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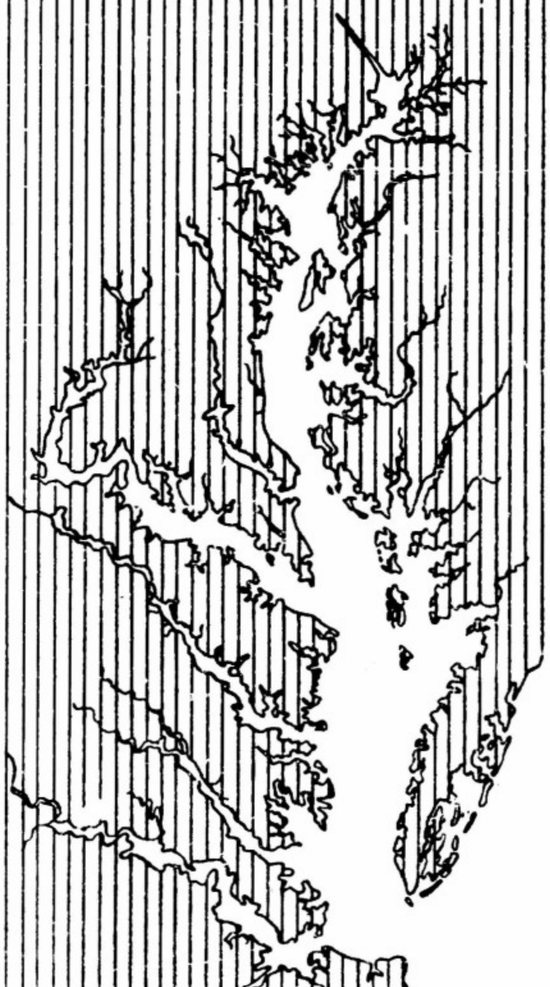

TECHNICAL REPORT VII

A STUDY OF FLUSHING IN THE DELAWARE MODEL

by

D.W. Pritchard

Reference 54-4
April 1954

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April 1954

D. W. Pritchard
Director

A STUDY OF FLUSHING IN THE DELAWARE MODEL

Introduction

Late in 1951 the Chesapeake Bay Institute was asked to assist the Oceanographic Division of the Hydrographic Office in a study of the flushing problem, using the Delaware River and Bay Model located at the U. S. Army Engineers Waterways Experiment Station, Vicksburg, Mississippi. The first test made showed that the dye used as a tracer contaminant was adsorbed in large quantities by the concrete bottom of the model, the glass sample bottles, and even by the dust which settled from the air into the model. Further tests were delayed until February 1952 while the model was painted with adsorption inhibiting plastic paint.

Eight separate tests were made on the model by introducing a known volume of dye and tracing the changes in the distribution of the dye by photometric analysis of samples. Considerable reduction of data was necessary to compensate for the adsorption and the body of this report will deal only with the reduced data.

Several appendices have been included. Appendix I deals with the sampling gear, the method of sampling, and the methods of field analysis. Tables of observed dye concentrations, by station and tidal cycle are given in Appendix II. Appendix III gives the reduction methods used to compensate for the adsorption and tables of corrected concentrations by station and tidal cycle. Appendix IV contains auxiliary data on salinity, high and low water profiles, and fresh water inflow as well as tables of cross-sectional areas, intersectional volumes, and accumulated volumes for each 5000 foot station.

Description of Flushing Tests

The Delaware Model

The region represented by the Delaware model includes all of the Delaware Bay and the tidal section of the Delaware River, from the Capes to Trenton. The model is constructed of concrete on a horizontal scale of 1 to 1000 and a vertical scale of 1 to 100. A chart of the model is given in Figure 1.

Information about the hydraulic adjustment and verification, and the salinity verification are presented in various reports of the Waterways Experiment Station (Corps of Engineers, U. S. Army 1951(a), 1951(b), and 1952). These reports were sufficiently conclusive to suggest that valuable information on flushing in the Delaware River and Bay could be obtained from the model.

The Flushing Tests

In the following discussion the tests are grouped according to the point of release. In Tests 1-A, 1, and 4 the dye was introduced at Station 52.5 which is located a short distance below Philadelphia. Station 292.5 below Artificial Island, was used as the release point in Tests 2 and 3. The dye was released from Station 111 located near Chester, for Tests 5, 6, and 7.

While some treatment is presented of the lateral and vertical distributions, the main discussion here will center on the variation in concentration along the axis of the estuary. In each case the data represent conditions at the time of high water slack.

The manner of introducing the dye is discussed in detail in Appendix I. Briefly, the dye was introduced at high water slack in a cylinder constructed so that the sides could be freed from the bottom and pulled out of the water, leaving the dye suspended momentarily in the water in a cylindrical shape. Then as the ebb tidal movement started, the dye was rapidly spread in both a lateral and a longitudinal direction. The diameter of the cylindrical container was 0.74 ft, equivalent to 740 ft in the prototype. The height of dye in the container was adjusted to be even with the surface of the water in the model at the time of release.

Test 1-A, 1, and 4 - Release Point 52.5

Test 1-A, which was the trial run made in December 1951, and Test 1, which was the first of the series of runs made in February 1952, were duplicate tests, the dye being released at Station 52.5 under conditions of mean tide and mean river flow (12,350 sec ft at Trenton). The dye concentration at release was 1000 ppm, and even though at this location in the tidal river the water is practically fresh, no density effects were observed.

Upon release the dye cylinder moved seaward with the ebbing tide while mixing laterally and longitudinally. After one tidal cycle the dye had spread longitudinally over nearly one tidal excursion assuming a nearly normal distribution, and after two tidal cycles it had a nearly uniform distribution laterally.

It was observed that in pockets in the shore line small eddies would sometimes trap water containing a high concentration of dye. After the high concentration of dye had passed, the entrapped dye would be slowly fed back into the main stream. This phenomenon was observed both on the ebb and on the flood tide and probably materially assists the spread of the highly concentrated contaminant. Figure 2 is a schematic representation of the process.

Figures 3a and 3b show the longitudinal distributions of the contaminant concentration from 1 to 58 tidal cycles after the dye was released for Test 1-A. (Test 1 was substantially the same as Test 1-A.) The solid vertical column shown at Station 52.5 represents the initial dye volume. After one tidal cycle the contaminant had spread over nearly one tidal excursion and the distribution approximated the normal curve. With increasing time the spread increased while the peak concentration moved seaward.

The rate of decrease of the peak concentration seems to be exponential and Figure 4 shows a semilog plot of peak concentration against time in tidal cycles for both Test 1-A and Test 1. Two exponential decay rates are evident. For the first two tidal cycles the rate of decrease is extremely rapid, falling from 1000 ppm for time zero to less than 6 ppm after two tidal cycles. For times greater than two tidal cycles, decay progresses at a much slower rate. It would seem, then, that the process governing the dispersion of the contaminant during the first two tidal cycles are fundamentally different from those acting after the second tidal cycle.

Figure 5 shows the movement of the peak concentration with time in tidal cycles by the solid line. The dashed line is the calculated net downstream water movement based on river inflow. It is to be noted that the peak concentration moves downstream more slowly than the net downstream water movement. This was the case in every test.

If instead of following the movement of the peak concentration, we consider the concentration of dye at a fixed point, we get a different picture. Figure 6 shows the change in concentration with time for stations above the release point while Figure 7 does the same thing for stations below the release point. For stations well above the release point (e.g. 20 and 30) an increase in concentration occurs during the first few tidal cycles and is followed by an approximately exponential decay after the local peak has been passed. For upstream stations nearer the release point (e.g. 40 and 50) the initial rise occurs during the first tidal cycle. The decay is very rapid during the first few tidal cycles becoming approximately exponential as time passes. For stations downstream from the release point the decay becomes approximately exponential with the passage of time but the initial increase prior to the passage of the peak concentration is not a simple exponential function.

The rate of increase in local concentration as the peak concentration approaches becomes progressively less for stations further from the release point. This can be accounted for by the fact that as the peak concentration approaches a given station the size of the peak is decreasing. So long as the rate of approach of the peak concentration is faster than the rate of decay of the peak, the local concentration will increase with time. For stations well below the release point, the decrease in peak concentration and the increase in spread may combine to produce a rather long interval just before the passage of the peak concentration when the local concentration will remain nearly constant. In later tests some local concentrations reached their peaks even before the peak concentration of the contaminant distribution had passed.

The data are insufficient to show conclusively the form of the local decrease in concentration with time for the later tidal cycles; although other evidence indicates that the local decay curve is not exponential for large times.

Test 4 was run under the same conditions as Tests 1-A and 1, except for river flow, which was set at the relatively low value of 3000 sec ft at Trenton. The general features of the contaminant distribution curves, as shown in Figure 8, were similar to those found for Tests 1-A and 1. However, not only was the rate of downstream movement decreased due to the decrease in river flow, but the rate of decrease in peak concentration is appreciably less in Test 4 than for Test 1-A or Test 1. Figure 9 shows the change in peak concentration with time for Test 4. The rapid decrease in concentration during the first tidal cycle is similar to that which occurred in the earlier tests. The plot of the logarithm of concentration versus the time in tidal cycles after the second tidal cycle also appears as a straight line, as in the case of Test 1-A and Test 1. However, the slope of this line in Test 4 is only one-half the slope of the decay curves for the earlier tests.

The movement of the peak concentration with time for Test 4 is shown in Figure 10. Again we see that the peak concentration moves at a slower rate than the calculated net water movement, though the differences are less here than in Tests 1-A and 1.

The local variation of contaminant concentration with time is shown in Figures 11 and 12 for selected stations above and below the release point. These figures also reveal the slower rate of decrease in the contaminant concentration for this test as compared to Tests 1-A and 1.

The rate of river inflow thus appears to exert a significant influence upon the rate of decrease in the contaminant concentration.

Tests 2 and 3 - Release Point 292.5

Station 292.5 is well into the estuary with salinities of about 15‰ for mean river flow. Test 2 was made with mean tide and mean river flow (12,350 sec ft at Trenton) while Test 3 was made with mean tide and high river flow (31,300 sec ft at Trenton).

Unfortunately, much of the data from Test 2 is unusable since large amounts of dye were adsorbed on the sample bottles. In addition, the density of the dye being less than the density of the water at the release point the contaminant was seen to "mushroom" and spread out in the surface layer during the earlier tidal periods. (In Test 3 the density of the dye was adjusted to that of the surrounding water and this difficulty was not repeated.) Only the data for tidal cycles 6, 24, 36, and 42 were usable.

The longitudinal distributions of the contaminant concentration for various tidal cycles for Test 3 are shown in Figure 13. The distributions recoverable from the data for Test 2 were similar to those for Test 3.

Figure 14 shows the movement of the peak concentration for Test 2 as well as the computed mean downstream water movement. In Test 2 where the dye "mushroomed" into the surface layers, the downstream movement of the peak concentration was greater than or equal to the computed net water displacement during the first ten tidal cycles. This would be expected since the surface layers have an average downstream motion greater than the average for the entire body of water. As vertical mixing progressed, the motion of the peak concentration decreased.

Figure 15 shows the movement of the peak concentration and computed net water displacement for Test 3. Here again the movement of the peak concentration is slower than the calculated net water flow. The difference for this test was the greatest observed.

Figure 16 plots peak concentration against time for Test 3. It also shows the usable data from Test 2. Although the data from Test 2 show more scatter than the data from Test 3, the rate of decrease in peak concentration seems to be about the same for both tests. As in the previous tests the relation seems to occur in two parts, an initial rapid decrease followed by a slower exponential decay.

Since so much data were lost in Test 2 a conclusive evaluation of the effects of changed river flow on concentration is not possible. However, it seems that the effect at Station 292.5 may not be so great as at Station 52.5.

Curves showing the local change in contaminant with time in Test 3 at stations above and below the release point are given in Figures 17 and 18 respectively.

Tests 5, 6, and 7 - Release Point 111

These three tests were conducted to determine the effects of change in tidal amplitude on the time change in contaminant concentration. The dye volume, with a concentration of 1000 ppm, was introduced at high water slack at Station 111 which is located near Chester, Pennsylvania. This station is very nearly the upper limit of salt water intrusion for the conditions of mean river flow under which these tests were run.

Test 5 was conducted under conditions of mean tide, Test 6 under conditions of spring tide, and Test 7 under conditions of neap tide. Since the tidal velocities and tidal excursions would vary under these varying tidal regimes, it would be expected that the diffusion, and hence the time change in concentration, would vary among these three tests. As will be pointed out below the expected variation was neither clearly established nor definitely disproved by the data.

The longitudinal distributions of the contaminant at various tidal cycles for these three tests are given in Figures 19, 20, and 21. These distribution curves are similar to those encountered in previous tests in that they have the general shape of a normal function, and the change in peak concentration with time is large at first, becoming smaller for later tidal cycles.

The downstream movement of the peak concentration was essentially the same for all three tests, and is shown in Figure 22. As with all the other tests, the observed movement of the peak is at a slower rate than the computed downstream water movement.

Figures 23, 24, and 25 are semilog plots of the peak contaminant concentration versus time for each of the three Tests 5, 6, and 7 respectively. Subsequent to the first two tidal cycles, the semilog plots of peak concentration versus time could be adequately described by a straight line for the first five tests. For Tests 5, 6, and 7, however, it appears that this simple exponential time variation is inadequate. In Figure 24 the curve from Test 1-A is also entered to show the sharp difference between the characteristic time change in concentration of the first five tests as compared to these last three tests.

The local time variation in concentration at selected stations is shown for these three tests in Figures 26, 27, 28, 29, 30, and 31.

The plots of peak concentration versus time do not show a systematic difference from test to test which can be readily ascribed to the differences in tidal regimes. One hypothesis concerning the effect of tide is that with higher tidal velocities mixing would be increased and hence the peak concentration should decrease at a faster rate, at least during the early stages. It is difficult to measure accurately the actual peak concentration at the first tidal cycle, and also after about 30 tidal cycles. Some information is obtained by comparing the peak concentrations for the three tests for tidal cycles after the 1st and prior to the 30th. In Table I the peak concentrations for the 3rd, 6th, 12th, and 20th tidal cycles subsequent to release are given for each of the three tests.

Table I

Effects of Tidal Regime

Tidal Cycle	Concentration in ppm for Tests 5, 6, and 7		
	Test 5 Mean Tide	Test 6 Spring Tide	Test 7 Neap Tide
3	5.45	4.58	5.81
6	3.25	2.83	3.34
12	2.09	1.42	1.75
20	1.05	0.76	0.84

The concentrations for all four tidal cycles are lowest for spring tide conditions when mixing should be at a maximum. The concentrations for tidal cycles 3 and 6 are highest for the neap tide conditions, as would be expected, but for tidal cycles 12 and 20 the concentrations are highest for Test 5, which was run under mean tidal conditions. The tidal mechanism for the model failed after cycle 30 during Test 5, and it may be that a slight malfunctioning occurred prior to the final failure, resulting in somewhat erroneous results. In any case the data presented in Table I, while not conclusive, do suggest that the decrease in concentration is at a more rapid rate the greater the tidal velocities, at least during the early stages of mixing.

Summary Discussion

The composite information from all eight tests leads to the following general statements concerning the distribution and rate of change of distribution of the dye contaminant.

1. Within the first tidal cycle subsequent to release, the contaminant, which was in all cases introduced at high water slack as a cylindrical volume having a prototype diameter of 740 feet, spread over a longitudinal distance approximately equal to a tidal excursion (about 40,000 feet) and laterally from shore to shore.

2. After the first tidal cycle the longitudinal distribution of the contaminant approximated a normal curve.

3. Lateral and vertical variations in the contaminant concentration were observed during the early stages of each test. The sampling procedure did not allow a detailed investigation of the lateral or vertical variations in concentration, though the pertinent features that were noted are listed below:

a. During the early stages of mixing, relatively concentrated segments of the contaminant volume were observed to become entrapped by eddies within small embayments or behind projecting marine structures. These entrapped contaminant segments would then feed out contaminant into the main stream after the main mixing volume had been carried out of the immediate area by the tidal currents. It appeared that this feature played a major role in contributing to the horizontal spread of the contaminant.

b. At prominent bends in the river the advanced portion of the contaminant volume was observed to cling closer to that shore having a more rapid downstream movement of water.

c. In Test 3, which was conducted in that part of the estuary which exhibits a net two-layered flow pattern similar to that described by Pritchard (1952) for the Chesapeake Bay, the upstream spread of the contaminant was observed to occur primarily along the bottom. During the early stages of the tests the vertical distribution for stations above the release point showed increasing concentration with depth, while those below the release point in general showed decreasing concentration with depth. After a few tidal cycles, vertical mixing had destroyed these general vertical variations in contaminant concentration.

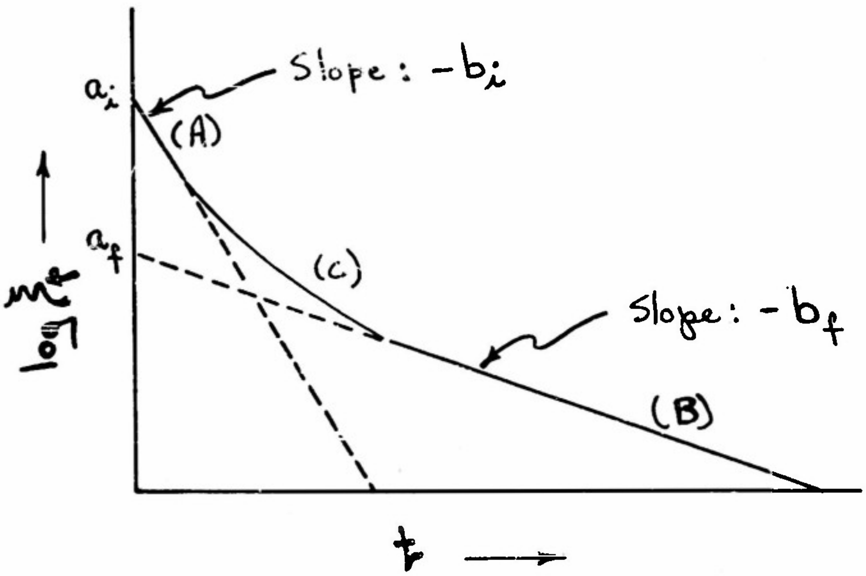
4. The change in peak concentration is characterized by a very rapid rate of decrease during the first tidal cycle followed by a less rapid rate of decrease. In the first five tests, namely 1-A, 1, 2, 3, and 4, the variation in peak concentration subsequent to the first tidal cycle can be represented by a simple function of time. In Tests 5, 6, and 7, however, the variation of peak concentration subsequent to the first tidal cycle cannot be adequately represented by a simple exponential rate. The reason for the difference between these groups of tests is not at present evident.

5. The downstream movement of the peak concentration is significantly slower than the calculated velocity of the mean downstream water movement.

Theoretical Considerations

A Preliminary Analysis of the Characteristic Features of the Flushing Study in the Delaware Model

The semilog plots of peak concentration versus time in tidal cycles for Tests 1-A, 1, 2, 3, and 4 (Figures 4, 9, and 16) are all of the form shown in the following diagram:



Since this is a semilog plot the straight lines indicated by (A) and (B) may be expressed formally using the slope-intercept form of the straight line as

$$\log \xi_{pi} = -b_i t + \log a_i$$

and $$\log \xi_{pf} = -b_f t + \log a_f \qquad \text{respectively}$$

where $\underline{-b_i}$, $\underline{-b_f}$ are slopes and $\log a_i$, $\log a_f$ are the intercepts. Since log A = B implies $e^B = A$, we may write:

$$\xi_{pi} = a_i e^{-b_i t} \qquad \text{for the initial period}$$

and $$\xi_{pf} = a_f e^{-b_f t} \qquad \text{for the final period}$$

If we sum these two equations

$$\xi_{pi} + \xi_{pf} = a_i e^{-b_i t} + a_f e^{-b_f t}$$

we may use the result as an approximation to ξ_p as indicated by the full line since to the left of the transition zone (C) the contribution of (B) to (A) is negligible and conversely. Within the transition zone, (C), (A), and (B) will both contribute and the sharp corner will be rounded off.

Therefore, formally at least, peak concentration as a function of time may be written

$$\xi_p = a_i e^{-b_i t} + a_f e^{-b_f t} \tag{1}$$

As pointed out above, a peculiarity of this function is that for values of t outside of the neighborhood of $t = 1$ only one of the terms makes a major contribution to the value of ξ_p. Thus during the first tidal cycle subsequent to release, the very rapid rate of decrease characterized by the first term of equation (1) predominates, and we have

$$\xi_p = a_i e^{-b_i t} \qquad \text{(first tidal cycle only)} \tag{2}$$

After the second tidal cycle, this first term becomes unimportant, and the change in peak concentration is characterized by the final rate of decrease given by

(3) $$\xi_p = a_f e^{-b_f t}$$ (after the second tidal cycle)

The variations in peak concentration for Tests 5, 6, and 7, subsequent to the second tidal cycle, do not appear to be adequately described by the exponential expression (3). For all tests, however, it appears that the expression

(4) $$\xi_p^n \frac{\partial \xi_p}{\partial t} = b'$$

holds. Here b' and n are constants. The form of the solution of this differential equation depends on the value of n. For the special case of n = -1, the solution of (4) is

(5) $$\ln \xi_p = a' + b't \quad \text{or} \quad \xi_p = ae^{b't}$$

which, when b' is identified with -b, is seen to be the expression which satisfied the observed concentration-time variations for Tests 1-A, 1, 2, 3, and 4.

For all n other than n = -1, the formal solution of (4) is

(6) $$\xi_p^{n+1} = bt + a \quad , \quad b = b'(n+1)$$

Designating (n + 1) by -m, this expression becomes

(7) $$\xi_p^{-m} = bt + a$$

By solving for t, (7) can be expressed as

(8) $$t = (1/b)\ \xi_p^{-m} + C \quad ; \quad C = -a/b$$

or $$\ln(t - c) = -m \ln \xi_p - \ln b$$

Thus a plot of $\ln \xi_p$ versus $\ln(t-c)$ should produce a straight line, of slope $\underline{m}$. It is possible to obtain an approximate value of the constant $\underline{c}$ graphically from a plot of data which is suspected of showing a functional variation given by (8). This has been done for Tests 5, 6, and 7, and the resulting log-log plots of the concentration versus the sum of the time plus the constant $\underline{c}$ are given in Figures 32, 33, and 34. It is seen that the relationship is reasonably linear, and the equations for the three sets of data are:

Test 5	$\xi_p^{-0.637}$	$= 0.0341\, t + 0.225$
Test 6	$\xi_p^{-0.914}$	$= 0.0513\, t + 0.0765$
Test 7	$\xi_p^{-0.740}$	$= 0.0506\, t + 0.114$

Since in equation (7) $n = -m - 1$, $\underline{n}$ varies between -1.63 and -1.92 for Tests 5, 6, and 7, while for the five previous tests we found $n = -1$.

For the present we will confine ourselves to a discussion of the characteristic features of the decay expression

(9a) $$\xi_p = ae^{-bt}$$

which can be expressed as

(9b) $$\ln \xi_p = a' - bt \quad ; \quad a' = \ln a$$

A plot of $\ln \xi_p$ against time would result in a straight line of slope $\underline{-b}$. The decay of radioactive material is represented by a function of this type, and borrowing from the nomenclature of the nuclear field we may consider a characteristic time related to the rate of flushing of a contaminant which we will call the "flushing half-life." The flushing half-life is defined as the time interval required to reduce a given concentration to a concentration one-half as great. It should be noticed that if the rate of change of concentration is given by equation (9), then the half-life is a characteristic parameter independent of time or concentration; that is, if ξ_{p_1} represents the concentration at time t_1, the same interval of time $\Delta t_{1/2}$ is required to reduce the concentration to $1/2\,(\xi_{p_1})$, as is required to reduce the concentration from $1/2\,(\xi_{p_1})$, to $1/4\,(\xi_{p_1})$, or from $1/4\,(\xi_{p_1})$, to $1/8\,(\xi_{p_1})$.

The half-life is readily obtained from the slope b, since

$$(10) \qquad \Delta t_{1/2} = \frac{b}{\ln (1/2)}$$

The flushing half-life is a convenient parameter for discussing certain features of the flushing tests. In Table II the half-life for the various tests and for the various characteristic portions of each test is given. It is seen that the half-life characteristic of the rate of concentration decrease during the first tidal cycle is only of the order of 1/100 of the half-life associated with the rate of concentration decrease subsequent to the second tidal cycle. Also we note that the half-life for Test 4, which was run under low river conditions, is two times the corresponding half-life for Tests 1-A and 1, which were run under conditions of mean river flow, other conditions being the same for the three tests.

Table II

Test	Half-life in tidal cycles	
	For first tidal cycle	After second tidal cycle
1-A and 1	0.16	10.6
2 and 3	0.11	13.5
4	0.15	24.4
5*	0.16	11.1
6*	0.15	10.8
7*	0.16	9.8

*Tests 5, 6, and 7 are included here for comparison, even though the peak concentration could not be adequately described by a simple exponential function of time. The calculations given are based on the concentration change from the fourth to the fortieth tidal cycles, neglecting the departure from the exponential form between these points.

Some Theoretical Considerations Suggested by the Model Study of Flushing

It can be shown (Pritchard, 1952, unpublished notes) that the one-dimensional expression for the time rate of change of mean concentration in a channel of varying cross section may be expressed as

$$\partial\xi/\partial t = -v\frac{\partial\xi}{\partial x} + \frac{1}{A}\frac{\partial}{\partial x}\left\{AK_{\xi}\,\partial\xi/\partial x\right\} \tag{13}$$

where $\underline{x}$ is the coordinate axis along the axis of the channel, $\underline{v}$ the mean velocity in the x-direction, A the cross sectional area, and K_{ξ} the horizontal eddy diffusivity. If it is assumed that the contaminant distribution approximates the normal curve, then it can also be shown that

$$(14) \qquad K_{\xi} = -\sigma^2 \frac{\partial \ln \xi_p}{\partial t}$$

where ξ_p is the peak concentration of the contaminant.

In Tests 1-A, 1, 2, 3, and 4 it was found that

$$\ln \xi_p = a - bt \qquad \text{equation (4)}$$

Therefore, for these tests,

$$(15) \qquad K_{\xi} = b\,\sigma^2$$

and the eddy diffusivity K_{ξ} varies as the square of the standard spread of the contaminant distribution.

In Tests 5, 6, and 7, however, it was found that

$$\xi_p^{-m} = a + bt \qquad \text{equation (7)}$$

for which the diffusivity would be given by

$$(16) \qquad K_{\xi} = \frac{\beta}{A^m}\,\sigma^{(2-m)} \quad \text{where} \quad \beta = \frac{b}{m}\left(\frac{M}{\sqrt{2\pi}}\right)^m,$$

A is the mean cross sectional area of the segment of the estuary occupied by the contaminant volume, and M is the total weight of the contaminant. From equation (16) it can be seen that, for these tests, the diffusivity varies inversely as the mth power of the cross sectional area and directly as the (2-m)th power of the standard spread of the contaminant distribution.

In Tests 5, 6, and 7 m had an approximate range from 0.5 to 1.0 showing extremes for the diffusivity of

(17a) $$K_{\xi} = \frac{\beta}{A^{0.5}} \sigma^{1.5}$$ and

(17b) $$K_{\xi} = \beta/A \, \sigma$$

Stommel (1949) has suggested that if L represents a scale factor characterizing the size of the area within which eddy diffusion is being investigated, then the eddy diffusivity is approximately proportional to the 4/3 power of L. This concept was developed for diffusion in an area unrestricted by lateral boundaries and would hence seem inapplicable to this study. It is interesting, therefore, to note that the mean exponent of σ for Tests 5, 6, and 7 is approximately equal to the 4/3 power suggested by Stommel.

That the movement of peak concentration was in all cases slower than the calculated net water movement calls for comment. Pritchard (1952, unpublished notes) has shown that, if the distribution of the contaminant approximates a normal curve, then the position of the peak concentration is given approximately by

(18) $$m = D_t - \frac{M^2}{4\pi} \left\{ \frac{1}{A_m^2 \xi_p^2} \frac{d \ln A_m}{dx} - \frac{1}{A_o^2 \xi_o^2} \frac{d \ln A_o}{dx} \right\}$$

m is the position of the peak concentration when the origin x = 0 is set at the position of the peak concentration at time t = 0. D_t is the net movement due to the velocity of the water, i.e. $D_t = \int_0^t v dt$ where $\underline{v}$ is the mean water velocity. The subscript "o" indicates the value of the parameter at time zero. The meanings of the other symbols are as previously explained.

In this study the factor in braces in the second term of the right-hand number of equation (18) was always positive and therefore $m < D_t$ is to be expected.

The development of a suitable theoretical description of other aspects of these flushing tests is in progress. However, in view of the unexplained difference between the characteristic rates of decay for the first five tests and for the last three tests, further experiments with the model would be desirable.

Suggestions Regarding Flushing in the Prototype

The question now arises as to the extent to which the results obtained from the model might be applied to the prototype. In this regard we may consider certain features of the model verification.

The model was constructed according to Froude scaling. The model velocity structure and salt distribution which would result from Froude scaling alone would not be comparable to the prototype, since the Reynolds scale would be far from satisfied. In order to increase the turbulence, the model was artificially roughened. The extent of this artificial roughening was empirically determined by roughening until the velocity distribution and the tidal heights matched those known to exist in the prototype.

It was then found that the salinity distribution in the model satisfactorily matched that found in the prototype under various river flow regimes.

This salinity verification implies that the artificial roughening of the model successfully scaled those eddies in the turbulent regime which are important in maintaining the salt distributions. There is strong indication, however, that the scale of the turbulent eddy system which is involved in any particular mixing process depends on the size of the contaminant volume being mixed. Therefore, the eddies which would be involved in the mixing of a highly concentrated contaminant spread over only a small area may not be properly scaled in the model, even though the eddies important in maintaining the salt distribution are properly scaled from the prototype to the model.

On the basis of the above reasoning, the following preliminary conclusions regarding the application of the results of the model studies on flushing to prototype conditions are presented.

1. It is doubtful that the extremely rapid rate of concentration decreases observed during the first tidal cycle in the model studies actually represent in magnitude the corresponding initial rate of mixing which would occur in the prototype. Immediately after introduction of the dye, large gradients exist and molecular diffusion would be of some importance in the model, though less so in the prototype since there can be no scaling of this phenomenon from the prototype to the model. Likewise, as discussed above, the eddy scale important to the mixing of the

restricted contaminant volume during this early phase may not be properly scaled in the model.

Undoubtedly, the rate of concentration decrease during the early phase of mixing in the prototype will be substantially greater than at later stages, since the initial contaminant volume may spread laterally as well as longitudinally (which is the case in the model also). However, the rapid decrease in concentration in the model during the first tidal cycle is substantially greater than would be expected as a result of the coupling of the lateral spread with the longitudinal mixing. This is a feature which may allow prototype verification, since it is possible that tracer material which could be followed for one or two tidal cycles might be safely added to the natural estuary.

2. The rate of concentration change observed in the model subsequent to the second tidal cycle is probably applicable to the prototype. By this time the contaminant had spread from shore to shore laterally and over approximately a tidal excursion longitudinally. The eddy regime contributing to the mixing would be of about the same order of magnitude as that which is important to the maintenance of the salt distribution, and hence probably properly scaled from prototype to model.

The flushing half-lives given in Table II for the period subsequent to the second tidal cycle after dye introduction are therefore probably representative of the expected rates of flushing in the prototype <u>for contaminant distributions which are spread over approximately a tidal excursion.</u>

3. The suggestion that the eddy diffusivity varies with at least the

first power, and possibly the second power, of the standard spread of the contaminant distribution throws some doubt on the application of techniques for computing flushing characteristics of an estuary which are based on the salinity distribution, or conversely, on the observed or computed distribution of fresh water. Though these techniques may adequately describe the fresh water-salt water distribution, they may not describe the concentration change of a contaminant which is introduced into the estuary with an initial distribution considerably different from the existing fresh water or salt water distribution.

Acknowledgements

Throughout my association with this project I have been impressed by the efficient and courteous assistance rendered by the U. S. Army Engineers Waterways Experiment Station. Particular mention should be made of the help given by Mr. Henry Simmons, Mr. William Robb, and their staff on the Delaware Model Project.

The U. S. Navy Hydrographic Office supplied the services of Mr. John Recknagel for all tests except the trial run. Mr. Recknagel handled the field project for the last four tests. His interest and conscientious work were of considerable importance to the successful completion of the project.

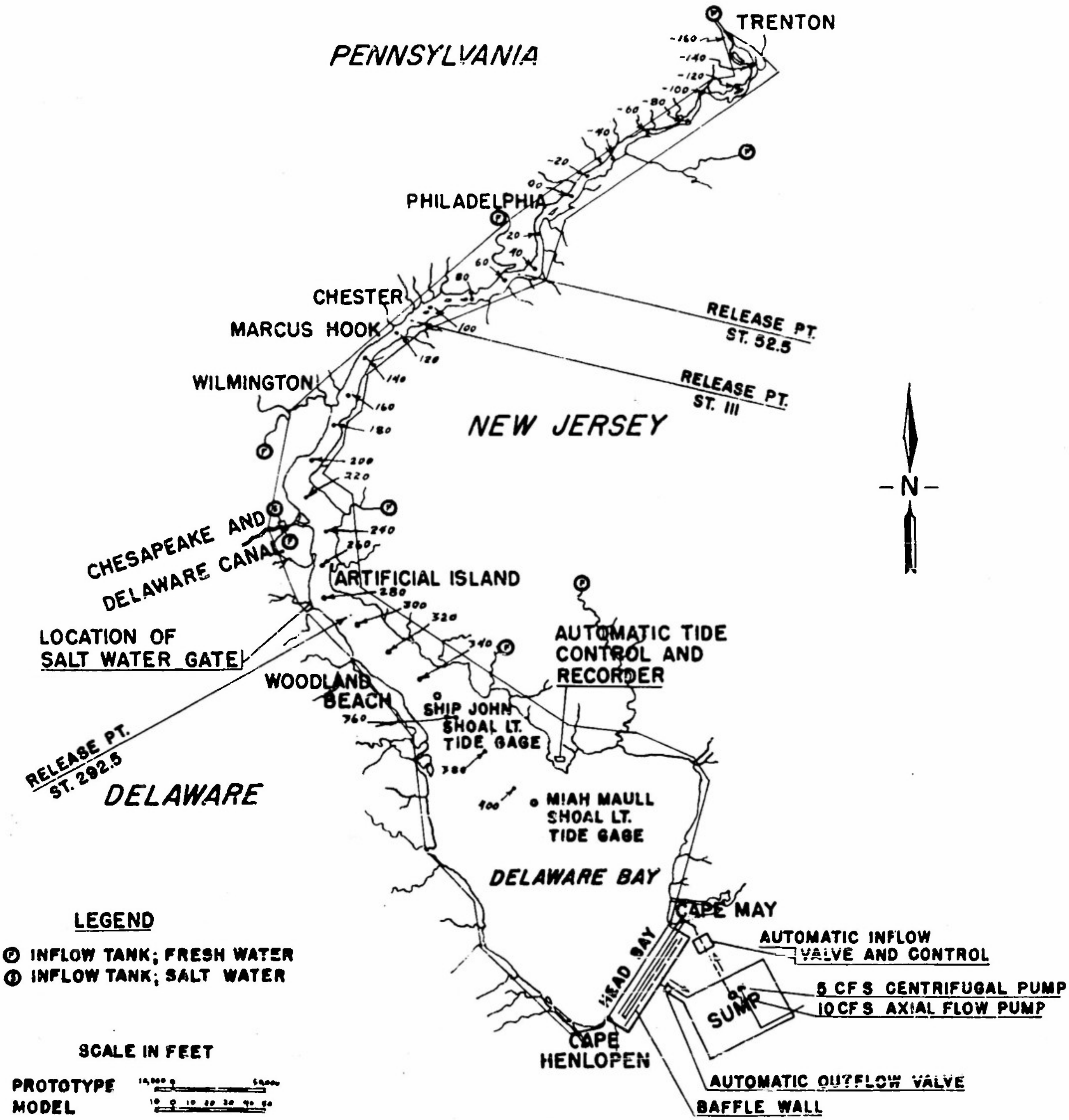


Figure 1 Location Map for Model Study of the Delaware Estuary.

