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EVALUATION OF POLLUTION CONDITIONS IN THE ARTHUR KILL

~~NYC Report~~

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The Arthur Kill is a tidal strait, 13 miles in length, connecting Newark Bay at Elizabethport with Raritan Bay at Tottenville. It separates Union and Middlesex Counties of New Jersey from the western shore of Staten Island. Because of its use for navigation by fairly larhe vessels, such as oil tankers, a channel 30 to 35 feet deep and from 400 to 800 feet wide has been dredged throughout the length of the Kill.

In considering the tidal and pollutional characteristics of the Kill, it has been found convenient to separate it into two zones, the dividing line being the southern end of the Fresh Kills Reach (Chart 286, U.S.C.&G.S.). The northern zone is comparatively narrow, connects with the polluted waters of Newark Bay and receives the major portion of the pollution discharging directly into the Arthur Kill. The southern zone is fairly wide, receives a lower pollutional load and terminates in the less polluted Raritan Bay.

A consideration in such separation is that the Fresh Kills area represents the limits of the tidal excursions from Newark Bay and Raritan Bay waters into the Arthur Kill. Pollution discharging into the Fresh Kills area therefore experiences difficulty in being carried out of the Kill through either the northern or southern route, and so a greater portion of its ultimate oxygen demand is exerted in the Kill.

Table 1

DIMENSIONS AND TIDAL CHARACTERISTICS OF THE ARTHUR KILL

Characteristic	Arthur Kill	Tottenville to Fresh Kills	Fresh Kills to Elizabeth
Length, miles	13	6	7
Area, sq. ft.	124,000,000	80,000,000	44,000,000
Volume, cu. ft., low water	2,170,000,000	1,230,000,000	940,000,000
Volume, cu. ft., high water	2,790,000,000	1,640,000,000	1,150,000,000
Tidal prism, cu. ft.	620,000,000	410,000,000	210,000,000
Tidal range, ft.	4.9	5.1	4.8
Duration of flood, hrs.	6.5	-	-
Duration of ebb, hrs.	5.9	-	-
Tidal circulation, days	-	1.80	2.57

Tidal lag at Elizabeth 0.7 hours after Tottenville.

The dimensional and tidal characteristics of the Kill are presented in Table 1. It is significant that the more highly polluted northern zone possesses only one-third of the total water surface in contact with the atmosphere for reaeration. Furthermore, the northern zone has greater average depth, hence tidal circulation is less effective in removing pollution.

It should be noted that there is little fresh water drainage into the Kill to aid in its circulation. Net flow out of the Kill, therefore, is comprised substantially of the flows associated with waste discharges.

The Interstate Sanitation Commission has classified the Arthur Kill as Class B waters except for the small portion of the Kill south of Outerbridge which is Class A.

History of Arthur Kill

The annual Harbor Pollution Survey of the City of New York has regularly included sampling the waters of the Arthur Kill since 1926. Samples for analysis are taken from near the water surface and several feet above the bottom during the summer, usually from mid-June to mid-September. The sampling points, from south to north, are as follows:

1. Tottenville, near the southern end of the Kill.
2. Fresh Kills, near the mid-point of the Kill.
3. B&O Drawbridge, near the northern end of the Kill in the vicinity of the outfall of the Elizabeth-Joint Meeting plant.
4. Shooters Island, just outside the Kill in Newark Bay, which is useful in evaluating the waters at the northern end.

