SEATO GRADUATE SCHOOL OF ENGINEERING

APPIED SCIENTIFIC RESEARCH CORPORATION OF THAILAND

COOPERATIVE RESEARCH PROGRAMME NO. 34

TREATMENT OF SEWERAGE AND INDUSTRIAL EFFLUENTS

RESEARCH PROJECT NO. 34/3

PHOTOSYNTHETIC OXYGEN PRODUCTION IN THE CHAOPHRAYA RIVER

# REPORT NO. 1

# CHAOPHRAYA RIVER POLLUTION AND PHOTOSYNTHETIC OXYGENATION

BY

M. B. PESCOD

TIWA LIMSIWAWONGSE

ASRCT, BANGKOK 1967

not for publication

SEATO GRADUATE SCHOOL OF ENGINEERING
APPIED SCIENTIFIC RESEARCH CORPORATION OF THAILAND

COOPERATIVE RESEARCH PROGRAMME NO. 34
TREATMENT OF SEWERAGE AND INDUSTRIAL EFFLUENTS

RESEARCH PROJECT NO. 34/3
PHOTOSYNTHETIC OXYGEN PRODUCTION IN THE CHAOPHRAYA RIVER

# REPORT NO. 1
# CHAOPHRAYA RIVER POLLUTION AND PHOTOSYNTHETIC OXYGENATION

BY
M. B. PESCOD
TIWA LIMSIWAWONGSE

ASRCT, BANGKOK 1967
not for publication

## F O R E W O R D

The present study is part of a cooperative programme between the SEATO Graduate School of Engineering and ASRCT on treatment of sewerage and industrial effluents. Initially the programme is concentrated on the pollution of the Chaophraya River, and is concerned particularly with matters relating to the proposed sewerage system for the central area of Bangkok.

This paper deals with the extent of the pollution of the Chaophraya River in the Bangkok area and the production of photosynthetic oxygen under different circumstances. This is of importance in assessing the extent of treatment needed before sewerage and other wastes are discharged into the river.

CHAOPHRAYA RIVER POLLUTION AND PHOTOSYNTHETIC OXYGENATION

By M.B. Pescod[1] and Tiwa Limsiwawongse[2]

## INTRODUCTION

### Previous work

The effects of polluting discharges on the Chaophraya River, Bangkok, received some attention in the period from August 1965 to July 1966 as a result of the cooperative efforts of a number of Thai Government Departments. Representative samples of river water were taken once every week at three stations in the river at high and low tides and these were analyzed for temperature, pH, turbidity, chloride, dissolved oxygen, biochemical oxygen demand (BOD), and most probable number of coliform organisms (MPN). The results of this study showed that the river was heavily polluted in the reach from Rama VI Bridge to Phra Pradaeng, shown in Fig. 1, particularly at low river discharges. Seasonal fluctuations in dissolved oxygen concentration at three stations can be seen in Fig. 2 for high- and low-tide conditions.

While these results give a general picture of the river condition, measurement of diurnal variation in dissolved oxygen concentration would be more indicative of the changes taking place as a result of tidal movements and other factors. A study of diurnal variations in dissolved oxygen in the river is also necessary for assessing the *in situ* effects of photosynthetic oxygenation. More accurate quantitative data on photosynthetic oxygen production can be obtained by incubating light and dark bottles filled with river water for different periods at different depths in the river, although there are certain disadvantages to the use of the technique.

This report presents the data collected on the river from June 1966 to March 1967. It covers the results on diurnal changes in dissolved oxygen concentration at various stations in the river and studies on photosynthetic oxygen production at the Memorial Bridge Station.

---

[1] SEATO Graduate School of Engineering, Bangkok.
[2] Technological Research Institute, ASRCT, Bangkok.

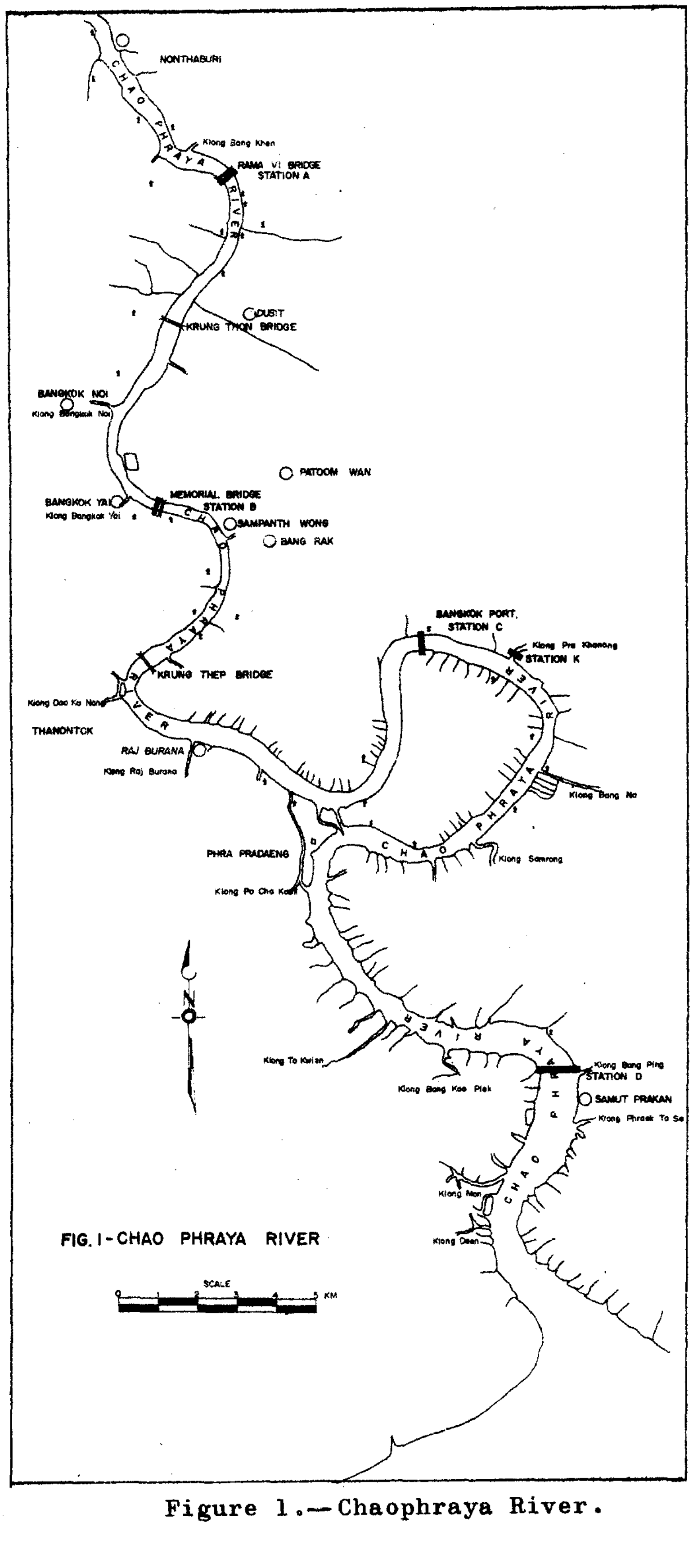


Figure 1.—Chaophraya River.

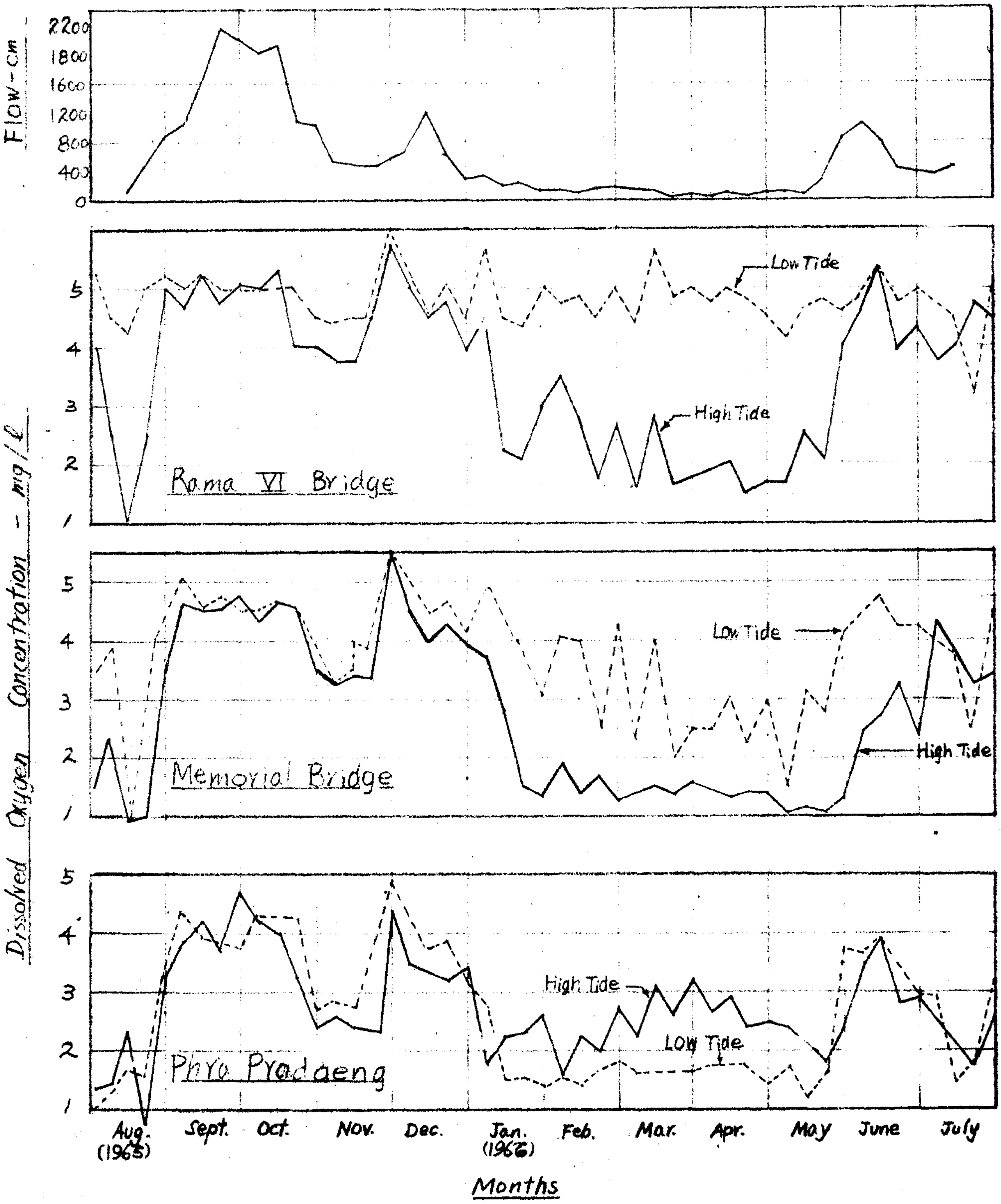


**Figure 2.—Seasonal and tide variations in dissolved oxygen in Chaophraya River.**

River regime

The lower reach of the Chaophraya River, on which Bangkok is situated, is the river estuary and is therefore subject to tidal fluctuations. NEDECO (1965) in their Siltation Report discussed the estuarine hydraulics at length and a study of that report will point out the complexity of the flow patterns in the estuary. River stage and velocity measurements made by the Royal Irrigation Department at Krung Thon Bridge during the study periods in March 1967 have confirmed this and have shown that it is not possible to compute actual river discharges at any station on the estuary from stage records alone. 1965-6 river discharges are shown in Fig. 2 from which it can be seen that minimum flows occur between January and May. The NEDECO (1965) Report showed that at river discharges below 100 $m^3$/sec, the estuary is well mixed and no stratification occurs. This was confirmed in the March 1967 studies when samples were taken at different depths in the river.