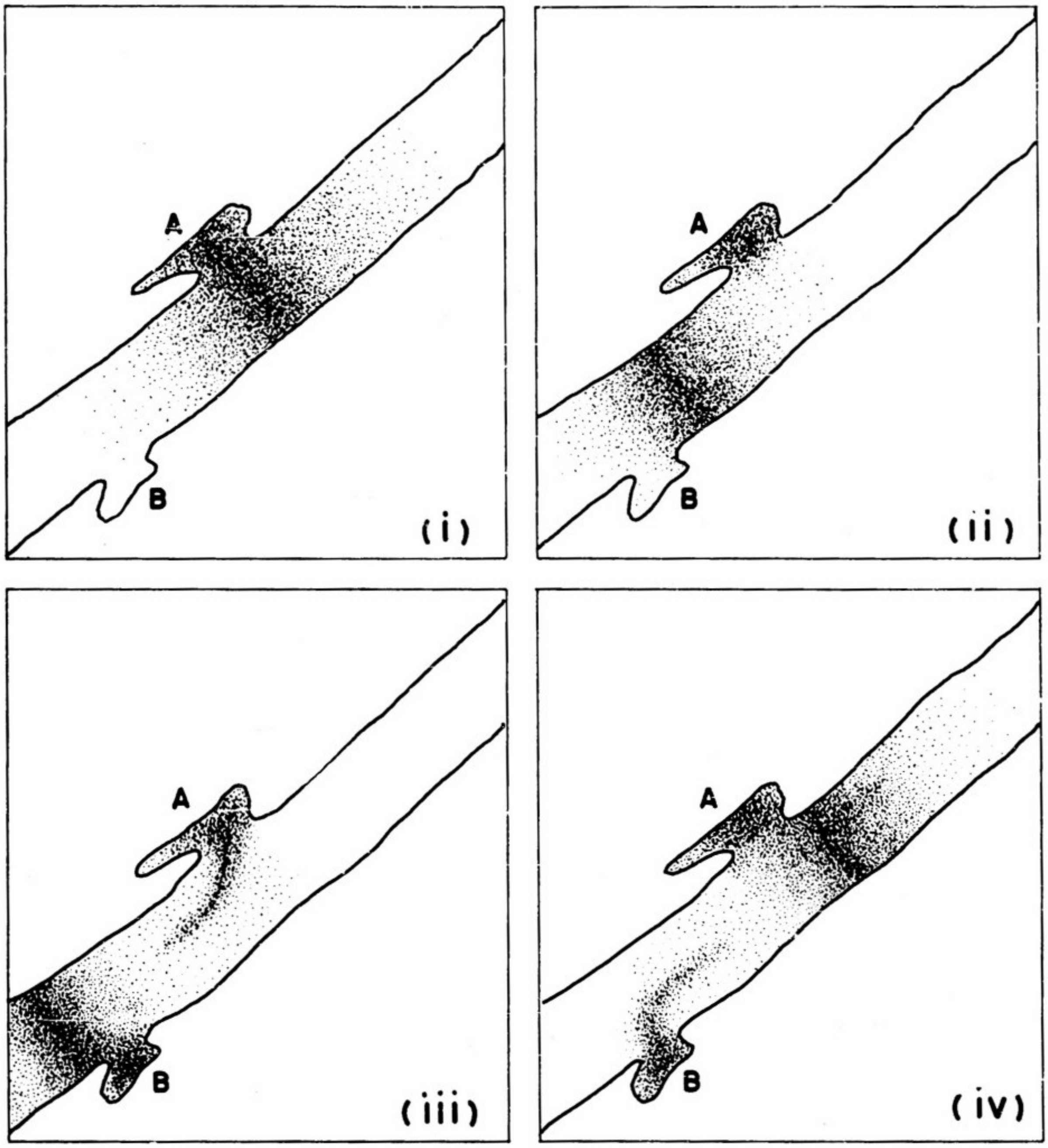


Figure 2. Schematic representation of dye entrappment by shore features. Concentration is indicated by intensity of shading. As peak concentration of main dye volume moves downstream on the ebb tide, a portion of the dye spreads into shore indenture A, as in diagram (i). This portion of the dye is entrapped by the indenture as the main dye volume moves on downstream, as shown in diagram (ii). In diagram (iii) the entrapped dye feeds out into the main channel, this contributing to the longitudinal spread. The main dye volume is shown in this diagram to have spread into a second shore indenture. In diagram (iv) the phenomena is shown repeated for a second indenture B on the flooding tide.

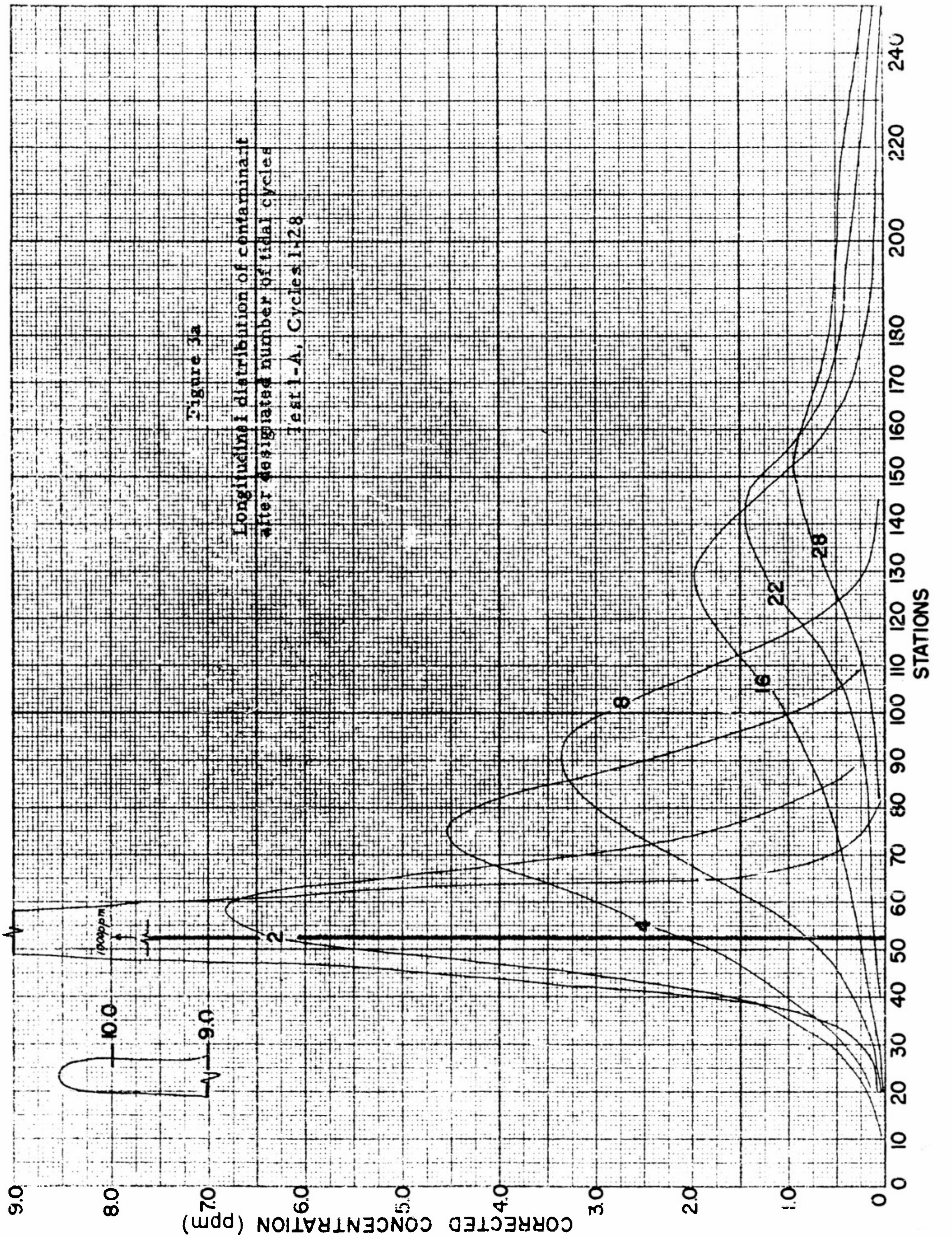


Figure 3a

Longitudinal distribution of contaminant after designated number of tidal cycles

Test 1-A, Cycles 1-28

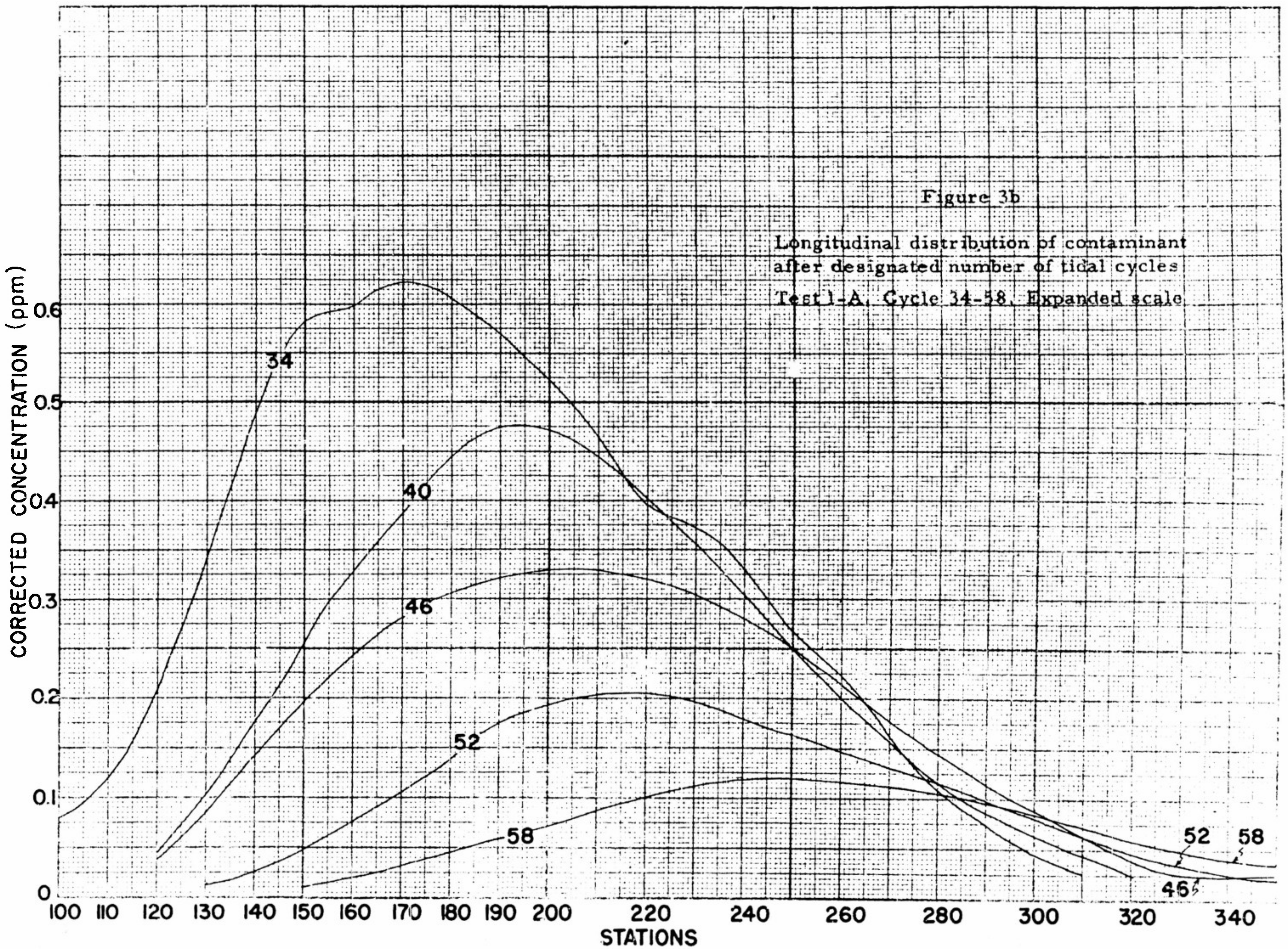


Figure 3b

Longitudinal distribution of contaminant after designated number of tidal cycles

Test 1-A, Cycle 34-58, Expanded scale

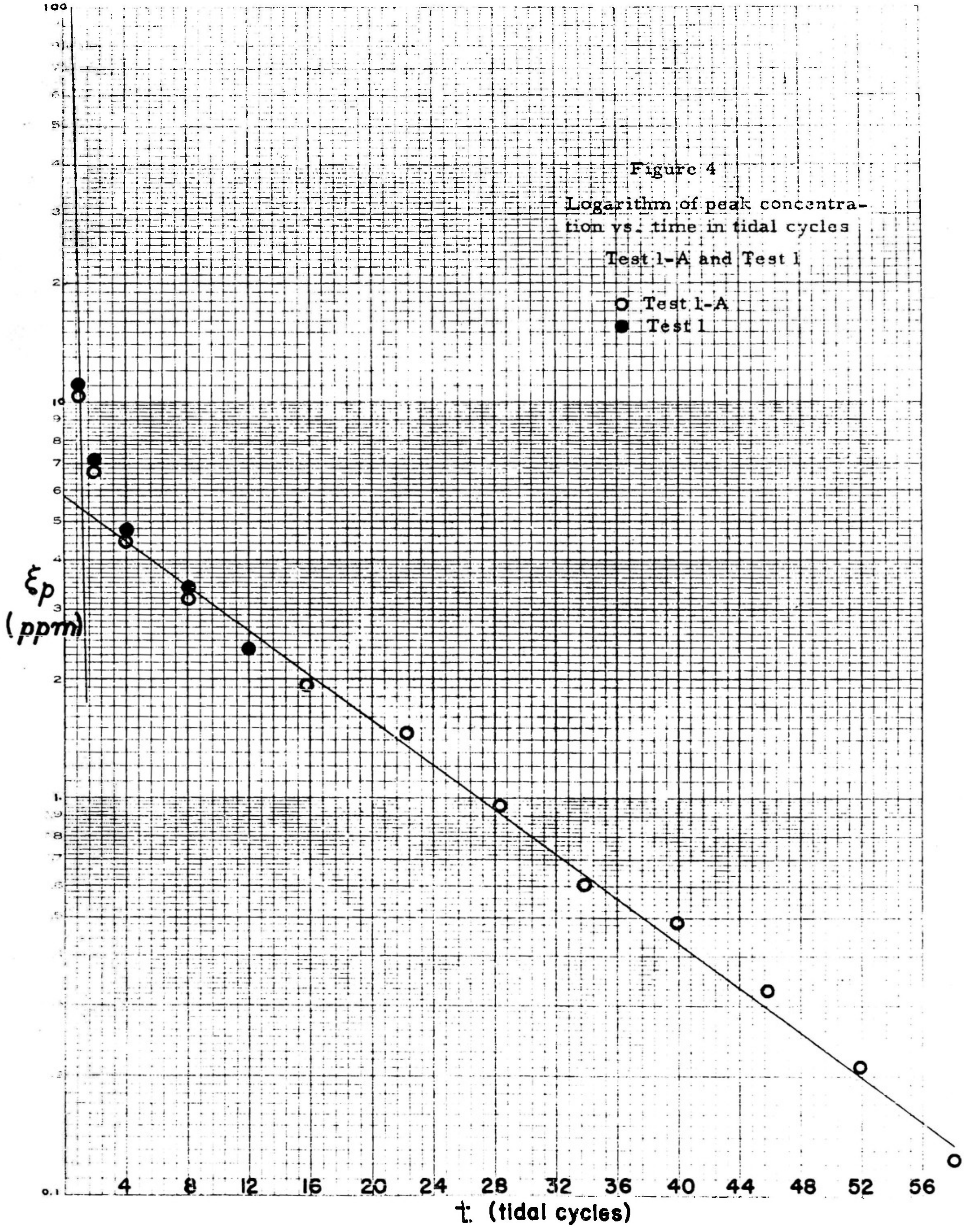


Figure 4
Logarithm of peak concentration vs. time in tidal cycles
Test 1-A and Test 1
Test 1-A
Test 1
ξp (ppm)
t (tidal cycles)
4
8
12
16
20
24
28
32
36
40
44
48
52
56

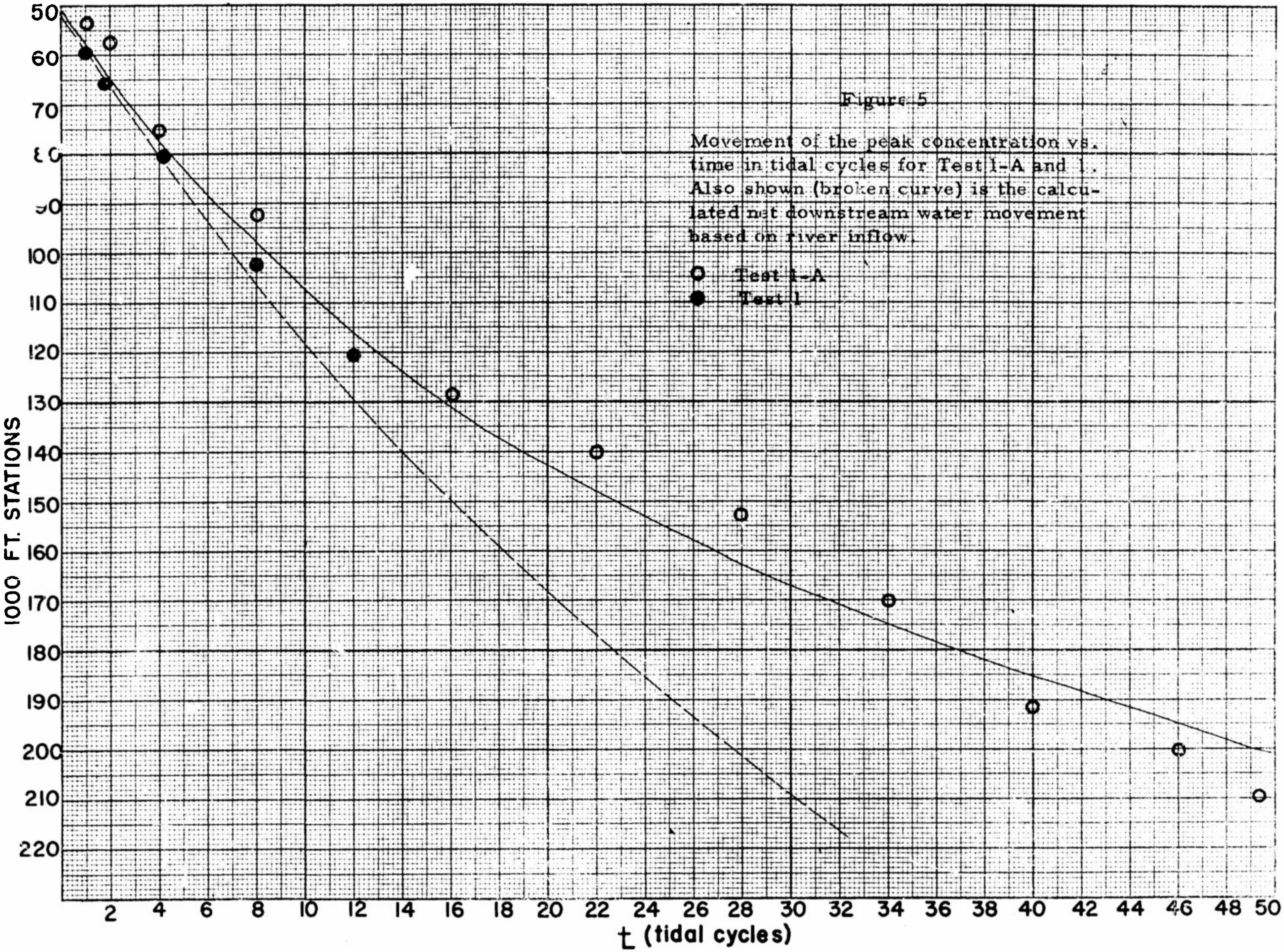


Figure 5

Movement of the peak concentration vs. time in tidal cycles for Test 1-A and 1. Also shown (broken curve) is the calculated net downstream water movement based on river inflow.

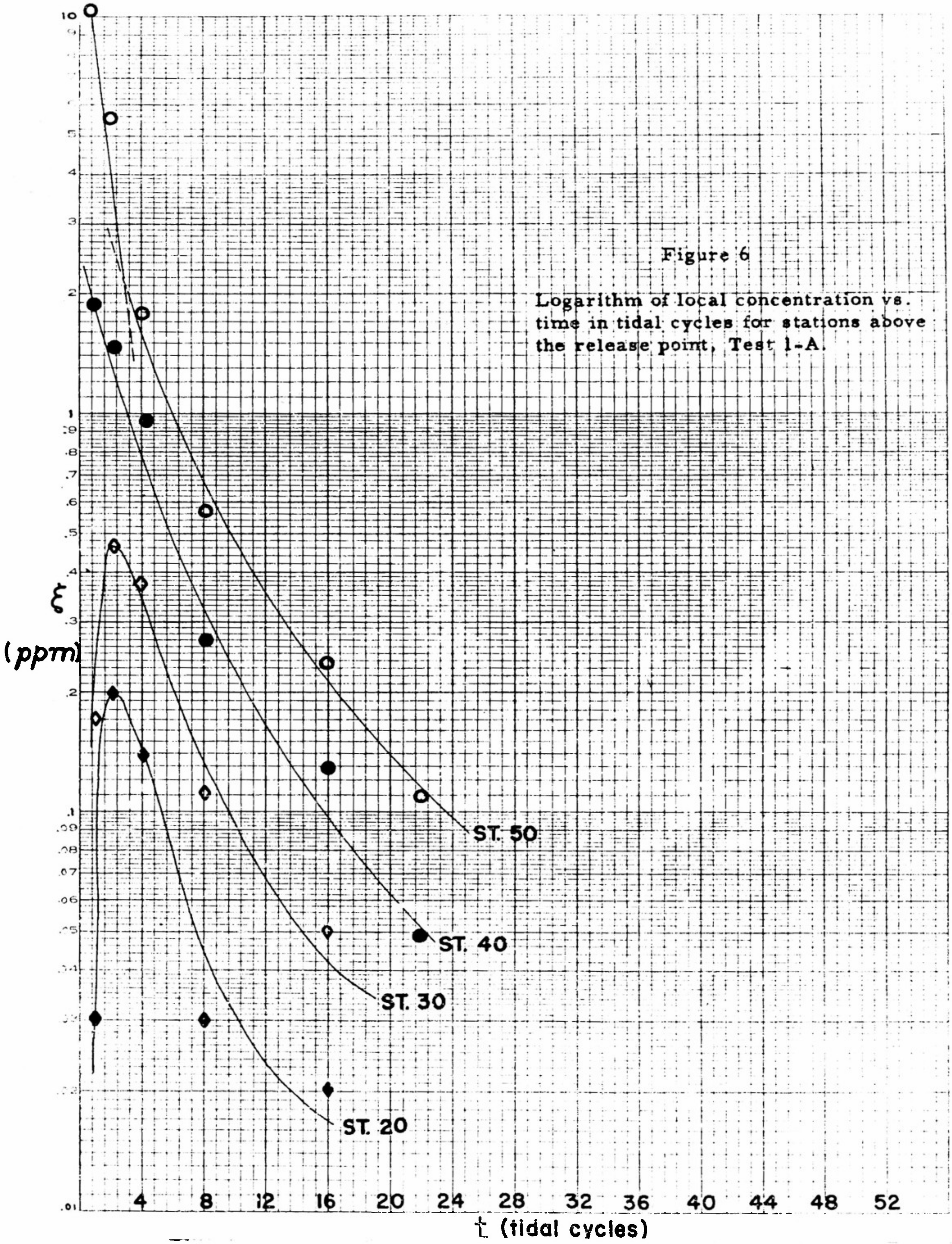


Figure 6
Logarithm of local concentration vs. time in tidal cycles for stations above the release point, Test 1-A.
ξ
(ppm)
10
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
.09
.08
.07
.06
.05
.04
.02
.01
ST. 50
ST. 40
ST. 30
ST. 20
4
8
12
16
20
24
28
32
36
40
44
48
52
t (tidal cycles)

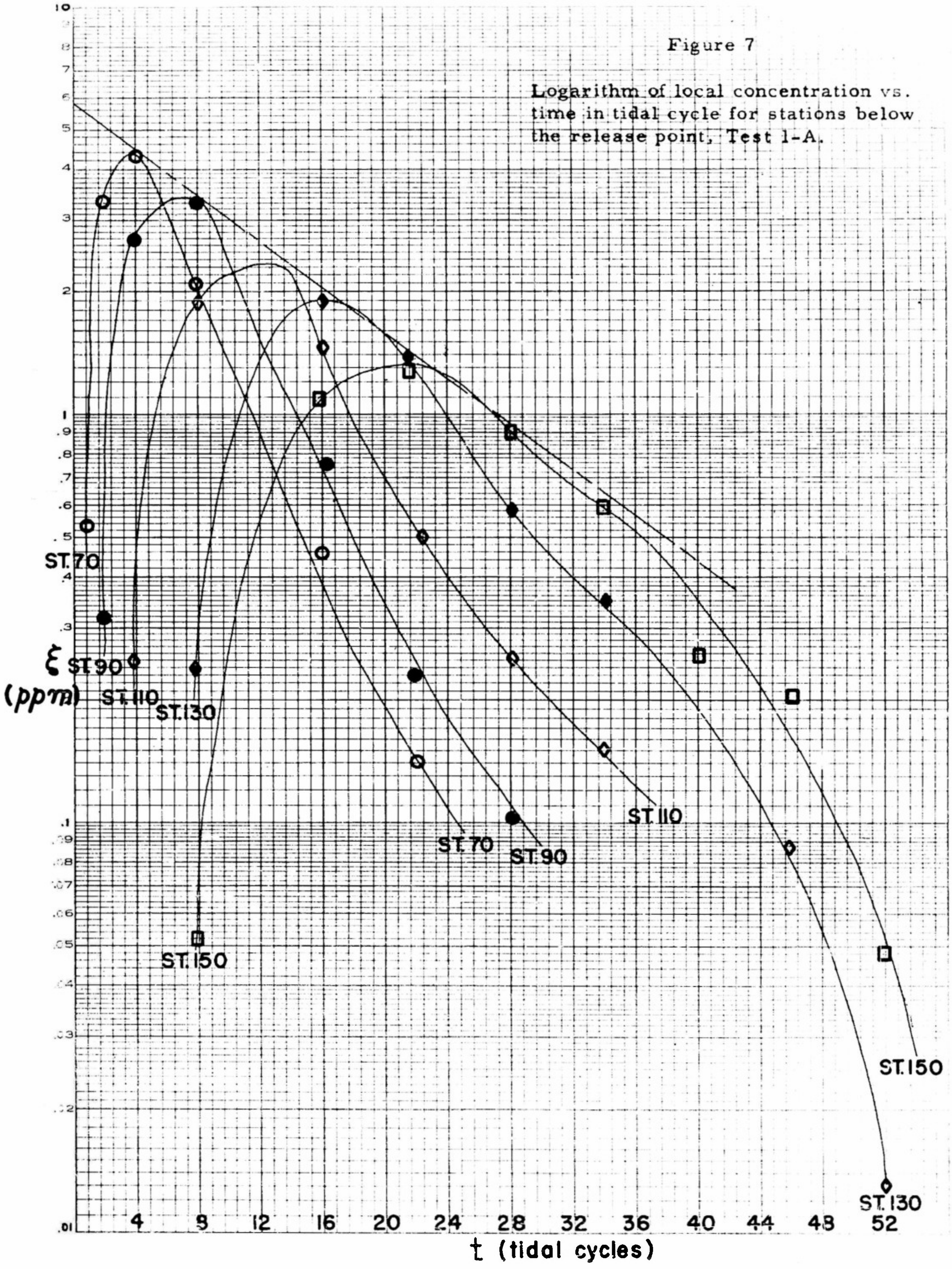


Figure 7
Logarithm of local concentration vs. time in tidal cycle for stations below the release point, Test 1-A.
ST.70
ST.90
ST.110
ST.130
ST.150
ξ (ppm)
t (tidal cycles)
4
8
12
16
20
24
28
32
36
40
44
48
52
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.1
.09
.08
.07
.06
.05
.04
.03
.02
.01

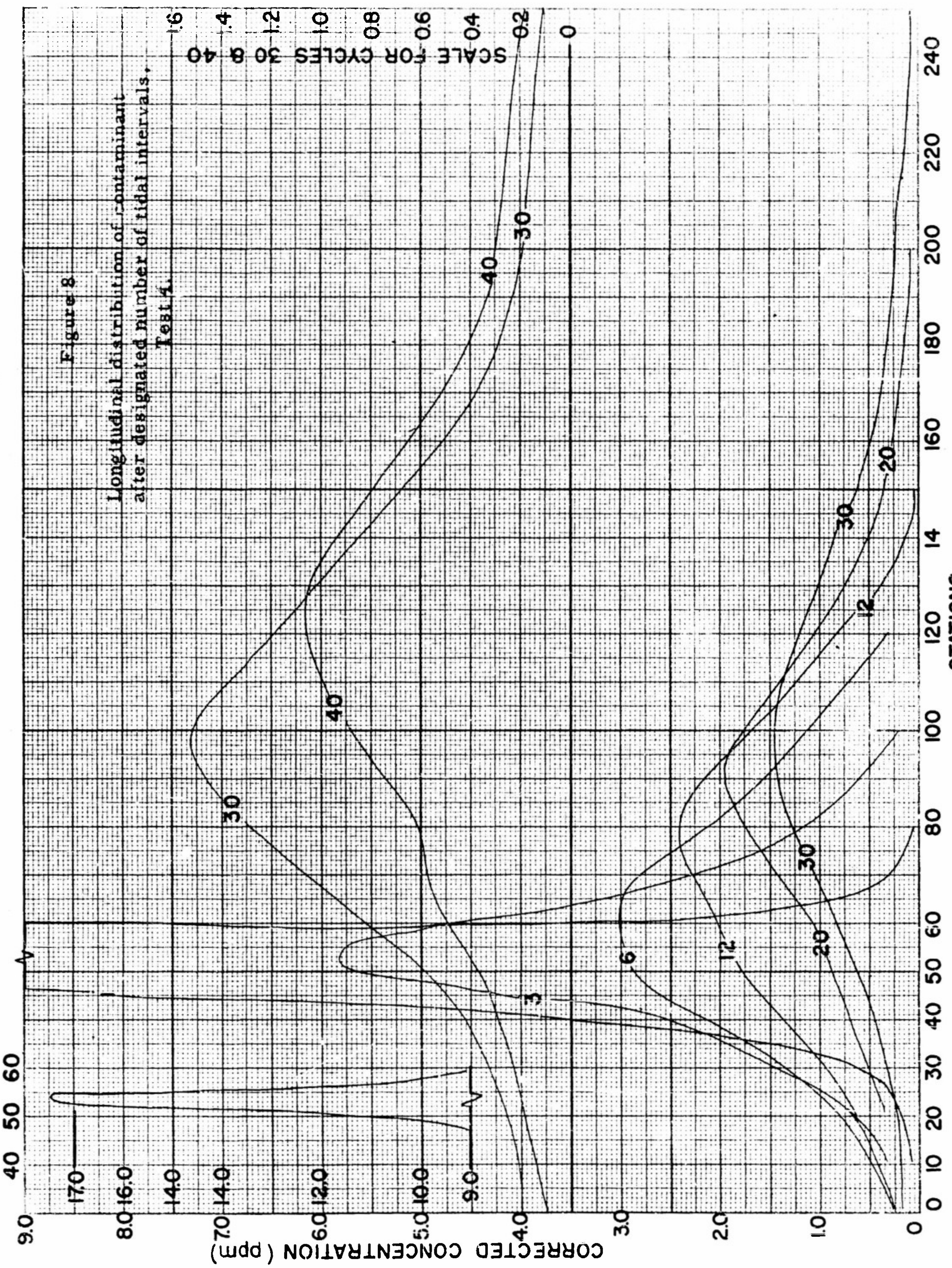


Figure 8

Longitudinal distribution of contaminant after designated number of tidal intervals. Test 4.

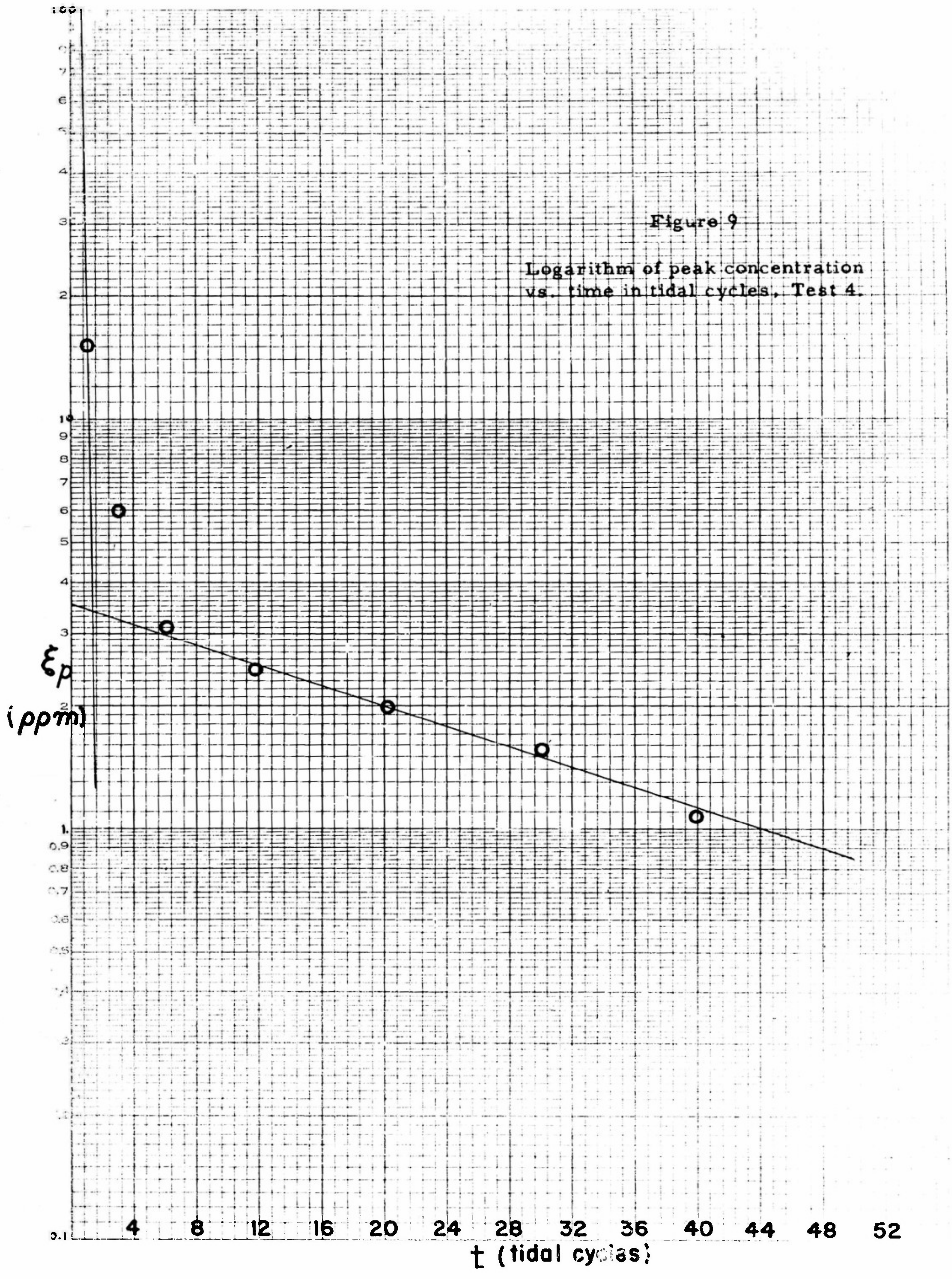


Figure 9
Logarithm of peak concentration vs. time in tidal cycles, Test 4.
ξ_p (ppm)
t (tidal cycles)
4 8 12 16 20 24 28 32 36 40 44 48 52
100
10
1.
0.1

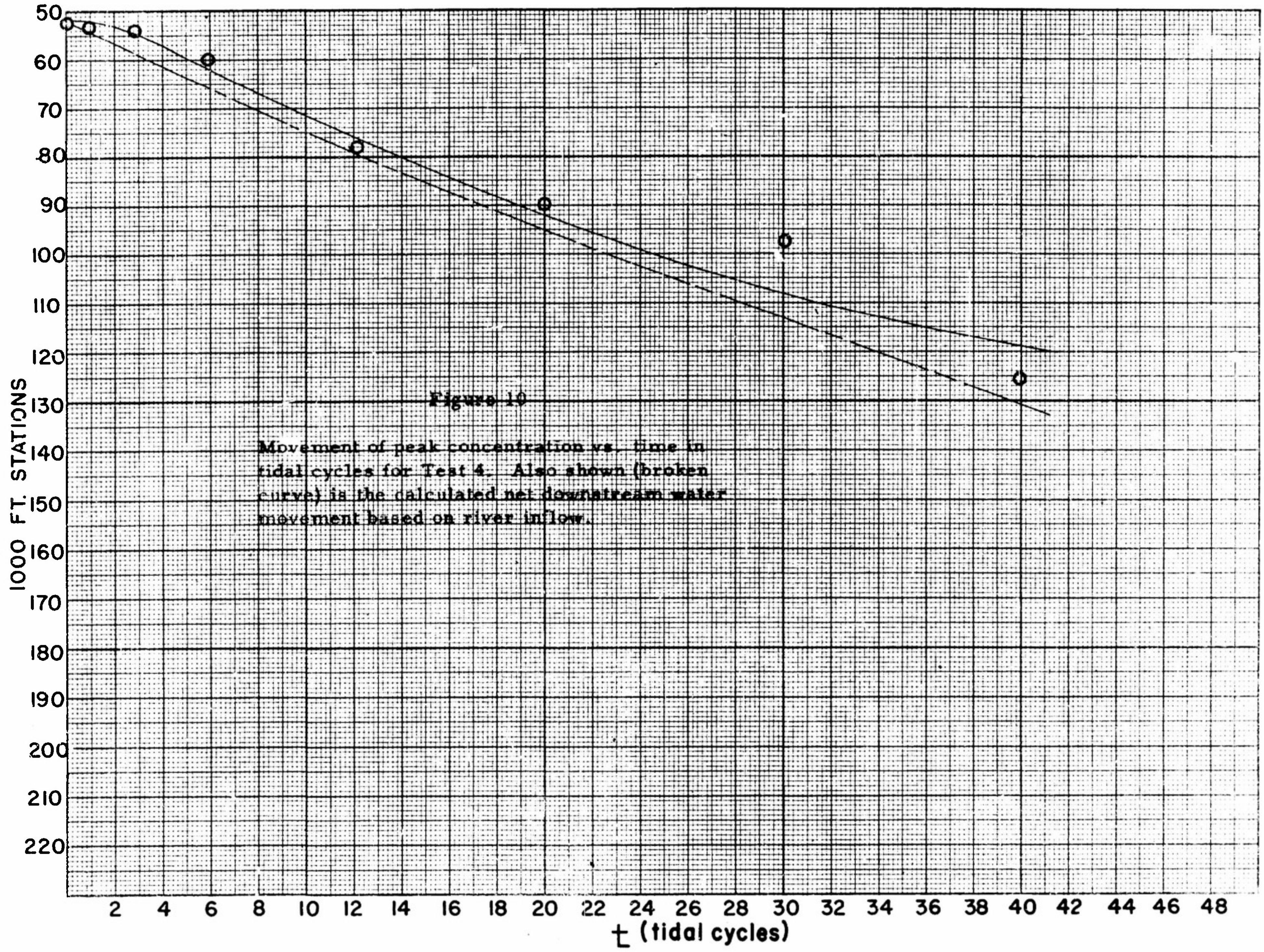


Figure 10

Movement of peak concentration vs. time in tidal cycles for Test 4. Also shown (broken curve) is the calculated net downstream water movement based on river inflow.