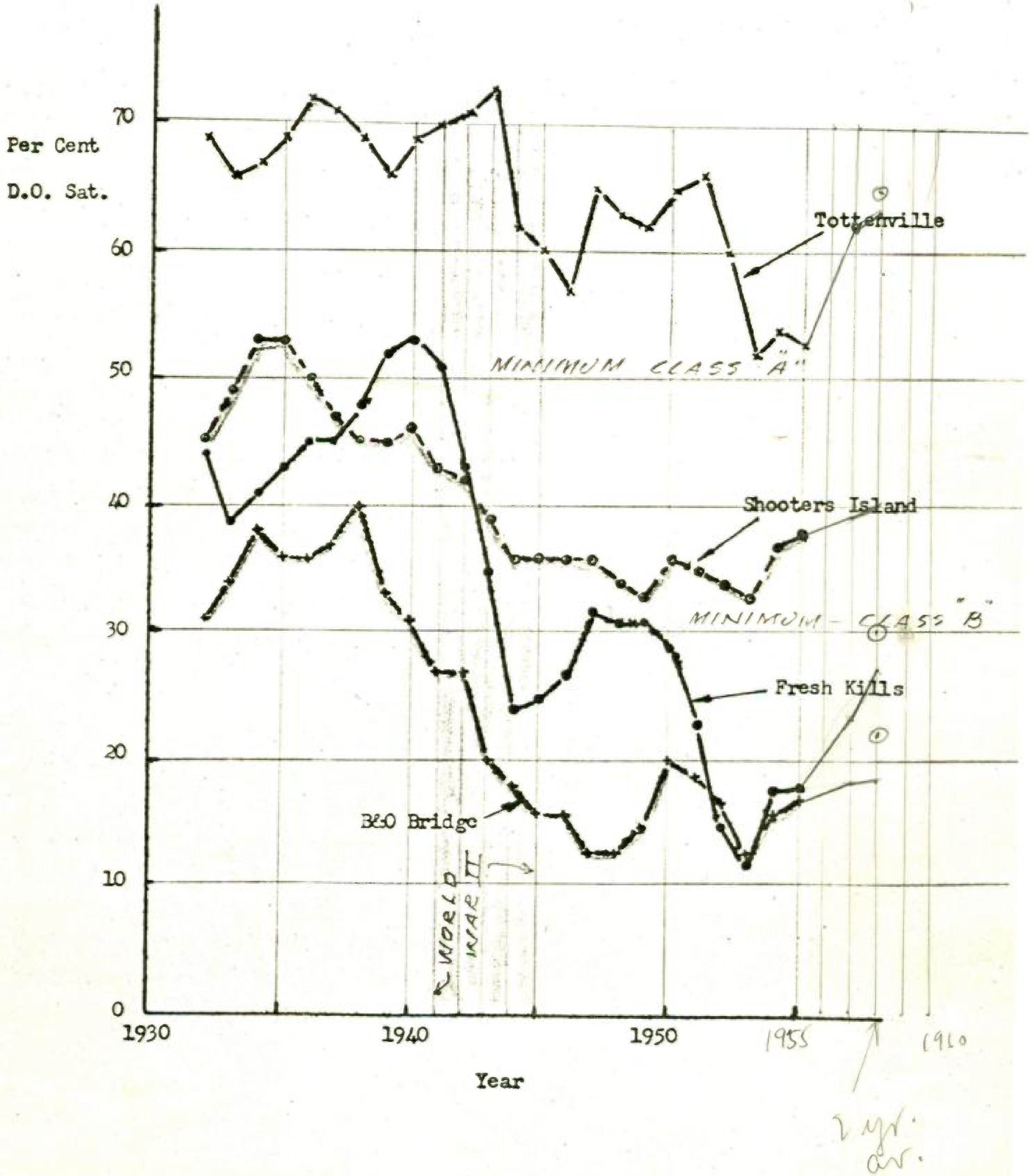
Individual survey records for dissolved oxygen are available since 1930. The average dissolved oxygen saturation for the respective

Figure 1

PER CENT D.O. SATURATIONS AT SAMPLING POINTS

IN ARTHUR KILL, 1930–1955

3-Year Moving Averages



sampling points is shown in Figure 1. A 3-year moving average was used in order to better illustrate trends and minimize the effect of variations in tidal and weather conditions.

This figure shows that the Arthur Kill at Tottenville is not as yet a serious sanitary problem. However, the trend in dissolved oxygen has been downward there since the early 1940's, and caution is indicated in regard to further increasing the pollutional load if it is desired to maintain an average oxygen saturation above 50 per cent. (Tottenville is in Class A waters.)

At Fresh Kills pollution conditions were not serious through the 1930's. However, in 1941 a sharp downward trend in the dissolved oxygen began which culminated in the waters of the Fresh Kills area becoming a nuisance. This trend coincided with the increased industrial activity during and after the war years.

The Arthur Kill at the B&O Bridge has been seriously polluted for decades by the discharge of large quantities of sewage in that immediate area. As a result of sharply increased industrial wastes loads superimposed on a gradually increasing sewage load, the waters of this area have so deteriorated as to now possess the unenviable distinction of being the most degraded of New York Harbor in regard to dissolved oxygen, as indicated in the Harbor Pollution Survey.