It is useful in studying the changes which are taking place in an estuary to compare different characteristics at high and low water slacks. Slack water is defined as the moment of zero velocity between tides which, in the case of the Chaophraya, does not occur at maxima or minima stage readings. The NEDECO (1965) report stated that: "maxima and minima of the salinity occur when the currents reverse their direction at the times of slack water." This criterion gives a reasonable basis for estimation of slack water conditions at points in the river where significant fluctuations in chloride concentration occur. Data collected during the March 1967 pollution studies have shown that maxima and minima of chlorides occur at the same time as maxima and minima of dissolved oxygen at each station, although at some stations a maximum of one and a minimum of the other are coincident whilst at others two maxima or two minima coincide. For the purposes of this report, maxima and minima of chloride concentration or dissolved oxygen concentration will be taken as definitive of slack water conditions.

## TECHNIQUES AND METHODS

### Field measurements

For dissolved oxygen concentration determinations in the field, various methods were used at different times and locations. Meters used were the Galvanic Cell Oxygen Analyzer (Precision Scientific Co.) and the Y.S.I. Model 51 Oxygen Meter (Yellow Springs Instrument Co.). Otherwise, the azide modification of the Winkler technique as described in "Standard Methods" (American Public Health Association et al. 1965) was adopted and, in any case, the meters were calibrated using this procedure. When meters were used, temperature measurement was by thermister associated with the instrument. Chloride concentration in the river water was normally determined using the Mohr method detailed in "Standard Methods" (American Public Health Association et al. 1965) but on one occasion a Beckman Model RB3 Solu Bridge was used in addition to chemical determination of chloride.

Assessment of photosynthetic oxygen production was made using the light and dark bottle technique described by HULL (1964) modified to suit local conditions. Twenty four hours was the usual duration of this test but on two occasions the test period was extended to 48 hours. On all occasions river water was incubated in light and dark BOD bottles contained in trays at various depths in the river and, every two hours, one light and one dark bottle were removed for dissolved oxygen measurement.

### Laboratory analyses

Except for suspended solids measurement, all physical, chemical, and biological determinations on river water samples were carried out according to "Standard Methods" (American Public Health Association et al. 1965). Suspended solids concentration was determined by the glass fibre disc method described by WYCKOFF (1964) and 4.25 cm Whatman glass paper filters, grade GF/A, were used.

Algal counts were made on a concentrated sample placed in a haemo-cytometer, with individual cells being counted for filamentous forms.

## CHARACTERISTICS OF CHAOPHRAYA RIVER WATER

A summary of the results of the analyses of river water sampled at Memorial Bridge over the period of the present studies is given in Table 1. The range of dissolved oxygen concentrations, from 3 to 68.2% of saturation, shows that the river is heavily polluted and is in danger of becoming anaerobic at periods of low discharge.

The absolute numbers of algae present in the river water are low when compared with the counts in the River Thames (Water Pollution Research Laboratory 1964). Table 2 gives the predominance of algal types for different sampling times and it is obvious that seasonal fluctuations occur. A relationship between algal numbers and turbidity is shown in Fig. 3 which implies that algae form a significant proportion of the turbidity present. In fact, this is not so since the suspended silt load in the river is very high, varying from less than 100 to more than 1000 mg/l (NEDECO 1965), but may be due to algae being present in direct proportion to the silt burden. Fig. 4 shows the seasonal fluctuations in turbidity at three stations on the river from which it may be deduced that the greatest concentrations of algae in the river water are likely to occur between June and September.

The pH range in Table 1 is very small and at all times would be suitable for algal growth. Extremes of pH (4.5 to 11.0) have been observed in the river for short periods of time at other stations and, during these periods, algal growth would be inhibited. Nitrogen and phosphate levels in the river indicate that the water has sufficient nutrient capacity to stimulate algal growth. The forms of nitrogen present are shown in Table 3 and it is obvious that ammonia-N and nitrite-N can be of little significance in the overall nitrogen balance. Most of the nitrogen present is in the oxidized form of nitrate, indicating extensive nitrification, and as such is readily utilized by algae. This form of nitrogen also acts as a reserve of oxygen which might be drawn upon by bacteria when the dissolved oxygen concentration in the river approaches zero.

Normal temperatures in the river would stimulate algal growth but mitigate against dissolved oxygen reserves by lowering the saturation value and increasing the rate of respiration of micro-organisms.

## TABLE 1

### SUMMARY OF CHAOPHRAYA RIVER ANALYSES

### SAMPLING STATION - MEMORIAL BRIDGE, BANGKOK

| Sample No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date } of Sampling<br>Time } | 13/vi/66<br>8:15 | 6/vii/66<br>8:20 | 19/vii/66<br>8:30 | 3/viii/66<br>8:20 | 22/viii/66<br>9:00 | 5/ix/66<br>9:00 | 25-26/xi/66 | 15-16/xii/66 | 12-13/i/67 | 20-21/i/67 | 20-22/iii/67 | 29-31/iii/67 |
| Turbidity | 232 | 212 | 285 | 276 | 366 | 215 | 53 | 52 | 78 | 66 | Max. 170<br>Min. 55 | Max. 235<br>Min. 55 |
| Algal Count per Litre | - | 2,535,748 | 3,009,240 | 2,909,240 | 3,935,153 | 2,535,748 | 781,245 | 1,446,750 | - | - | - | - |
| Dissolved Oxygen at 0.5 m Deep, mg/l | 3.9 | 2.3 | 0.6 | 3.9 | 4.9 | 5.3 | Max. 4.20<br>Min. 3.80 | Max. 3.45<br>Min. 2.65 | Max. 4.10<br>Min. 2.30 | Max. 4.20<br>Min. 2.30 | Max. 3.5<br>Min. 0.2 | Max. 3.1<br>Min. 0.3 |
| Dissolved Oxygen % of Saturation | 51.5 | 30 | 8 | 51.1 | 64.2 | 68.2 | Max. 53.8<br>Min. 48.9 | Max. 44.4<br>Min. 34.0 | Max. 58.9<br>Min. 28.9 | Max. 49.8<br>Min. 27.3 | Max. 45<br>Min. 3 | Max. 40<br>Min. 4 |
| Total Phosphate, mg/l | 1.4 | 1.7 | 1.3 | 3.2 | 1.0 | 2.0 | 0.64 | 0.95 | 0.48 | 0.90 | - | - |
| Sulphate, mg/l | 622.7 | 676.5 | 618.6 | 686.1 | 388.9 | 933.5 | 798 | - | 460 | 316 | - | - |
| Total Nitrogen, mg/l | 10.04 | 3.0[illegible] | 5.76 | 4.74 | 4.25 | 13.03 | 4.785 | 13.485 | 2.24 | 2.52 | - | - |
| pH | 7.4 | 7.4 | 7.0 | 7.1 | 7.2 | 7.4 | 7.9 | 6.4 | 7.1 | 6.9 | Max. 7.4<br>Min. 6.85 | Max. 7.0<br>Min. 6.95 |
| Temperature, °c | 30 | 29 | 30 | 29.5 | 29.5 | 28.5 | Max. 28.5<br>Min. 28.0 | Max. 28.6<br>Min. 28.3 | Max. 27.2<br>Min. 26.8 | Max. 24.0<br>Min. 23.8 | Max. 29.4<br>Min. 27.4 | Max. 30<br>Min. 28.8 |
| Suspended Solids, mg/l | - | - | - | - | - | - | 40 | 56 | 58 | 46 | - | - |

## TABLE 2

## ABUNDANCE OF ALGAL GROUPS AS PERCENTAGE OF TOTAL

| Sample No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Date of Sampling | 10/v/66 | 13/vi/66 | 19/vii/66 | 3/viii/66 | 22/viii/66 | 5/ix/66 | 25-26/xi/66 | 15-16/xii/66 |
| Desmids | 30 | – | 3.8 | – | 4.4 | 6.65 | 17.8 | 16 |
| Diatoms | 25 | 6.75 | 5.8 | 1.0 | 28 | 40 | 13.7 | 16 |
| Greens | 16.7 | 53.25 | 5.8 | 17.3 | 36.7 | 13.30 | – | 68 |
| Blue-greens | 25 | – | 18.8 | 47.1 | 29.4 | 40.05 | 68.5 | – |
| Flagellates | 3.3 | 40 | 55.8 | 34.6 | 1.5 | – | – | – |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

## TABLE 3

## FORMS OF NITROGEN IN CHAOPHRAYA RIVER WATER SAMPLES

| Sample No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Ammonia Nitrogen, mg/ℓ | 0.04 | 0.01 | 0.06 | 0.03 | 0.01 | 0 | 0 | 0.03 | 0.01 | 0.02 |
| Organic Nitrogen, mg/ℓ | 0.90 | 1.71 | 2.18 | 1.95 | 1.72 | 2.02 | 1.40 | 1.03 | 1.12 | 1.12 |
| Nitrite Nitrogen, mg/ℓ | 0.02 | 0.04 | 0.02 | 0.06 | 0.02 | 0.01 | 0.085 | 0.025 | 0.01 | 0.08 |
| Nitrate Nitrogen, mg/ℓ | 9.08 | 1.30 | 3.50 | 2.70 | 2.50 | 11.00 | 3.30 | 12.40 | 1.10 | 1.30 |
| Total Nitrogen, mg/ℓ | 10.04 | 3.06 | 5.76 | 4.74 | 4.25 | 13.03 | 4.785 | 13.485 | 2.24 | 2.52 |