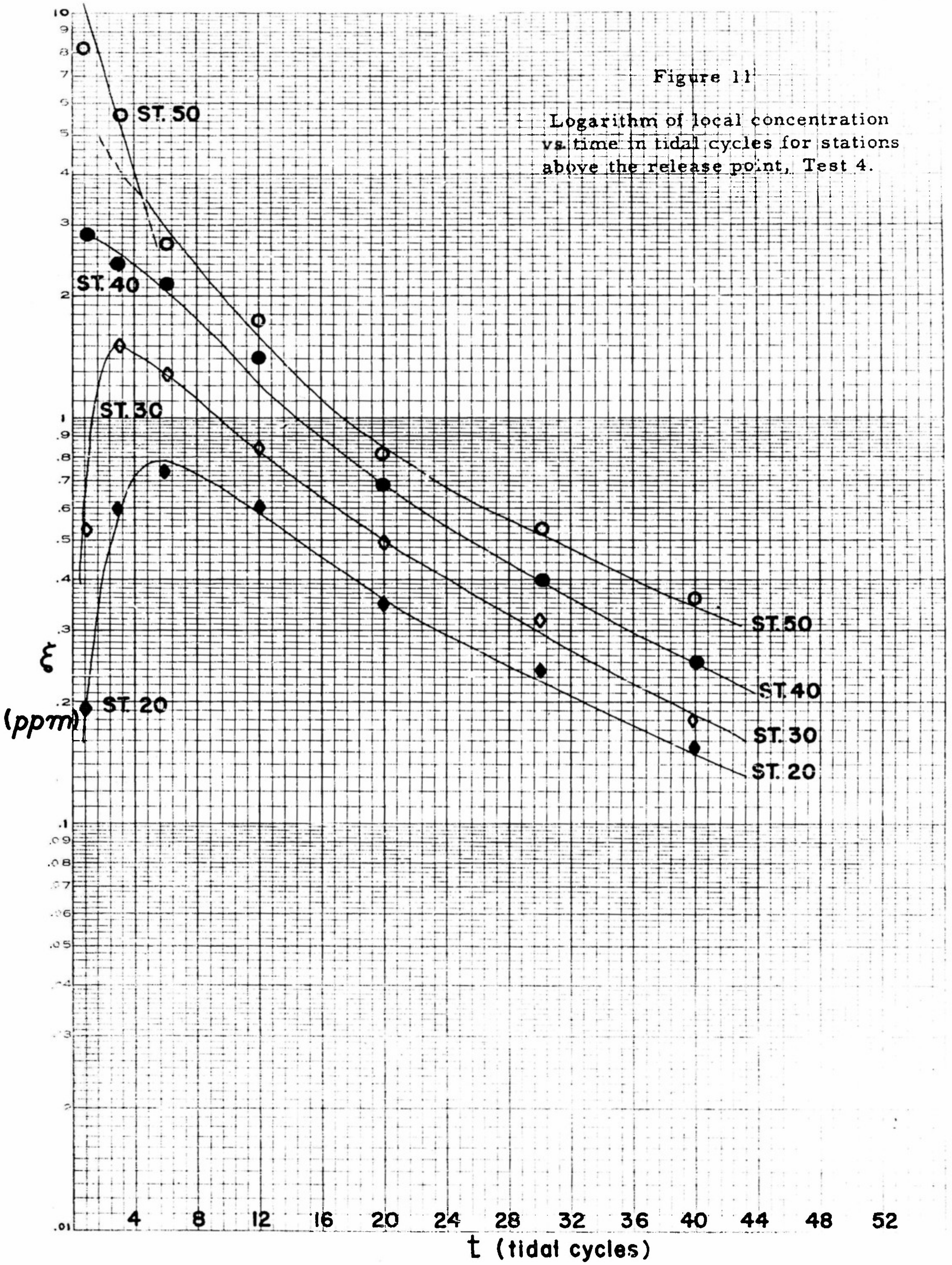


Figure 11

Logarithm of local concentration vs. time in tidal cycles for stations above the release point, Test 4.

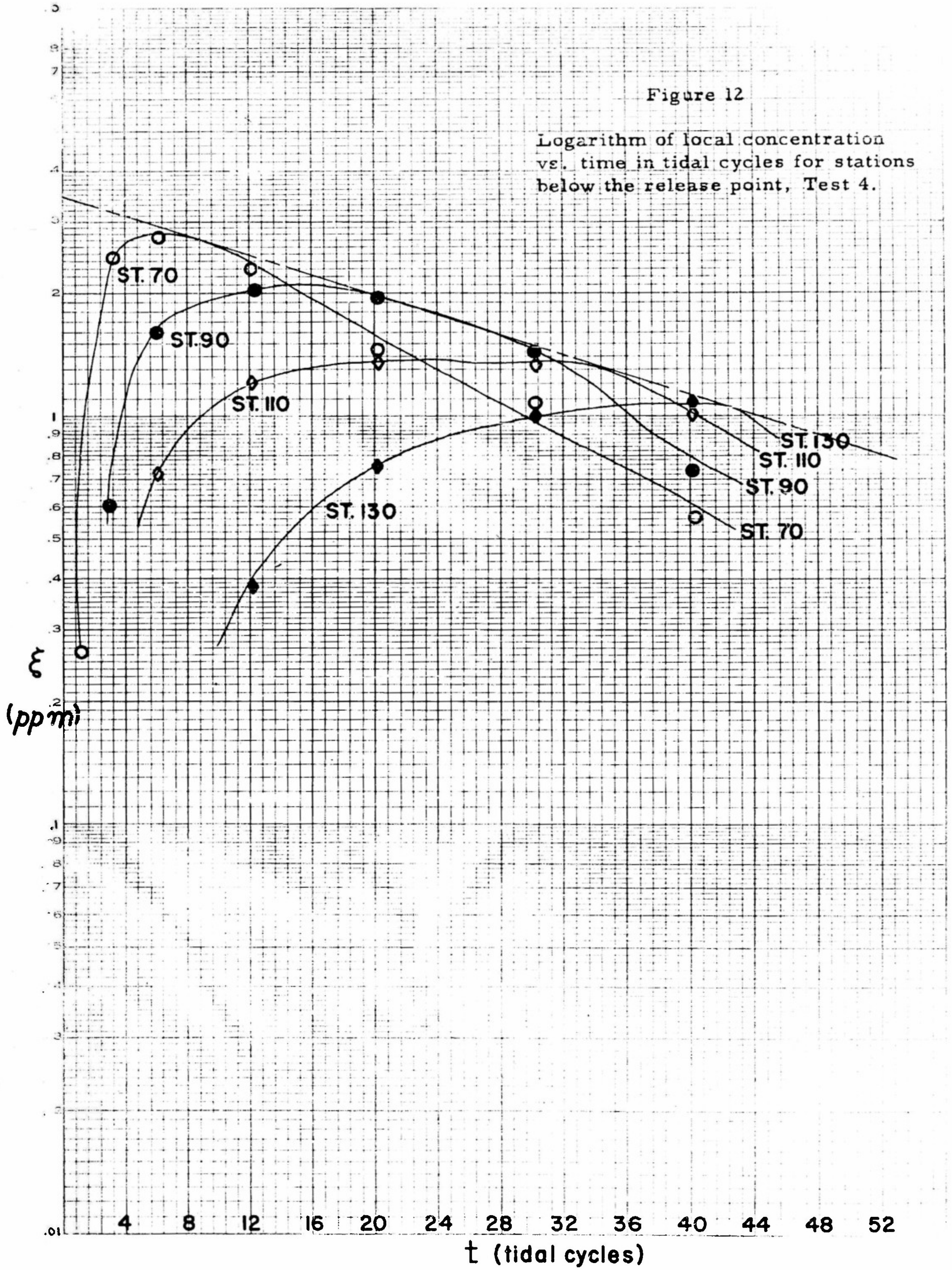


Figure 12

Logarithm of local concentration vs. time in tidal cycles for stations below the release point, Test 4.

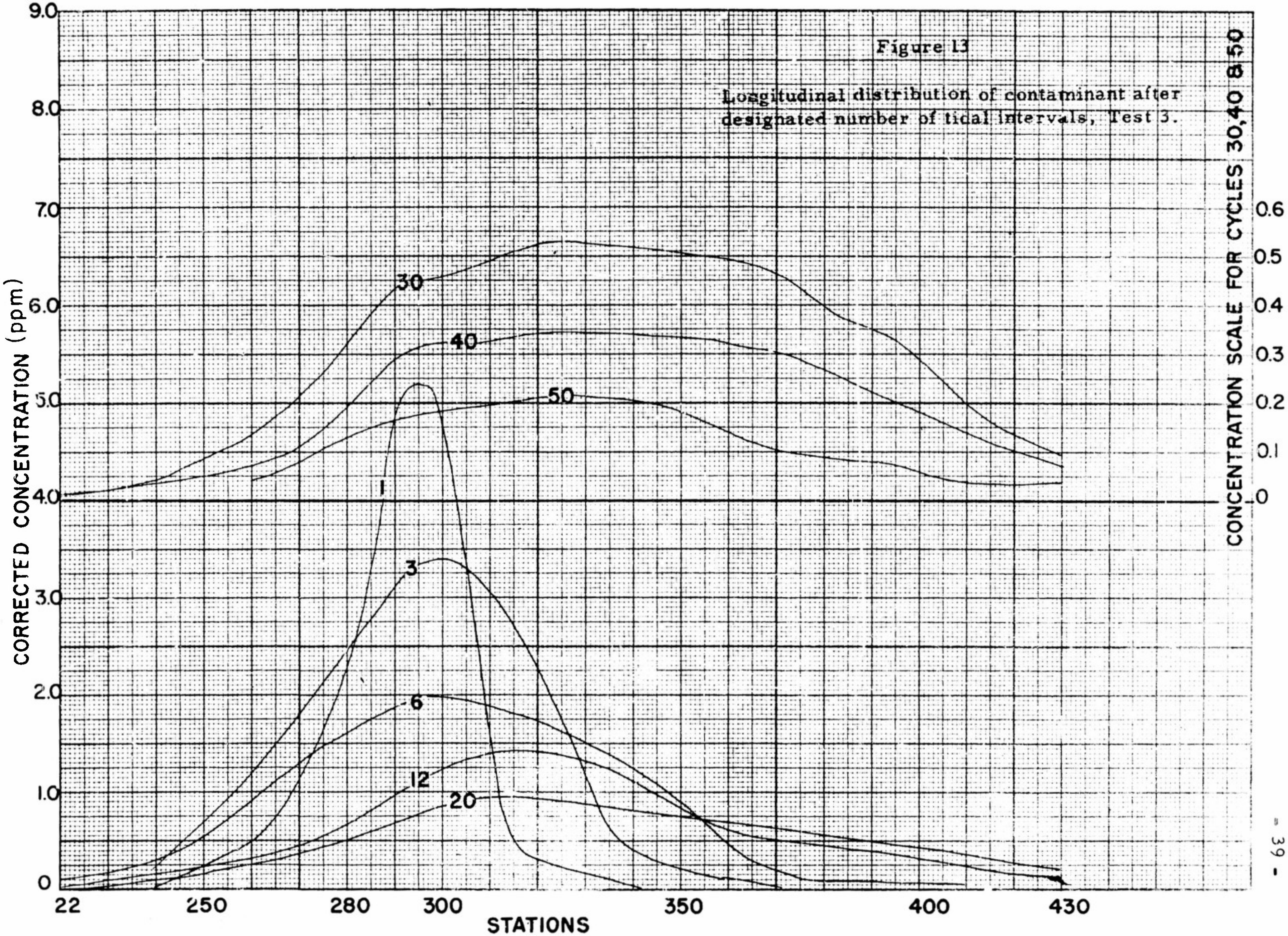


Figure 13

Longitudinal distribution of contaminant after designated number of tidal intervals, Test 3.

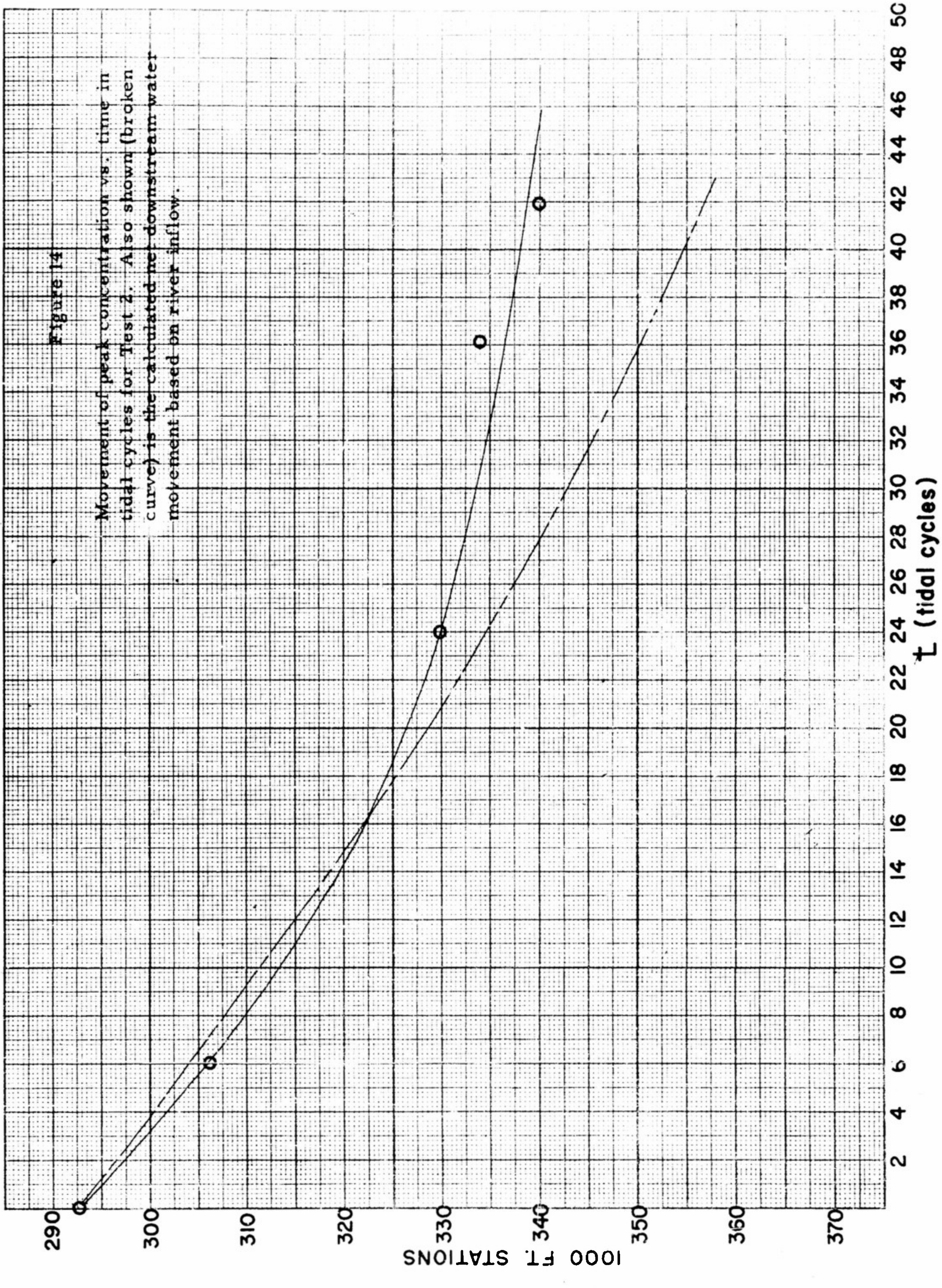


Figure 14

Movement of peak concentration vs. time in tidal cycles for Test 2. Also shown (broken curve) is the calculated net downstream water movement based on river inflow.

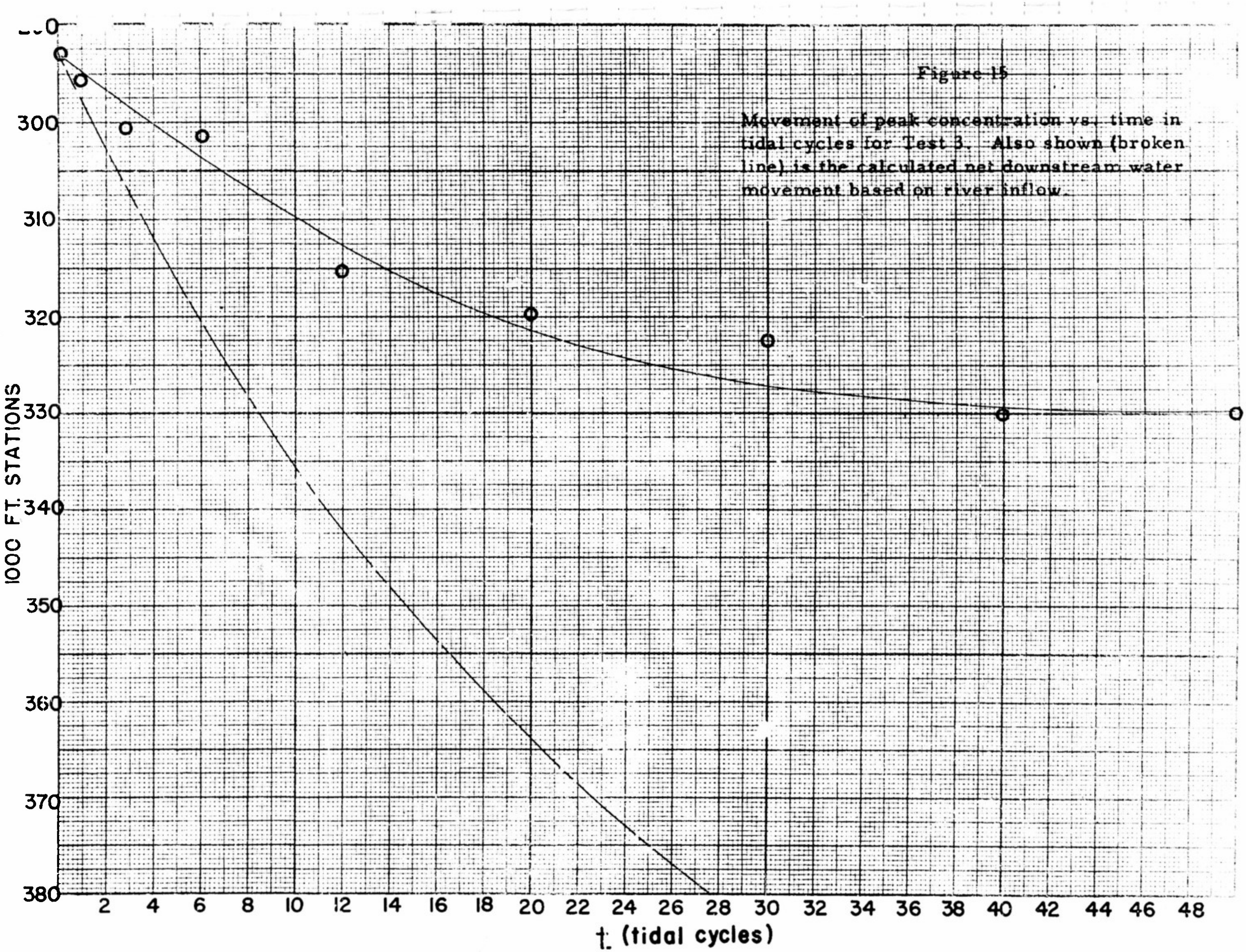


Figure 15

Movement of peak concentration vs. time in tidal cycles for Test 3. Also shown (broken line) is the calculated net downstream water movement based on river inflow.

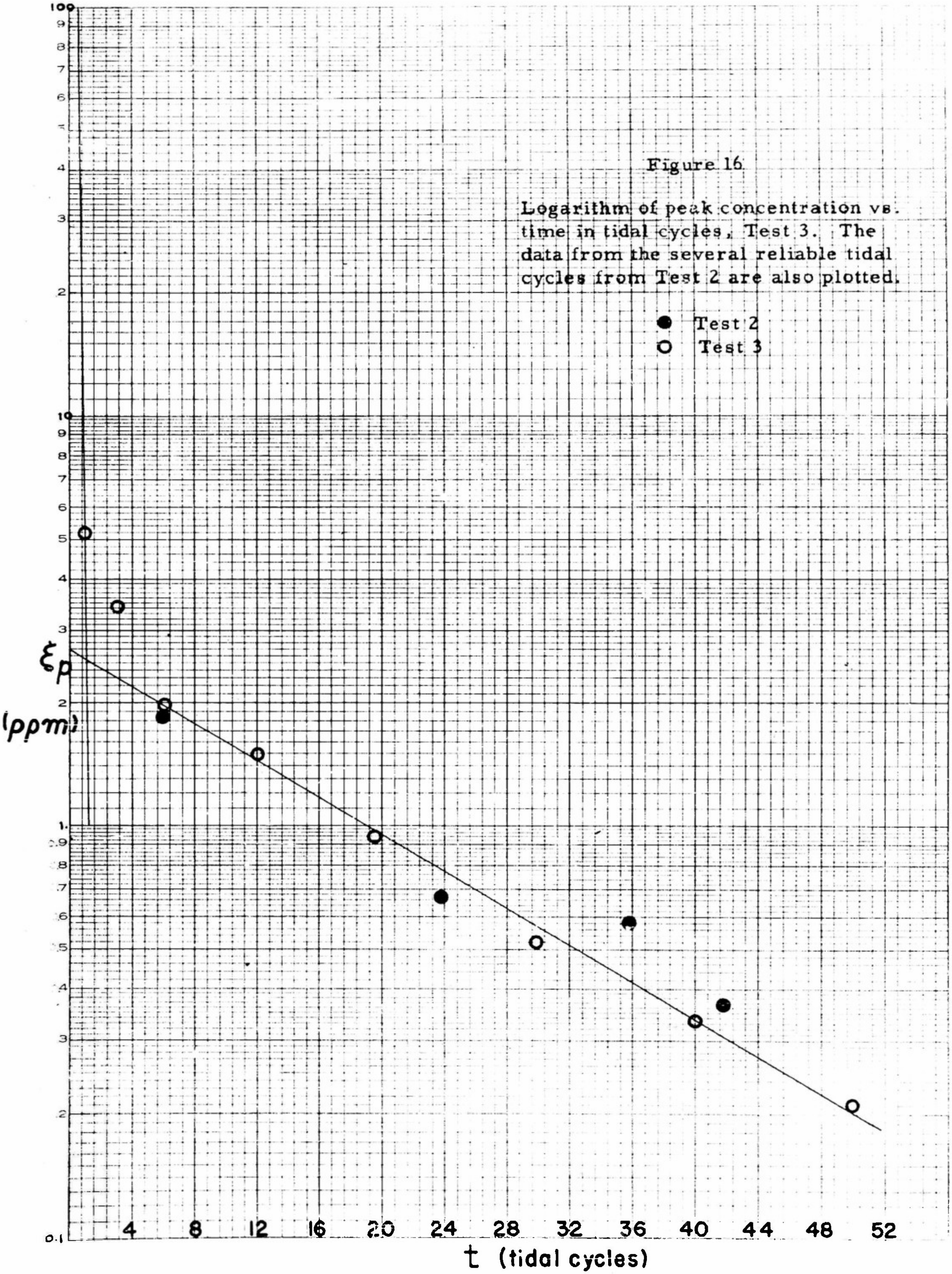


Figure 16
Logarithm of peak concentration vs. time in tidal cycles, Test 3. The data from the several reliable tidal cycles from Test 2 are also plotted.
Test 2
Test 3
ξ_p (ppm)
t (tidal cycles)
100
10
1.
0.1
4
8
12
16
20
24
28
32
36
40
44
48
52

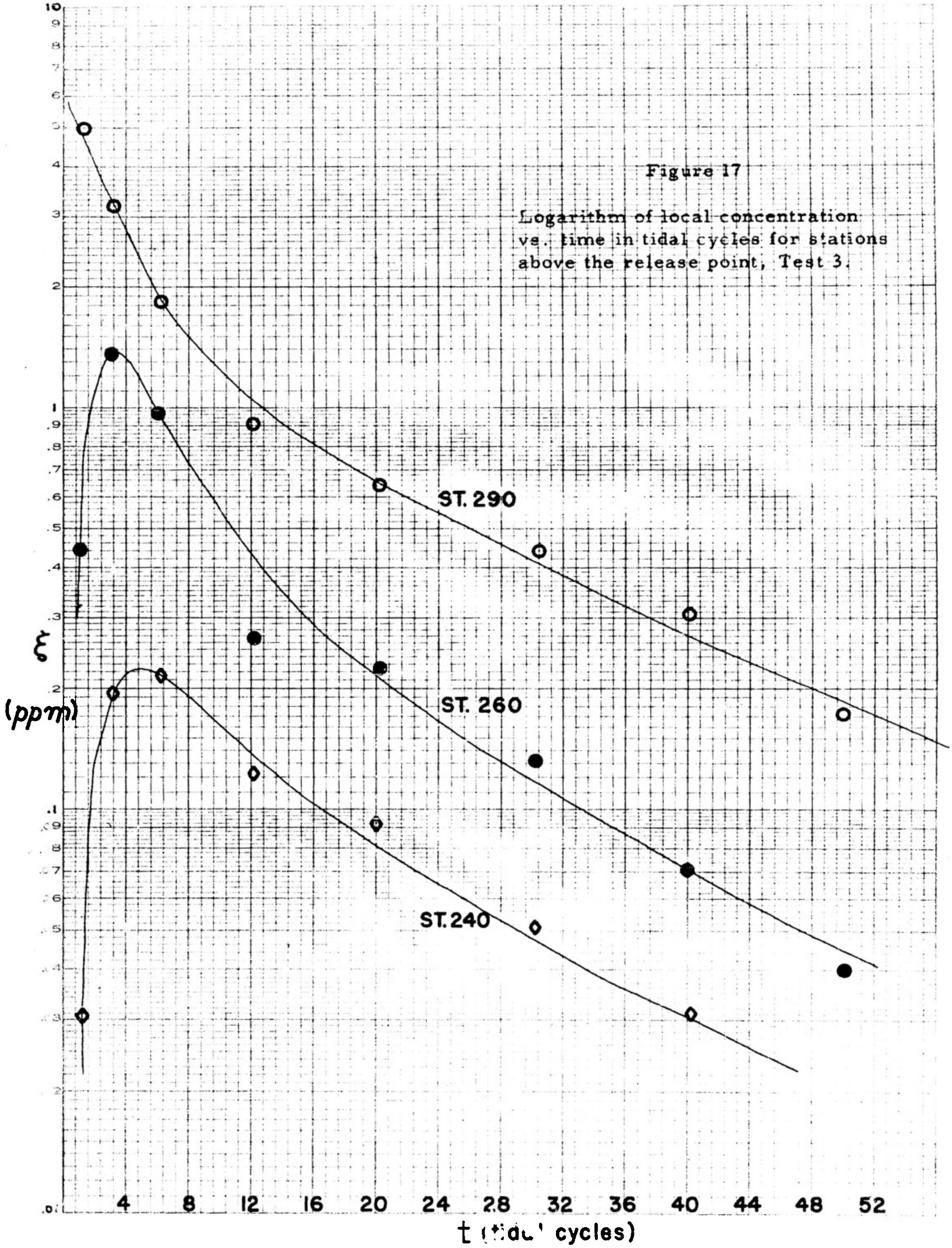
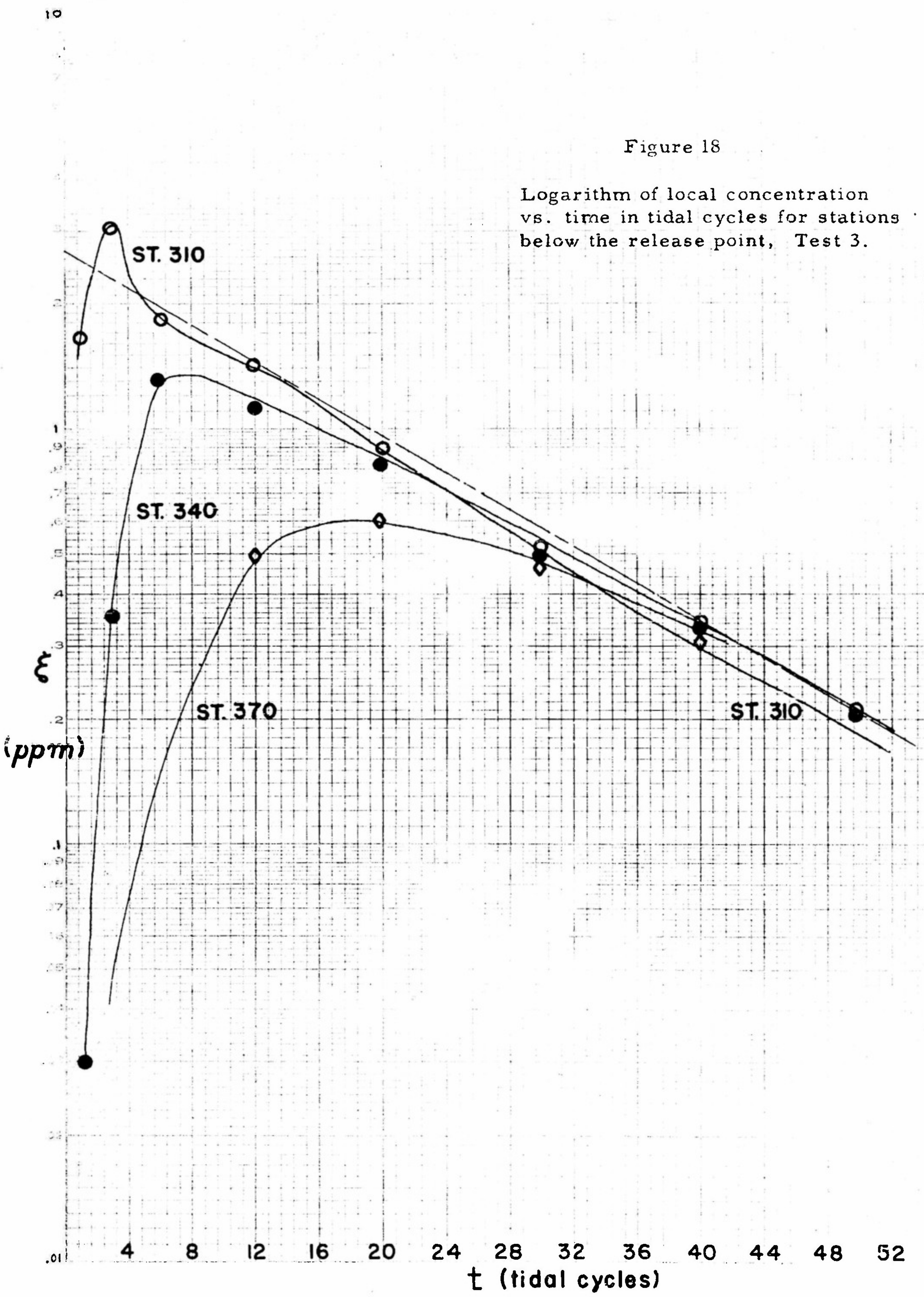


Figure 17

Logarithm of local concentration vs. time in tidal cycles for stations above the release point, Test 3.

Figure 18

Logarithm of local concentration vs. time in tidal cycles for stations below the release point, Test 3.



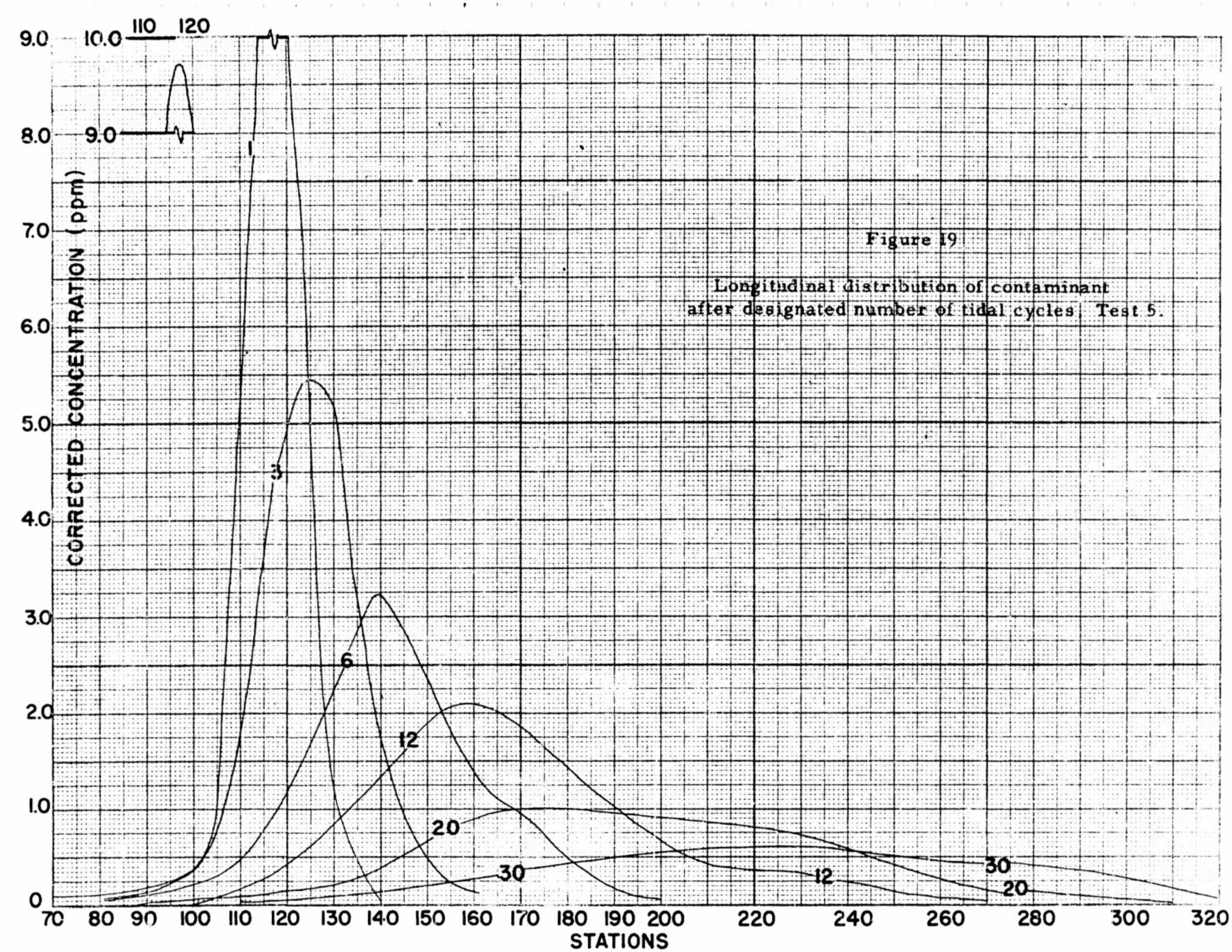


Figure 19

Longitudinal distribution of contaminant after designated number of tidal cycles. Test 5.