Sanitary conditions just outside the northern entrance to the Arthur Kill may be judged by the data for Shooters Island. These data show a downward trend of dissolved oxygen starting at about the same period as the other stations. However, the rate of decrease is significantly less at Shooters Island, the average dissolved oxygen not yet having been lowered to 30 per cent of saturation. This apparently results from the high rate of interchange between the waters of Upper New York Bay and Newark Bay through the relatively short Kill Van Kull.

Pollutional Load on Arthur Kill

The extreme conditions in the Arthur Kill, which became apparent during the war, are evidently the result of a large and growing pollutional load. The magnitude of this load may be evaluated in a number of ways. Since the major problem is that of abating a nuisance, the pertinent characteristic of the load is its biochemical oxygen demand.

The records of the Interstate Sanitation Commission were consulted for information as to the direct loads imposed on the Arthur Kill. These loads consist of raw domestic sewage, effluents from municipal sewage plants, and large quantities of industrial wastes discharged in or near the Arthur Kill. Of the total B.O.D. discharged, not all can be considered as directly applied load because some is carried out of the Kill immediately and does not reappear. Thus for Perth Amboy, situated at the southern end of the Kill, only one-half of the discharged load is considered to apply directly, the other half being carried away into Raritan Bay on the ebb tide.

The pollutional load on the Arthur Kill is shown in Table 2. This indicates that the industrial waste load comprises about one-half of the entire biochemical oxygen demand on the Arthur Kill. The Interstate Sanitation Commission Industrial Wastes Inventory also shows quantities of acids, oils, greases and toxic substances contributing to the degradation of these waters, the main sources arising from Union

Table 2

POLLUTIONAL LOAD ON ARTHUR KILL

Source	Population (Thousands)	Flow M.G.D.	Total 5-Day B.O.D. Discharged Lbs/Day	Total 5-Day B.O.D. Applied Lbs/Day
Port Richmond	35	5	3,000	1,000
Industrial, East Shore (6 plants)	-	7	18,000	9,000
Elizabeth Joint Meeting	350	38	38,000	26,000
Elizabeth (untreated)	50	5	10,000	5,000
Linden-Roselle	53	13	8,000	8,000
Rahway Valley	60	9	4,000	4,000
Industrial, West Shore (23 plants)	-	218	44,000	44,000
Staten Island, sewered (est.)	10	2	2,000	2,000
Carteret	13	3	2,000	2,000
Woodbridge	21	3	3,000	3,000
Perth Amboy	41	7	9,000	4,000
			Total	108,000
Industrial				53,000
Municipal				55,000
East Side				12,000
West Side				96,000

County, New Jersey.

The other single large source of pollution is the discharge of settled sewage from the Elizabeth-Joint Meeting plant. Inasmuch as the outfall is situated about one-and-one-quarter miles inside the northern entrance to the Arthur Kill, two-thirds of the load was estimated to apply directly to the Kill.

With the addition of the other smaller sources of pollution, a total applied load of some 108,000 lbs per day of 5-day 20°C B.O.D. is exerting its influence in the Arthur Kill, as compared to a total of 141,000 lbs per day discharged.

Another way of computing the B.O.D. load on the Arthur Kill is from the B.O.D. analyses made by the Harbor Survey. Such figures are available continuously from 1939. From these figures a profile of the average 5-day 20°C B.O.D. in the Kill may be drawn. This profile, in conjunction with the corresponding mean volumes of water, may be used to calculate the total biochemical oxygen demand present in the Kill, regardless of origin. Of this total B.O.D. present, some is brought into the Kill from the Raritan and Newark Bay ends by tidal circulation. The wastes directly discharged into the Kill superimpose their demand on this base level of pollution. If this base level is determined by obtaining the average B.O.D. of the waters entering the Kill, then the direct load can be evaluated.

A formula has been derived to show the relationship between total load present and the daily addition. Assuming perfect mixing and a uniform rate of addition and displacement, the following formula may be used:

$$\text{Daily Load} = \left[p + \frac{1}{D}\right]\left(\text{Total Load Present}\right)$$

where p = the proportion of the total carbonaceous B.O.D. present that is satisfied per day

and D = the theoretical detention period in days, so that $\frac{1}{D}$ represents the daily displacement.

Essentially, the formula states that, under equilibrium conditions, the total accumulated load present will be biochemically oxidized and displaced at individual rates whose sum equals the rate of daily application of load.