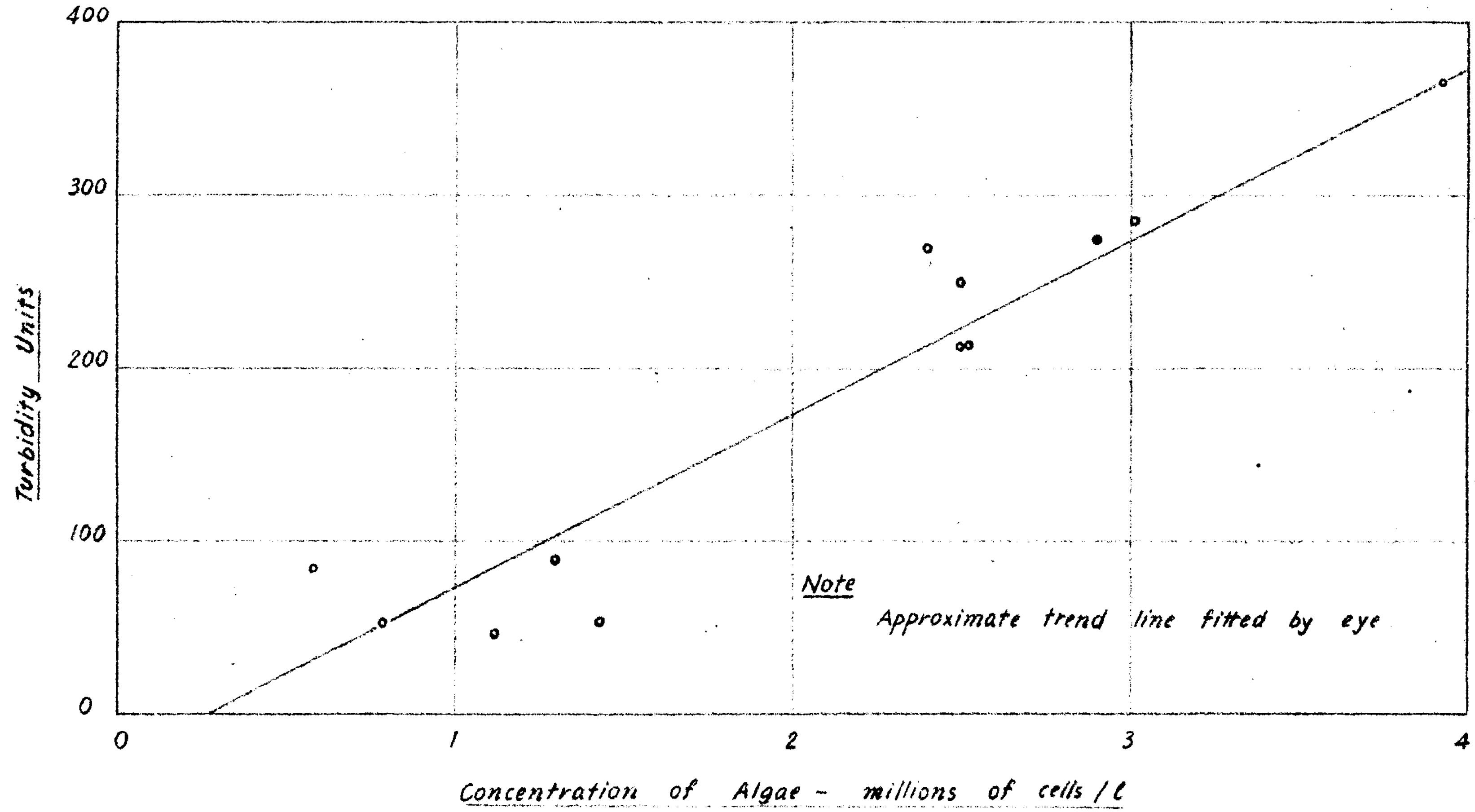


Figure 3.—Relationship between turbidity and concentration of algae in the Chaophraya River.

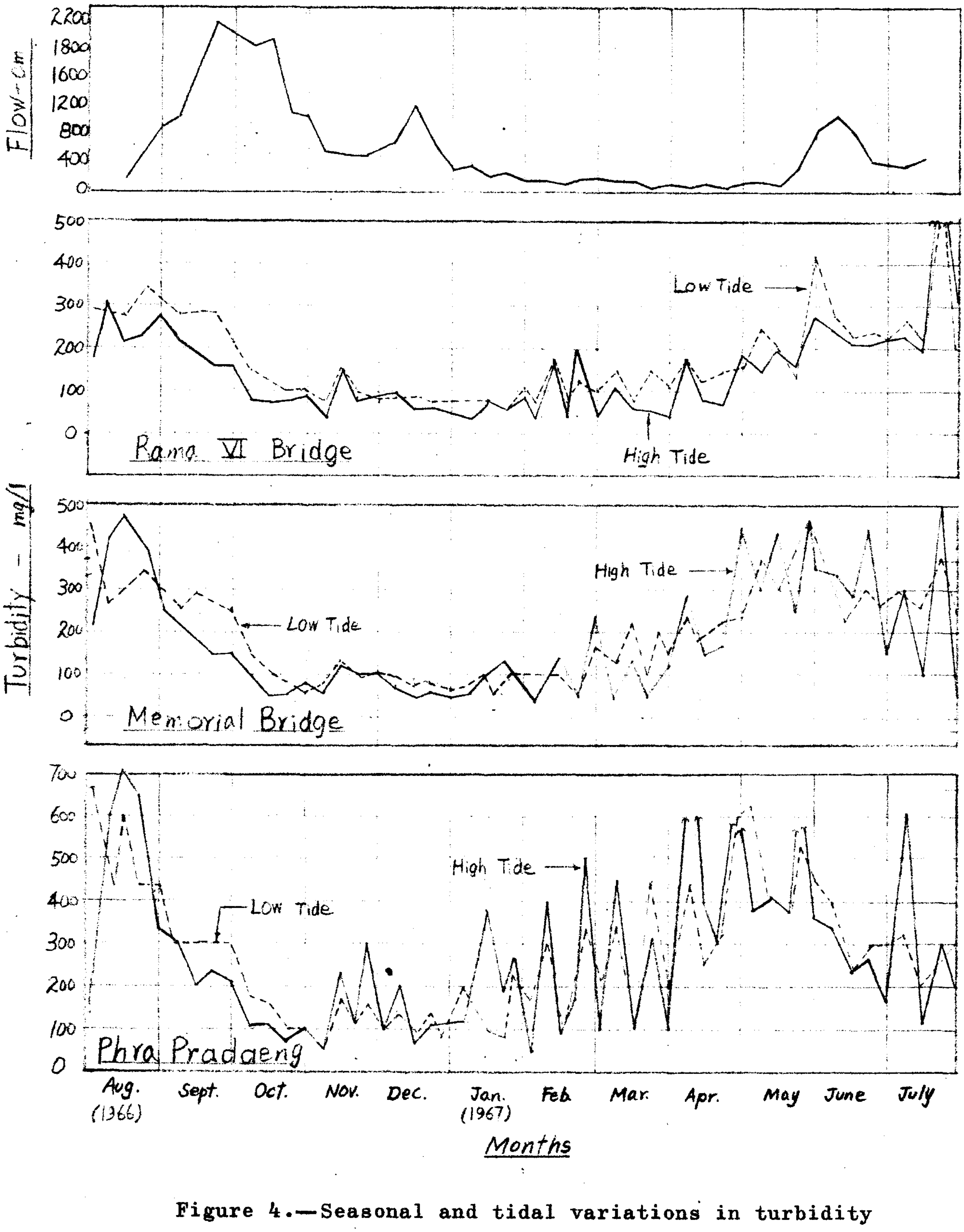


**Figure 4.—Seasonal and tidal variations in turbidity in the Chaophraya River.**

## DIURNAL VARIATIONS IN DISSOLVED OXYGEN IN THE RIVER

### Effect of sample depth

The upper curves in Fig. 5 show the effect of sampling depth on surface dissolved oxygen concentration at Memorial Bridge, and no highly significant difference is noted. At the time of year (October) when these tests were run, discharge in the river was very high and, at high tide, the estuary was likely to have been stratified. The lower curves in Fig. 5 show the effect of sampling depth on the dissolved oxygen levels over the whole depth of the river at low river discharge. Under these flow conditions the estuary was well-mixed at all states of the tide and again, no significant difference is noted between the curves.

### Effect of tidal variations on dissolved oxygen at Memorial Bridge

Fig. 6 shows the dissolved oxygen concentration changes in the river at different times for different tidal conditions, as indicated by the stage curves supplied by the Royal Irrigation Department. General observation to be made from these plots are that, at Memorial Bridge, maximum dissolved oxygen concentration in the river occurs at low water slack and minimum at high water slack. This is indicative of a great deal of pollution exerting an oxygen demand entering the river below Memorial Bridge and being carried up past this station on the flood tide. The fact that the maximum dissolved oxygen recorded at Memorial Bridge during the studies was only 68% of saturation (as shown in Fig. 5) shows that some pollution of the river does occur above this point. Any effect that photosynthetic oxygenation might have on the dissolved oxygen concentration in the river is masked in these data by the large fluctuations caused by tidal movements. However, the fact that it can be masked shows that the effect is likely to be slight.