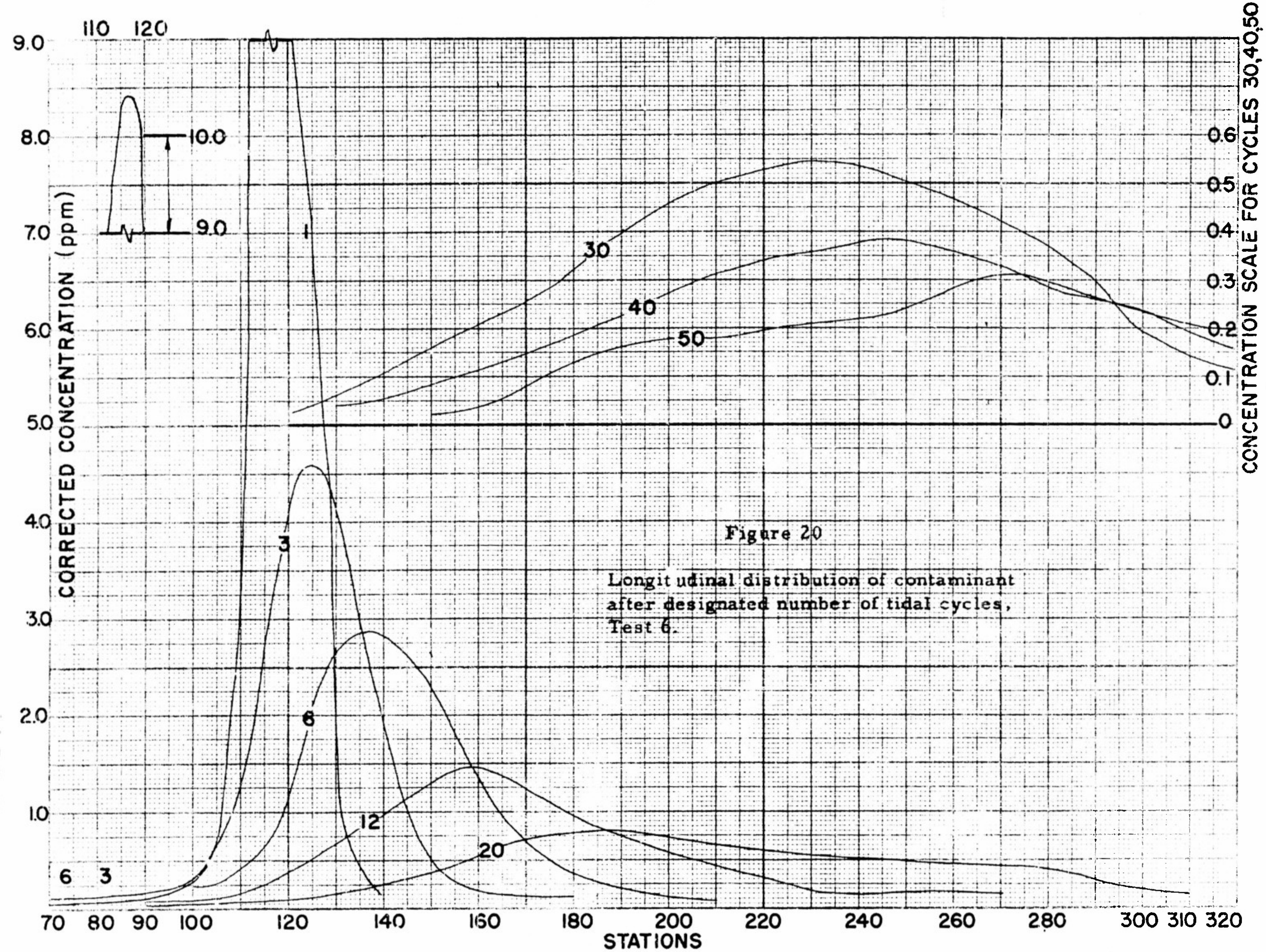


Figure 20

Longitudinal distribution of contaminant after designated number of tidal cycles, Test 6.

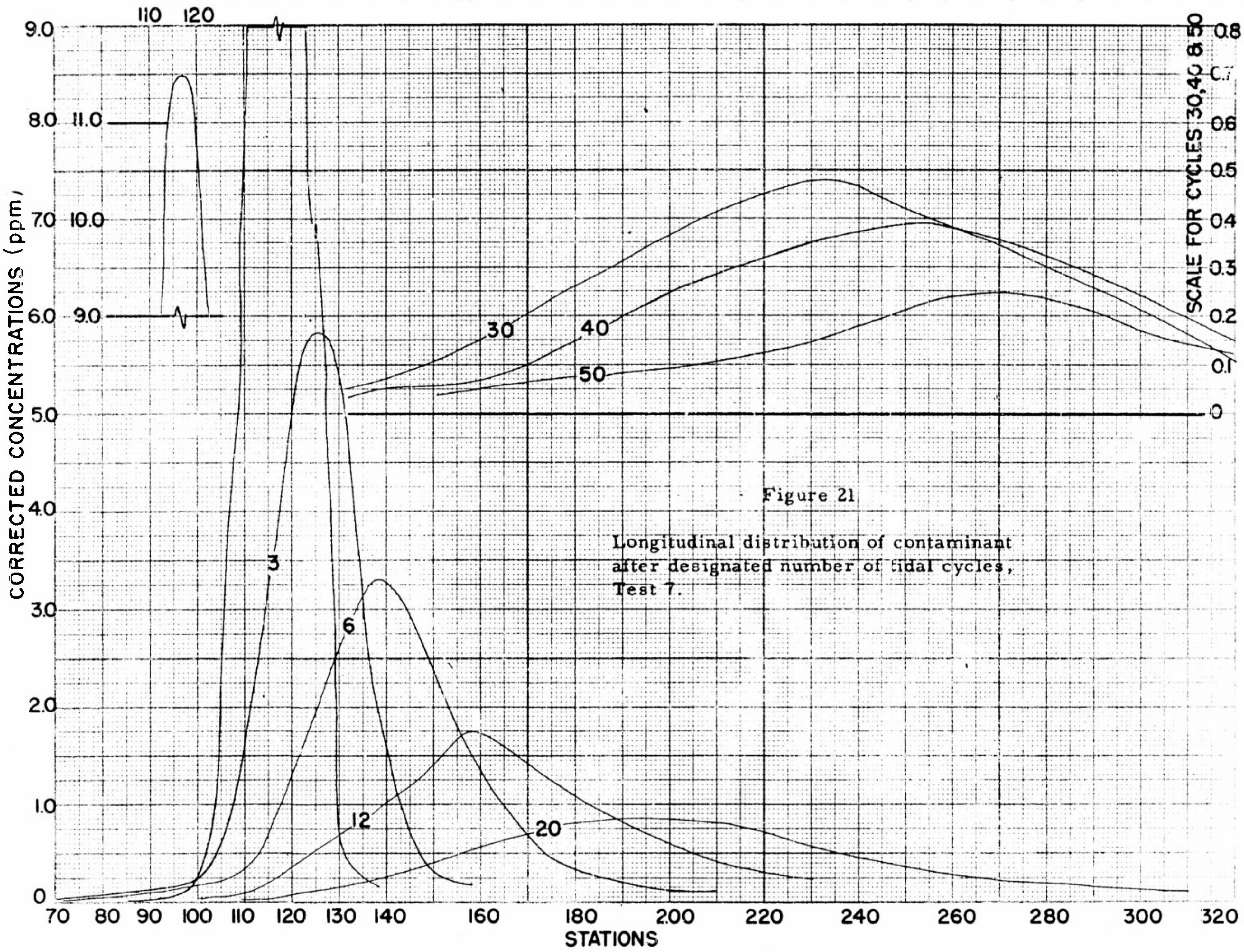


Figure 21

Longitudinal distribution of contaminant after designated number of tidal cycles, Test 7.

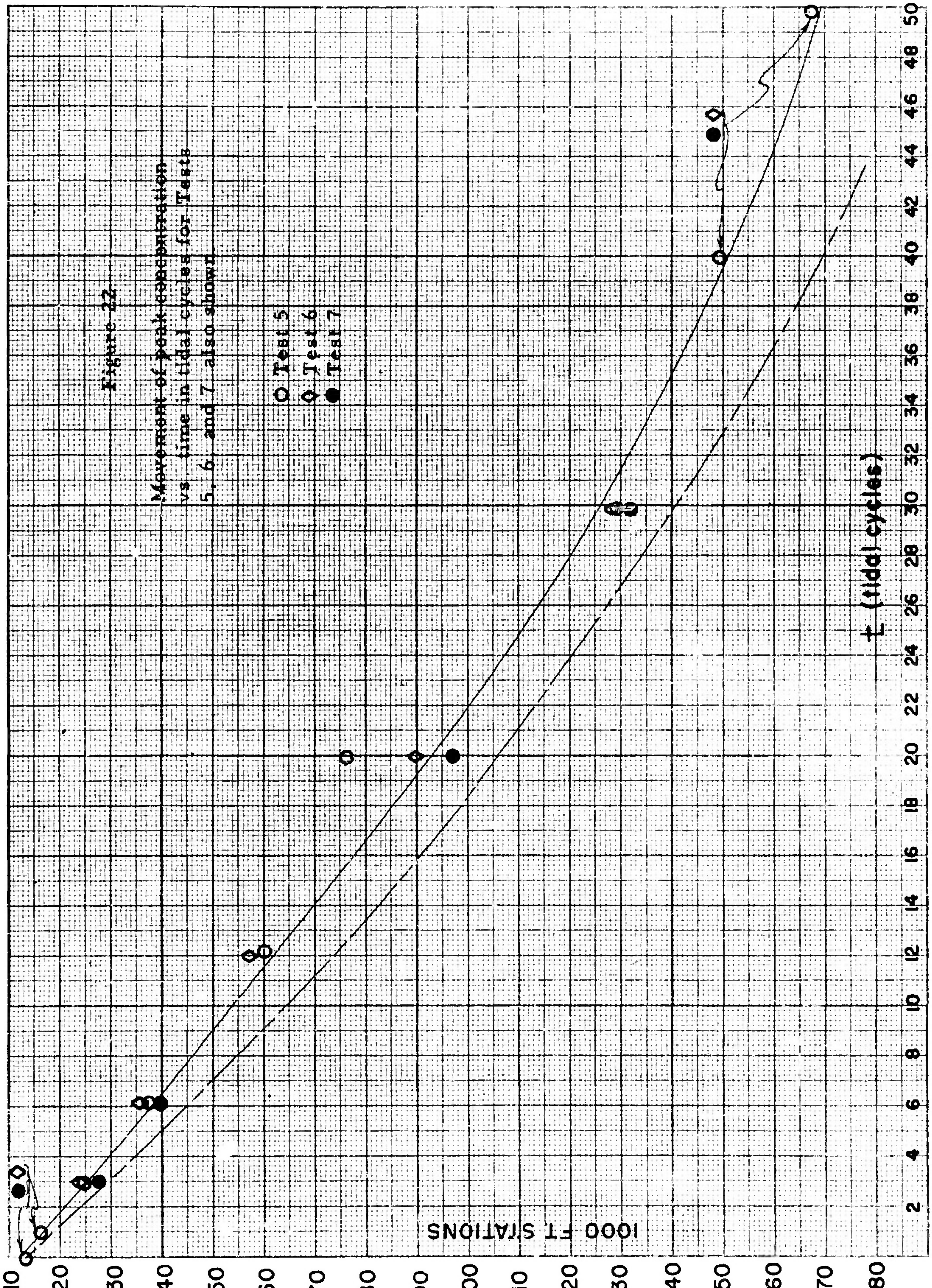


Figure 22
Movement of peak concentration vs. time in tidal cycles for Tests 5, 6, and 7 also shown
O Test 5
◇ Test 6
● Test 7
t (tidal cycles)
1000 FT STATIONS
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50

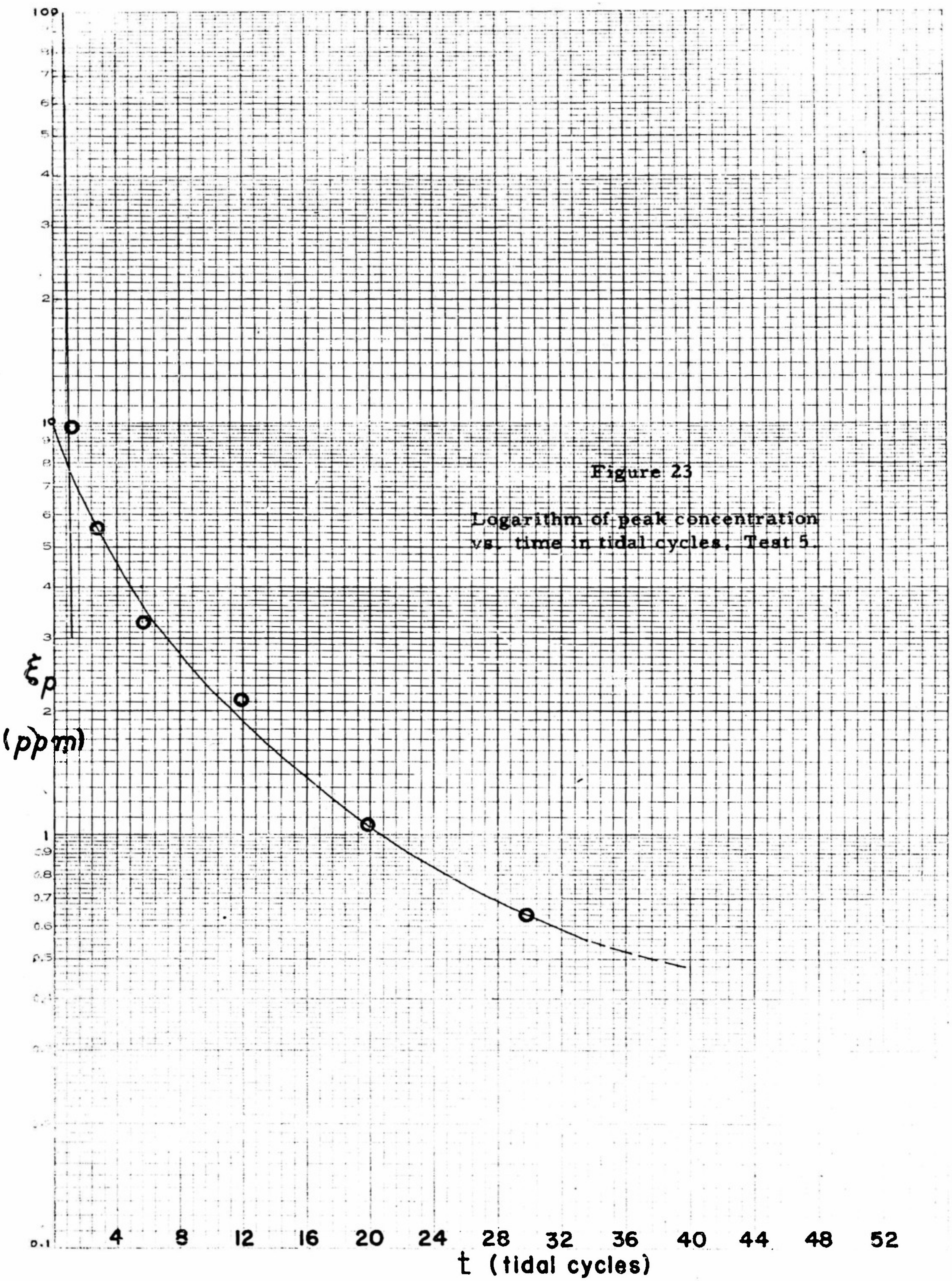


Figure 23

Logarithm of peak concentration vs. time in tidal cycles. Test 5.

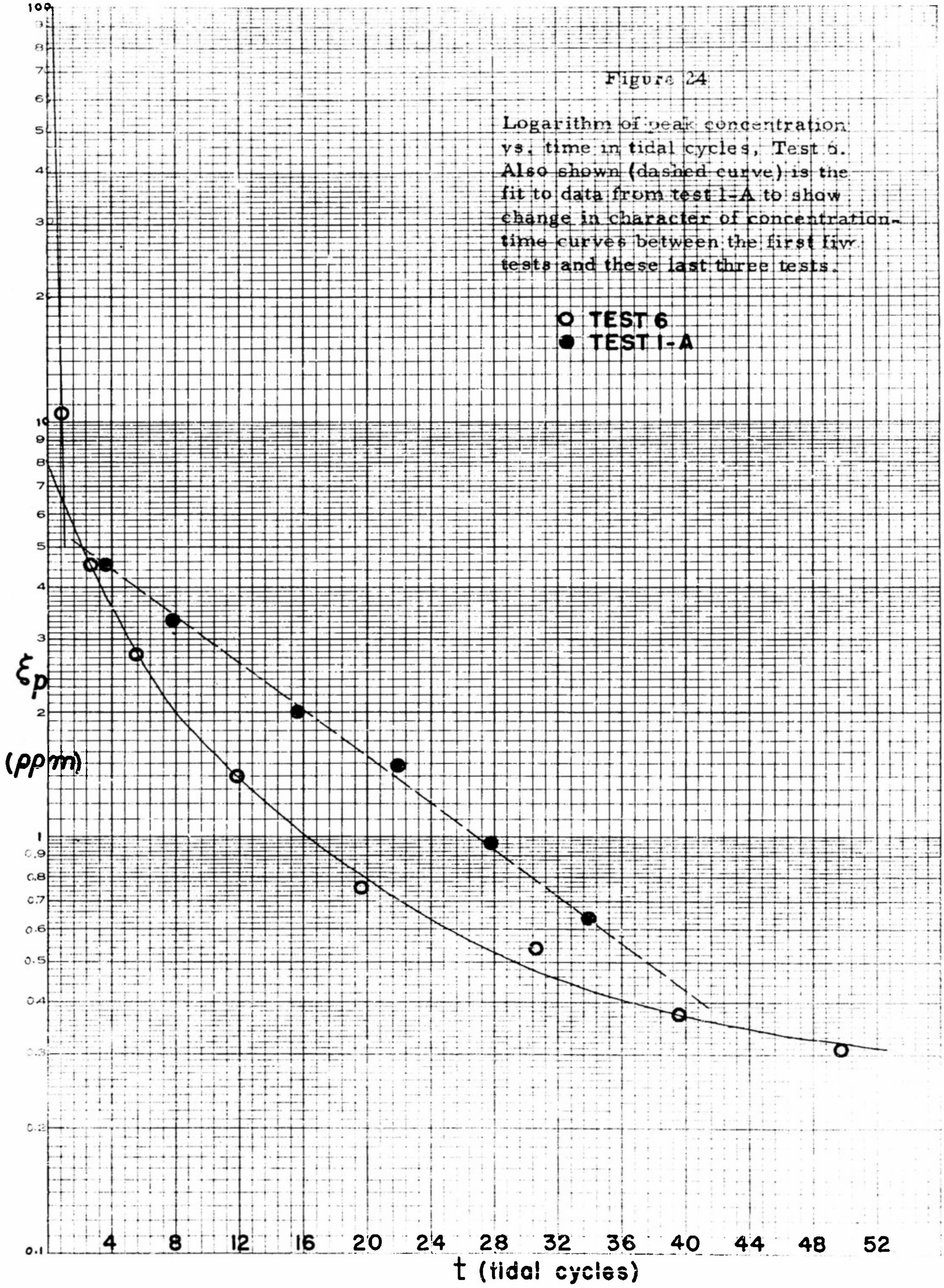


Figure 24

Logarithm of peak concentration vs. time in tidal cycles, Test 6. Also shown (dashed curve) is the fit to data from test 1-A to show change in character of concentration-time curves between the first five tests and these last three tests.

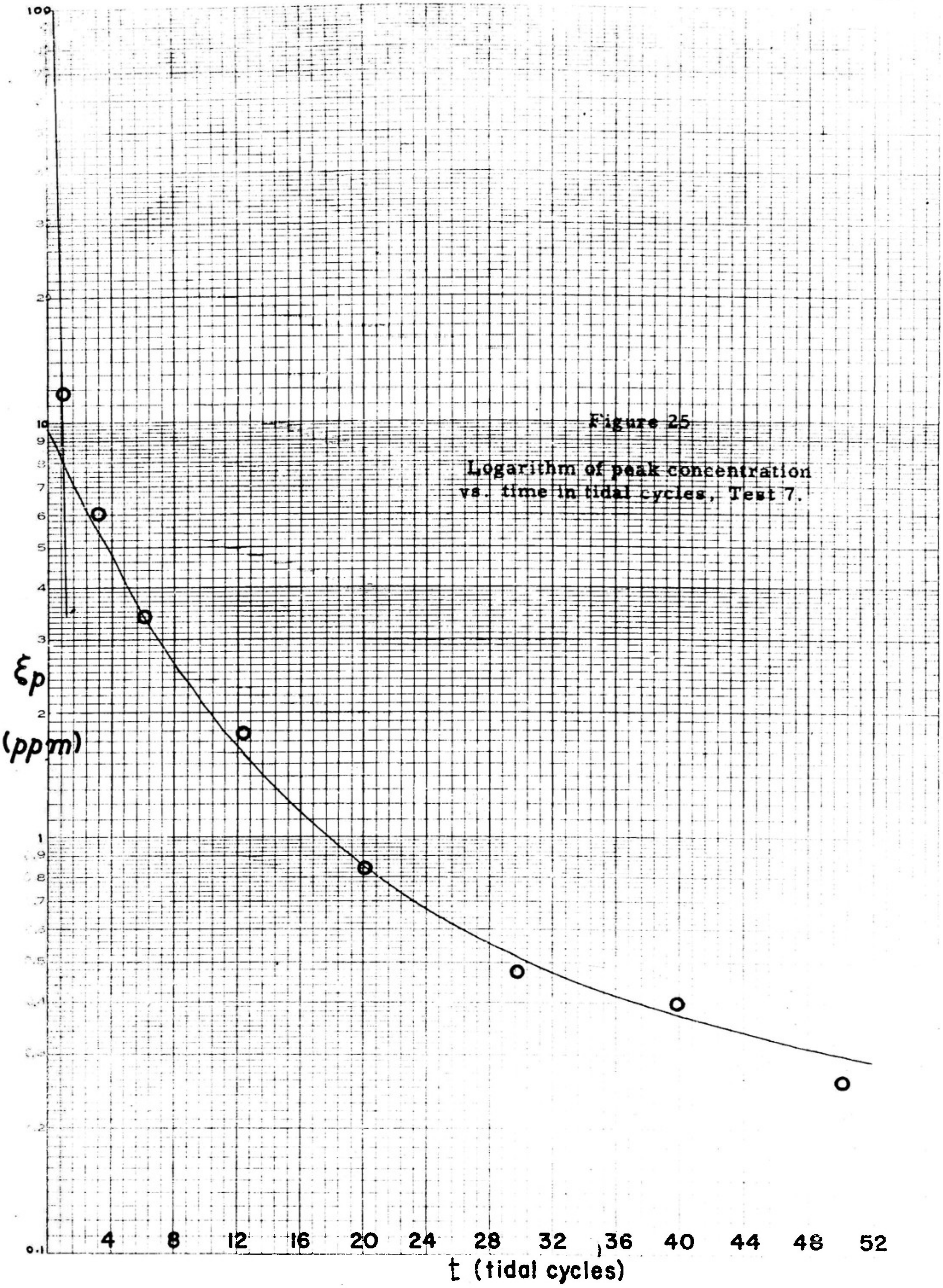


Figure 25

Logarithm of peak concentration vs. time in tidal cycles, Test 7.

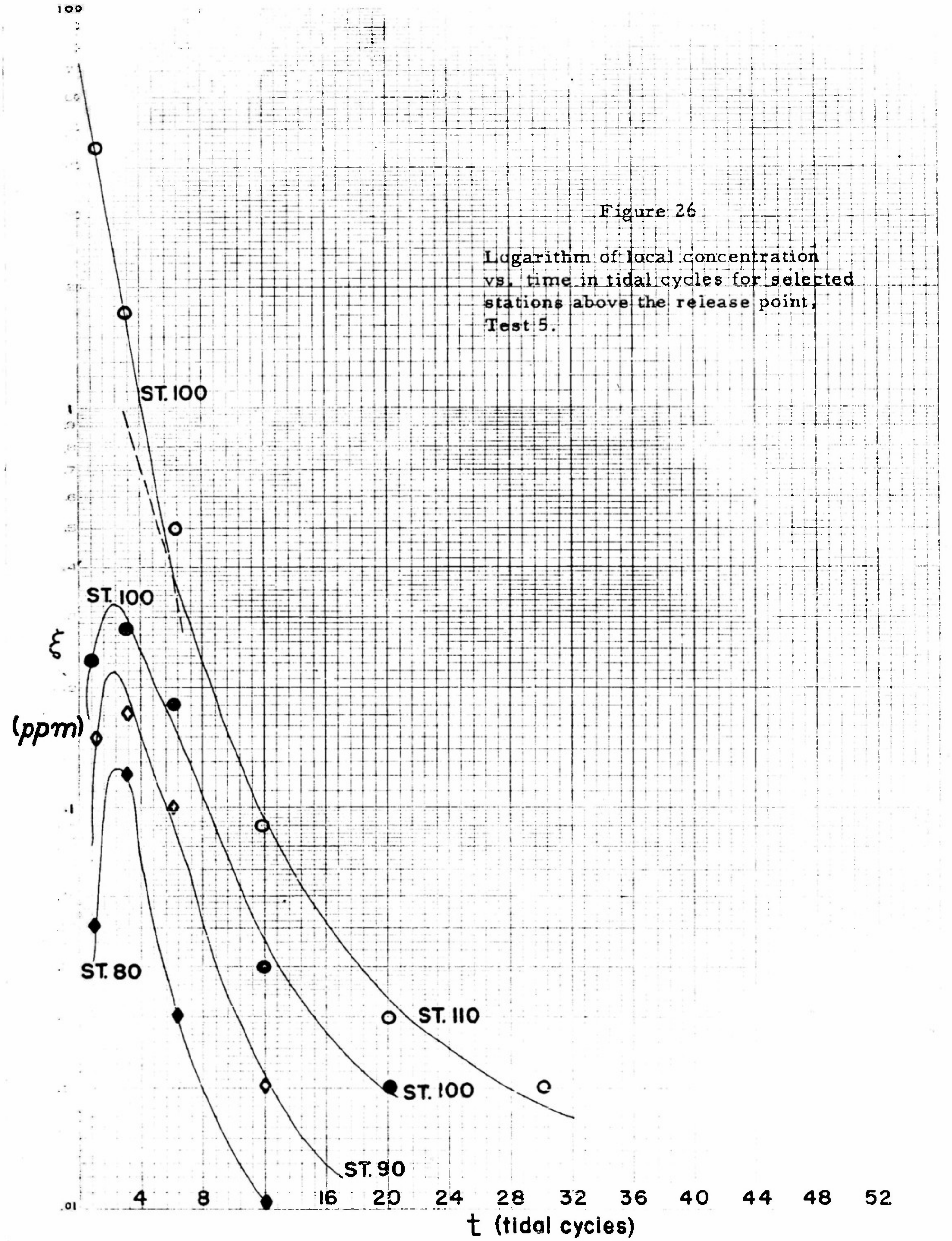


Figure 26

Logarithm of local concentration vs. time in tidal cycles for selected stations above the release point, Test 5.

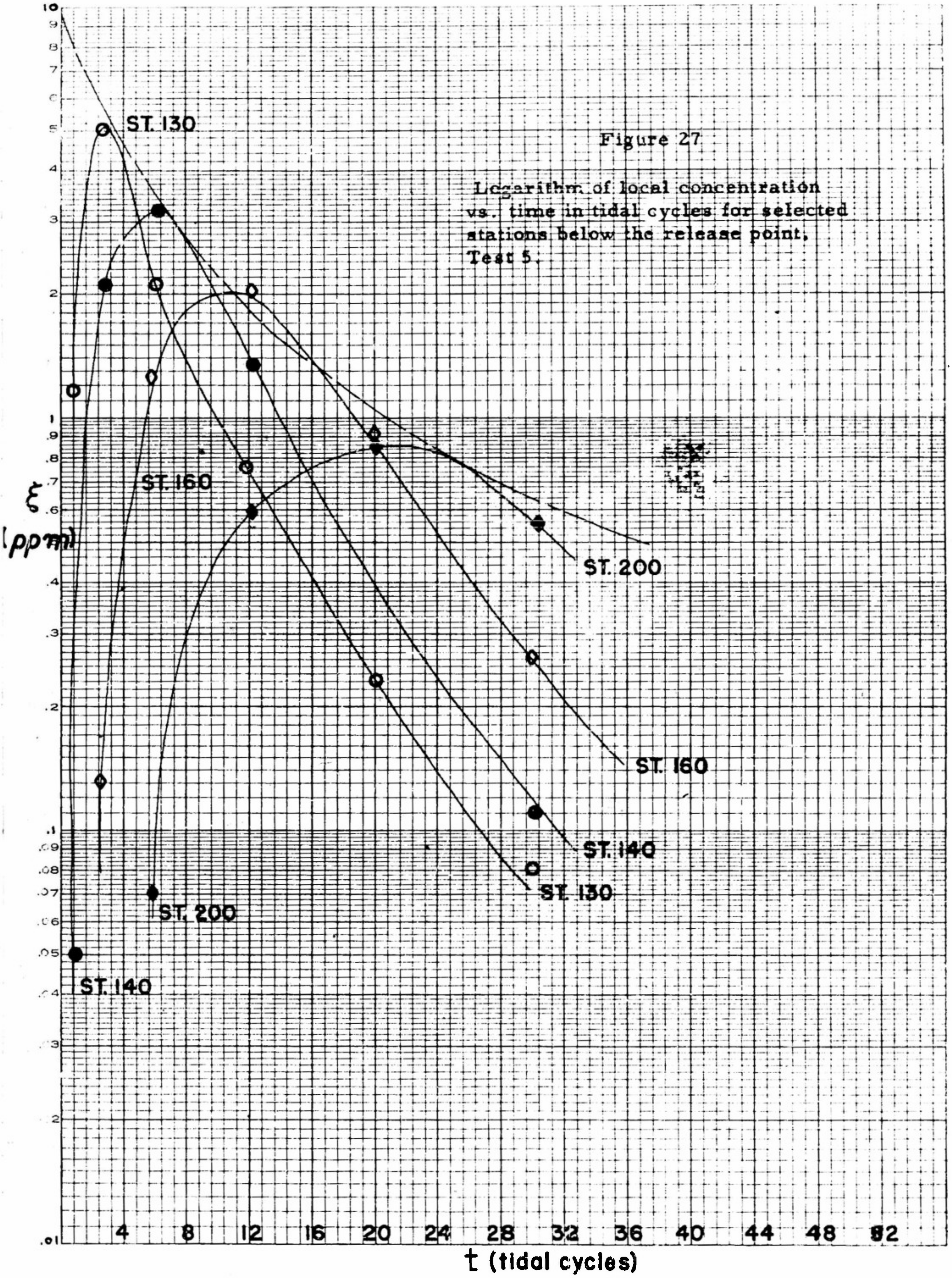


Figure 27

Logarithm of local concentration vs. time in tidal cycles for selected stations below the release point, Test 5.

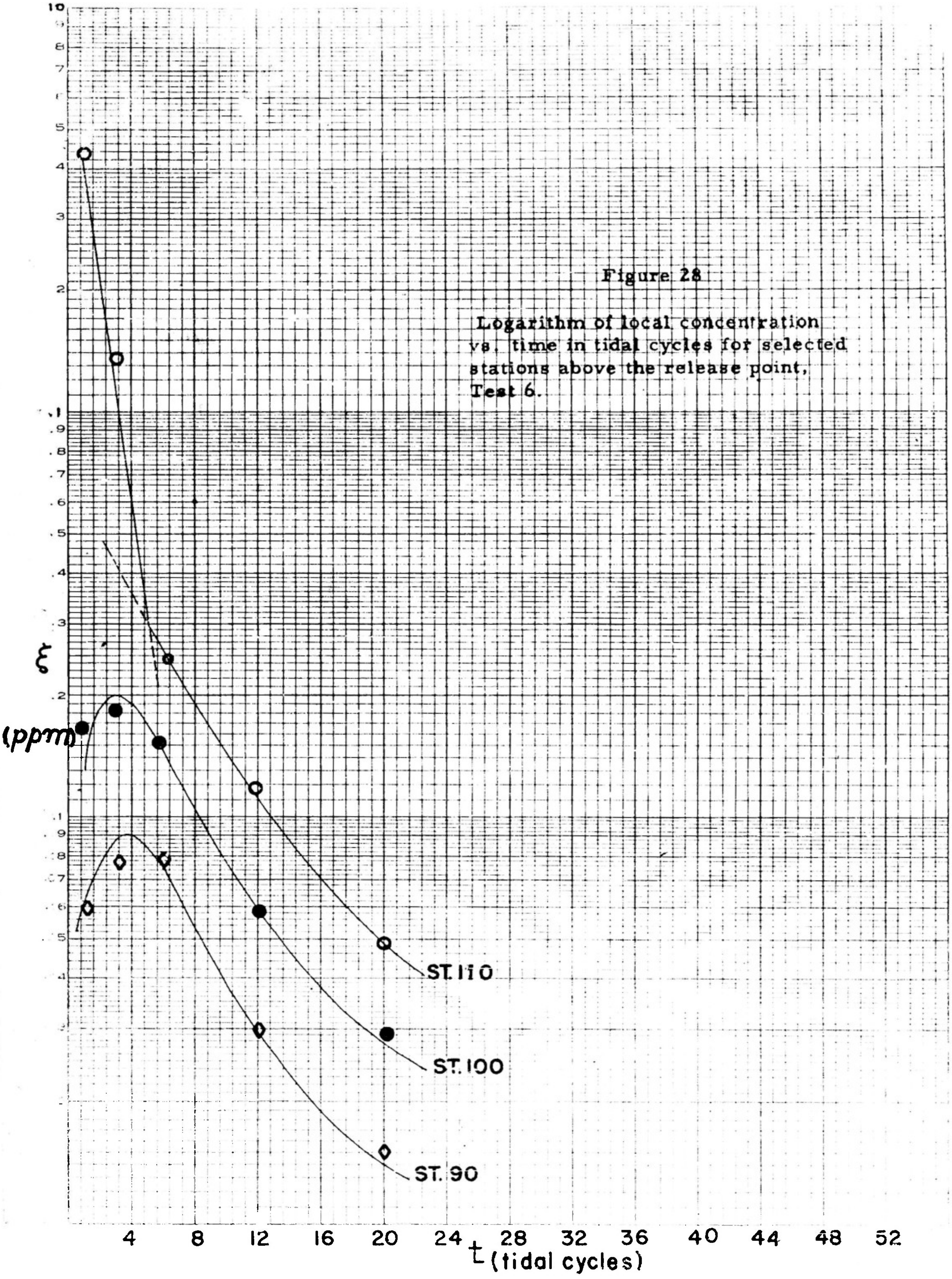


Figure 28

Logarithm of local concentration vs. time in tidal cycles for selected stations above the release point, Test 6.