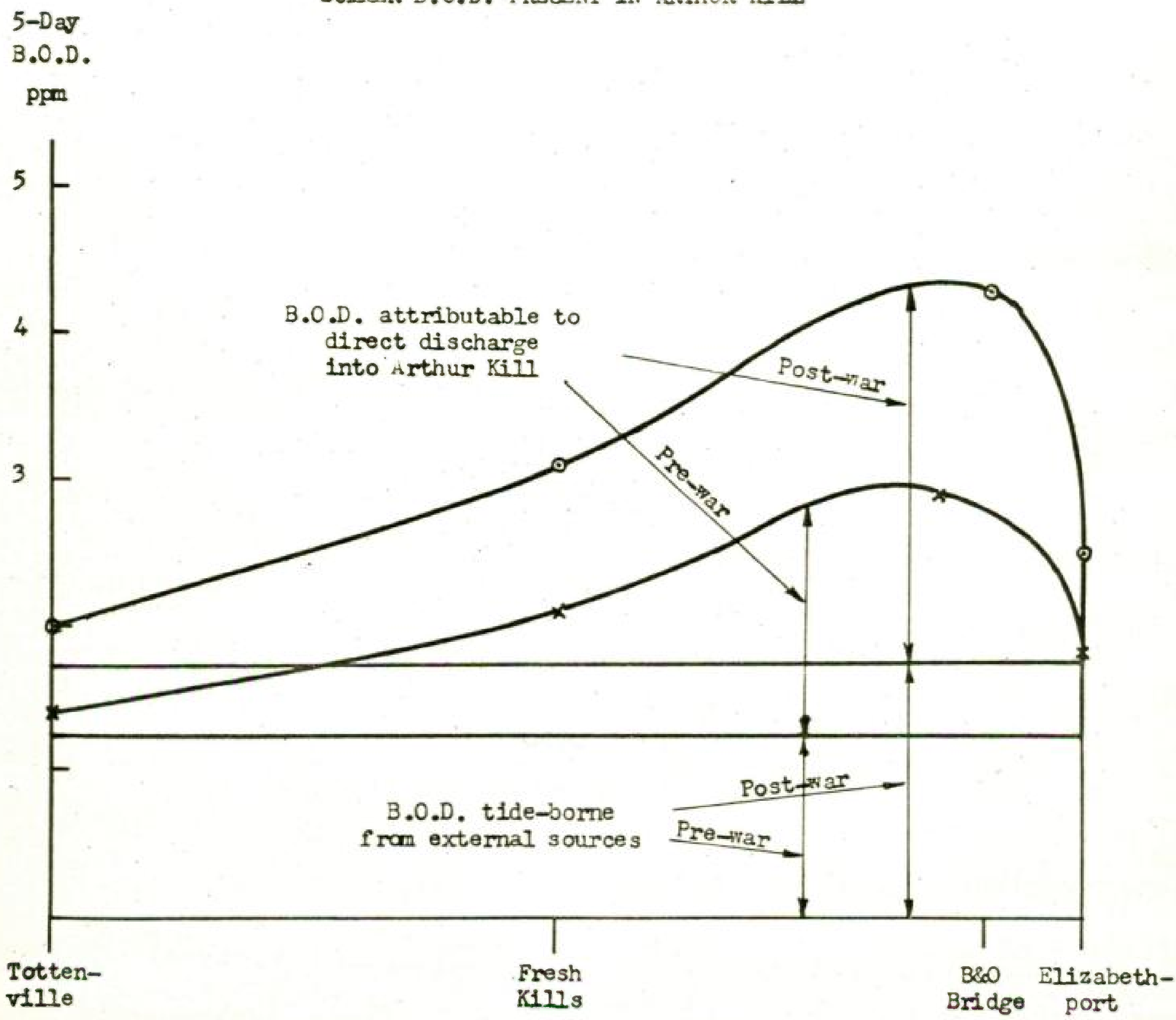
The B.O.D. of the waters of the Arthur Kill are shown in Figure 2 for two periods, namely, 1939-1941, depicting pre-war conditions, and 1945-1954, showing post-war conditions.

For the post-war period the average B.O.D. of waters entering the Kill was found to be about 1.75 ppm. B.O.D. values above this level therefore indicate direct shore line load additions, while 1.75 ppm was brought in from external sources. The corresponding pre-war datum was about 1.25 ppm.

For purposes of calculation, the northern and southern zones of the Kill were considered separately, inasmuch as different detention periods and densities of loading are known to exist. The total 5-day 20°C B.O.D. present was computed, reach by reach, by finding the average concentration and the respective volume for each reach. The datum could then be subtracted from the total present to furnish the values of B.O.D. accumulated from direct shore line additions.