### Seasonal changes in dissolved oxygen at Memorial Bridge

Fig. 7 has been drawn to show the seasonal changes which occur in maximum and minimum dissolved oxygen concentration in the river at Memorial Bridge. These, of course, are intimately related to the river discharge, but it is significant to notice that even at very high flows

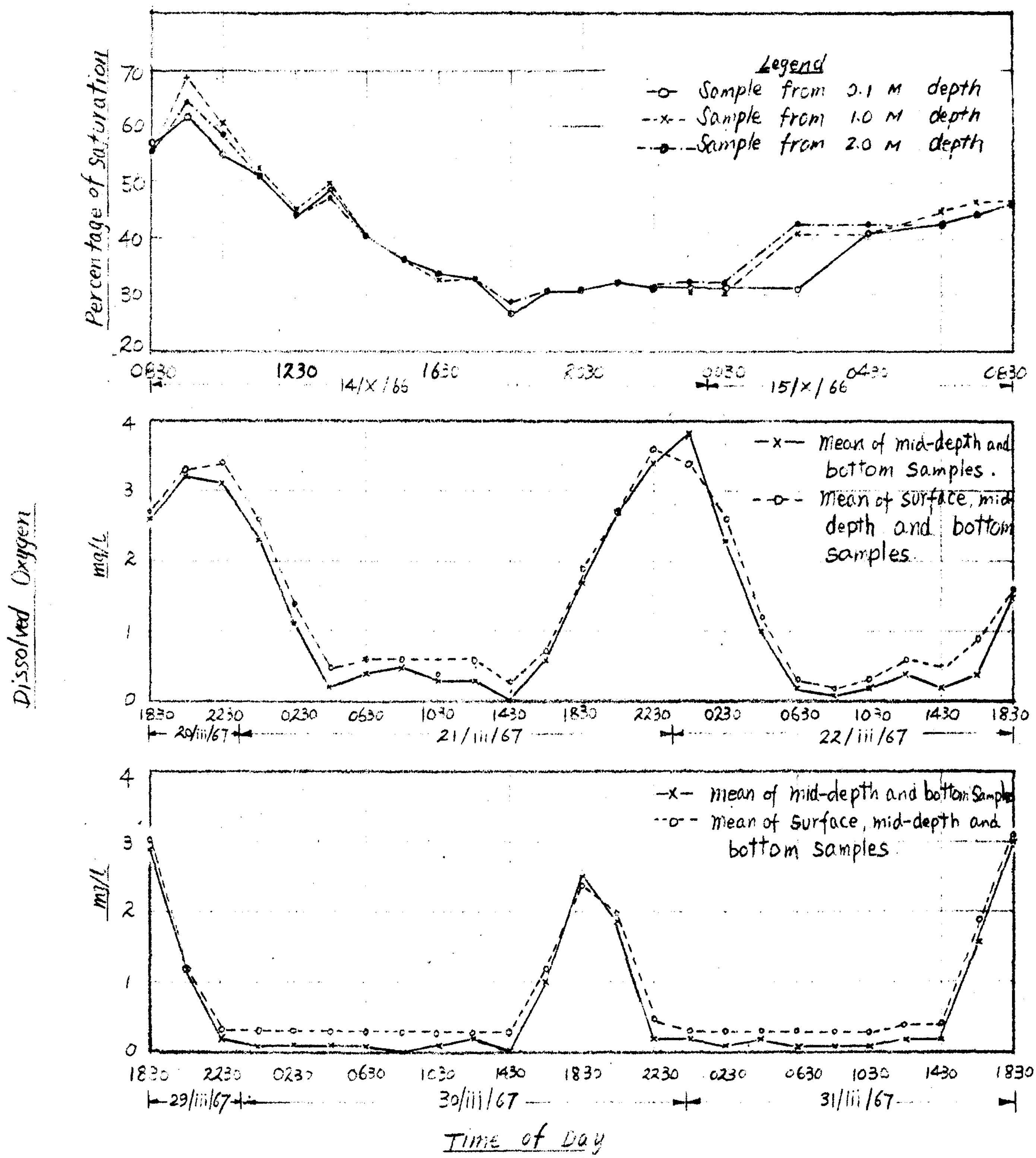


**Figure 5.—Diurnal variations of dissolved oxygen concentration in the Chaophraya River.**

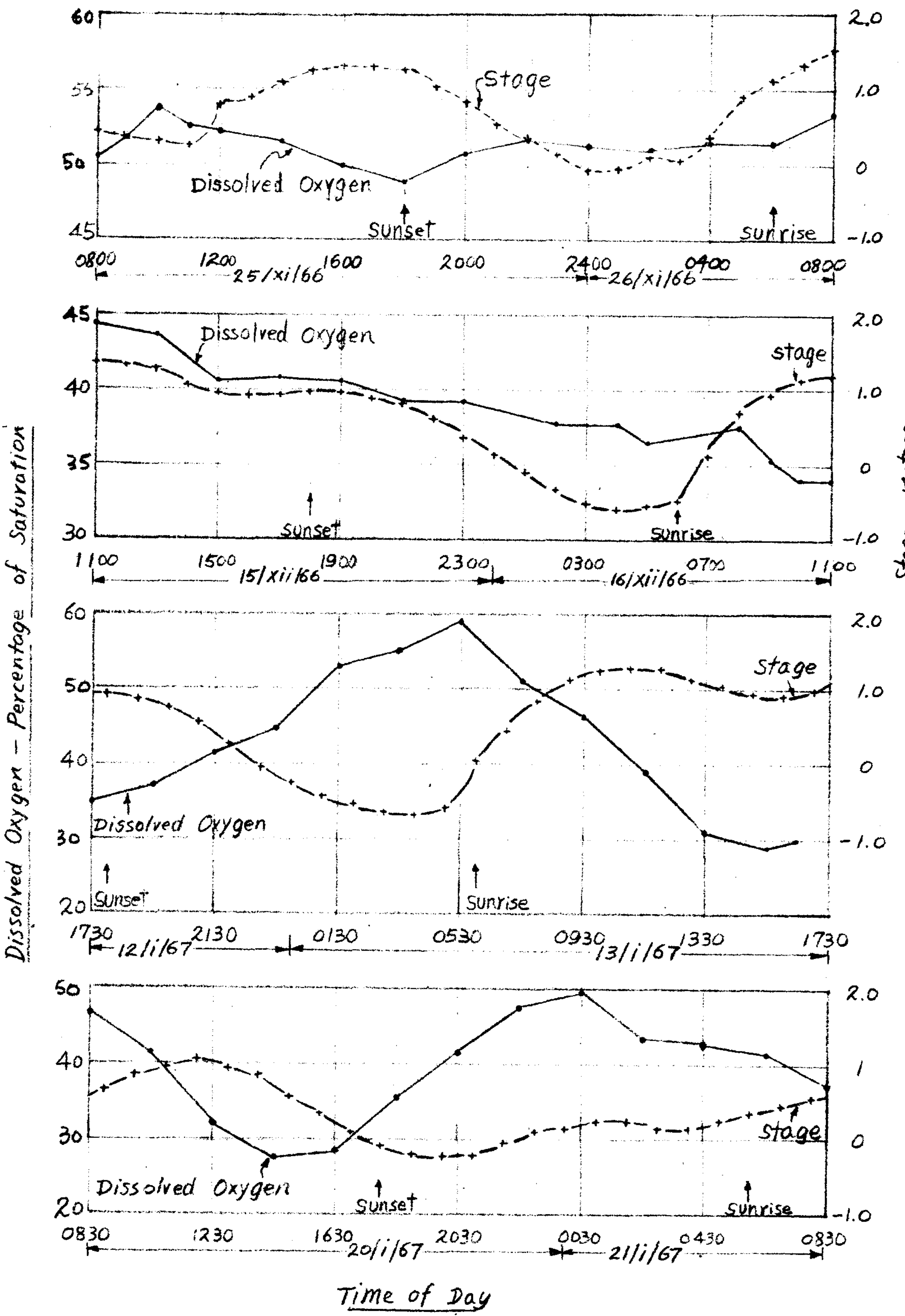


Figure 6.—Diurnal variations in dissolved oxygen concentration at 1 m depth in the Chaophraya River at Memorial Bridge.

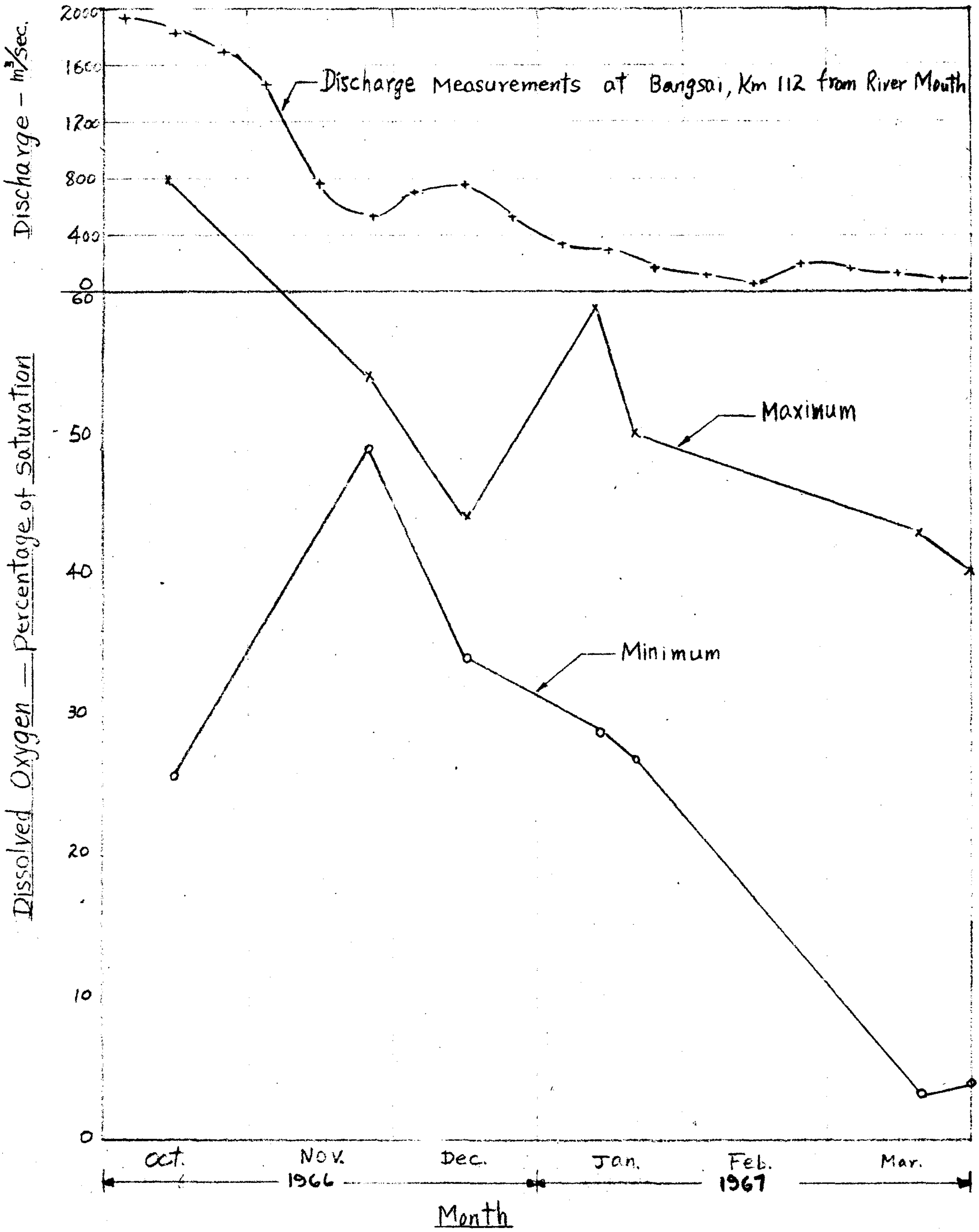


**Figure 7.—Maximum and minimum dissolved oxygen in the Chaophraya River at Memorial Bridge.**

in the river the maximum dissolved oxygen concentration is only 68% of saturation. At low flows this falls to 40% of saturation which is the oxygen reserve to be drawn on by micro-organisms in breaking down the polluting load. At low river discharge the minimum dissolved oxygen at Memorial Bridge is very close to zero and this reflects the inadequacy both of the initial oxygen reserve and of its replanishment, by surface reaeration and photosynthetic oxygenation, to contend with the high load of pollution from the city of Bangkok. There is a great danger of the river becoming anaerobic at Memorial Bridge at high tide unless something is done to limit the discharge of organic pollution to the river.