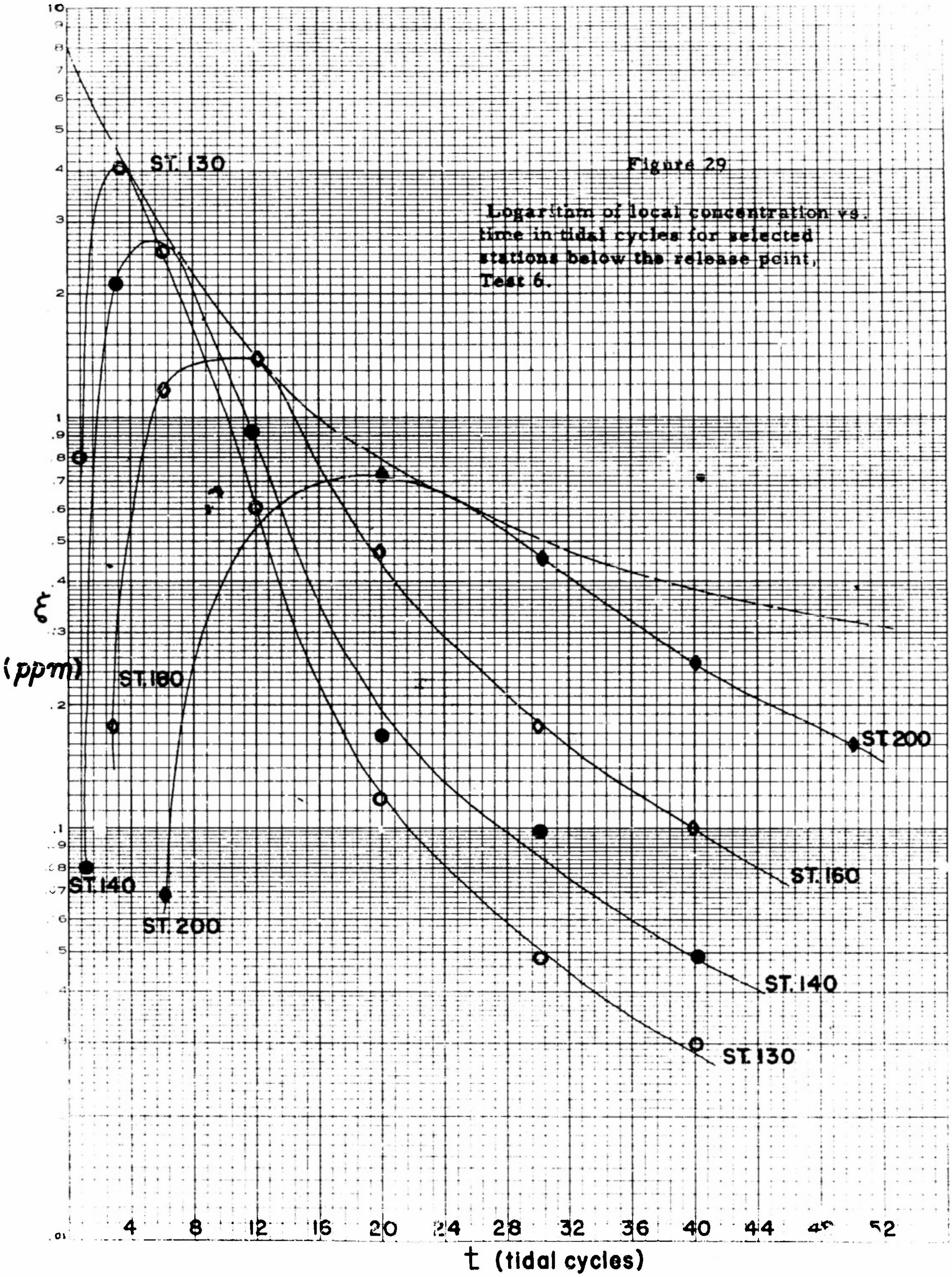


Figure 29

Logarithm of local concentration vs. time in tidal cycles for selected stations below the release point, Test 6.

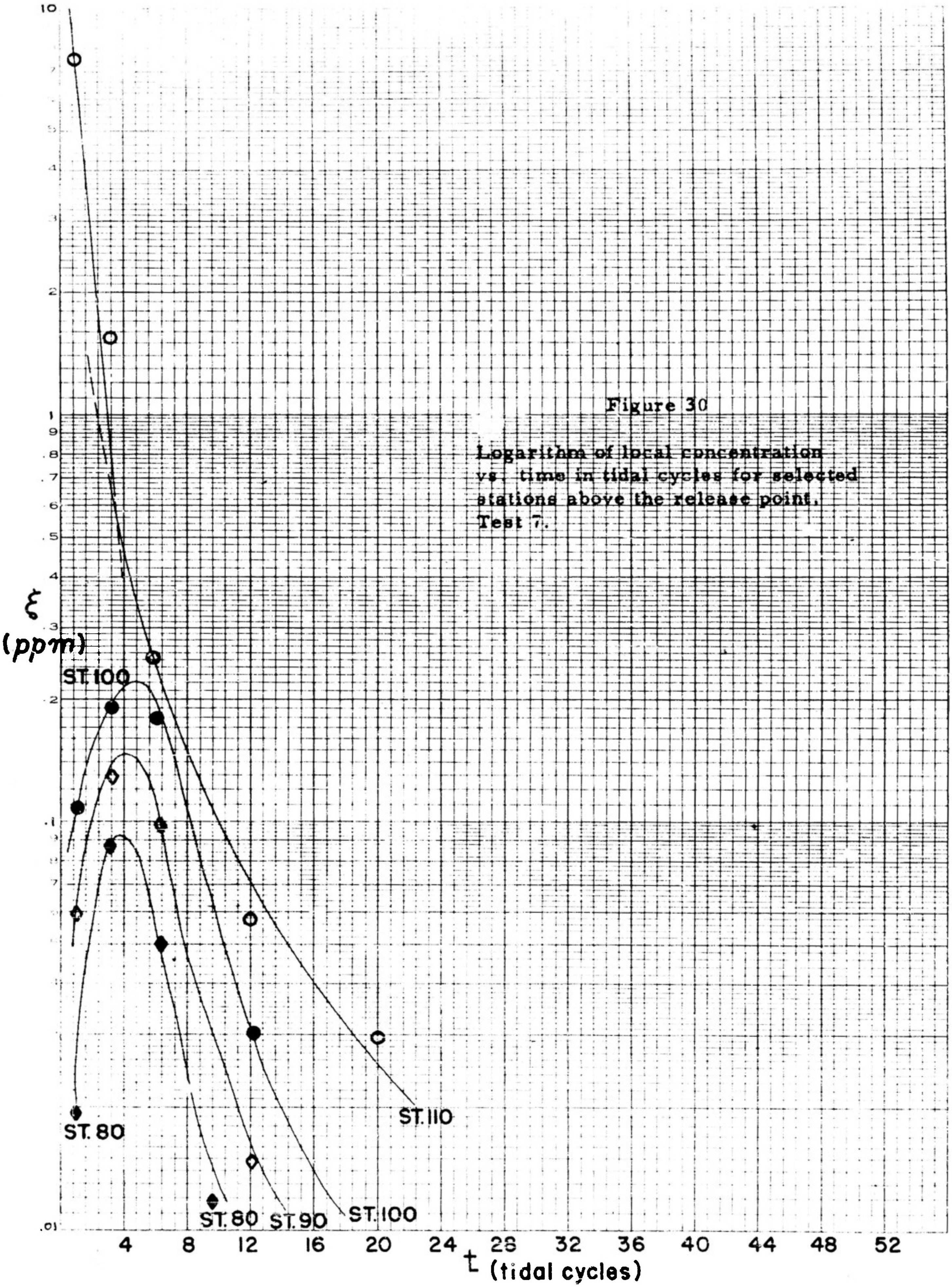


Figure 30

Logarithm of local concentration vs. time in tidal cycles for selected stations above the release point. Test 7.

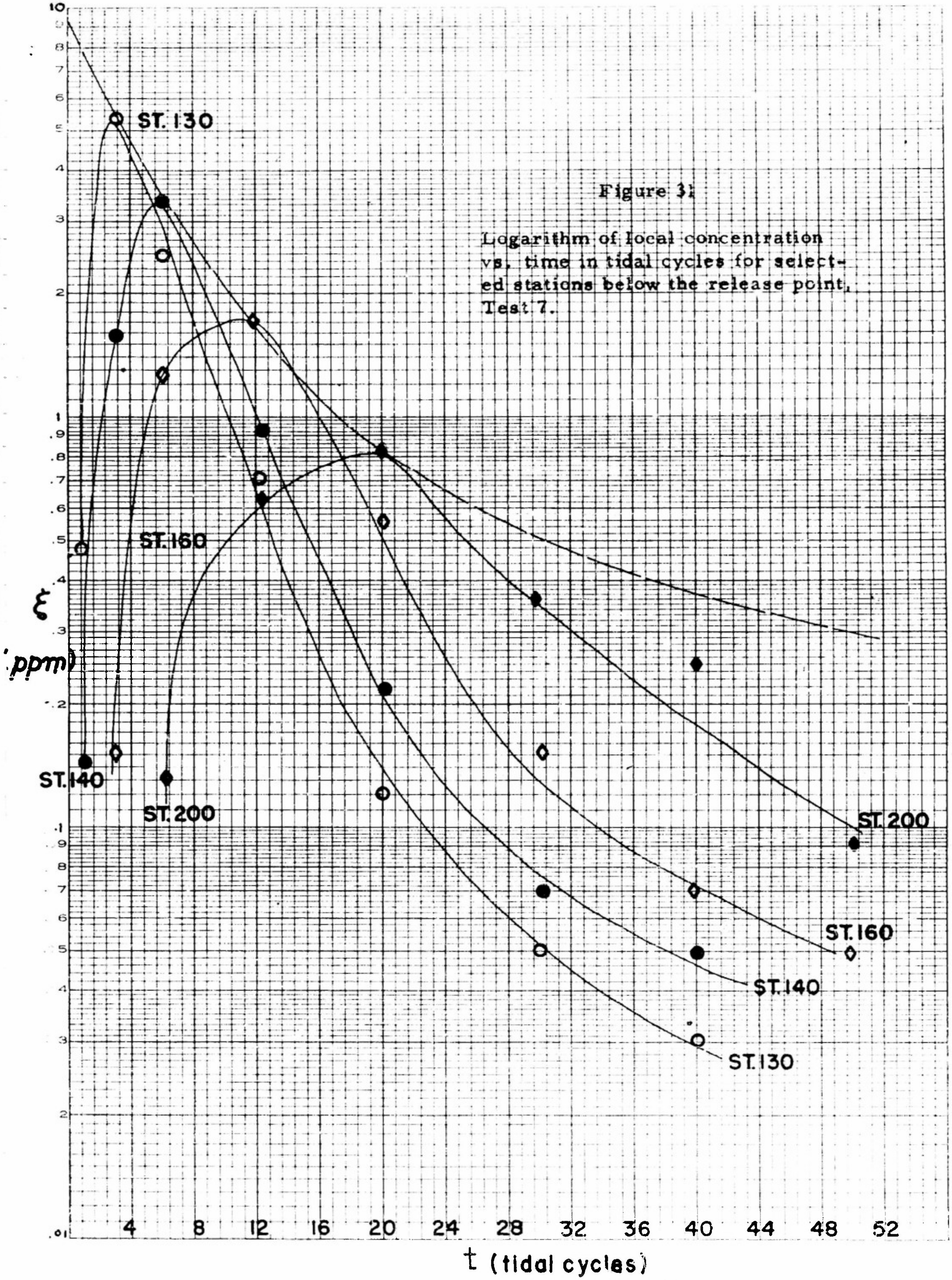


Figure 31

Logarithm of local concentration vs. time in tidal cycles for selected stations below the release point, Test 7.

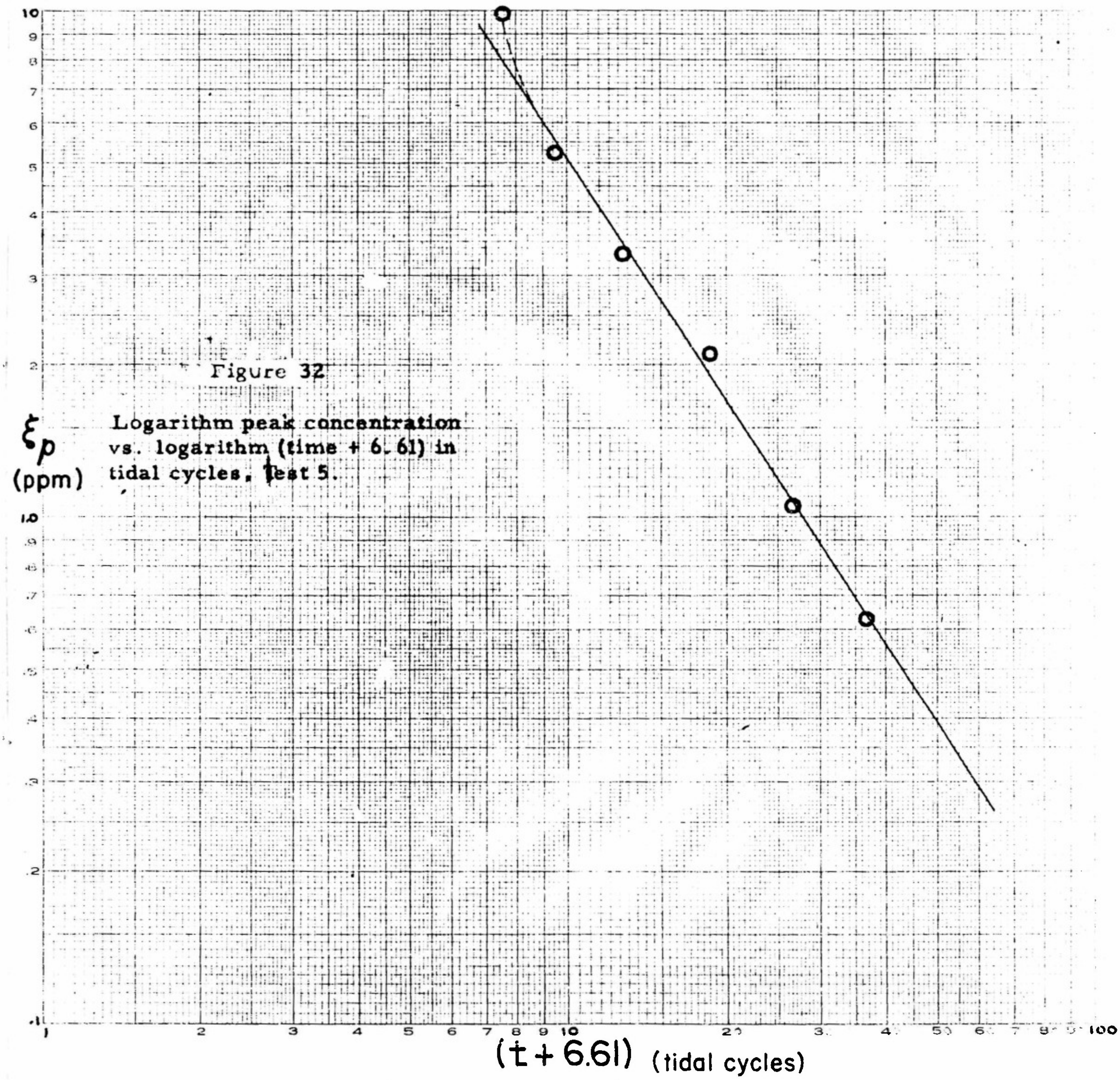


Figure 32
Logarithm peak concentration vs. logarithm (time + 6.61) in tidal cycles, test 5.
ξ_p
(ppm)
(t + 6.61) (tidal cycles)

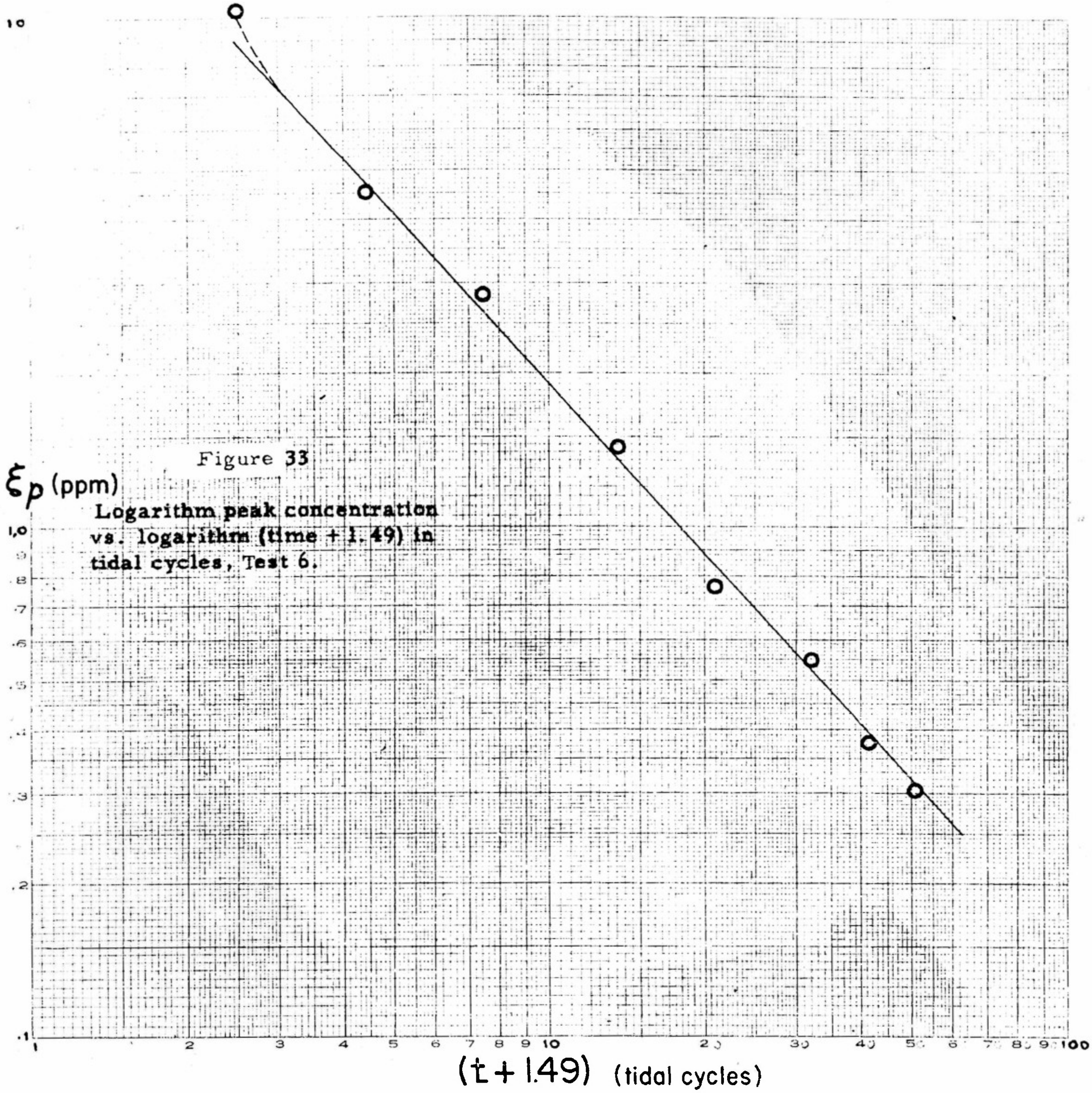


Figure 33

Logarithm peak concentration vs. logarithm (time + 1.49) in tidal cycles, Test 6.

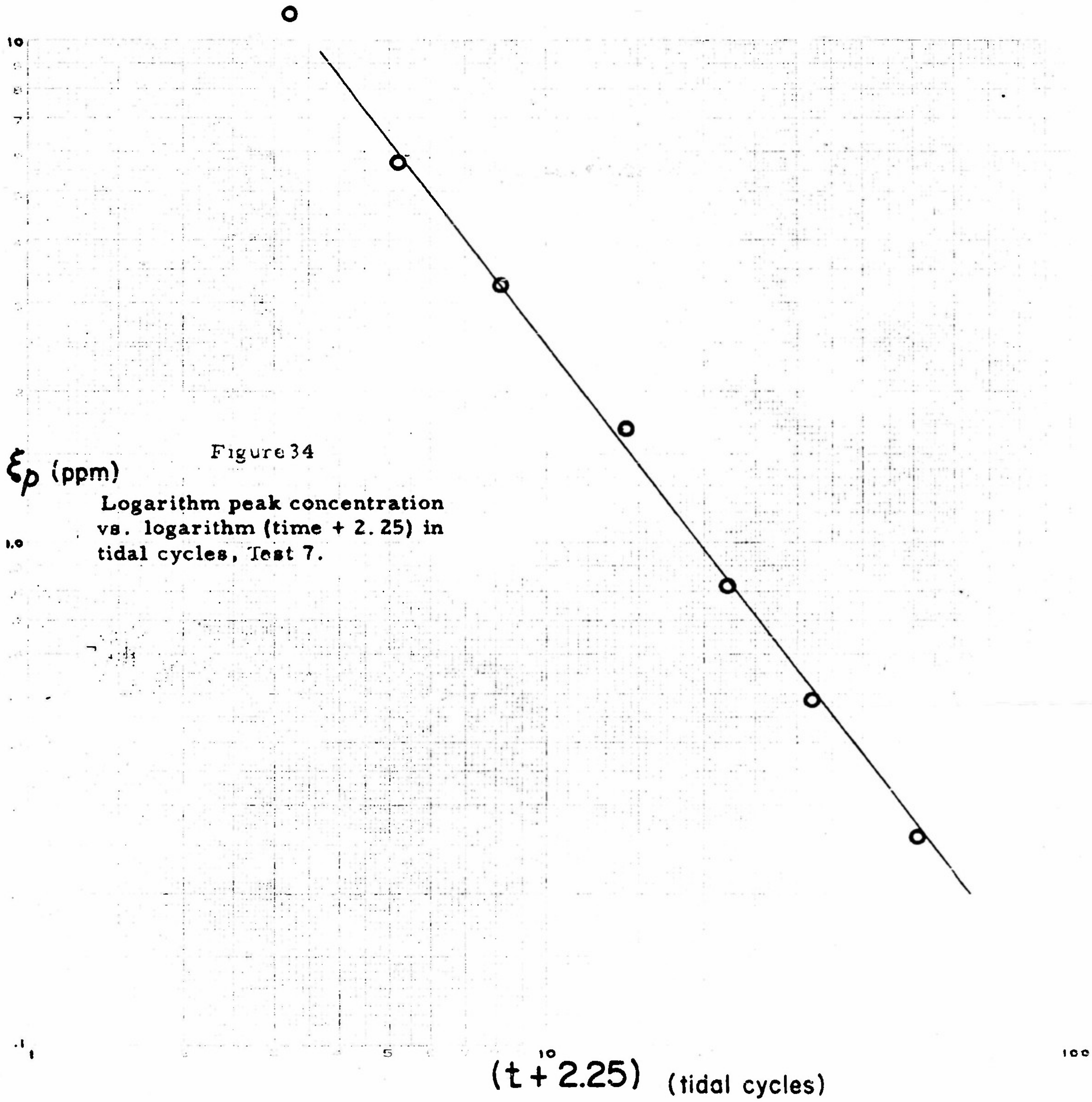


Figure 34

Logarithm peak concentration vs. logarithm (time + 2.25) in tidal cycles, Test 7.

APPENDIX I

Description of the Dye Release Gear, the Water Sampling Equipment, the Method of Sampling, and the Determination of Dye Concentration

Dye Release Gear

The gear used to release the methylene blue used in these experiments is shown in Figure A-I-1. It consists of an open brass cylinder held firmly against a rubber lined base by means of a two inch wide bar and two outrigged rods. The rods were screwed into threaded holes in projections of the bottom piece, and pulled down on the two inch bar which was placed across the top of the cylinder. The bottom of the cylinder was thus drawn tightly down on the rubber sheet which was bonded to the base and leakage from the container was prevented.

At the appropriate release point a recess was made in the bottom of the model of just the correct size and shape to hold the bottom piece of the container. The depth of the water at the release point was accurately measured at high water, and the height of dye in the container was made to agree with this depth of water.

During the flooding tide just prior to the release time the dye container was introduced into the model, the bottom piece resting in the recession. The rods were unscrewed from the bottom and withdrawn, while one man held his foot securely on the rod across the top of the container, bearing down with sufficient force to prevent leakage of dye from the bottom of the container. At precisely high water slack of the tidal period chosen for release, the cylinder, now no longer secured to the bottom piece, was lifted quickly but carefully upward from the model, leaving the bottom piece remaining in the recess in the model bottom, and the cylindrical dye volume suspended in the water of the model. Since the recess had been made to just fit the bottom piece of the container, the bottom of the model with the bottom piece in place was without any indentation or protrusion resulting from the release of the dye.

Sampling Equipment

Since the model has a vertical scale of 1 to 100, 0.01 foot of depth in the model corresponds to 1 foot of depth in the prototype. The sampling equipment, therefore, had to be made relatively small so as not to interfere with the flow.

The basic unit of the sampling gear was a thin glass tube, bent at a right angle near the end and drawn to an elongated point. The glass tubing was connected by plastic tubing to a 50 ml syringe. The assembly could be operated by hand as a single unit, or grouped together with other similar assemblies to give a multiple depth sampler. In any case the glass tubing was taped to a metal rod so that the metal rod projected at least a slight amount below the lowest glass tip.

In the single unit hand samplers, the glass tube was taped to the metal rod so that the bent tip was about 0.2 ft from the bottom of the rod corresponding to a prototype distance above the bottom of 20 ft. In this manner the rod could be placed with its end on the bottom at the desired sampling position in mid channel and the sample would be drawn from about middepth, since the channel up to Philadelphia is maintained at the prototype depth of 40 feet.

The multi-depth sampling gear is shown in Figure A-I-2. The glass tubes were taped to a metal rod so that the bent tips occurred at appropriate intervals -- usually surface, middepth, and bottom. The rod was part of a tripod assembly usually employed in measuring the surface elevation of the water in the model, and the sampling assembly was thus supported in position by the tripod. The plastic tubes leading from the three glass tubes were connected to three 50 ml syringes secured to a wooden rack. The pistons for the syringes were all clamped to a wooden bar, which in turn was connected to a cable leading over a pulley at the top of the wooden rack. This cable was attached to a bar secured to three household rattraps.

A spring latch held the three rattraps, which were connected in the open or "set" position. In this position the cable was just taut with the pistons in the syringe all the way in. When the latch was released, the spring on the rattraps would pull down on the cable, and, hence, up on the syringes and the sample would be drawn.

In Test 1-A, use was made of a motor driven multi-sampler which took eleven simultaneous samples, drawing the sample evenly over the 7-1/2 minute tidal period of the model. This mechanism was not employed after the first test, since there was some difficulty in fitting the results from these samples with the samples taken at high water slack.

Sampling Procedure

Before introduction of the dye, the rattrap samplers were set up at appropriate stations above and below the release point. Other locations were chosen where single hand-drawn samples were to be obtained. On selected high water slack periods, subsequent to the release, samples were collected at the designated positions.

Since the tide in the Delaware is partially progressive, a particular phase of the tide occurs downstream first and can be followed up the Bay and the River. Small strips of paper were strewn on the surface of the model, and the time of high water slack determined at each particular station by noting the time when these floats stopped moving upstream. Thus, the sampling was not simultaneous at all stations, but related to the tidal stage, the first samples being taken at the downstream edge of the spread of the dye, and the last samples for any particular tidal cycle at the upstream end of the spread. With several individuals participating in the sampling, it was quite possible to keep pace with the progressing tidal phase as it moved upstream.

The samples were transferred from the syringes into wide mouth quart jars. As will be pointed out in a later appendix, this was far from the most satisfactory procedure. The jars were then assembled for analysis.

Determination of the Dye Concentration

The concentration of dye was determined photometrically using both a Beckman model DU spectrophotometer and a Coleman spectrophotometer.

At the beginning of each run a sample was taken from the dye volume to be introduced, and appropriate volumetric dilutions were made from this sample. The Beers-law calibration curve of adsorption versus concentration was then obtained for each instrument, using the diluted samples.

Samples of water from the model were also drawn prior to the dye introduction to serve as blanks in the calibration.

The ground around the model is quite dusty, and even though the model is well washed down between tests, there occurs in the model water some suspended material which appeared to interfere with the determination of low concentrations. The procedure employed in eliminating this difficulty is essentially the procedure described by Carritt and Carpenter (1951) in their paper on corrections for turbidity interference in chlorophyll analysis.

The procedure depends upon the contrast between the extinction curve due to the dye and the extinction curve resulting from the turbidity. This difference is shown in Figure A-I-3. The broken line A represents schematically the extinction curve for the dye in distilled water. This curve is characterized by a sharp maximum in the extinction at a wave length of 665 $m\mu$. The dashed line B is representative of the typical extinction curve resulting from turbidity. This curve shows a steady decrease with wave length, with no characteristic adsorption peak.

The addition of these two curves gives curve C, drawn as a continuous line. The typical extinction curve for the dye is moved up and modified somewhat by the turbidity.

Normally the extinction E_m at the characteristic wave length λ_m is taken as proportional to the concentration. However, if the sample is somewhat turbid, the resulting extinction E_m' would indicate a larger dye concentration than actually existed. If two points, E_a and E_b are taken on the dye extinction curve well away from the peak extinction at wave lengths λ_a and λ_c respectively, and E_c is the linear interpolation between E_a and E_b at wave length λ_m then the distance E_c to E_m is also proportional to the concentration. However, the distance $E_m - E_c$ is approximately equal to the distance $E'_m - E'_c$ on the combined extinction curve for both dye and turbidity.

The procedure calls for running a calibration curve of the difference, $E_m - E_c$ versus concentration. To do this, measurements are made of the extinction readings at the three wave lengths λ_a, λ_m, and λ_b. From the extinctions E_a and E_b the correction E_c can be obtained since

$$E_c = E_a - (E_a - E_b) \frac{\lambda_m - \lambda_a}{\lambda_b - \lambda_a}$$

The difference $E_m - E_c$ is then taken as proportional to the concentration. The unknown samples are analyzed in the same manner, and hence the influence of the turbidity is essentially eliminated.

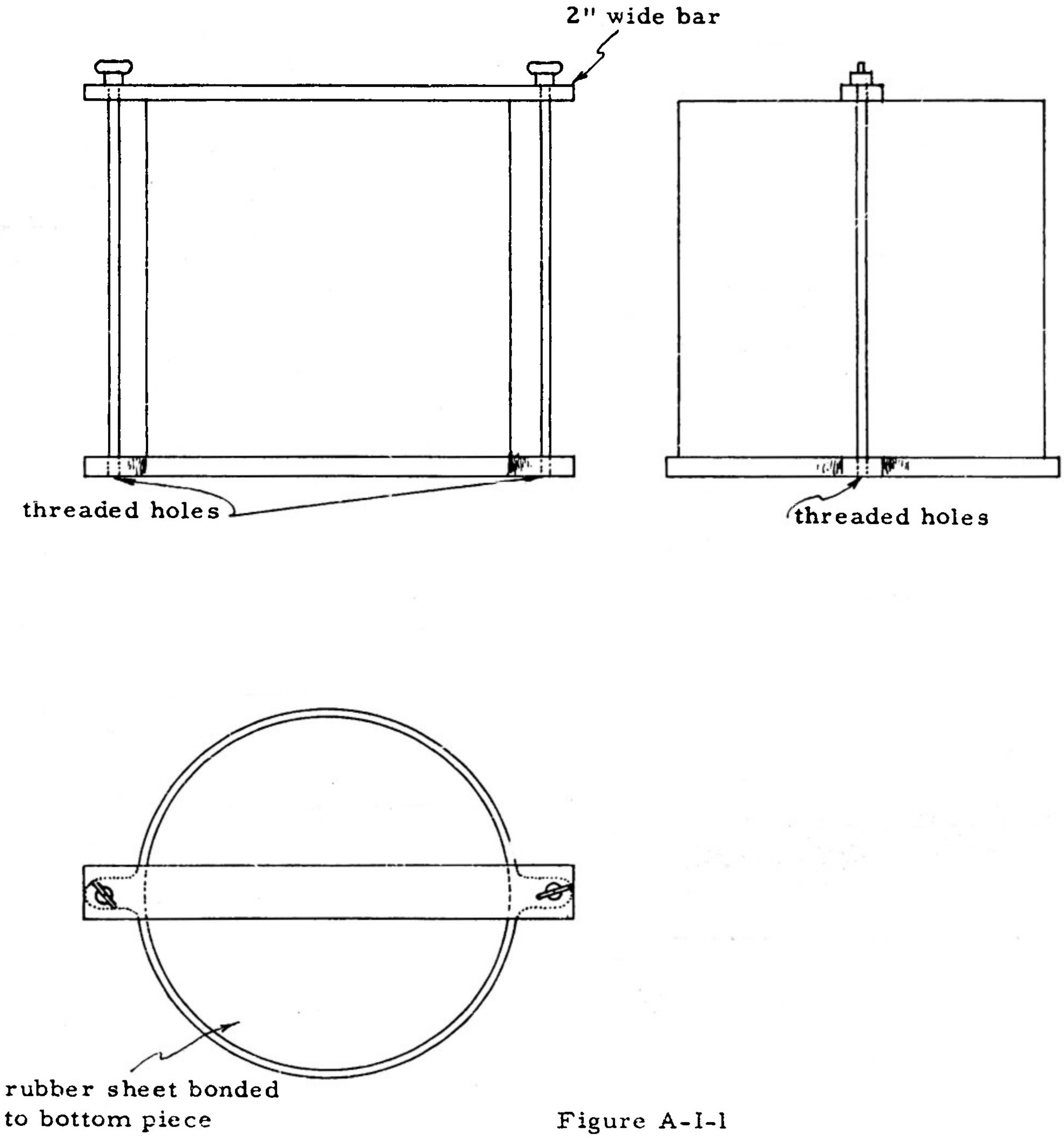


Figure A-I-1

Schematic drawing of dye release gear

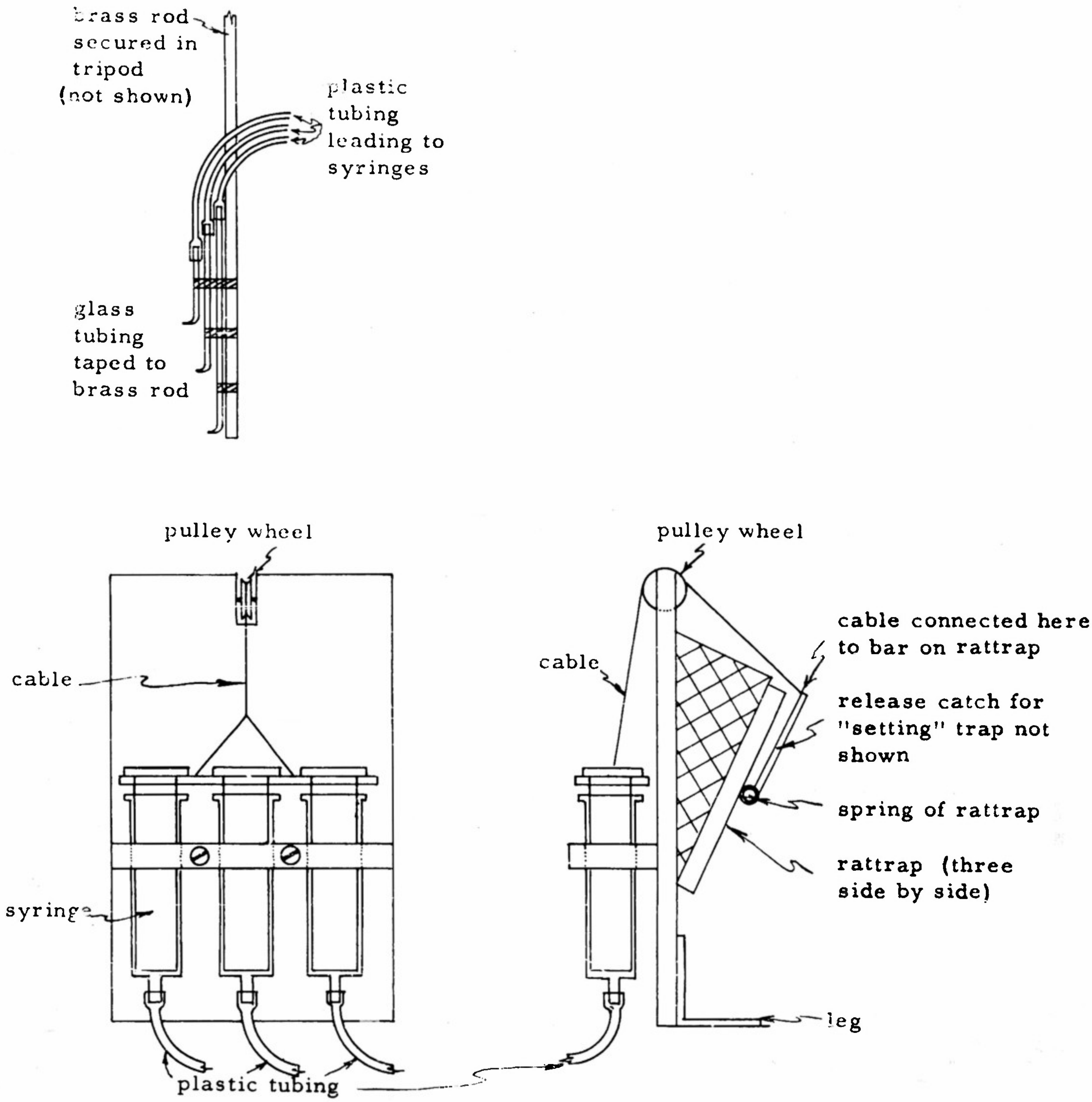


Figure A-I-2. Three depth rattrap sampler

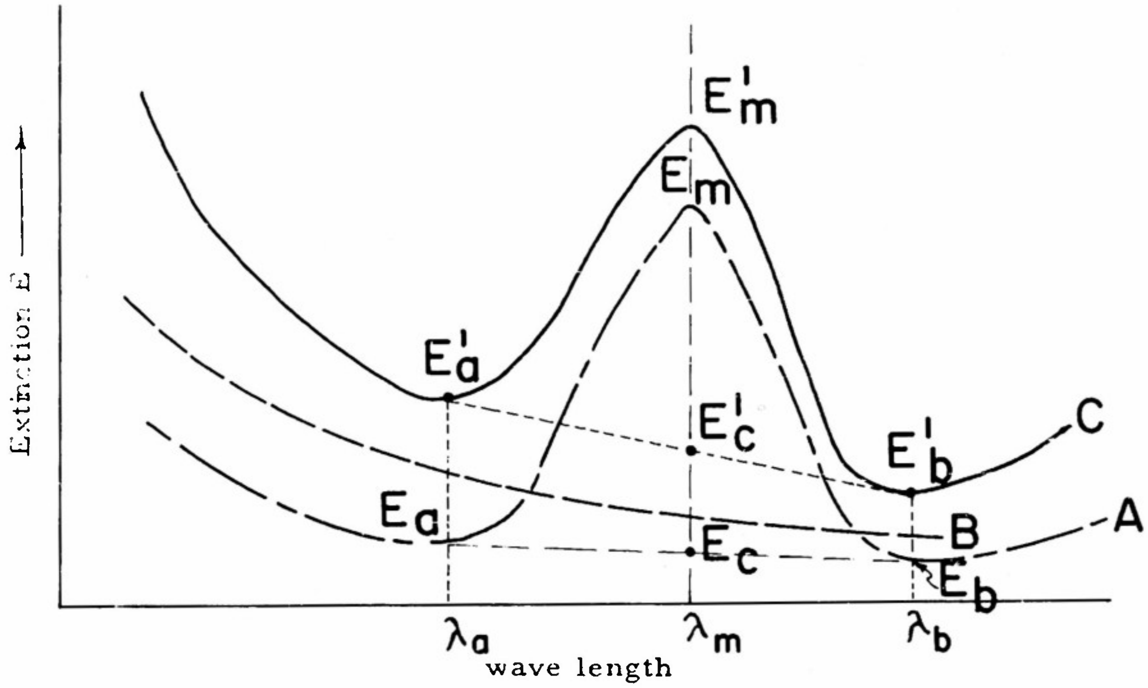


Figure A-I-3. Effect of turbidity (curve B) on the extinction of dye. The curve for the dye in distilled water is A, and in water of turbidity given by curve B the combined extinction curve is given by C. The distance (E_m - E_c) is, however, approximately equal to (E'_m - E'_c), and may also be expressed as a function of dye concentration.