Figure 2

SUMMER B.O.D. PRESENT IN ARTHUR KILL



The totals obtained for each zone during the pre-war and post-war periods are shown below:

Table 3

POUNDS OF 5-DAY 20°C B.O.D. PRESENT IN ARTHUR KILL

Zone	Due to direct shore line addition	Due to external sources	Total present
		Pre-War	
Northern	81,000	82,000	163,000
Southern	40,000	112,000	152,000
Total	121,000	194,000	315,000
		Post-War	
Northern	125,000	114,000	239,000
Southern	63,000	157,000	220,000
Total	188,000	271,000	459,000

For the summer temperatures encountered in the Kill, 0.24 of the total carbonaceous B.O.D. is satisfied daily. The northern zone detention of 2.34 days (including the effect of some fresh water runoff) accounts for a displacement of 0.43 per day, giving a total ratio of 0.67 per day. For the southern zone, with a detention of 1.8 days, the corresponding ratio is 0.80. These ratios times the quantity of B.O.D. present is equal to the daily load application. Thus, the northern zone stores one-and-one-half times the daily load addition, while the southern zone holds one-and-one-quarter days load.

The direct shore line additions to provide the computed quantities of B.O.D. present above the datum levels are shown below:

Table 4

COMPUTED DAILY APPLIED LOAD (SHORE LINE), 5-DAY 20°C B.O.D.

Zone	Pre-War	Post-War	Per Cent Difference (of Post-War)
Northern	55,000	84,000	35
Southern	32,000	51,000	37
Total	87,000	135,000	36

Also included is the percentage difference between pre- and post-war loads based on the post-war value. As such, it is the proportion of present direct load to be removed to return to pre-war direct load.

The table finds an average applied shore line load of 135,000 lbs of 5-day 20°C B.O.D. per day for the period 1945-1954. The daily applied load, from Table 2, was found to be 108,000 lbs per day. The total applied loads, as derived in these different manners, are thus in reasonable agreement. However, the computed daily B.O.D. load (from Table 4) in the southern zone is higher than can be accounted for by shore line sources, as given in Table 2. This clearly indicates that a significant portion of the direct load on the northern zone finds its way southward by tidal interchange, thus appearing as a direct load on the southern zone.

Returning to Table 3, it is apparent that a major portion of the B.O.D. burden on the Arthur Kill results from external sources, especially so in the southern zone. For the pre-war period this accounted for 62 per cent of the total B.O.D. present, while the corresponding figure for the post-war period was 59 per cent. Furthermore, there was a large increase in total load between the two periods. To restore the load from external sources to the pre-war magnitude, the post-war load must be reduced by 28 per cent.

In connection with the effects on the Arthur Kill of the loads previously discussed, it is interesting to examine the observed dissolved oxygen profiles for these periods. These are shown in Figure 3.

The Interstate Sanitation Commission requires that for Class B waters the dissolved oxygen should not be depressed below 30 per cent saturation during any week. For pre-war conditions this criterion was substantially met, except for the area in the vicinity of the B&O Bridge. On the other hand, as a result of the previously demonstrated increases in internal and external load, the oxygen was so depressed that, for the post-war period, over one-half of the length of the Arthur Kill averaged less than 30 per cent dissolved oxygen saturation for the entire summer. In order to restore the Arthur Kill to reasonable compliance with the standards of the Interstate Sanitation Commission, it appears necessary to at least reduce the load to that prevailing prior to the war. The previous computations have indicated that this would be accomplished by reducing the present direct shore line load by 36 per cent and the load from external sources by 28 per cent. If there is any future increase of load, a greater proportion of that total future load would have to be removed to restore pre-war conditions.

It might be pointed out that the effect of application of a given load on the dissolved oxygen in the Kill will vary according to location. Such relationships have been plotted on Figure 4 for Fresh Kills, B&O Bridge and Shooters Island. It can be seen that a given B.O.D. concentration at Shooters Island depresses the dissolved oxygen less than the same B.O.D. at B&O Bridge. This is to be expected inasmuch as the waters at Shooters Island freely interchange with those in Kill Van Kull and Newark Bay. The large volumes of water interchanging with Shooters Island waters reduces the response to load.