## Dissolved oxygen changes in the river

Fig. 8 and Fig. 9 show the fluctuations in dissolved oxygen concentration in the river at four stations, located as shown in Fig. 1, on two different occasions in March 1967. On each occasion, samples were taken for analysis every two hours over a 48-hour period and this work, involving many men and a great deal of organization, was carried out in cooperation with Camp, Dresser & McKee, the Consulting Engineers to the Drainage and Sewerage Planning Committee. On the same figures, stage records have been plotted to show the condition of the tide. Peaks and troughs in the dissolved oxygen curves coincided with maxima or minima of chloride concentration and may be considered to occur at slack water periods. These did not exactly coincide with extreme high or low stages. Although on the two occasions tested the tide conditions were different, the trends in dissolved oxygen were the same for any particular station.

Rama VI Bridge.—At Rama VI Bridge, the low tide situation gives the condition of the fresh water flow in the river before being polluted by the city wastes and represents the reserve of dissolved oxygen for future use. All available records of dissolved oxygen at high and low tide conditions have been plotted on Fig. 10 and, for the low tide condition at this station, it can be seen that only about 60% of the possible oxygen concentration is present at any time. Some of these data represent flood conditions in the river and therefore it appears that even before reaching Bangkok, the Chaophraya River is already carrying a burden of organic pollution.

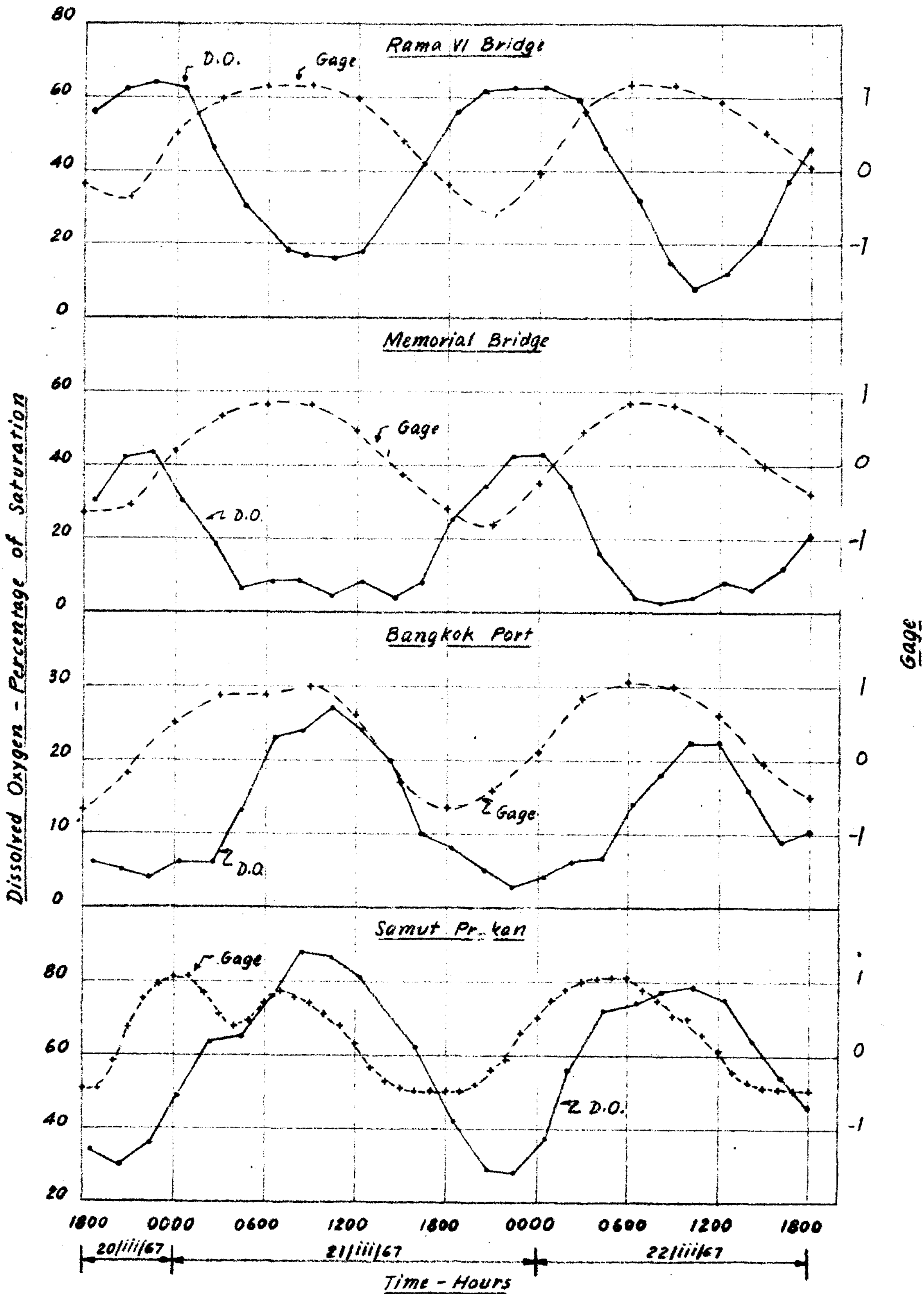


Figure 8.—Dissolved oxygen and stage variations at four stations on the Chaophraya River.