APPENDIX II

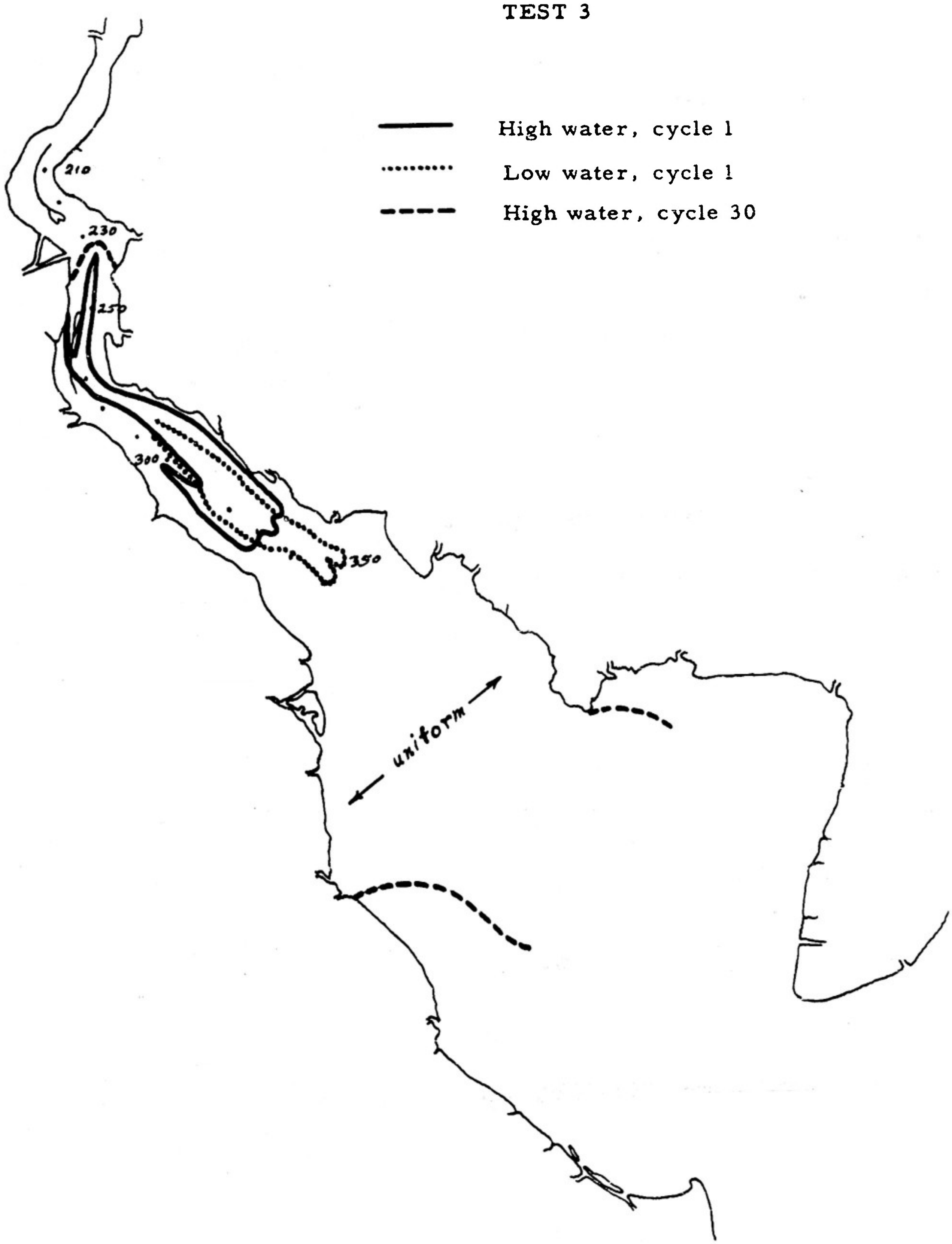
Visual Observations of the Spread of the Dye. Tables of Observed Dye Concentrations.

For Tests 3 through 7 the location of the visible limits of the dye was noted and charts were made during the tests. Notes were also made of any interesting features that were observed. These charts are presented in this appendix.

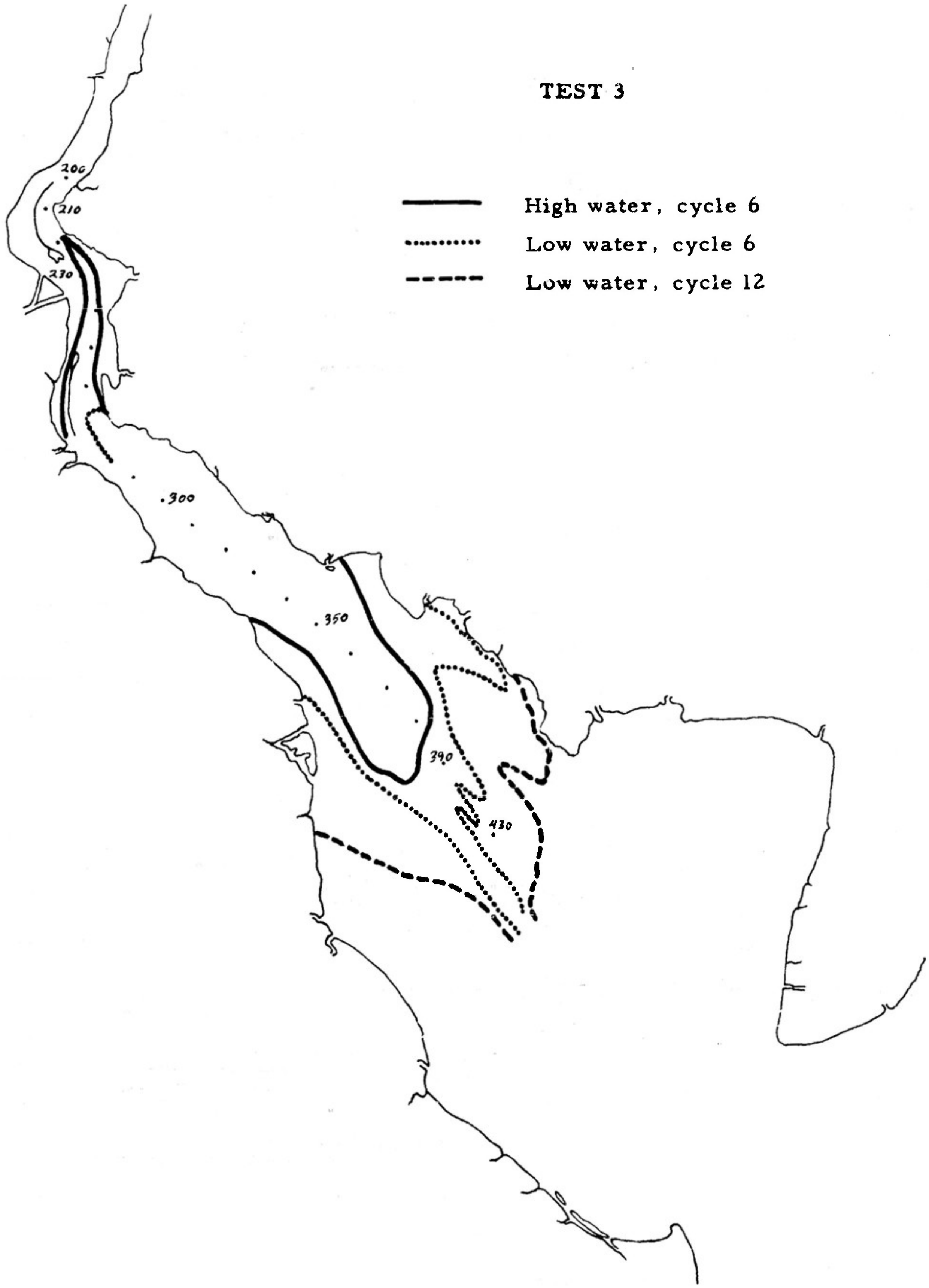
It was found that the limits of the dye concentration as determined visually corresponded to an average concentration of less than 0. 1 ppm. This corresponds to more than a ten thousand fold dilution of the initial concentration.

This appendix also contains tables of the observed dye concentrations.

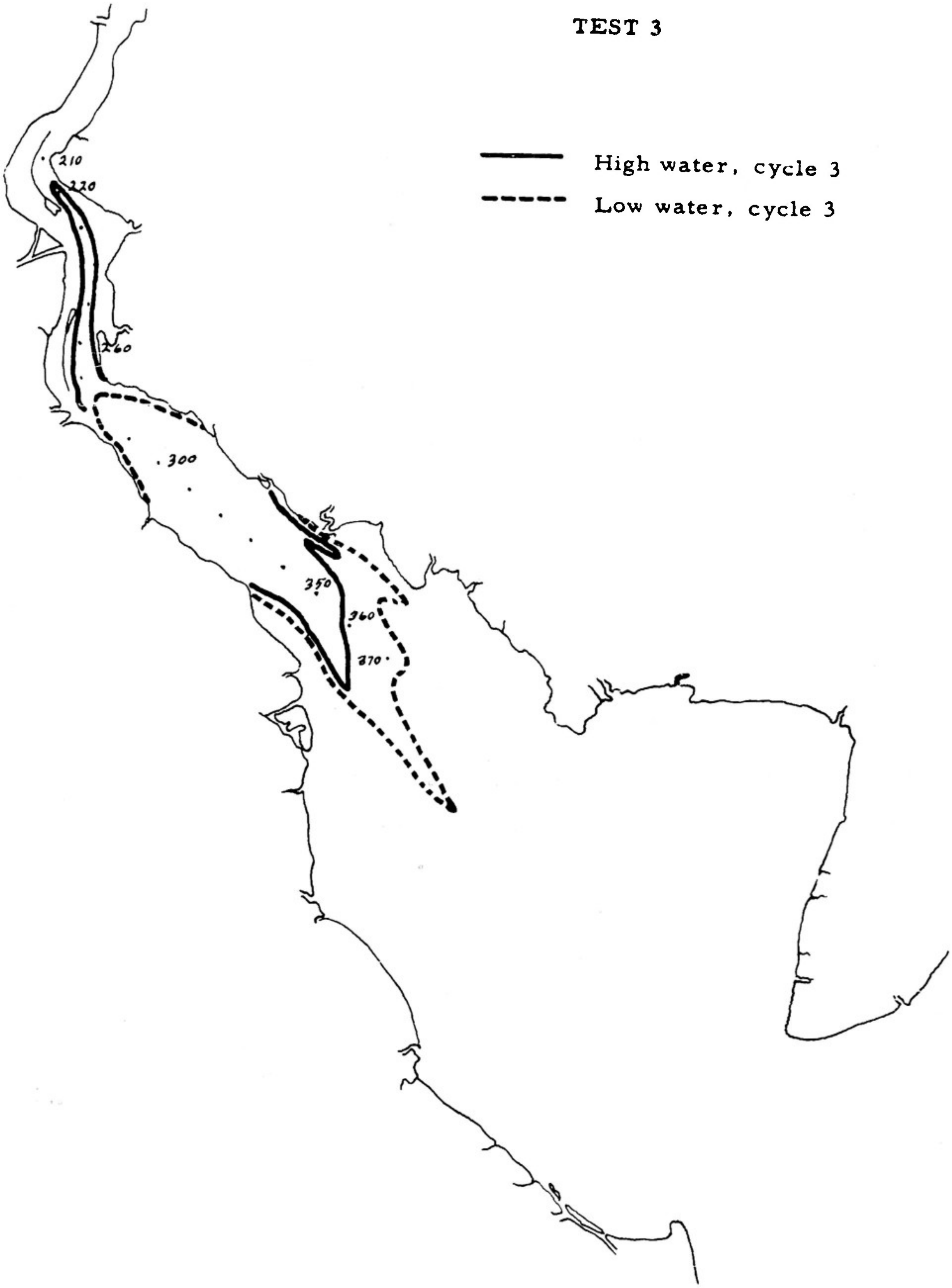
TEST 3


High water, cycle 1
Low water, cycle 1
High water, cycle 30
210
230
250
300
350
uniform

TEST 3

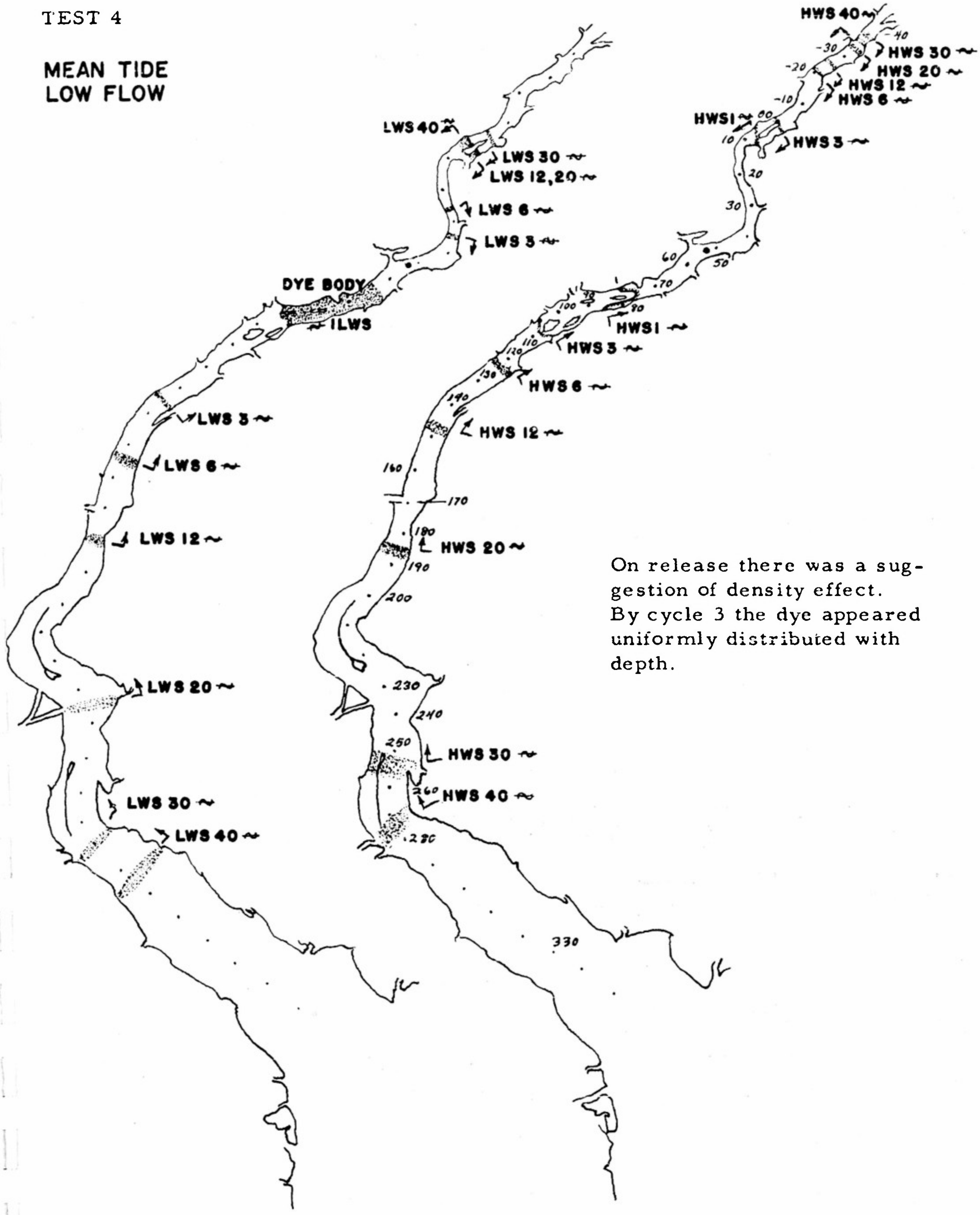

High water, cycle 6
Low water, cycle 6
Low water, cycle 12
200
210
230
300
350
390
430

TEST 3


High water, cycle 3
Low water, cycle 3
210
220
260
300
350
360
370

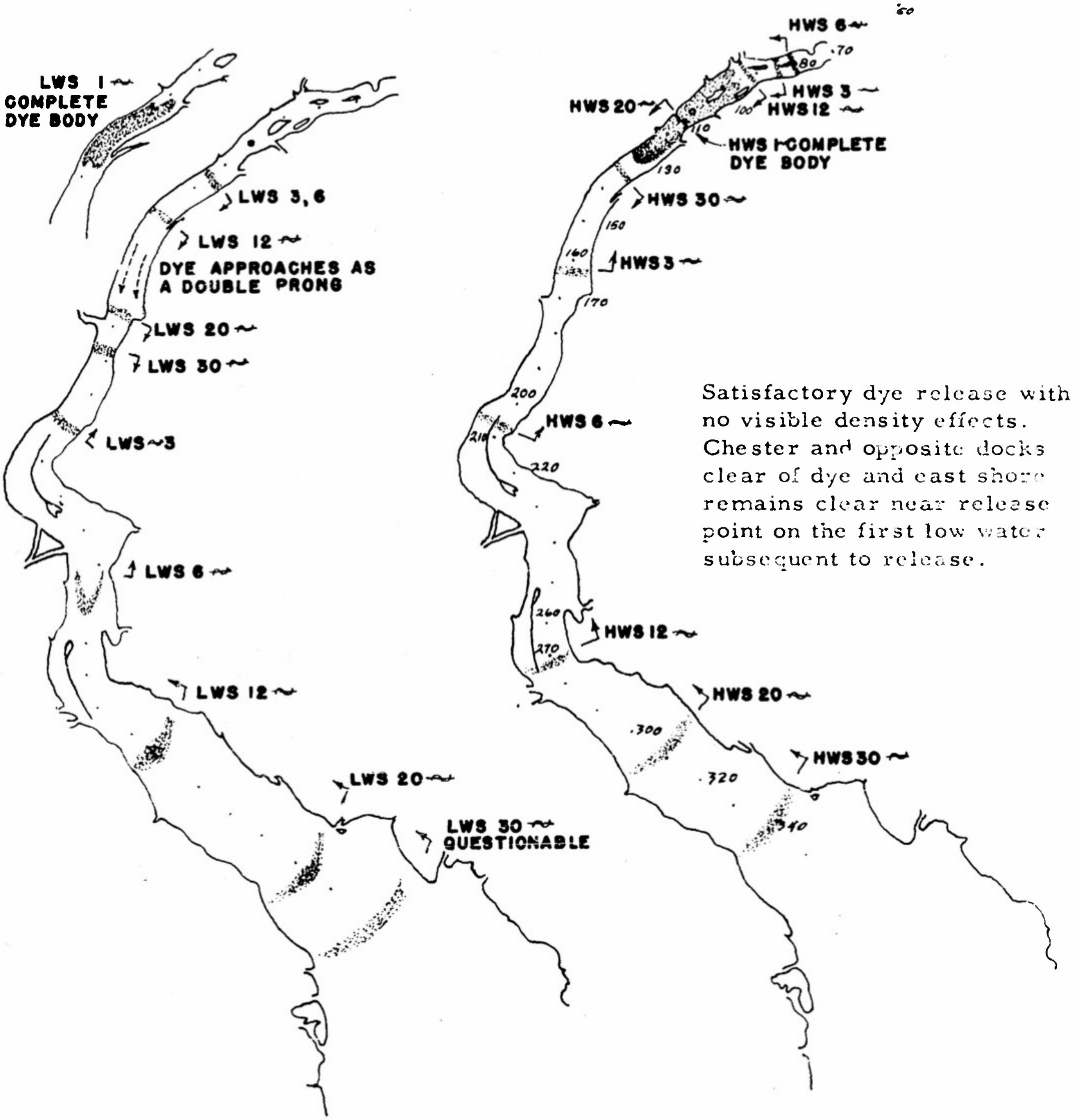
TEST 4

MEAN TIDE
LOW FLOW



On release there was a suggestion of density effect. By cycle 3 the dye appeared uniformly distributed with depth.

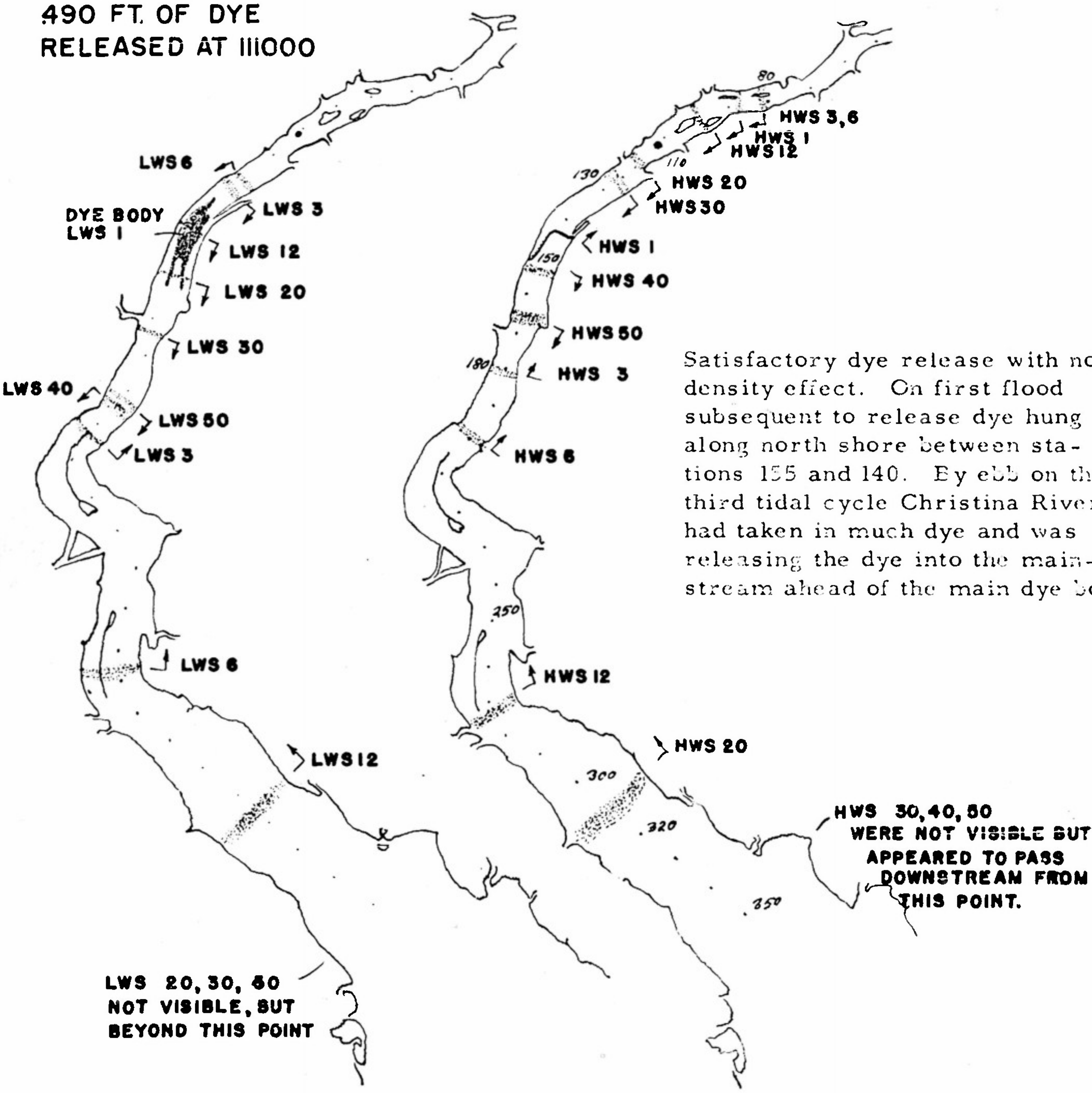
TEST 5
MEAN TIDE
MEAN FLOW
RELEASE AT CHESTER. 111+000



Satisfactory dye release with no visible density effects. Chester and opposite docks clear of dye and east shore remains clear near release point on the first low water subsequent to release.

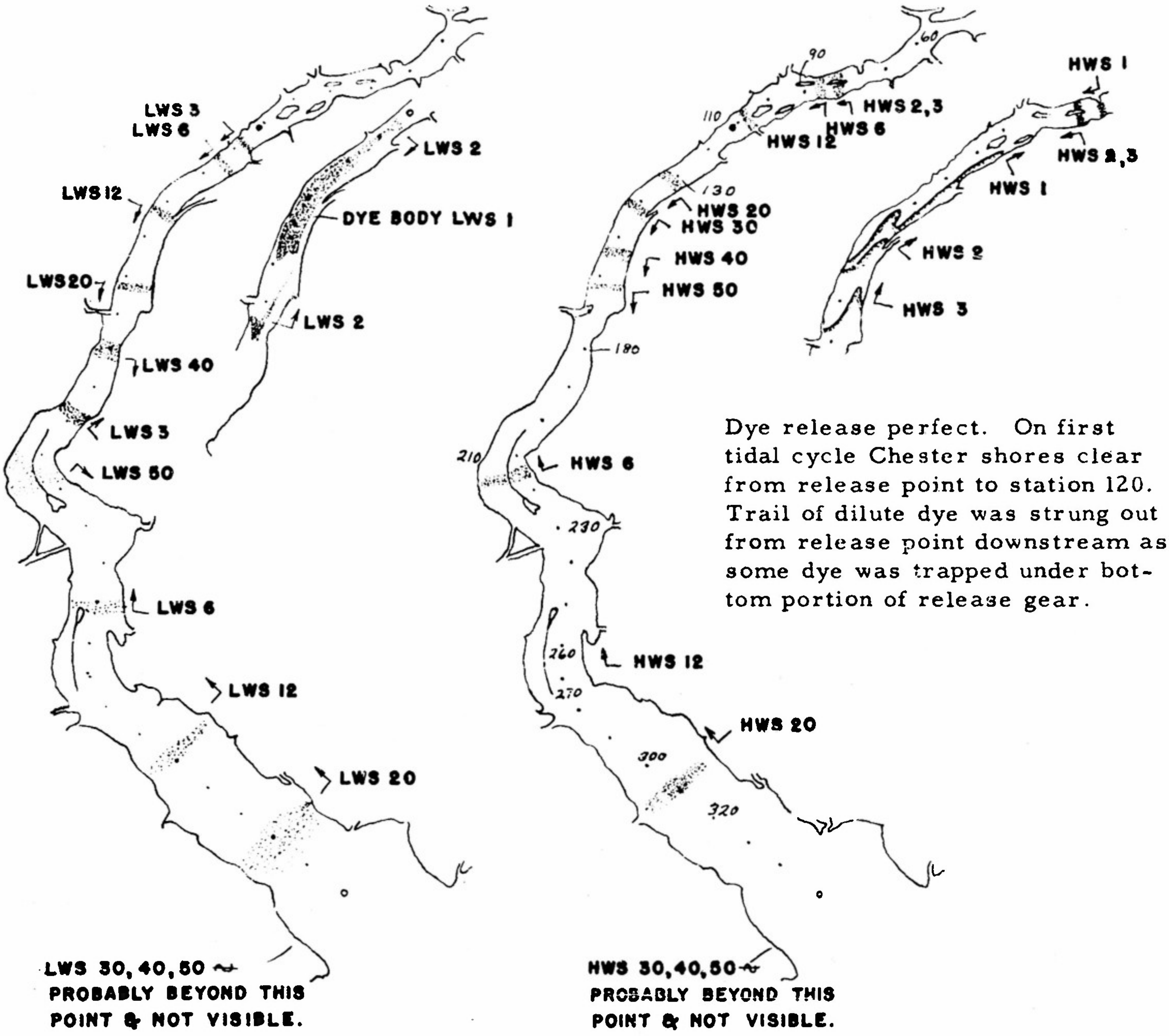
TEST 6

SPRING TIDE
MEAN FLOW
490 FT. OF DYE
RELEASED AT 111000



Satisfactory dye release with no density effect. On first flood subsequent to release dye hung along north shore between stations 155 and 140. By ebb on the third tidal cycle Christina River had taken in much dye and was releasing the dye into the mainstream ahead of the main dye body.

TEST 7



Dye release perfect. On first tidal cycle Chester shores clear from release point to station 120. Trail of dilute dye was strung out from release point downstream as some dye was trapped under bottom portion of release gear.

TEST 1-A

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 1	30	M	.084
	52.5	S	5.82
		M	6.38
		B	5.92
TIDAL CYCLE 2	13	S	.006
		M	.037
		B	.075
	30	M	.300
	52.5	S	4.05
		M	4.10
		B	4.21
	75	M	1.22
TIDAL CYCLE 4	-10	M	.006
	52.5	S	1.30
		M	1.18
		B	1.33
	127W*	S	.647
		M	.587
		B	.681
	127*	S	.612
		10 ft	.453
		20 ft	.702
		30 ft	.466
		B	.480
	127E*	S	.447
		B	.379
	127EE*	M	.193

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 8	-10	M	.006
	13	S	.023
		M	.033
		B	.016
	30	M	.071
	52.5	S	.469
		M	.374
		B	.456
	75	M	1.64
	100	M	.171(?)
	127W*	S	1.53
		M	1.28
		B	1.11
	127*	S	1.37
		10 ft	1.63
		20 ft	1.68
		30 ft	1.52
		B	1.51
	127E*	S	1.19
		B	1.33
	127EE*	M	1.22
	160	M	.006

*Integrated sample over complete tidal cycle

TEST 1-A

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 16	-10	M	.000
	13	S	.004
		M	.000
		B	.018
	30	M	.032
	52.5	S	.143
		M	.135
		B	.183
	100	M	.559
	127W*	S	.687
		M	.688
		B	.753
	127*	S	.768
		10	.853
		20	.766
		30	.867
		B	.836
	127E*	S	.678
		B	.848
	127EE*	M	.748
	160	M	.362
	200	M	.045
	240	M	.024
	280	M	.016
TIDAL CYCLE 22	52.5	S	.060
		M	.075
	75	M	.083
	100	M	.185
	127W*	S	.246
		M	.253
		B	.285
TIDAL CYCLE 22 (cont'd)	127*	S	.386
		10	.426
		20	.330
		30	.381
		B	.329
	127E*	S	.381
		B	.375
	127EE*	M	.396
	160	M	.439
	200	M	.194
	240	S	.116
		M	.083
		B	.072
	280	M	.007
TIDAL CYCLE 28	75	M	.011
	100	M	.047
	127W*	S	.098
		M	.083
		B	.111
	127*	S	.107
		10	.127
		20	.118
		30	.122
		B	.100
	127E*	S	.100
		B	.136
	127EE*	M	.128
	160	M	.418
	200	S	.277
		M	.275
		B	.277
	240	S	.278
		M	.110
		B	.073
	280	M	.042

TEST 1-A

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 34	100	M	.031
	127W*	S	.041
		M	.051
		B	.050
	127*	S	.051
		10	.051
		20	.062
		30	.046
		B	.045
	127E*	S	.032
		B	.061
	127EE*	M	.045
	160	M	.300
	200	S	.268
		M	.227
		B	.240
	240	S	.185
		M	.150
		B	.115
	280	M	.051
	315	M	.011
TIDAL CYCLE 40	127	M	.038
	160	M	.1[illegible]2
	200	S	.202
		M	.228
		B	.227
	240	S	.157
		M	.142
		B	.125
	280	M	.056
	315	M	.017
TIDAL CYCLE 40 (cont'd)	127	M	.033
	127EE	M	.031
	160	M	.113
	200	S	.130
		M	.156
		B	.138
	240	S	.125
		M	.127
		B	.097
	280	S	.113
		M	.073
		B	.097
	315	S	.038
		M	.008
		B	.026
	350	M	.011
	C&D Canal	M	.058
TIDAL CYCLE 49	315	S	.045
		M	.024
		B	.024
TIDAL CYCLE 52	127	M	.004
	160	M	.031
	200	S	.098
		M	.093
		B	.084
	240	S	.074
		M	.083
		B	.077
	280	S	.062
		M	.046
		B	.058
	315	S	.037
		M	.016
		B	.021
	350	M	.011

TEST 1-A

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 54½	280	S	.107
		M	.073
		B	.078
	315	S	.061
		M	.032
		B	.032
	350	M	.032
TIDAL CYCLE 58	160	M	.019
	200	S	.011
		M	.032
		B	.017
	240	S	.047
		M	.075
		B	.042
	280	S	.055
		M	.044
		B	.044
	280EE	M	.081
	315	S	.038
		M	.027
		B	.027
	350	M	.019

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 64	200	S	.000
		M	.024
		B	.004
	240	S	.012
		M	.019
		B	.024
	280	S	.016
		M	.010
		B	.010
	280EE	M	.004
	280E	M	.002
	315	S	.000
		M	.000
		B	.000
	350	M	.000

TEST 1

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 1	54	S(c)	7.87
		M(c)	6.10
		B(c)	4.37
	54R	M(c)	2.84
	54L	M(c)	6.02 *
	60	S(c)	6.30
		M(c)	8.45
		B	- *
	70	S(c)	.795
		M(c)	.550
		B(c)	1.60
	80	S	n.d.
		M	n.d.
		B	n.d.
TIDAL CYCLE 2	54	S(c)	3.05
		M	- *
		B(c)	.698
	54R	M(c)	1.63
	54L	M(c)	2.25*
	60	S(c)	4.42
		M(c)	5.87
		B(c)	4.94
	70	S(c)	4.42
		M(c)	4.94
		B(c)	5.21
	80	S(c)	.848
		M(c)	1.80
		B(c)	2.14
	10	M	n.d.
	90	S	n.d.
		M	n.d.
		B(c)	.219
	100	S(c)	.493
		M(c)	.279
		D	n.d.

