reliable than the values for MPN or B.O.D.

The three accompanying plots of the variation in dissolved oxygen saturation, bio-chemical oxygen demand, number of coliform organisms, and salinity indicate to some extent the seasonal variation. As indicated by the data, the percent saturation of dissolved oxygen does not appear to vary considerably from June to October. Apparently, the lowest percentage saturation was obtained during the survey conducted June 28, 29, 30. However, on no occasion did the dissolved oxygen saturation fall below 60% at any of the stations. For other sections in the tidal waters of the Metropolitan area, it appears that seasonal variations are such that a minimum dissolved oxygen saturation occurs late in September.

The dissolved oxygen concentrations that were observed were all above 50% of the saturated values. Of the approximately 300 samples that were analyzed for dissolved oxygen concentrations only one of these contained less than 5.0 parts/million of dissolved oxygen. The standards of the New York State Water Pollution Control Board require that for trout waters not less than 5.0 parts/million of dissolved oxygen be maintained in the waters and for non-trout waters, not less than 4.0 parts/million.

The salinities at each of the various stations indicate by their increasing values throughout the time period that the survey period was one of increasing fresh water flows. At the Verplanck station, for instance, salinities averaged 220 parts per million for the week of June 21, 22, 23, increasing to an average of 1,041 parts/million for the week of October 4, 5, and 6. The increase in salinities was accompanied at each of these stations by an increase in the MPN of coliform organisms. This increase was especially noticeable at the Verplanck station where presumably less fresh water was available for the dilution of the sewage discharged into the Hudson River from Peekskill.

There is no apparent relationship between the values for bio-chemical oxygen demand and the MPN of coliform organisms. At each of the three stations, a decrease in the bio-chemical oxygen demand was noted while an increase in the MPN of coliform organisms was occuring.

The overall averages (geometric) for the MPN/ 100 ml. at the Bear Mountain, West Point, and Verplanck stations respectively, were 1900., 2600., and 5200., respectively. It is difficult to forecast future values for MPN concentrations, however, it appears reasonable to assume that the MPN's in the vicinity of the Verplanck sampling station will decrease when the sewage emanating from Peekskill is treated.

It is a weakness of the coliform determination as recommended by "Standard Methods" that organisms of other than animal origin are sometimes included in the MPN count. In this respect the MPN determinations on the surveys conducted in the Bear Mountain area may reflect the presence of micro-organisms washed into the river from the soil during periods of rain. However, it would require a considerable amount of work to determine the magnitude of this effect.

SUMMARY

A survey of the Hudson River was conducted in the vicinity of Bear Mountain Bridge by the Interstate Sanitation Commission during 1954. A total of 260 samples were obtained during the period from early June to October. Sampling stations were established at West Point near Constitution Island, at Bear Mountain Bridge, and at Verplanck.

Dissolved oxygen saturations averaged about 70% of saturation and greater than 5.0 parts per million in concentration. Geometric averages for the Most Probable Number of coliform organisms per 100 ml. were 1900., 2600., and 5200. for the Bear Mountain, West Point, and Verplanck stations respectively.

Statistical analyses indicate that in general the waters of the Interstate Sanitation District are not being deteriorated by the normal flow of Hudson River water southward.

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A P P E N D I X

SUMMARY DATA SHEET

1954 BEAR MOUNTAIN SURVEY

	6/21	6/22	6/23	Weekly Summary
BEAR MOUNTAIN				
1. Number Samples	15	20	20	55
2. MPN (Arith.)	13	11-	13-	12-
3. MPN (Geom.)	11	8.3-	6.9-	8.4-
4. D.O. (% Sat.)	69	69	68	69
5. B.O.D. (p.p.m.)	0.95	1.12	1.09	1.05
6. Salinity (Chlorides)	-	33	24	29
WEST POINT				
1. Number Samples	5	5	5	15
2. MPN (Arith.)	17	25	25	22
3. MPN (Geom.)	16	20	20	19
4. D.O. (% Sat.)	73	73	69	72
5. B.O.D. (p.p.m.)	1.75	1.50	0.98	1.41
6. Salinity (Chlorides)	-	16	3	10
VERPLANCK				
1. Number Samples	5	5	5	15
2. MPN (Arith.)	19	18	26	21
3. MPN (Geom.)	18	14	24	18
4. D.O. (% Sat.)	74	74	68	72
5. B.O.D. (p.p.m.)	1.53	1.44	1.10	1.36
6. Salinity (Chlorides)	-	261	179	220

SUMMARY DATA SHEET

1954 BEAR MOUNTAIN SURVEY

	6/28	6/29	6/30	Weekly Summary
BEAR MOUNTAIN				
1. Number Samples	20	20	15	55
2. MPN (Arith.)	16	23	33+	24+
3. MPN (Geom.)	13	16	28+	17+
4. D.O. (% Sat.)	63	64	62	63
5. B.O.D. (p.p.m.)	1.40	0.74	0.60	0.91
6. Salinity (Chlorides)	27	25	20	24
WEST POINT				
1. Number Samples	5	5	5	15
2. MPN (Arith.)	29	30	47	35
3. MPN (Geom.)	25	26	35	28
4. D.O. (% Sat.)	67	67	63	66
5. B.O.D. (p.p.m.)	1.21	0.73	0.22	0.72
6. Salinity (Chlorides)	4	3	4	4
VERPLANCK				
1. Number Samples	5	5	5	15
2. MPN (Arith.)	33	59+	80+	57
3. MPN (Geom.)	31	55+	68+	49
4. D.O. (% Sat.)	68	71	72	70
5. B.O.D. (p.p.m.)	1.30	0.90	0.86	1.03
6. Salinity (Chlorides)	181	203	297	227