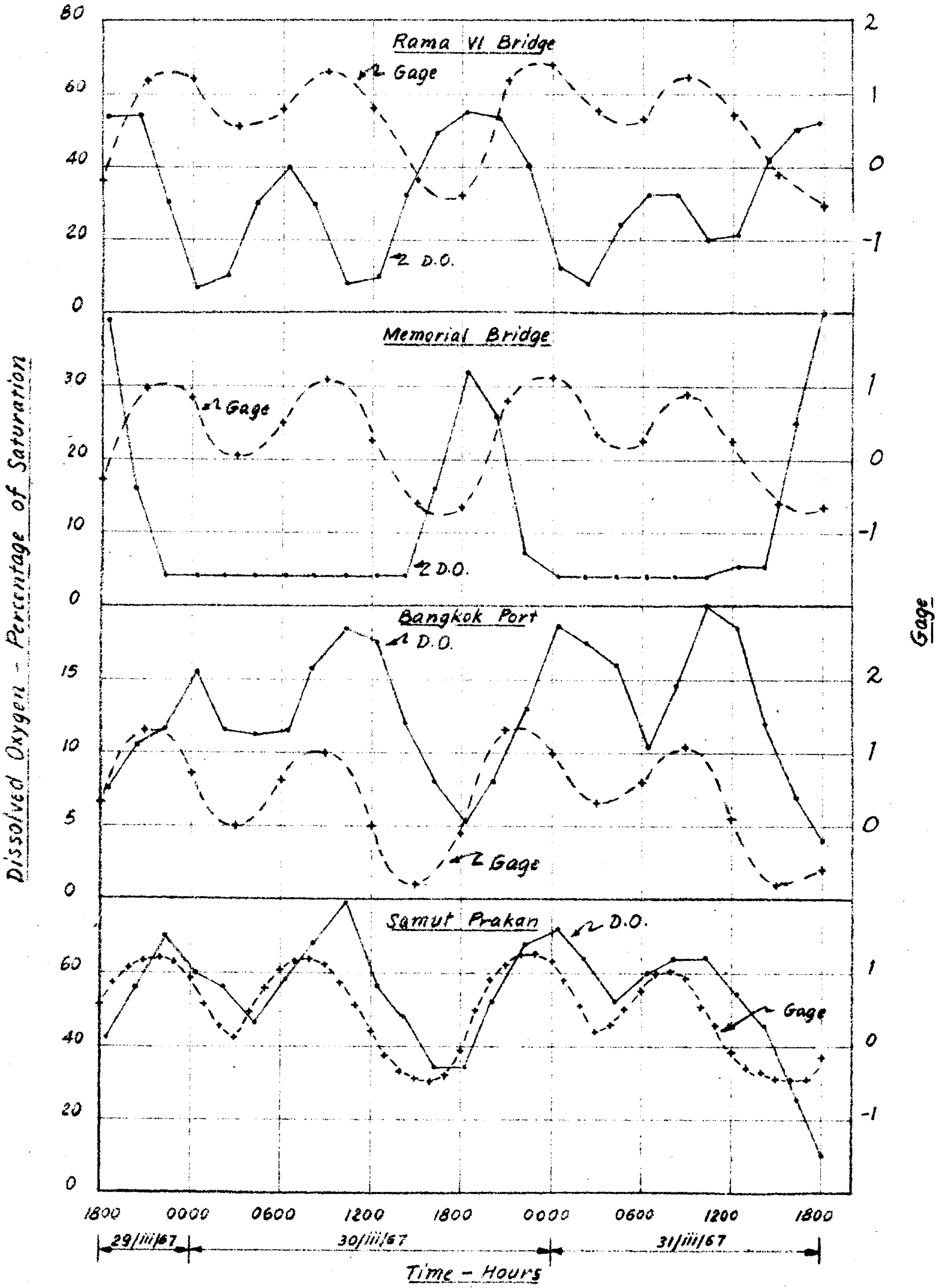


**Figure 9.—Dissolved oxygen and stage variations at four stations on the Chaophraya River.**

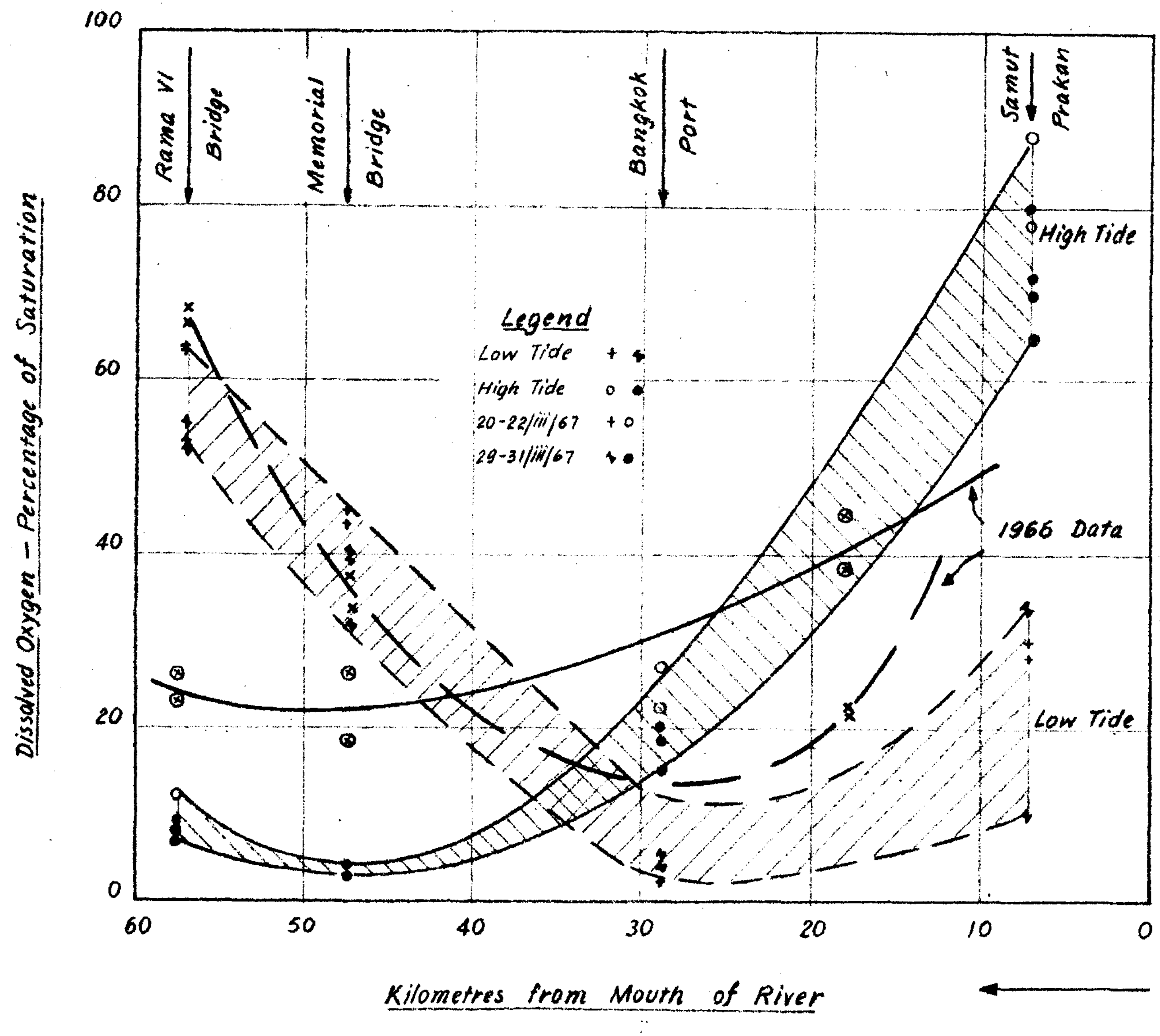


Figure 10.—Dissolved oxygen changes in the river. (Maximum and minimum D.O. levels in the river at equivalent zero velocity conditions)

At high water slack at Rama VI Bridge minimum dissolved oxygen concentration is always experienced and this is due to the main pollutional load from Bangkok being carried up past the station. The worst conditions, which occur during low discharge in the river (March and April), have been plotted in Fig. 10. Data from 1966 show higher reserves of dissolved oxygen than do the 1967 figures which suggests that the condition of the river is worsening. This might not be strictly true, since the 1966 data were not obtained on a continuous basis and might not reflect the worst condition of the river, but records at other stations seem to confirm the suggestion. The reserve of dissolved oxygen at Rama VI Bridge, under low flow conditions, is a mere 6 to 12% of the saturation value.

Memorial Bridge.—The data plotted in Fig. 8 and Fig. 9 support the information already presented for this station. In Fig. 10, all available results at low river discharge have been plotted and the low tide condition shows a dissolved oxygen level of only about 40% of saturation. The high tide condition is worst and is critical, with only 2 to 4% of the saturation value available. Any increase in pollution over the present level would certainly result in anaerobic conditions prevailing for long periods at this station. 1966 data support the suggestion that the river condition is worsening as a result of increasing pollution.

Bangkok Port.—The results for the Bangkok Port Station contained in Fig. 8 and Fig. 9 show clearly that the major pollution of the river occurs between Memorial Bridge and this station. At the time of the tests, with low river discharge, the worst condition was always at low tide. Under flood tide conditions, the intrusion of salt water from the Gulf of Siam tended to dilute the polluted fresh water flow and gave rise to slightly increased dissolved oxygen levels. In Fig. 10 the high and low tide data for this station have been plotted, for low river discharges, and the range of available oxygen, from 2 to 27%, indicates that the river cannot support further pollution without anaerobic conditions arising in the Port area.

Samut Prakan.—The results of salt water mixing are more apparent at the Samutprakan Station where maximum and minimum dissolved oxygen levels have improved from the Bangkok Port. This can be seen in Fig. 8 and Fig. 9 which also show that high tide gives a maximum of dissolved oxygen and low tide a minimum.

Considering the overall picture of dissolved oxygen over the reach of the river from Rama VI Bridge to Samut Prakan, there is no doubt that the river is heavily polluted and is in danger of becoming anaerobic. In Fig. 10 envelope curves have been drawn to represent the range of conditions applying at low and high tides for low river discharges. The trend of low tide data clearly indicates an oxygen sag curve, with depression of dissolved oxygen from Rama VI Bridge to Bangkok Port giving a minimum dissolved oxygen level at or near the Port. Between the Port and Samut Prakan, there is definite evidence of dissolved oxygen recovery, even allowing for the salt water dilution effect. At high tide the sag curve is moved upstream, due to the tidal excursion, and the minimum dissolved oxygen level now occurs at or near Memorial Bridge. These general observations apply to the river for relatively constant low flows and represent the equilibrium conditions which are established in a tidal estuary due to diffusion phenomena and tidal movements.

In Fig. 10, lines representing 1966 data have been drawn and comparision of these with the 1967 curves suggests that the river condition is worsening each year. It is obvious that if further pollution of the river is allowed to occur, an anaerobic zone will extend from above Memorial Bridge to below the Port area at low river discharges. Even at the present time it is likely that anaerobic conditions in the river result from the first major rainfall after the dry season flushing organic deposits from the drains and khlongs into the river.

## PHOTOSYNTHETIC OXYGEN PRODUCTION

### Oxygen production at surface

Typical results from tests involving samples of river water taken from 1 m depth and incubated in light and dark bottles just below the surface of the river at Memorial Bridge are given in Fig. 11. They reflect the changes which occur in the light and dark bottles over a 24-hour period for different setting up times. The curves for 15 and 16 December 1966 are typical of many obtained in the present studies and conform to those suggested by Owens and Edwards (1964) for River Avon water, but the magnitude of the differences between the light and

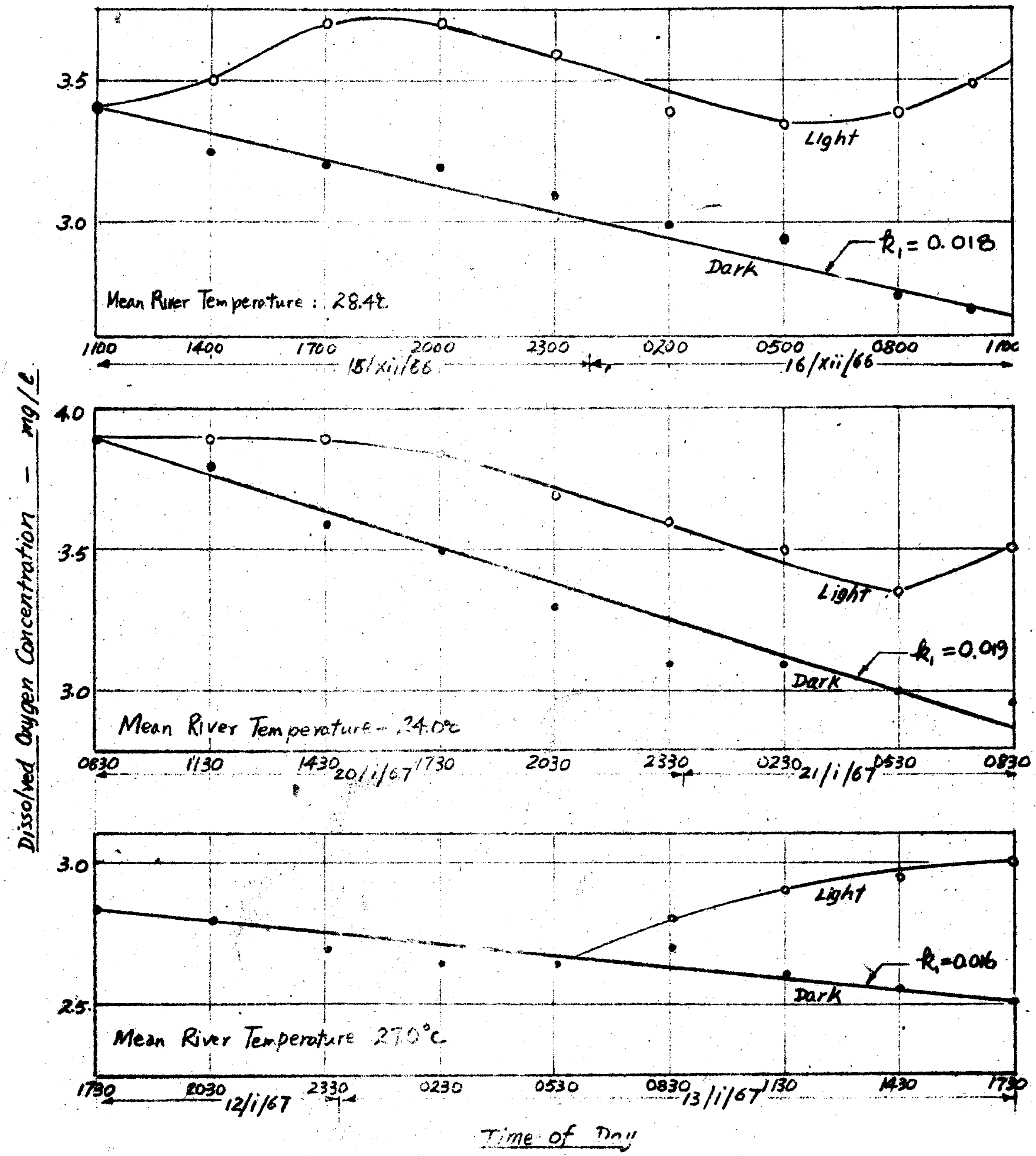


**Figure 11.—Changes in dissolved oxygen content of Chaophraya River water incubated just below the river surface in light and dark bottles for 24 hours.**

dark bottles is markedly less than they observed. During the daylight hours photosynthetic oxygen production more than matched the respiration demand in the light bottle and dissolved oxygen concentration increased with time. Between sunset and sunrise respiration proceeded at a rate similar to that in the dark bottle. This rate gives a deoxygenation rate constant ($k_1$) of 0.018 at 28.4°C.