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 4	54	M	- *
	54R	M(c)	.618
	54L	M(c)	1.40
	60	M(c)	2.12
	70	M	- *
	80	M(c)	3.85
	10	M	n.d.
	0	M	n.d.
	90	M	- *
	100	M(c)	1.95*
	110	M(c)	.120*
	120	M	- *
TIDAL CYCLE 8	54	M	- *
	54R	M(c)	.064
	54L	M(c)	.205
	60	M	- *
	70	M(c)	.789
	80	M(c)	1.43
	90	M(c)	2.42
	100	M	- *
	110	M(c)	.888*
	120	M(c)	1.84
	130	S(c)	.377
		M	- *
		B	- *
	140	S	- *
		M	- *
		B	n.d.

*Evident adsorption of dye on sample bottle n.d.
Sample showed no visible evidence of dye--not run in photometer

TEST 1

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 8 (cont'd)	150	M	n.d.
	160	M	n.d.
TIDAL CYCLE 12	54	M(c)	.038
	60	M	- *
	70	M	- *
	80	M	- *
	90	M	- *
	100	M(c)	.675
	110	M(c)	1.38
	120	M(c)	1.90
	130	S M(c) B(c)	- * 1.23 1.60
	140	S(c) M B(c)	.990 - * .975
	150	S(c) M(c) B(c)	1.10 .813 .497
	160	M	- *
TIDAL CYCLE 16	54	M	n.d.
	60	M	n.d.
	70	M	n.d.
	90	M(c)	.175
	100	M	- *
	110	M	- *
	120	M(c)	.668

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 16 (cont'd)	130	S(c) M B(c)	.754 - * .620
	150	S M(c) B(c)	n.d. .493 .386
	160	S(c) M B(c)	.013 - * .447
	170	M	- *
	180	S M B	n.d. - * n.d.
	190	M(c)	.115
	200	M(c)	.085
	210	M	n.d.
	220	M	n.d.
	240	M	n.d.
TIDAL CYCLE 22	54	M	.020
	60	M	n.d.
	70	M	n.d.
	90	M	n.d.
	100	M	n.d.
	110	M	n.d.
	120	M(c)	.060
	130	M(c) B	.020 n.d.
	140	S M(c) B	n.d. .000 n.d.

TEST 1

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 22 (cont'd)	150	S	n.d.
		M(c)	.169
		B	n.d.
	160	S	- *
		B	- *
	170	M(c)	.352
	180	S	- *
		M(c)	.620
		B(c)	.352
	190	M(c)	.475
	200	S	n.d.
		M(c)	.000
		B	n.d.
	220	S	n.d.
		M(c)	.100
		B	n.d.
	240	M	n.d.
	260	M	n.d.
	280	M	n.d.
TIDAL CYCLE 28	90	M	n.d.
	100	M	n.d.
	110	M(c)	.013
	130	S	n.d.
		M	n.d.
		B	n.d.
	140	M(c)	.026
	150	S	n.d.
		M(c)	.026
		B	n.d.
	160	S(c)	.041
		B(c)	.065

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 28 (cont'd)	170	M(c)	.279
	180	S(c)	.175
		M(c)	.432
		B(c)	.386
	190	M	- *
	200	S	n.d.
		M(c)	.041
		B	n.d.
	220	S	n.d.
		M(c)	.210
		B	n.d.
	240	S(c)	.017
		M(c)	.056
		B(c)	.056
	260	S	n.d.
		M	n.d.
		B	n.d.
	280	S	n.d.
		M	n.d.
		B	n.d.
	300	S	n.d.
		M	n.d.
		B	n.d.

TEST 1

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 34	90	M	n.d.
	100	M	n.d.
	110	M	n.d.
	130	S	n.d.
		M	n.d.
		B	n.d.
	140	M	n.d.
	150	S	n.d.
		M(c)	.020
		B	n.d.
	160	S	n d.
		M(c)	.055
		B(c)	.013
	170	M(c)	.026
	180	S	n.d.
		M	- *
		B(c)	.017
	190	M	- *
	200	S	n.d.
		M	n.d.
		B	n.d.
	220	S	n.d.
		M(c)	.130
		B	n.d.
	240	S	n.d.
		M	n.d.
		B	n.d.
	260	S	n.d.
		M	n.d.
		B	n.d.
	280	S	n.d.
		M	n.d.
		B	n.d.
	300	S	n.d.
		M(c)	.020
		B	n.d.
	320	M	n.d.

TEST 1

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 40	100	M(b)	.008
	110	M(b)	.000
	130	S(b) M(b) B(b)	.000 .055 .001
	150	M(b) B(b)	.000 .000
	160	S M B(b)	n.d. n.d. .003
	180	S(b) M(b) B(b)	.000 .008 .004
	200	S M B(c)	n.d. n.d. .070
	220	S(c) M(c) B(c)	.110 .060 .060
	240	S M(c) B(c)	n.d. .041 .000
	260	S M(c) B	n.d. .001 n.d.
	280	S M B	n.d. n.d. n.d.
	300	S(c) M B(c)	.041 n.d. .013
	320	S M B	n.d. n.d. n.d.
	350	M	n.d.

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 46	100	M(b)	.000
	110	M(b)	.001
	130	S M(b) B(b)	n.d. .000 .000
	150	M	n.d.
	160	S M(b) B	n.d. .009 n.d.
	180	S M(b) B	n.d. .003 n.d.
	200	M(c)	.026
	220	S M B	n.d. n.d. n.d.
	240	M(b) B(b)	.014 .015
	260	M(b)	.045
	280	M(b)	.001
	300	S(b) M(b) B	.020 .000 .000
	320	S	n.d.
	350	M(b) B	.001 n.d.

TEST 1

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 52	100	M(b)	.000
	110	M(b)	.000
	130	S(b)	.000
		M(b)	.000
		B(b)	.000
	150	M(b)	.000
	160	S(b)	.000
		M(b)	.000
		B(b)	.000
	180	S	n.d.
		M(b)	.000
		B	n.d.
	200	S(b)	.003
		B	.003
	220	S(b)	.009
		M(b)	.017
		B(b)	.042
	240	S(b)	.054
		M(b)	.019
	260	S(b)	.010
		M(b)	.008
		B(b)	.000
	280	S(b)	.022
		M(b)	.026
		B(b)	.016
	300	S(b)	.010
		M(b)	.007
		B(b)	.014
	320	S(b)	.005
		M(b)	.006
	350	S	.007
		M	.000
		B	.000

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 56	300	M	.045
	320	M	.031
TIDAL CYCLE 58	200	M	.005
	220	M	.022
	240	M	.044
	260	M	.049
	280	M	.035
	350	M	.023

TEST 2

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 6	220	S	n.d.
		M	n.d.
		B	n.d.
	240	S	n.d.
		M	n.d.
		B	.022
	260	S	.215
		M	.605
		B	.540
	280	S	.740
		M	.870
		B	.990
	300	S	1.24
		M	1.25
		B	1.23
	300E	M	.885
	300W	M	2.73
	320	S	.955
		M	1.09
		B	1.01
	320E	M	.855
	320W	M	2.04
	340	S	1.40
		M	.800
		B	.456
	350	S	.780
		M	.334
		B	- *
	350E	M	.100
	350W	M	.930
	370	S	.165
		M	.054
		B	.039

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 6 (cont'd)	390	S	n.d.
		M	n.d.
		B	n.d.
	390E	M	n.d.
	390W	M	n.d.
	410	S	n.d.
		M	n.d.
		B	.005

TEST 2

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 24	180	M	n.d.
	200	M	n.d.
	220	S	n.d.
		M	.039
		B	.063
	240	S	.024
		M	.103
		B	.063
	260	S	.073
		M	.170
		B	.140
	280	S	.186
		M	.230
		B	.158
	300	S	.175
		M	.347
		B	.321
	300E	M	.460
	300W	M	.469
	320	S	.302
		M	.386
		B	.315
	320E	M	.442
	320W	M	.406
	340	M	.347
	350	S	.180
		M	.066
		B	.117
	350E	M	.370

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 24 (cont'd)	350W	M	.460
	370	S	.194
		M	.153
		B	.238
	390	S	.199
		M	.162
		B	.190
	390E	M	.080
	390W	M	.158
	410	S	.085
		M	.054
		B	.054
	430	S	.028
		M	n.d.
		B	n.d.
	430E	M	n.d.
	430W	M	n.d.

TEST 2

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 36	180	M	n.d.
	200	M	.020
	220	S	.024
		M	.038
		B	.024
	240	S	.015
		M	.058
		B	.000
	260	S	.000
		M	.063
		B	.149
	280	S	.126
		M	.152
	300	S	.134
		M	.135
		B	.135
	300E	M	.185
	300W	M	.213
	320	S	.315
		M	.285
		B	.208
	320E	M	.239
	320W	M	.410
	340	M	.267
	350	S	.000
		M	.267
		B	.135
	350E	M	.217
	350W	M	.140
	370	S	.081
		M	.117
		B	.135

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 36	390	S	.117
		M	.073
		B	.063
	390E	M	.208
	390W	M	.103
	410	S	n.d.
		M	.032
		B	n.d.
	430	S	n.d.
		M	n.d.
		B	.066
	430E	M	.050
	430W	M	n.d.

TEST 2

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 42	180	M	n.d.
	200	M	n.d.
	220	S M B	n.d. n.d. .020
	240	S M B	.020 .020 n.d.
	260	S M B	.040 .027 .040
	300	S M B	.038 .094 .038
	300E	M	.226
	300W	M	.180
	320	S M B	.145 .099 .095
	320E	M	.235
	320W	M	.239
	340	M	.185
	350	S M B	.066 .099 .084
	350E	M	.238
	350W	M	.130
	370	S M B	.080 .046 .099

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 42 (cont'd)	390	S M B	.063 .054 .049
	390E	M	.172
	390W	M	.080
	410	S M B	.046 .032 .040
	430	S M B	n.d. .020 n.d.
	430E	M	.054
	430W	M	n.d.

TEST 3

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 1	260	S	.068
		M	.265
		B	.905
	280	S	.350
		M	2.55
		B	4.02
	280E	M	.615
	280W	M	1.12
	300	S	2.07
		M	8.00
		B	3.84
	300E	M	.008
	300W	M	.450
	320	S	.322
		M	.265
		B	.111
	320E	M	.033
	320W	M	.377
	330	S	.127
		M	.029
		B	.037
	350	S	.016
		M	.033
		B	.143
	350E	M	.044
	350W	M	.037

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 3	260	S	.347
		M	1.37
		B	1.44
	280	S	.989
		M	2.18
		B	1.67
	280E	M	1.24
	280W	M	1.99
	300	S	2.08
		M	3.25
		B	2.74
	300E		1.85
	300W		2.34
	320	S	2.75
		M	1.46
		B	1.09
	320E	M	1.95
	320W	M	3.35
	330	S	1.28
		M	.905
		B	.320
	350	S	.298
		M	.074
		B	.017
	350E	M	.033
	350W	M	.231

TEST 3

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 6	220	M	.049
	240	S	.100
		M	.171
		B	.201
	260	M	.650
	280	S	.762
		M	1.28
		B	1.35
	280E	M	1.13
	280W	M	1.10
	300	M	1.38
	300E	M	1.34
	300W	M	1.42
	320	S	1.38
		M	1.11
		B	.868
	320E	M	1.55
	320W	M	1.63
	330	S	1.44
		M	1.08
		B	.713
	350	S	1.00
		M	.491
		B	.320
	350E	M	.241
	350W	M	1.16
	370	M	.075
	390	S	.045
		M	.016
		B	.020
	390E	M	.043
	390W	M	.143
	410	M	.041

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 12	220	M	.017
	240	S	.074
		M	.143
		B	.099
	280	S	.465
		M	.420
		B	.295
	300	M	.870
	320	S	.889
		M	.869
		B	.680
	320E	M	.873
	320W	M	.838
	330	M	.975
	350	S	.830
		M	.619
		B	.382
	350E	M	.566
	350W	M	.842
	390	M	.205
	390E	M	.119
	390W	M	.219
	430	S	.099
		M	.059
		B	.029
	430E	M	.021
	430W	M	.017

TEST 3

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 20	220	M	.017
	240	S	.074
		M	.041
		B	.043
	280	S	.185
		M	.250
		B	.279
	300	M	.484
	320	S	.365
		M	.400
		B	.410
	320E	M	.471
	320W	M	.409
	330	M	.510
	350	S	.360
		M	.489
		B	.435
	350E	M	.521
	350W	M	.571
	390	M	.233
	390E	M	.280
	390W	M	.301
	430	S	.099
		M	.068
		B	.070
	430E	M	.046
	430W	M	.020

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 30	220	M	.004
	240	S	.043
		M	.017
		B	.016
	280	S	.103
		M	.214
		B	.214
	300	M	.250
	320	S	.285
		M	.289
		B	.300
	320E	M	.275
	320W	M	.268
	330	M	.250
	350	S	.300
		M	.265
		B	.265
	350E	M	.345
	350W	M	.325
	390	M	.176
	390E	M	.302
	390W	M	.339
	430	S	.119
		M	.070
		B	.053
	430E	M	.127
	430W	M	.049

TEST 3

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 40	220	M	.005
	240	S	.004
		M	.004
		B	.008
	280	S	.061
		M	.083
	300	M	.184
	320	S	.159
		M	.176
		B	.131
	320E	M	.196
	320W	M	.168
	330	M	.176
	350	S	.168
		M	.180
		B	.151
	350E	M	.188
	350W	M	.155
	390	M	.111
	390E	M	.214
	390W	M	.129
	430	S	.049
		M	.082
		B	.021
	430E	M	.100
	430W	M	.070

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 50	280	S	.053
		M	.059
		B	.083
	300	M	.090
	320	S	.090
		M	.100
		B	.090
	320E	M	.119
	320W	M	.115
	330	M	.089
	350	S	.107
		M	.100
		B	.083
	350E	M	.127
	350W	M	.131
	390	M	.041
	390E	M	.143
	390W	M	.107
	430	S	.033
		M	.016
		B	.012
	430E	M	.090
	430W	M	.041

TEST 4

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 1	20	S	.138
		M	.094
		B	.106
	30	M	.271
	40	S	2.21
		M	1.56
		B	.770
	54	S	>10
		M	>10
		B	>10
	54R	M	8.60
	54L	M	8.65
	60	S	2.98
		M	2.98
		B	3.50
	70	M	.138
	80	S	.028
		M	.086
		B	.061

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 3	10	M	.280
	20	S	.451
		M	.505
		B	.538
	30	M	1.50
	40	S	1.95
		M	2.26
		B	1.84
	54	S	5.28
		M	4.64
		B	4.55
	54R	M	3.50
	54L	M	5.91
	60	S	3.12
		M	3.71
		B	4.08
	70	M	2.04
	80	S	.840
		M	.912
		B	1.07
	100	S	.170
		M	.199
		B	.178

TEST 4

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 6	20	S	.670
		M	.638
		B	.530
	40	S	1.79
		M	1.74
		B	1.63
	54R	M	2.09
	54L	M	2.98
	60	M	2.56
		B	2.15
	70	M	2.48
	80	S	1.61
		M	1.82
		B	1.78
	90	M	1.29
	100	S	1.02
		M	1.10
		B	.711
	120	S	.203
		M	.170
		B	.411

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 12	-30	M	.069
	-10	M	.178
	10	M	.340
	20	S	.451
		M	.490
		B	.495
	40	M	1.11
	54	S	1.57
		M	1.42
		B	1.35
	80	M	1.90
	100	S	1.32
		M	1.24
		B	1.32
	120	S	.510
		B	.749
	140	S	.061
		B	.089

TEST 4

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 20	-30	M	.073
	-10	M	.214
	10	M	.311
	20	S	.251
		M	.271
		B	.195
	40	S	.540
		M	.468
		B	.389
	60	S	.800
		M	.730
		B	.745
	80	S	1.35
		M	1.36
		B	1.20
	100	S	1.36
		M	1.20
		B	1.29
	120	S	.790
		M	.705
		B	.699
	140	S	.331
		M	.352
		B	.337
	160	S	.315
		M	.126
		B	.126
	180	S	.085
		M	.053
		B	.081
	200	M	.065

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 30	-50	M	.056
	-30	M	.073
	-10	M	.130
	10	M	.230
	20	M	.166
	30	M	.300
	40	S	.283
		M	.259
		B	.292
	60	S	.591
		M	.485
		B	.440
	80	S	.840
		M	.800
		B	.840
	100	S	.943
		M	.928
		B	1.04
	120	M	.741
	140	S	.588
		M	.507
		B	.534
	160	M	.263
	180	S	.214
		M	.190
		B	.170
	200	M	.118
	220	M	.101
	240	M	.073
	260	M	.065

TEST 4

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 40	-50	M	.036
	-30	M	.053
	-10	M	.069
	10	M	.118
	20	M	.065
	60	S M B	.304 .288 .292
	80	S M B	.255 .360 .449
	100	S M B	.540 .538 .469
	120	M	.630
	140	S M B	.544 .545 .538
	160	M	.364
	180	S M B	.255 .235 .248
	200	S M B	.000 .259 .122
	220	M	.153
	240	M	.089
	260	M	.060

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 40 (cont'd)	280	M	.056
	300	M	.056

TEST 5

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 1	80	M	.034
	90	S	.184
		M	.093
		B	.034
	100	S	.223
		M	.083
	110	S	3.35
		M	3.15
		B	2.18
	120	S	7.12
		M	7.02
		B	3.82
	130	S	.246
		M	.367
		B	1.03
	140	M	.026

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 3	70	M	.118
	80	M	.098
	90	S	.078
		M	.165
		B	.093
	100	S	.219
		M	.181
		B	.205
	110	S	1.35
		M	1.23
		B	1.22
	120	S	3.82
		M	4.15
		B	3.65
	130	S	3.86
		M	4.16
		B	4.19
	140	S	1.63
		M	1.66
		B	1.58
	150	S	.336
		M	.398
		B	.332
	160	M	.098

TEST 5

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 6	70	M	.000
	80	M	.012
	90	S	.066
		M	.072
		B	.062
	110	S	.394
		M	.367
		B	.348
	130	S	.000
		M	2.30
		B	2.30
	140	S	2.38
		M	2.58
		B	2.51
	150	S	1.97
		M	1.86
		B	1.70
	160	S	1.08
		M	.885
		B	.900
	170	M	.778
	190	M	.102

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 12	80	M	.026
	90	M	.012
	100	M	.053
	130	S	.493
		M	.508
		B	.466
	140	M	.797
	150	S	1.22
		M	1.32
		B	1.30
	160	M	1.45
	170	S	1.17
		M	1.21
		B	1.30
	190	M	.645
	210	M	.263
	230	M	.259
	250	M	.078

TEST 5

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 20	90	M	.008
	110	M	.026
	130	S M B	.152 .120 .120
	150	S M B	.513 .304 .348
	170	S M B	.693 .680 .645
	190	M	.600
	210	M	.546
	230	M	.453
	250	M	.278
	270	M	.098

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 30	110	M	.026
	130	S M B	.048 .043 .066
	150	M	.098
	170	S M B	.223 .228 .233
	190	S M B	.296 .308 .304
	210	S M B	.300 .358 .381
	230	M	.394
	250	S M B	.332 .286 .283
	270	S M B	.283 .219 .173
	290	M	.242
	310	M	.102

TEST 6

	Station	D pth	Conc. (ppm)
TIDAL CYCLE 1	80	M	.023
	90	S	.000
		M	.071
		B	.071
	100	S	.079
		M	.083
		B	.179
	110	S	2.96
		M	2.27
		B	3.40
	120	S	5.60
		M	5.97
		B	6.45
	130	S	.583
		M	.535
		B	.463
	140	M	.052

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 3	70	M	.012
	80	M	.150
	90	S	.047
		M	.054
		B	.058
	100	S	.063
		M	.131
		B	.219
	110	S	1.10
		M	.950
		B	1.09
	120	S	3.24
		M	3.20
		B	3.24
	130	S	3.22
		M	3.26
		B	3.10
	140	S	1.85
		M	1.64
		B	1.61
	150	S	.553
		M	.435
		B	.307
	160	M	.148
	170	M	.135

TEST 6

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 6	70	M	.052
	80	M	.071
	90	S M B	.043 .098 .063
	110	S M B	.035 .207 .372
	130	S M B	1.97 1.97 1.90
	140	S M B	2.20 1.98 1.94
	150	S M B	1.88 1.95 1.75
	160	S M B	.799 .857 1.05
	170	S M B	1.15(?) .387 .352
	190	M	.111
	210	M	.027

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 12	80	M	.003
	90	M	.012
	110	M	.071
	130	S M B	.395 .419 .415
	140	M	.657
	150	S M B	.926 .483 .830
	160	M	.981
	170	S M B	.774 .457(?) .750
	190	S M B	.527 .423 .488
	210	S M B	.367 .251 .248
	230	M	.074
	250	M	.039
	270	M	.030

TEST 6

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 20	90	M	.007
	110	M	.030
	130	S M B	.079 .047 .103
	150	S M B	.183 .203 .215
	170	S M B	.363 .381 .387
	190	S M B	.483 .500 .478
	210	S M B	.443 .463 .427
	230	M	.358
	250	M	.263
	270	S M B	.299 .235 .292
	290	M	.167
	310	M	.079

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 30	110	M	.000
	130	S M B	.030 .019 .054
	150	M	.091
	170	S M B	.087 .154 .188
	190	M	.243
	210	S M B	.299 .295 .318
	230	M	.332
	250	M	.303
	290	M	.183
	310	M	.079
	330	M	.054
	350	M	.047

TEST 6

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 40	130	M	.030
	150	M	.030
	170	S M B	.035 .083 .103
	190	M	.119
	210	S M B	.171 .191 .163
	230	M	.199
	250	S M B	.235 .183 .243
	270	M	.188
	290	S M B	.188 .139 .143
	310	M	.087
	330	M	.083
	350	M	.054
	430	M	.019

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 50	150	M	.000
	170	S M B	.047 .035 .054
	190	M	.087
	210	S M B	.103 .115 .087
	230	M	.119
	250	S M B	.143 .167 .143
	270	M	.187
	290	S M B	.139 .111 .111
	310	M	.103
	330	M	.071
	350	M	.063
	390	M	.054
	430	M	.027

TEST 7

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 1	80	M	.013
	90	S	.050
		M	.079
		B	.058
	100	S	.097
		M	.109
		B	.025
	110	S	4.45
		M	4.28
		B	3.61
	120	S	6.25
		M	5.62
		B	10.0
	130	S	.280
		M	.298
		B	.433
	140	M	.088

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 3	70	M	.013
	80	M	.050
	90	S	.125
		M	.071
		B	.050
	100	S	.092
		M	.147
		B	.213
	110	S	1.15
		M	1.10
		B	1.59
	120	S	4.06
		M	3.65
		B	3.64
	130	S	4.38
		M	3.85
		B	3.87
	140	S	1.05
		M	1.10
		B	1.03
	150	S	.363
		M	.259
		B	.188
	160	M	.117

TEST 7

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 6	70	M	.003
	80	M	.029
	90	S	.100
		M	.037
		B	.104
	110	S	.255
		M	.008
		B	.275
	130	S	1.87
		M	1.99
		B	1.91
	140	S	2.20
		M	2.36
		B	2.22
	150	S	1.96
		M	1.72
		B	1.60
	160	S	1.22
		M	.810
		B	.961
	170	M	.535
	190	M	.150
	210	M	.050

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 12	80	M	.003
	90	M	.003
	110	M	.021
	130	S	.417
		M	.500
		B	.525
	140	M	.625
	150	S	.803
		M	.950
		B	1.05
	160	M	1.18
	170	S	.741
		M	.988
		B	1.00
	190	M	.592
	210	M	.272
	230	M	.138
	250	M	.400

TEST 7

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 20	90	M	.037
	110	M	.008
	130	S	.075
		M	.067
		B	.088
	150	S	.204
		M	.259
		B	.273
	170	S	.363
		M	.433
		B	.550
	190	S	.467
		M	.483
		B	.471
	210	M	.467
	230	M	.284
	250	M	.204
	270	M	.142
	290	M	.130
	310	M	.075

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 30	130	S	.047
		M	.008
		B	.050
	150	M	.058
	170	S	.138
		M	.134
		B	.100
	190	M	.213
	210	S	.242
		M	.242
		B	.259
	230	M	.273
	250	M	.250
	270	M	.192
	290	M	.150
	310	M	.104
	330	M	.050
	350	M	.033

TEST 7

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 40	130	M	.029
	150	M	.033
	170	S M B	.050 .047 .067
	190	M	.121
	210	S M B	.154 .176 .172
	230	M	.142
	250	S M B	.234 .204 .234
	270	M	.157
	290	S M B	.225 .142 .200
	310	M	.104
	330	M	.079
	350	M	.067
	430	M	.042

	Station	Depth	Conc. (ppm)
TIDAL CYCLE 50	150	M	.025
	170	S M B	.033 .033 .025
	190	M	.054
	210	S M B	.063 .054 .083
	230	M	.071
	250	S M B	.121 .100 .142
	270	M	.147
	290	M	.109
	310	S M B	.092 .067 .079
	330	M	.071
	350	M	.063
	390	M	.047
	430	M	.042

APPENDIX III

Correction of Observed Concentrations. Tables of Corrected Concentration.

The high adsorption of the methylene blue on any surface with which it came in contact -- the plaster and concrete of the model, dust, sample jars, and even the photometer cells -- caused considerable difficulty. It was found in laboratory tests that the adsorption on the model itself could be materially reduced by painting it with a clear plastic paint and this was done between Test 1-A and the rest of the tests. The residual loss on the model, together with the losses on other surfaces, was compensated by a correction factor calculated in the following way.

If no dye were lost then the integral of the dye concentration, expressed as weight per unit volume, over the entire volume of the model would equal the weight of the dye introduced. The difference between this integral and the original weight of dye is therefore a measure of the dye lost by adsorption. The ratio of the integral to the weight of dye introduced may serve as a correction factor for changing observed concentration to corrected concentration which is an estimate of the value the observed concentration would have shown had adsorption not been present.

Consideration of the stations where samples were taken across the estuary showed that after the first one or two tidal cycles the mean sectional concentration could be estimated from the mid-channel samples. Using the mid-channel observations, concentration was plotted against longitudinal distance and a smooth curve drawn through the points. An example of such a curve is shown in Figure A-III-1 where the open circles denote concentrations estimated from single samples and the solid circles denote concentrations estimated from an average of samples at surface, middepth, and bottom. In drawing the smoothed curves more weight was given to these latter points when a departure from the actual estimates seemed necessary.

From the smoothed curves the concentration at each 10,000 foot station was read. Each concentration was then multiplied by the appropriate mean cross sectional area and the integration was carried out numerically. The ratio of the total dye represented by the distribution curve to the amount of dye originally introduced was formed. This ratio was computed for each tidal cycle and plotted as a function of time. A smooth curve through these points provided the correction factor.

Four correction curves of this sort were used, one for Test 1-A, one for Tests 1 and 4, one for Tests 2 and 3, and one for Tests 5, 6, and 7.

As was to be expected, the correction factors for Test 1-A, run before the model had been painted, were significantly higher than those for Test 1, run after the model had been painted, although the tests were otherwise the same.

The data analyzed in the text of this report have all been corrected in this way. When the difference in the nature of the decay during the later tidal periods between the first five and the last three tests was noted the question arose as to whether the difference was real or an artifact of the correction method. Since the essential difference still remains if raw data are used, although with somewhat different values for the logarithmic slopes, it seems unlikely that the difference is a result of the applied correction. Figure A-III-2 shows the uncorrected data for Tests 1-A and 6 as an example. For Test 1-A the logarithm of concentration versus time is still approximately linear while for Test 6 the straight line is still not suitable. Figure A-III-2 should be compared with Figure 24 which shows the same plot for the corrected data from the same two tests.

The table in this appendix gives the corrected concentrations for each tidal cycle by 10,000 foot stations.

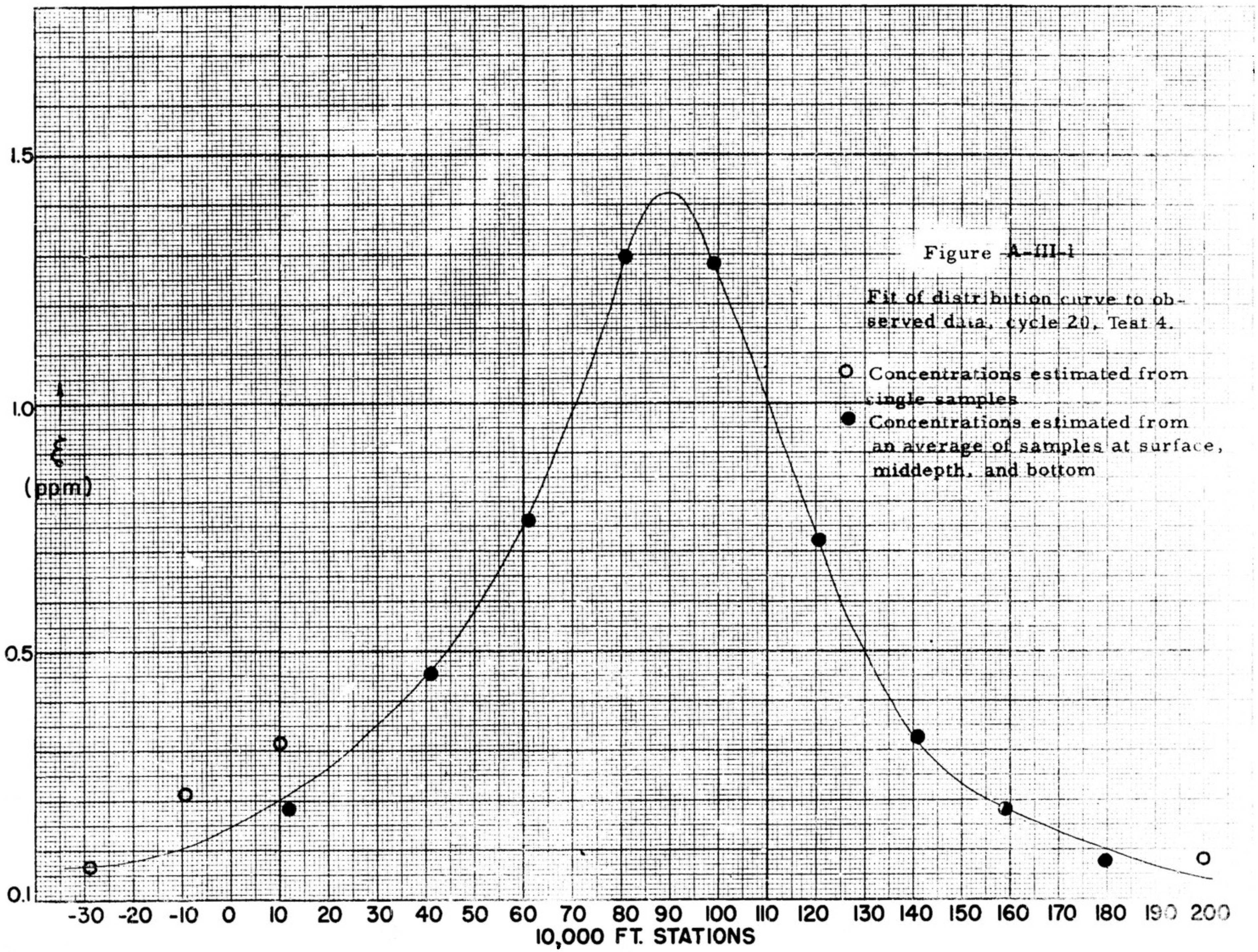


Figure A-III-1

Fit of distribution curve to observed data, cycle 20, Test 4.