Fresh Kills, when lightly loaded, had acceptable dissolved oxygen conditions because of some contact with the relatively clean waters to the south. As load on Fresh Kills increased, a sharp reduction in dissolved oxygen occurred. This sensitivity to load application reaffirms that pollution in this area is not readily removed by tidal currents. Caution should be exercised when considering safe loading conditions in the vicinity of Fresh Kills.

Figure 3

SUMMER SATURATION PROFILE ALONG ARTHUR KILL

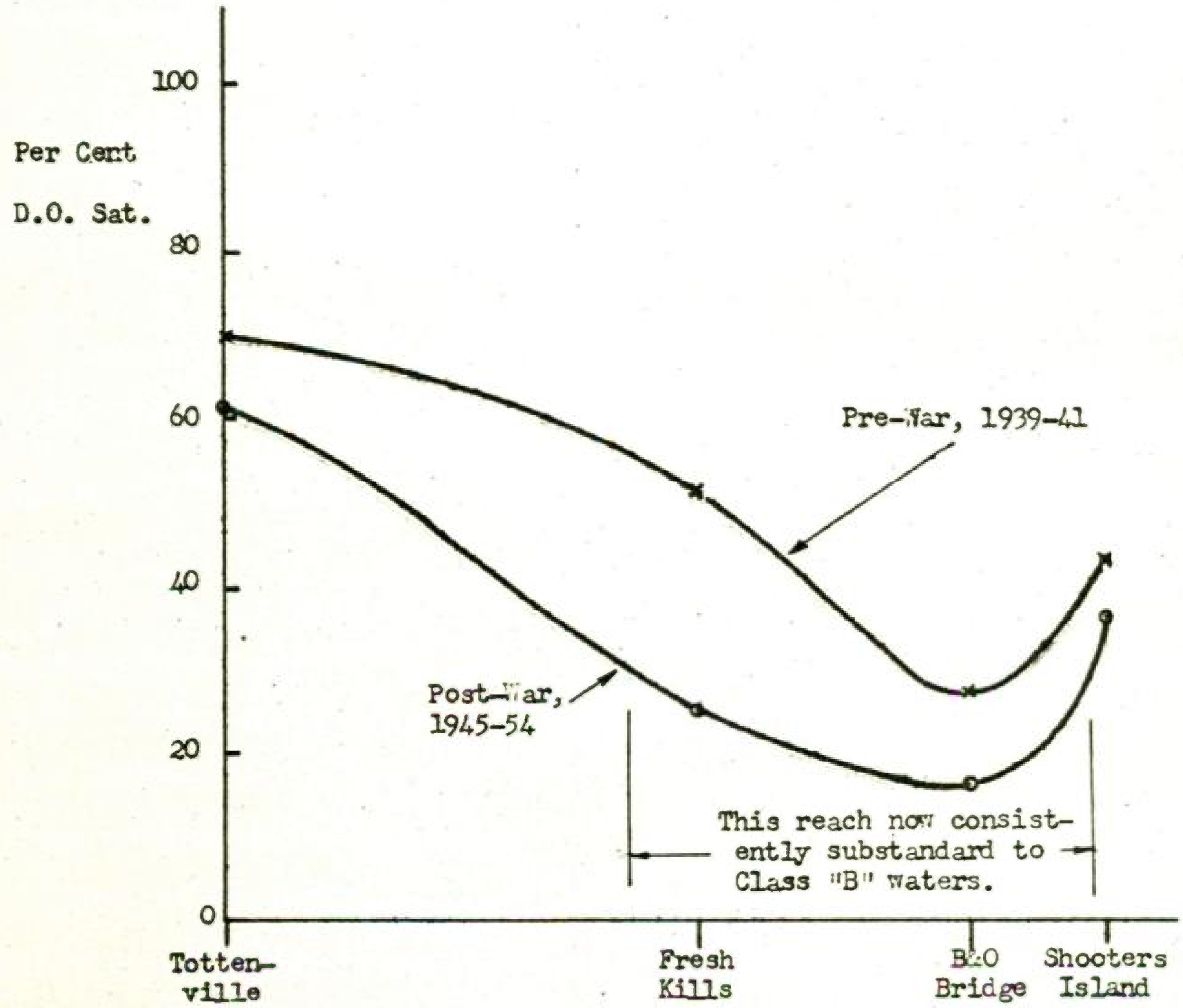


Figure 4

Relation of Per Cent Saturation D.O. to 5-Day B.O.D.,

Based on Grouped Averages of 1939-1954 Data