Although the curves shown for 20 and 21 January 1967, are similar to the previous ones they differ in that, for the first daylight period, photosynthetic oxygen production was only sufficient to match respiration demands. This prevented a drop in dissolved oxygen in the light bottle but did not give rise to an increase. During the hours of darkness, respiration proceeded at a rate giving a deoxygenation constant of 0.019 at 24.0°C. The temperature of the river at the time of this test might very well explain the apparent drop in oxygen production by the algae present, although this could equally well be attributed to a decrease in their numbers. At the beginning of the second daylight period, the oxygen level did rise in the light bottle.

The curves for 12 and 13 January 1967 show the effect of changing the setting-up time to night. Respiration in both light and dark bottles proceeded at a constant rate during the hours of darkness with a deoxygenation constant of 0.016 at 27.0°C. This constant respiration rate continued in the dark bottles throughout the daylight hours but, in the light bottles, photosynthetic oxygen production exceeded respiration demands and the dissolved oxygen concentration increased.

These curves are typical of many others produced from the data collected during the present studies. The difference in dissolved oxygen between the light and dark bottles after 24 hours represents the photosynthetic oxygen produced, for the conditions of the test, and approximates that produced in the river near the surface. For samples incubated just below the river surface between November 1966 to March 1967, the photosynthetic oxygen production ranged from 0.5 to 1.3 mg/l day. In the same period, the 1-day BOD's of the river water ranged from 0.25 mg/l to 1.1 mg/l.

Fig. 12 shows the changes occurring in light and dark bottles over a 48-hour period of incubation in the river near the surface on two

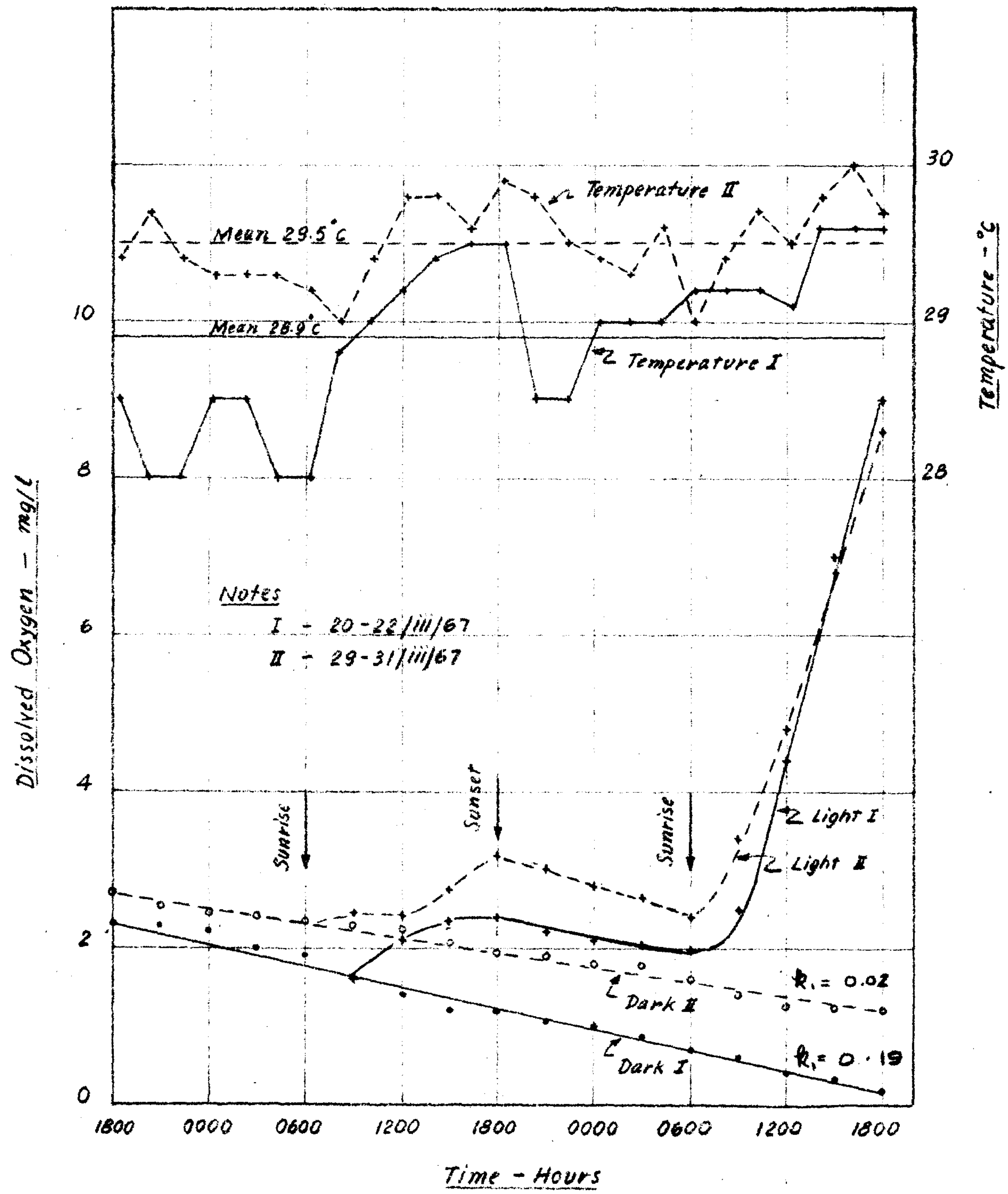


Figure 12.—Light and dark bottle results at surface of river at Memorial Bridge.

occasions in March 1967. For the first 36 hours the curves are very similar to the ones shown in Fig. 11 but after that time, during the second period of daylight, the dissolved oxygen in the light bottles increased very rapidly to concentrations in excess of the saturation values. This was unexpected since no indication of such an effect was suggested by diurnal oxygen changes in the river. A possible explanation for this is that the walls of the bottles allowed prolific growths of algae to occur within the two day period of the test. In fact, a similar effect can be noted in the curves in Fig. 11, for 20 and 21 January 1967, during the second daylight period.

Effect of depth on oxygen production

Fig. 13 presents the results of light and dark bottle studies carried out simultaneously at different depths in the river at Memorial Bridge on two occasions. These curves are typical of many produced in the course of the studies and show how incubation at increasing depth reduced the photosynthetic oxygen production to a point where no oxygen was produced by photosynthetic micro-organisms. This was the lower limit of photosynthesis and gave the extent of the euphotic zone. It is said that at this depth the transmitted light is 1 per cent of the light incident on the surface. Table 4 lists results obtained at different times and it can be seen that the depth of the euphotic zone in the Chaophraya River, even at low turbidity levels, was within the range of 1 to 1.5 m. The depth at which the light bottle curve crosses the initial dissolved oxygen line is termed the compensation depth and is the point at which photosynthetic oxygen production matches the respiration demand. This depth varied a great deal and on one occasion the oxygen produced did not match the respiration demand.

Total photosynthetic oxygen production

The area enclosed by the final light bottle curve, the surface, and the final dark bottle line is a measure of the total photosynthetic oxygen production for the column of water. Over the period of these studies the largest and smallest areas enclosed gave gross photosynthetic oxygen productions of 0.78 and 0.20 $g/m^2$ day. These are low when compared with maximum and minimum photosynthetic oxygen production rates

TABLE 4

RIVER PHOTOSYNTHETIC ZONES

| Data | River Turbidity mg/l | Depth of euphotic zone | Compensation Depth | Surface Photosynthetic Oxygen Production mg/l.day | Respiration Oxygen Demand mg/l.day |
|---|---|---|---|---|---|
| 4-5/xi/66 | - | 1.15 | 0.7 | 0.80 | 0.25 |
| 25-26/xi/66 | 53 | 1.25 | 0.25 | 0.85 | 0.65 |
| 15-16/xii/66 | 52 | 1.10 | 0.10 | 0.85 | 0.70 |
| 12-13/i/67 | 78 | 1.00 | 0.35 | 0.50 | 0.35 |
| 20-21/i/67 | 66 | 1.05 | - | 0.50 | 0.95 |
| 20-21/iii/67 | 55-170 | 1.5 | 0.25 | 1.30 | 1.10 |
| 29-30/iii/67 | 55-235 | 1.0 | 0.10 | 1.20 | 0.8 |