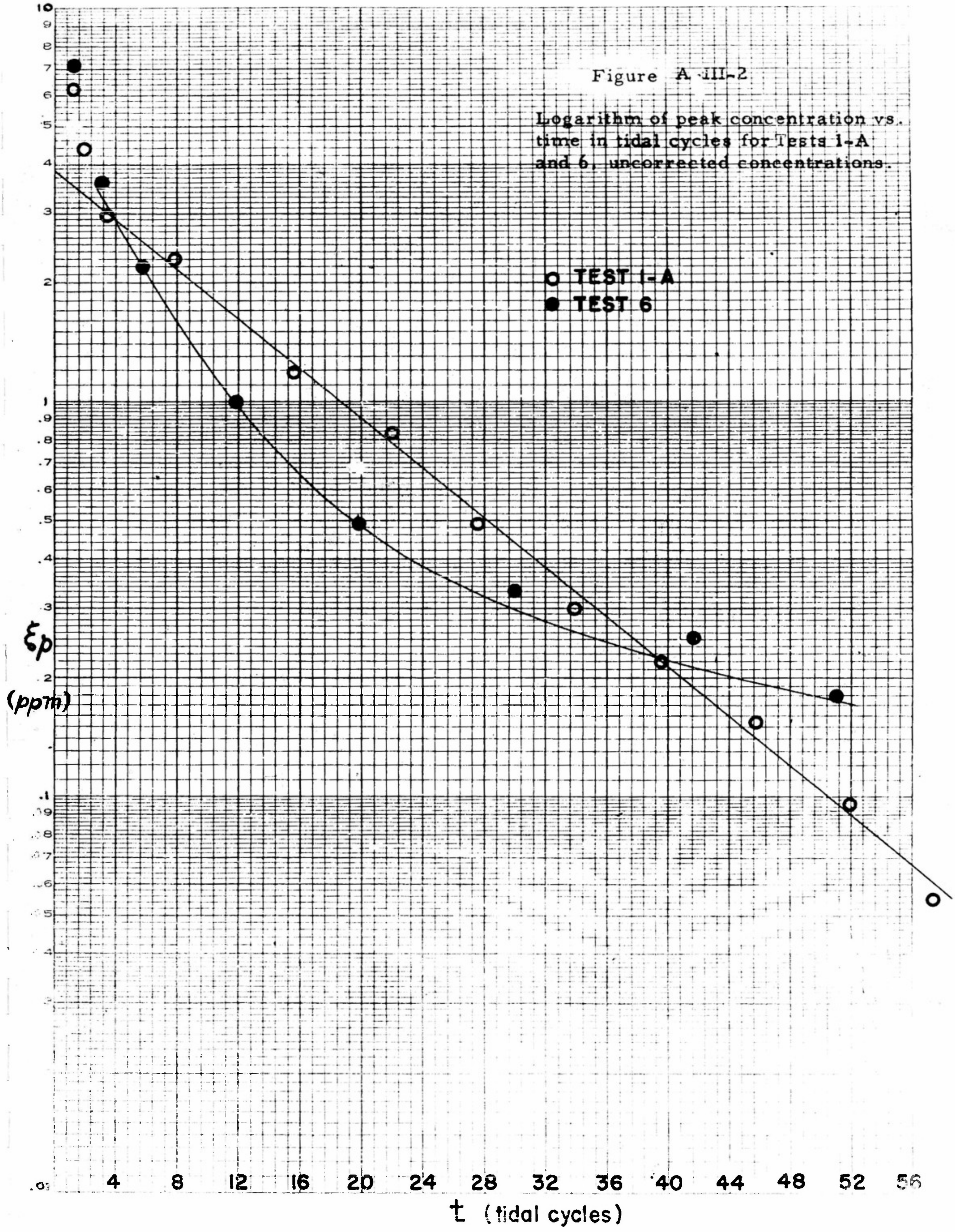


Figure A-III-2
Logarithm of peak concentration vs. time in tidal cycles for Tests 1-A and 6, uncorrected concentrations.
TEST 1-A
TEST 6
ξ_p (ppm)
t (tidal cycles)
4
8
12
16
20
24
28
32
36
40
44
48
52
56

TEST 1-A - DELAWARE RIVER

	Station	Corrected Conc.
TIDAL CYCLE 1	20	0.03
	30	0.17
	40	1.90
	50	10.30
	53.5*	10.56
	60	6.0[illegible]
	70	0.52
	80	0.03
TIDAL CYCLE 2	10	0.05
	20	0.20
	30	0.47
	40	1.49
	50	5.57
	57.5*	6.83
	60	6.77
	70	3.31
	80	1.21
	90	0.31
TIDAL CYCLE 4	10	0.02
	20	0.14
	30	0.38
	40	0.96
	50	1.79
	60	2.91
	70	4.24
	75*	4.48
	80	4.28
	90	2.66
	100	1.07
	110	0.24
TIDAL CYCLE 8	20	0.03
	30	0.11
	40	0.27
	50	0.57
	60	1.19
	70	2.05
	80	2.97
	90	3.34
	92.5*	3.35

	Station	Corrected Conc.
TIDAL CYCLE 8 (cont'd)	100	3.02
	110	1.89
	120	0.80
	130	0.23
	140	0.08
	150	0.05
	160	0.03
TIDAL CYCLE 16	20	0.02
	30	0.05
	40	0.13
	50	0.24
	60	0.34
	70	0.45
	80	0.57
	90	0.74
	100	0.96
	110	1.43
	120	1.81
	128*	1.98
	130	1.93
	140	1.60
	150	1.08
	160	0.59
	170	0.34
	180	0.24
	190	0.13
	200	0.10
	210	0.08
	220	0.08
	230	0.08
	240	0.07
	250	0.05
	260	0.05
	270	0.03
	280	0.03
TIDAL CYCLE 22	40	0.05
	50	0.11
	60	0.13
	70	0.14
	80	0.18
	90	0.23
	100	0.32

* Location peak concentration

TEST 1-A

	Station	Corrected Conc.
TIDAL CYCLE 22 (cont'd)	110	0.50
	120	0.85
	130	1.31
	140*	1.48
	150	1.30
	160	0.77
	170	0.59
	180	0.50
	190	0.43
	200	0.36
	210	0.27
	220	0.27
	230	0.20
	240	0.18
	250	0.14
	260	0.11
	270	0.09
TIDAL CYCLE 28	80	0.04
	90	0.10
	100	0.11
	110	0.25
	120	0.38
	130	0.57
	140	0.78
	150	0.93
	153*	0.95
	160	0.87
	170	0.72
	180	0.65
	190	0.57
	200	0.51
	210	0.48
	220	0.42
	230	0.34
	240	0.30
	250	0.25
	260	0.21
	270	0.17
	280	0.11

	Station	Corrected Conc.
TIDAL CYCLE 34	100	0.08
	110	0.15
	120	0.21
	130	0.34
	140	0.49
	150	0.59
	160	0.61
	170*	0.63
	180	0.61
	190	0.57
	200	0.53
	210	0.46
	220	0.40
	230	0.38
	240	0.34
	250	0.27
	260	0.23
	270	0.17
	280	0.11
	290	0.08
	300	0.05
	310	0.03
TIDAL CYCLE 40	120	0.04
	130	0.11
	140	0.18
	150	0.25
	160	0.33
	170	0.38
	180	0.45
	190	0.48
	193*	0.48
	200	0.48
	210	0.45
	220	0.40
	230	0.35
	240	0.31
	250	0.26
	260	0.21
	270	0.17
	280	0.12
	290	0.09
	300	0.07
	310	0.05
	320	0.03

TEST 1-A

	Station	Corrected Conc.
TIDAL CYCLE 46	120	0.04
	130	0.08
	140	0.14
	150	0.20
	160	0.25
	170	0.28
	180	0.31
	190	0.33
	200*	0.34
	210	0.33
	220	0.32
	230	0.30
	240	0.28
	250	0.26
	260	0.22
	270	0.19
	280	0.15
	290	0.12
	300	0.09
	310	0.06
	320	0.05
	330	0.04
	340	0.03
	350	0.03
TIDAL CYCLE 52	130	0.01
	140	0.03
	150	0.05
	160	0.07
	170	0.11
	180	0.14
	190	0.18
	200	0.21
	210*	0.21
	220	0.21
	230	0.19
	240	0.18
	250	0.16
	260	0.15
	270	0.13
	280	0.12
	290	0.11
	300	0.09
	310	0.07
	320	0.05
	330	0.04
	340	0.03
	350	0.02

	Station	Corrected Conc.
TIDAL CYCLE 58	150	0.01
	160	0.02
	170	0.03
	180	0.05
	190	0.06
	200	0.07
	210	0.09
	220	0.11
	230	0.12
	240*	0.12
	250	0.12
	260	0.12
	270	0.12
	280	0.11
	290	0.10
	300	0.09
	310	0.08
	320	0.06
	330	0.05
	340	0.05
	350	0.04

TEST 1

	Station	Corrected Conc.
TIDAL CYCLE 1	60*	11.06
	70	1.80
TIDAL CYCLE 2	60	6.58
	64.5*	7.05
	70	5.98
	80	1.96
	90	0.31
TIDAL CYCLE 4	60	2.62
	70	4.06
	80*	4.68
	90	4.03
	100	2.32
	110	0.16
TIDAL CYCLE 8	70	0.96
	80	1.81
	90	3.01
	100	3.32
	102.5*	3.37
	110	3.16
	120	2.21
	130	0.52
TIDAL CYCLE 12	60	0.09
	70	0.18
	80	0.28
	90	0.43
	100	0.85
	110	1.75
	120*	2.41
	130	1.80
	140	1.24
	150	1.09

TEST 2

	Station	Corrected Conc.
TIDAL CYCLE 6	220	0.01
	230	0.01
	240	0.03
	250	0.33
	260	0.63
	270	0.93
	280	1.22
	290	1.50
	300	1.79
	306*	1.83
	310	1.79
	320	1.50
	330	1.50
	340	1.26
	350	0.79
	360	0.40
	370	0.13
	380	0.09
	390	0.07
	400	0.03
	410	0.01
TIDAL CYCLE 24	220	0.09
	230	0.09
	240	0.09
	250	0.13
	260	0.18
	270	0.27
	280	0.36
	290	0.45
	300	0.54
	310	0.59
	320	0.63
	330*	0.68
	340	0.63
	350	0.47
	360	0.39
	370	0.36
	380	0.32
	390	0.29
	400	0.18
	410	0.09
	420	0.04
	430	0.04

	Station	Corrected Conc.
TIDAL CYCLE 36	220	0.02
	230	0.04
	240	0.06
	250	0.10
	260	0.14
	270	0.20
	280	0.24
	290	0.28
	300	0.32
	310	0.37
	320	0.53
	330	0.57
	334*	0.59
	340	0.53
	350	0.30
	360	0.24
	370	0.18
	380	0.16
	390	0.14
	400	0.12
	410	0.10
	420	0.08
	430	0.06
TIDAL CYCLE 42	220	0.02
	230	0.02
	240	0.02
	250	0.04
	260	0.04
	270	0.06
	280	0.08
	290	0.10
	300	0.12
	310	0.20
	320	0.22
	330	0.30
	340*	0.37
	350	0.18
	360	0.16
	370	0.14
	380	0.10
	390	0.08
	400	0.06
	410	0.04
	420	0.02
	430	0.02

TEST 3

	Station	Corrected Conc.
TIDAL CYCLE 1	240	0.03
	250	0.18
	260	0.44
	270	1.12
	280	2.41
	290	4.84
	295*	5.22
	300	4.84
	310	1.65
	320	0.26
	330	0.18
	340	0.03
	350	0.01
TIDAL CYCLE 3	240	0.19
	250	0.68
	260	1.34
	270	1.88
	280	2.47
	290	3.12
	300*	3.44
	310	3.07
	320	2.24
	330	1.05
	340	0.36
	350	0.18
	360	0.10
	370	0.06
TIDAL CYCLE 6	220	0.07
	230	0.14
	240	0.21
	250	0.53
	260	0.96
	270	1.29
	280	1.60
	290	1.86
	300	1.96
	302.5*	1.97
	310	1.86
	320	1.74
	330	1.54
	340	1.29
	350	0.89
TIDAL CYCLE 6 (cont'd)	360	0.56
	370	0.14
	380	0.09
	390	0.04
	400	0.03
	410	0.01
TIDAL CYCLE 12	220	0.04
	230	0.07
	240	0.12
	250	0.22
	260	0.26
	270	0.40
	280	0.60
	290	0.90
	300	1.25
	310	1.44
	315*	1.48
	320	1.47
	330	1.32
	340	1.10
	350	0.87
	360	0.59
	370	0.49
	380	0.38
	390	0.31
	400	0.25
	410	0.21
	420	0.18
	430	0.13
TIDAL CYCLE 20	220	0.02
	230	0.03
	240	0.09
	250	0.14
	260	0.22
	270	0.31
	280	0.41
	290	0.65
	300	0.84
	310	0.91
	320*	0.95
	330	0.86
	340	0.81
	350	0.77

TEST 3

	Station	Corrected Conc.
TIDAL CYCLE 20 (cont'd)	360	0.67
	370	0.60
	380	0.48
	390	0.41
	400	0.34
	410	0.29
	420	0.21
	430	0.17
TIDAL CYCLE 30	220	0.02
	230	0.02
	240	0.04
	250	0.08
	260	0.13
	270	0.21
	280	0.32
	290	0.43
	300	0.47
	310	0.49
	320	0.51
	322.5*	0.53
	330	0.53
	340	0.51
	350	0.51
	360	0.49
	370	0.47
	380	0.39
	390	0.34
	400	0.28
	410	0.19
	420	0.13
	430	0.09
TIDAL CYCLE 40	220	0.02
	230	0.02
	240	0.03
	250	0.04
	260	0.07
	270	0.10
	280	0.18
	290	0.30
	300	0.32
	310	0.32

	Station	Corrected Conc.
TIDAL CYCLE 40 (cont'd)	320	0.34
	330*	0.34
	340	0.34
	350	0.34
	360	0.32
	370	0.30
	380	0.26
	390	0.22
	400	0.18
	410	0.14
	420	0.10
	430	0.06
TIDAL CYCLE 50	260	0.04
	270	0.08
	280	0.12
	290	0.17
	300	0.19
	310	0.19
	320	0.21
	330*	0.21
	340	0.21
	350	0.19
	360	0.14
	370	0.10
	380	0.08
	390	0.08
	400	0.06
	410	0.04
	420	0.04
	430	0.04

TEST 4

	Station	Corrected Conc.
TIDAL CYCLE 1	10	0.09
	20	0.19
	30	0.52
	40	2.87
	50	11.66
	53.5*	17.40
	60	5.57
	70	0.26
	80	0.09
TIDAL CYCLE 3	10	0.34
	20	0.59
	30	1.50
	40	2.40
	50	5.66
	54*	5.92
	60	4.49
	70	2.46
	80	1.16
	90	0.60
	100	0.22
TIDAL CYCLE 6	0	0.24
	10	0.49
	20	0.73
	30	1.26
	40	2.16
	50	2.75
	60*	3.03
	70	2.82
	80	2.07
	90	1.59
	100	1.13
	110	0.73
	120	0.31
TIDAL CYCLE 12	0	0.25
	10	0.43
	20	0.60
	30	0.85
	40	1.40
	50	1.74
	60	2.06
	70	2.32
	78.5*	2.43
	80	2.41

	Station	Corrected Conc.
TIDAL CYCLE 12 (cont'd)	90	2.08
	100	1.65
	110	1.21
	120	0.79
	130	0.38
	140	0.10
	150	0.04
TIDAL CYCLE 20	20	0.35
	30	0.48
	40	0.66
	50	0.83
	60	1.06
	70	1.44
	80	1.82
	90*	1.96
	100	1.79
	110	1.79
	120	1.04
	130	0.75
	140	0.48
	150	0.35
	160	0.25
	170	0.18
	180	0.14
	190	0.10
	200	0.07
TIDAL CYCLE 30	0	0.19
	10	0.20
	20	0.23
	30	0.31
	40	0.40
	50	0.54
	60	0.79
	70	1.04
	80	1.27
	90	1.47
	98*	1.52
	100	1.50
	110	1.36
	120	1.15
	130	1.01
	140	0.85
	150	0.65
	160	0.47
	170	0.36
	180	0.28

TEST 4

	Station	Corrected Conc.
TIDAL CYCLE 30 (cont'd)	190	0.23
	200	0.19
	210	0.16
	220	0.14
	230	0.12
	240	0.11
	250	0.08
TIDAL CYCLE 40	0	0.10
	10	0.12
	20	0.15
	30	0.18
	40	0.25
	50	0.36
	60	0.50
	70	0.56
	80	0.58
	90	0.73
	100	0.86
	110	0.99
	120	1.04
	126*	1.06
	130	1.04
	140	0.94
	150	0.78
	160	0.63
	170	0.50
	180	0.41
	190	0.33
	200	0.30
	210	0.26
	220	0.25
	230	0.23
	240	0.18
	250	0.17
	260	0.15
	270	0.13
	280	0.12
	290	0.10
	300	0.08

TEST 5

	Station	Corrected Conc.
TIDAL CYCLE 1	80	0.05
	90	0.15
	100	0.23
	110	4.41
	116.75*	9.71
	120	9.04
	130	1.14
	140	0.05
TIDAL CYCLE 3	70	0.08
	80	0.12
	90	0.17
	100	0.28
	110	1.70
	120	4.95
	125*	5.45
	130	5.15
	140	2.09
	150	0.45
	160	0.13
TIDAL CYCLE 6	80	0.03
	90	0.10
	100	0.18
	110	0.49
	120	1.04
	130	2.05
	139.5*	3.25
	140	3.24
	150	2.39
	160	1.26
	170	1.00
	180	0.39
	190	0.13
	200	0.07
TIDAL CYCLE 12	80	0.01
	90	0.02
	100	0.04
	110	0.09
	120	0.36
	130	0.77
	140	1.33
	150	1.86
	160*	2.09

	Station	Corrected Conc.
TIDAL CYCLE 12 (cont'd)	170	1.80
	180	1.33
	190	0.94
	200	0.61
	210	0.39
	220	0.38
	230	0.36
	240	0.23
	250	0.12
	260	0.07
	270	0.06
TIDAL CYCLE 20	100	0.02
	110	0.03
	120	0.08
	130	0.23
	140	0.42
	150	0.62
	160	0.90
	170	1.05
	175*	1.05
	180	1.01
	190	0.94
	200	0.86
	210	0.84
	220	0.81
	230	0.70
	240	0.56
	250	0.41
	260	0.25
	270	0.16
	280	0.14
	290	0.11
	300	0.08
	310	0.08
TIDAL CYCLE 30	110	0.02
	120	0.05
	130	0.08
	140	0.11
	150	0.16
	160	0.26
	170	0.36
	180	0.43
	190	0.49
	200	0.56
	210	0.57

TEST 5

	Station	Corrected Conc.
TIDAL CYCLE 30 (cont'd)	220	0.62
	230*	0.64
	240	0.57
	250	0.52
	260	0.46
	270	0.43
	280	0.38
	290	0.33
	300	0.28
	310	0.16
	320	0.08

TEST 6

	Station	Corrected Conc.
TIDAL CYCLE 1	90	0.06
	100	0.17
	110	4.38
	116.5*	10.43
	120	9.12
	130	0.81
	140	0.08
TIDAL CYCLE 3	70	0.01
	80	0.04
	90	0.08
	100	0.19
	110	1.37
	120	4.13
	124.5*	4.58
	130	4.10
	140	2.18
	150	0.55
	160	0.18
	170	0.17
	180	0.13
TIDAL CYCLE 6	70	0.05
	80	0.07
	90	0.08
	100	0.16
	110	0.26
	120	1.11
	130	2.57
	137*	2.83
	140	2.78
	150	2.26
	160	1.17
	170	0.60
	180	0.30
	190	0.16
	200	0.07
	210	0.04

	Station	Corrected Conc.
TIDAL CYCLE 12	90	0.03
	100	0.06
	110	0.12
	120	0.30
	130	0.59
	140	0.94
	150	1.29
	158.5*	1.42
	160	1.41
	170	1.10
	180	0.88
	190	0.73
	200	0.57
	210	0.42
	220	0.26
	230	0.12
	240	0.09
	250	0.06
	260	0.04
	270	0.03
TIDAL CYCLE 20	90	0.02
	100	0.03
	110	0.05
	120	0.09
	130	0.12
	140	0.17
	150	0.31
	160	0.47
	170	0.59
	180	0.73
	190*	0.76
	200	0.73
	210	0.69
	220	0.62
	230	0.55
	240	0.47
	250	0.41
	260	0.44
	270	0.45
	280	0.37
	290	0.23
	300	0.17
	310	0.12

TEST 6

	Station	Corrected Conc.
	120	0.02
	130	0.05
	140	0.10
	150	0.15
	160	0.18
	170	0.23
	180	0.33
	190	0.39
	200	0.46
TIDAL CYCLE 30	210	0.49
	220	0.52
	230*	0.54
	240	0.52
	250	0.49
	260	0.46
	270	0.41
	280	0.34
	290	0.30
	300	0.18
	310	0.13
	320	0.11
	330	0.08
	340	0.05
	350	0.03
	130	0.03
	140	0.05
	150	0.07
	160	0.10
	170	0.14
	180	0.17
	190	0.21
	200	0.26
TIDAL CYCLE 40	210	0.31
	220	0.32
	230	0.34
	240	0.36
	250*	0.38
	260	0.36
	270	0.32
	280	0.29
	290	0.26
	300	0.22
	310	0.19
	320	0.15
	330	0.12

	Station	Corrected Conc.
TIDAL CYCLE 40 (cont'd)	340	0.10
	350	0.09
	360	0.07
	370	0.07
	150	0.02
	160	0.03
	170	0.09
	180	0.12
	190	0.15
	200	0.17
	210	0.17
	220	0.19
	230	0.21
	240	0.22
TIDAL CYCLE 50	250	0.24
	260	0.29
	270*	0.31
	280	0.28
	290	0.26
	300	0.22
	310	0.21
	320	0.19
	330	0.19
	340	0.19
	350	0.17
	360	0.17
	370	0.17

TEST 7

	Station	Corrected Conc.
TIDAL CYCLE 1	80	0.02
	90	0.06
	100	0.11
	110	7.60
	116.50*	11.52
	120	11.02
	130	0.49
	140	0.14
TIDAL CYCLE 3	70	0.06
	80	0.09
	90	0.13
	100	0.19
	110	1.57
	120	4.86
	126.5*	5.81
	130	5.38
	140	1.60
	150	0.33
	160	0.15
TIDAL CYCLE 6	70	0.01
	80	0.05
	90	0.10
	100	0.18
	110	0.26
	120	1.20
	130	2.51
	139.5*	3.34
	140	3.32
	150	2.30
	160	1.26
	170	0.68
	180	0.35
	190	0.18
	200	0.13
	210	0.07

	Station	Corrected Conc.
TIDAL CYCLE 12	90	0.02
	100	0.03
	110	0.06
	120	0.33
	130	0.70
	140	0.91
	150	1.38
	158*	1.75
	160	1.71
	170	1.39
	180	1.10
	190	0.84
	200	0.61
	210	0.36
	220	0.25
	230	0.17
TIDAL CYCLE 20	110	0.03
	120	0.08
	130	0.12
	140	0.22
	150	0.39
	160	0.55
	170	0.70
	180	0.78
	190	0.83
	197*	0.84
	200	0.84
	210	0.81
	220	0.70
	230	0.55
	240	0.42
	250	0.31
	260	0.27
	270	0.22
	280	0.19
	290	0.17
	300	0.14
	310	0.12

TEST 7

	Station	Corrected Conc.
TIDAL CYCLE 30	130	0.05
	140	0.07
	150	0.10
	160	0.15
	170	0.20
	180	0.26
	190	0.31
	200	0.36
	210	0.41
	220	0.45
	230	0.48
	232.5*	0.48
	240	0.46
	250	0.41
	260	0.38
	270	0.33
	280	0.28
	290	0.25
	300	0.20
	310	0.15
	320	0.11
	330	0.08
	340	0.07
	350	0.05
TIDAL CYCLE 40	130	0.03
	140	0.05
	150	0.05
	160	0.07
	170	0.09
	180	0.14
	190	0.19
	200	0.24
	210	0.29
	220	0.32
	230	0.34
	240	0.38
	250*	0.39
	260	0.38
	270	0.34
	280	0.31
	290	0.27
	300	0.22
	310	0.19

	Station	Corrected Conc.
TIDAL CYCLE 40 (cont'd)	320	0.15
	330	0.14
	340	0.14
	350	0.12
	360	0.10
	370	0.09
TIDAL CYCLE 50	150	0.03
	160	0.05
	170	0.06
	180	0.07
	190	0.08
	200	0.09
	210	0.10
	220	0.12
	230	0.15
	240	0.17
	250	0.21
	260	0.24
	270*	0.26
	280	0.24
	290	0.21
	300	0.17
	310	0.14
	320	0.12
	330	0.10
	340	0.10
	350	0.09
	360	0.09
	370	0.09

APPENDIX IV

A. Auxiliary Data on Salinity Distribution, High and Low Water Profiles, and Fresh Water Inflow.

B. Table of Cross Sectional Area, Intersectional Volume, and Accumulated Volume for each 5000 ft. Station.

DELAWARE RIVER MODEL
Salinity Profile Data
Tests 2-3-4

1000 ft Channel Stations	Test 2, Mean Tide Mean flow (20,200) Top	Test 2 Middepth	Test 2 Bottom	Test 3, Mean Tide High flow (49,000) Top	Test 3 Middepth	Test 3 Bottom	Test 4, Mean Tide Low flow (5,905) Top	Test 4 Middepth	Test 4 Bottom
430	27,385	27,385	27,385	23,260	26,124	26,812	26,697	27,155	27,270
400	25,208	25,208	25,666	21,197	23,145	23,947			
350	23,603	24,291	25,781	13,979	17,302	19,135	21,999	21,999	22,801
300	15,583	18,677	19,020	6,875	9,854	11,114	15,812	16,958	17,302
280	12,030	14,265	15,132	4,813	6,784	8,114			
250	7,734	9,453	9,453	1,169	1,994	2,338	9,625	10,541	10,656
220	4,813	5,226	5,730	848	825	894			
210				458	619	711			
200	2,854	3,506	3,553	527	573	550	6,588	6,588	7,963
190				413	619	435			
180	1,410	1,902	2,109	206	229	252	4,010	4,640	5,099
160	642	688	705	69	57	57	3,094	3,437	3,495
150	264	332	367	34	34	34			
140	160	172	172				1,971	2,040	2,040
130	69	80	80						
120	46	50	50				665	825	917
100							458	665	458
90							160	183	206
80							92	92	115

NOTE: Quantities are PPM total salt. Subtract average fresh-water salinity (40 PPM) and divide result by 1.81 to obtain equivalent chlorine.

DELAWARE RIVER MODEL
Salinity Profile Data
Tests 5-6-7

1000 ft Channel Stations	Test 5, Mean Tide Mean flow (20,200)			Test 6, Spring Tide Mean flow (20,200)			Test 7, Neap Tide Mean flow (20,200)		
	Top	Middepth	Bottom	Top	Middepth	Bottom	Top	Middepth	Bottom
250	7,390	8,823	9,854	6,989	7,906	8,250	11,771	12,375	13,291
210	3,437	4,469	4,469	2,521	3,667	3,667	5,328	6,416	6,646
190	1,834	2,682	2,842	1,306	2,040	2,200	2,635	3,724	3,953
160	527	504	504	1,215	1,375	1,375	894	1,054	1,054
150	229	252	275	206	206	229	321	390	504
130	115	115	115	92	92	92	69	69	69

NOTE: Quantities are PPM total salt. Subtract average fresh-water salinity (40 PPM) and divide result by 1.81 to obtain equivalent chlorine.

DELAWARE RIVER MODEL
Data For
High and Low Water Profile

Location		Mean		Spring		Neap	
Gage	1000 ft Channel Station	High Water Elev	Low Water Elev	High Water Elev	Low Water Elev	High Water Elev	Low Water Elev
Miah Maull	431	5.7	0.3	6.3	-0.3	5.3	0.8
Ship John	350	6.1	0.1	6.6	-0.3	5.6	0.8
Woodland Beach	325	6.2	0.1	7.0	-0.1	6.0	0.75
Artificial Island	278	6.15	0.25	6.75	-0.15	5.7	0.6
Reedy Point	233	6.0	0.45	6.5	0.0	5.7	0.65
New Castle	198	6.1	0.5	6.8	0.4	5.95	0.9
Edge Moor	157	6.25	0.5	6.6	0.2	5.9	0.7
Marcus Hook	124	6.45	0.5	6.6	0.1	6.0	0.65
Baldwin	96	6.45	0.55	6.6	0.1	5.8	0.6
Fort Mifflin	60	6.55	0.5	6.7	0.1	6.15	0.6
Philadelphia	15	6.5	0.45	6.8	0.2	6.15	0.6
Torresdale	-38	6.7	0.5	7.2	0.2	6.5	0.6
Burlington	-81	7.15	0.8	7.4	0.2	6.9	0.8
Florence	-104	7.4	0.7	7.6	0.4	7.0	0.5
Fieldsboro	-129	7.6	0.9	8.1	0.8	7.4	0.8
Trenton	-160	7.75	0.9	8.5	0.8	7.55	0.9

FRESH-WATER INFLOW DISTRIBUTION

Inflow Location	Prototype C.F.S. Mean Flow Tests 1-A,1,2,5,6,7	Prototype C.F.S. High Flow Test 3	Prototype C.F.S. Low Flow Test 4	Remarks
Trenton	12,350	31,300	3,000	
Rancocas	875	0	0	Combined with Schuylkill
Schuylkill	3,250	8,700	2,000	
Christina	1,100	2,650	480	
Salem	450	1,100	0	Combined with Christina
Cohansey	425	1,000	0	Combined with Christina
Maurice	1,750	4,250	425	
(Total Fresh-water Inflow)	20,200	49,000	5,905	

CROSS-SECTIONAL AREAS AND SEGMENT VOLUMES - DELAWARE RIVER

Station	Cross-section Area $\times 10^{-2}$ ft^2			Segment Volume $\times 10^{-6}$ ft^3			Accumulated Volume $\times 10^{-6}$ ft^3		
	low tide	mean tide	high tide	low tide	mean tide	high tide	low tide	mean tide	high tide
- 160	22	53	83				0		0
				23	39	55			
- 155	70	104	138				23	39	55
				47	63	79			
- 150	117	148	178				70	102	134
				86	111	136			
- 145	228	298	367				156	213	270
				102	133	163			
- 140	178	231	284				258	346	433
				84	109	134			
- 135	156	203	250				342	455	567
				85	107	129			
- 130	184	226	268				427	562	696
				114	150	186			
- 125	273	376	479				541	712	882
				121	157	193			
- 120	212	253	294				662	869	1075
				106	128	150			
- 115	212	223	233				768	997	1225
				101	133	164			
- 110	192	272	351				869	1129	1389
				94	126	158			
- 105	184	232	279				963	1255	1547
				100	124	148			
- 100	214	264	313				1063	1379	1695
				106	128	151			
- 95	209	251	292				1169	1508	1846
				113	142	170			
- 90	242	315	388				1282	1649	2016
				113	144	174			
- 85	212	261	310				1395	1793	2190
				113	138	162			
- 80	239	289	338				1508	1930	2352
				116	144	172			
- 75	223	287	350				1624	2074	2524
				128	159	189			
- 70	289	349	408				1752	2233	2713
				147	182	216			
- 65	298	377	456				1899	2414	2929
				133	171	209			
- 60	234	306	378				2032	2585	3138
				128	167	205			

Station	Cross-section Area $\times 10^{-2}$ ft^2			Segment Volume $\times 10^{-6}$ ft^3			Accumulated Volume $\times 10^{-6}$ ft^3		
	low tide	mean tide	high tide	low tide	mean tide	high tide	low tide	mean tide	high tide
- 55	278	360	441				2160	2752	3343
				229	277	324			
- 45	303	366	428				2550	3232	3913
				169	213	257			
- 40	373	474	575				2719	3445	4170
				191	241	290			
- 35	392	488	583				2910	3685	4460
				185	237	288			
- 30	348	459	569				3095	3922	4748
				184	245	306			
- 25	387	520	753				3279	4167	5054
				217	279	342			
- 20	482	594	705				3496	4446	5396
				218	280	342			
- 15	390	527	664				3714	4726	5738
				201	259	317			
- 10	415	511	606				3915	4985	6055
				214	260	306			
- 05	440	530	620				4129	5425	6361
				256	316	375			
00	585	733	880				4385	5561	6736
				308	373	438			
+ 05	649	761	873				4693	5934	7174
				326	377	428			
+ 10	654	746	837				5019	6311	7602
				299	337	375			
+ 15	543	603	662				5318	6648	7977
				321	355	389			
+ 20	740	817	894				5639	7003	8366
				336	374	411			
+ 25	604	677	749				5975	7376	8777
				310	347	383			
+ 30	635	708	781				6285	7723	9160
				309	346	382			
+ 35	601	673	744				6594	8068	9542
				363	418	473			
+ 40	852	1001	1149				6957	8486	10015
				357	424	490			
+ 45	701	819	937				7314	8909	10505
				373	430	487			
+ 50	791	901	1010				7697	9339	10992
				450	518	586			
+ 55	1010	1173	1335				8137	9858	11578
				507	590	673			

Station	Cross-section Area $\times 10^{-2}$ ft^2			Segment Volume $\times 10^{-6}$ ft^3			Accumulated Volume $\times 10^{-6}$ ft^3		
	low tide	mean tide	high tide	low tide	mean tide	high tide	low tide	mean tide	high tide
+ 60	1016	1185	1354	479	561	643	8644	10448	12251
+ 65	899	1059	1218	518	586	654	9123	11009	12894
+ 70	1175	1289	1402	493	546	598	9641	11595	13548
+ 75	796	887	978	388	457	525	10134	12140	14146
+ 80	754	937	1119	412	509	605	10522	12597	14671
+ 85	885	1089	1292	438	531	624	10934	13105	15276
+ 90	866	1039	1212	456	547	638	11372	13636	15900
+ 95	958	1150	1341	491	595	699	11828	14183	16538
+ 100	1008	1232	1456	463	570	676	12319	14778	17237
+ 105	846	1047	1248	459	551	642	12782	15348	17913
+ 110	991	1157	1322	509	578	646	13241	15898	18555
+ 115	1047	1174	1301	516	598	680	13750	16476	19201
+ 120	1016	1218	1420	598	691	783	14266	17074	19881
+ 125	1378	1547	1716	613	699	785	14864	17764	20664
+ 130	1074	1250	1425	573	665	756	15477	18463	21449
+ 135	1219	1408	1597	649	750	851	16050	19128	22205
+ 140	1375	1589	1803	651	758	865	16699	19878	23056
+ 145	1230	1444	1658	630	734	838	17350	20636	23921
+ 150	1292	1494	1696	646	750	854	17980	21369	24759
+ 155	1292	1506	1720	662	773	883	18626	22119	25613
+ 160	1356	1585	1814	662	784	905	19288	22892	26496
+ 165	1292	1549	1805	821	945	1068	19950	23676	27501

Station	Cross-section Area x 10^{-2} ft^2			Segment Volume x 10^{-6} ft^3			Accumulated Volume x 10^{-6} ft^3		
	low tide	mean tide	high tide	low tide	mean tide	high tide	low tide	mean tide	high tide
+ 170	1993	2231	2469				20771	24620	28469
				843	954	1065			
+ 175	1381	1587	1793				21614	25574	29534
				646	739	833			
+ 180	1202	1371	1540				22260	26314	30367
				702	804	906			
+ 185	1606	1845	2083				22962	27118	31273
				820	939	1057			
+ 190	1673	1908	2142				23782	28056	32330
				840	958	1075			
+ 195	1687	1923	2159				24622	29014	33405
				851	973	1094			
+ 200	1717	1968	2219				25473	29986	34499
				832	966	1099			
+ 205	1609	1892	2175				26305	30952	35598
				824	965	1107			
+ 210	1687	1970	2253				27129	31917	36705
				842	1007	1172			
+ 215	1681	2058	2435				27971	32924	37977
				810	990	1170			
+ 220	1559	1902	2244				28781	33914	39047
				817	1003	1189			
+ 225	1709	2111	2513				29598	34917	40236
				948	1152	1355			
+ 230	2082	2493	2904				30546	36069	41591
				1059	1286	1512			
+ 235	2154	2649	3144				31605	37354	43103
				997	1198	1398			
+ 240	1832	2138	2444				32602	38552	44501
				902	1065	1227			
+ 245	1776	2120	2464				33504	39616	45728
				888	1061	1233			
+ 250	1776	2123	2469				34392	40677	46961
				1002	1180	1358			
+ 255	2232	2598	2964				35394	41857	48319
				1102	1279	1457			
+ 260	2174	2517	2860				36496	43136	49776
				1147	1320	1493			
+ 265	2413	2763	3112				37643	44456	51269
				1164	1353	1542			
+ 270	2244	2650	3055				38807	45809	52811
				1195	1384	1572			
+ 275	2536	2884	3232				40002	47193	54383
				1308	1497	1685			

Station	Cross-section Area x 10^{-2} ft^2			Segment Volume x 10^{-6} ft^3			Accumulated Volume x 10^{-6} ft^3		
	low tide	mean tide	high tide	low tide	mean tide	high tide	low tide	mean tide	high tide
+ 280	2694	3101	3507				41310	48689	56068
				1358	1584	1811			
+ 285	2739	3237	3735				42668	50274	57879
				912	1169	1426			
+ 290	2909	3439	3969				43580	51443	59305
				1486	1766	2045			
+ 295	3037	3624	4211				45066	53208	61350
				1605	1924	2243			
+ 300	3385	4074	4762				46671	55132	63593
				1707	2053	2398			
+ 305	3443	4137	4831				48378	57185	65991
				1763	2117	2470			
+ 310	3607	4328	5049				50141	59301	68461
				1833	2178	2522			
+ 315	3724	4381	5038				51974	61479	70983
				1930	2282	2633			
+ 320	3994	4744	5493				53904	63760	73616
				2073	2458	2844			
+ 325	4298	5090	5882				55977	66219	76460
				2100	2470	2840			
+ 330	4103	4790	5476				58077	68688	79300
				1976	2316	2656			
+ 335	3799	4472	5145				60053	71005	81956
				1978	2342	2705			
+ 340	4114	4895	5676				62031	73346	84661
				2310	2753	3196			
+ 345	5127	6118	7109				64341	76099	87857
				2607	3119	3630			
+ 350	5303	6357	7410				66948	79218	91487
				2658	3165	3671			
+ 355	5328	6302	7275				69606	82372	95158
				2739	3225	3711			
+ 360	5628	6600	7571				72345	85607	98869
				2934	3442	3950			
+ 365	6107	7168	8228				75279	89049	102819
				3155	3711	4266			
+ 370	6515	7675	8836				78434	92759	107085
				3551	4225	4899			
+ 375	7694	9228	10762				81935	96985	111984
				4104	4919	5735			
+ 380	8729	10456	12183				86089	101904	117719
				4728	5535	6342			

Station	Cross-section Area x 10^{-2} ft^2			Segment Volume x 10^{-6} ft^3			Accumulated Volume x 10^{-6} ft^3		
	low tide	mean tide	high tide	low tide	mean tide	high tide	low tide	mean tide	high tide
+ 385	8573	10219	11865				90817	107439	124061
				4365	5129	5894			
+ 390	10316	12145	13974				95182	112569	129955
				5193	6152	7111			
+ 395	10455	12463	14470				100375	118721	137066
				5258	6284	7310			
+ 400	10577	12674	14770				105633	125005	144376
				6326	7523	8719			
+ 405	11468	13719	15969				111959	132527	153095
				5849	6928	8006			
+ 410	12131	14391	16650				117808	139455	161101
				6265	7387	8509			
+ 415	12927	15156	17385				124073	146824	169610
				6636	7765	8895			
+ 420	13617	15907	18196				130709	154607	178505
				6960	8112	9264			
+ 425	14224	16543	18862				137669	162719	187769
				7638	8960	10282			
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