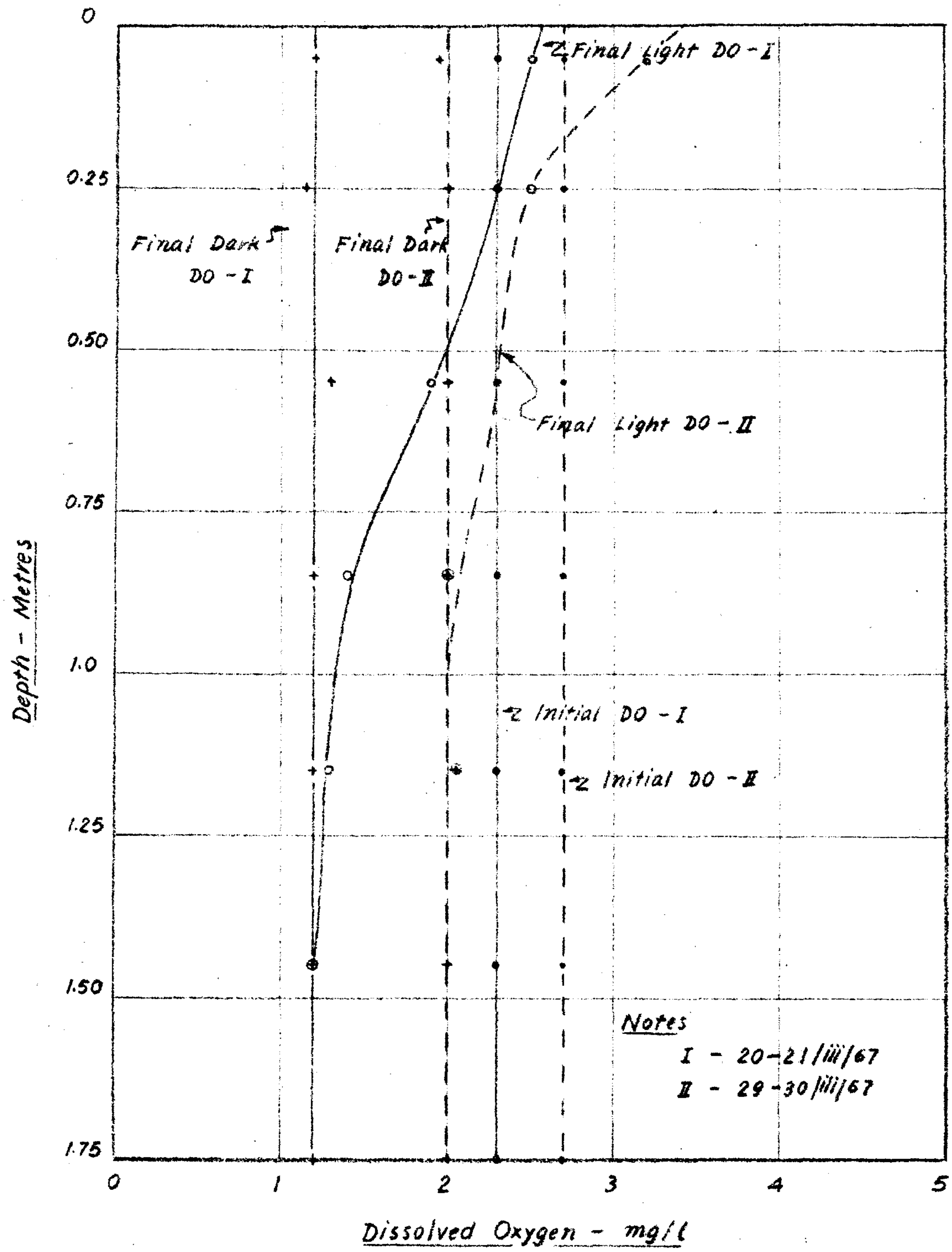


Figure 13.—Photosynthetic oxygen contribution in 1 day at different depths.

in the Delaware River Estuary of 2.05 and 8.53 $g/m^2$ day (HULL 1964) and in relation to the respiration demands for the same columns of water of approximately 17 and 16 $g/m^2$ day. The cross-section of the river at Memorial Bridge has the greatest depth of any in the Chaophraya estuary and the respiration demands in this reach would be the greatest encountered. However, only where the river depth is in the region of 1.5 m would the oxygen supply by photosynthesis be sufficient to match the respiration demand.

Seasonal variation in photosynthesis

The main factors affecting photosynthetic oxygen production in the river are river water turbidity and algae concentration, temperature, and intensity of radiation. However, the fact that high counts of algae occur at high turbidity levels would be offset by the fact that, under these conditions, light transmission through the water would be less. It is not possible at this time to state definitely which factor is the more important although the data in Table 4 tend to suggest that increased turbidity reduces oxygen production. If this is so, then June to September would be the period of lowest photosynthetic oxygen production. In Fig. 14 are presented the 4-5 year average monthly radiation intensities, measured at Bangkok, and the river temperature variations for the year 1965-6, measured at Memorial Bridge. It is obvious that the conditions for greatest stimulation of photosynthesis occur in April.

From these considerations it appears that the estimates of photosynthetic oxygen production developed for the end of March 1967 approximate to the maximum likely to occur over the year. At this same time, the river discharge is at a minimum and the pollution condition of the river is worst.

## CONCLUSIONS

Normal conditions in the Chaophraya River provide a satisfactory environment for algal growth and photosynthesis. Although the numbers of algae in the river water increase to a certain extent with increasing turbidity, the effect of turbidity in reducing light transmission seems to affect adversely the photosynthetic oxygen production.

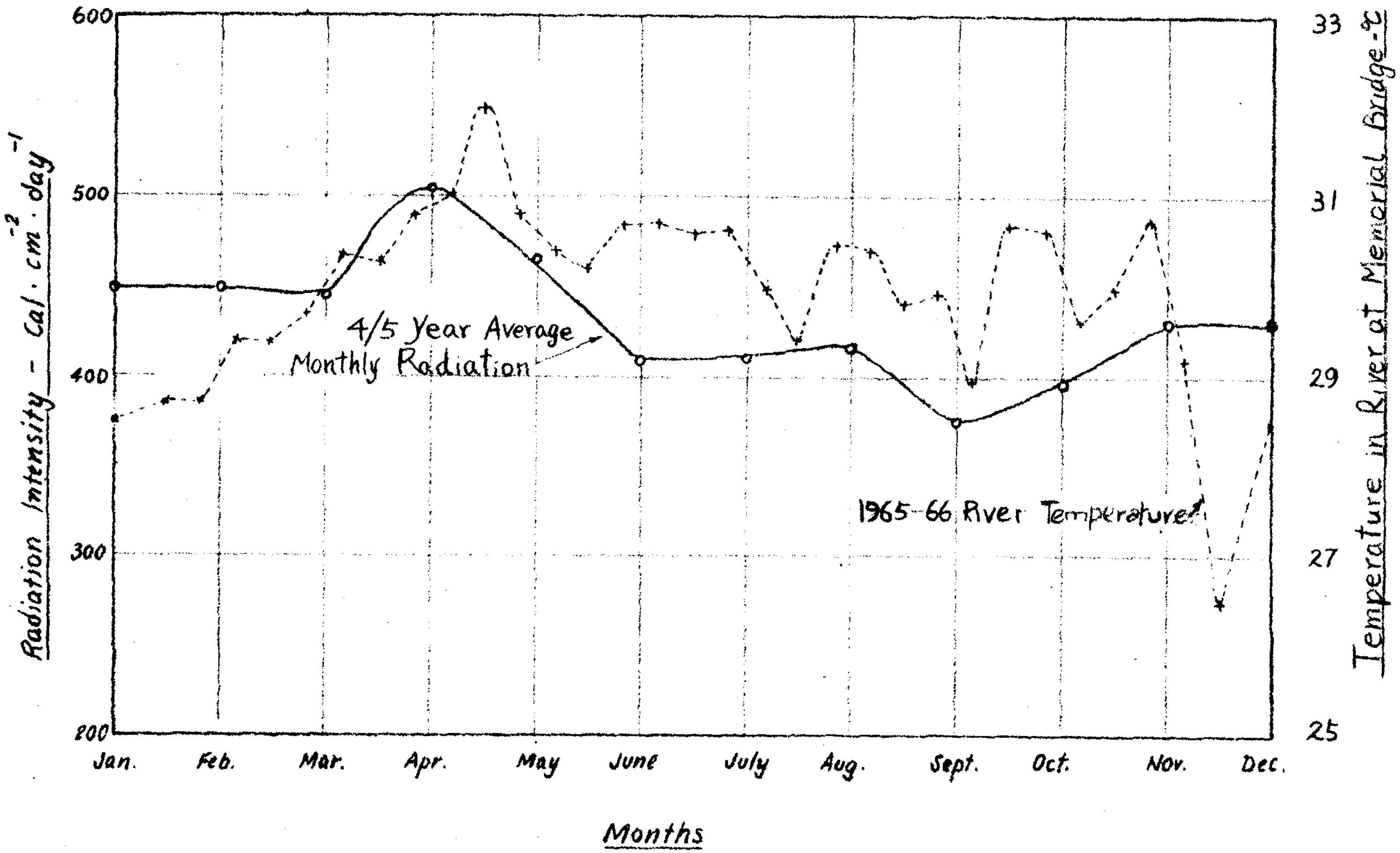


Figure 14.—Radiation and river temperature variations.

Dissolved oxygen concentrations in the river are closely related to tidal movements. The lowest levels of dissolved oxygen are recorded at high or low water slacks depending upon the location of the station. At and below Bangkok Port the greatest oxygen level occurs at high tide whilst above the Port the greatest level occurs at low tide. The lowest dissolved oxygen concentration occurs at low river discharge, when the estuary is non-stratified, and, at this time, the river is very close to becoming anaerobic in the reach from Memorial Bridge to the Port. A definite oxygen sag curve is observed at low river flows with depression of dissolved oxygen from Rama VI Bridge to a minimum at or near Memorial Bridge for high tide conditions and Bangkok Port for low tide conditions. Some recovery occurs between the Port and Samut Prakan, towards the river mouth, but this is the result of many days of residence in the estuary. There is evidence to indicate that the river condition is becoming worse each year.

Light and dark bottle studies have shown that photosynthetic oxygen production by phytoplankton is normally in the range from 0.5 to 1.3 mg/l day at the river surface. This falls off to zero very quickly with the usual depth of the euphotic zone being from 1 to 1.5 m. The gross photosynthetic oxygen production at Memorial Bridge ranged from 0.20 to 0.78 $g/m^2$ day whereas the respiration demands for oxygen at the same section at the same times were 16 and 17 $g/m^2$ day. Thus photosynthesis can supply from 1.25 to 4.6% of the oxygen demand at this section of the river. The contribution of oxygen by photosynthesis at other stations on the river should make up a greater proportion of the demand because of the lower depths of the sections.

## REFERENCES

AMERICAN PUBLIC HEALTH ASSOCIATION, AMERICAN WATERWORKS ASSOCIATION, and WATER POLLUTION CONTROL FEDERATION (1965).—"Standard Methods for the Examination of Water and Wastewater." 12th ed. (American Public Health Association, Inc.: New York.)

HULL, C.H.J. (1964).—"Photosynthetic Oxygenation of a Polluted Estuary, Advances in Water Pollution Research." vol. 3, (Pergamon Press: London.)

NEDECO (NETHERLANDS ENGINEERING CONSULTANTS) (1965).—"A Study on the Siltation of the Bangkok Port Channel." (The Hague.)

OWENS, M. and EDWARDS, R.W. (1964).—A chemical survey of some English rivers. Proc.Soc.Wat.Treat.Exam. **13**:134-144

WATER POLLUTION RESEARCH LABORATORY (1964).—"Effects of Polluting Discharges on the Thames Estuary." (H.M. Stationery Office: London.)

WYCOFF, B.M. (1964).—Rapid solids determination using glass fibre filters. Wat.Sewage Wks **111**:277-280.