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Evaluation of Alternatives to Meet the Dissolved Oxygen Objectives of the Lower San Joaquin River

Prepared for

California State Water Resource Control Board
Sacramento, California

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1. INTRODUCTION

INTRODUCTION

This report has been prepared, at the request of the California State Water Resources Control Board (the Board), to assist in identifying and evaluating alternatives to achieve the water quality objectives for dissolved oxygen (D.O.) in the Lower San Joaquin River. Numerous factors affect D.O. concentration and analyses of the influence of these factors can lead to the identification of measures that can help improve D.O.

The Sacramento and San Joaquin are two major rivers that bring freshwater into the San Francisco Bay-Delta. The flows of these two rivers are controlled by a large number of reservoirs, canals, and pumps. In the San Joaquin River system, these are located upstream of Vernalis. The Board has set rules and regulations that control flows and limit the pumping to satisfy the water right interests as well as to meet certain water quality criteria for the protection of the Bay-Delta ecosystem.

In these rules and regulations, the Board explicitly recognizes the relationship between diversions and Delta outflows which in turn control such water quality as salinity, total dissolved solids (TDS), and electrical conductivity (EC). Diversions are further recognized to be able to change flow directions in certain channels which send young fish to pumps for entrainment loss.

For these reasons, the Board requires the maintenance of a minimum Delta outflow to meet the EC criteria specified in Decision 1485. During the irrigation season of April to September, EC must be below 700 us/cm and TDS must be below 420 mg/l at Vernalis. According to the 1995 Bay/Delta Plan, the Delta outflow from February to June must keep the X2 (location where the salinity is 2,000 mg/l) between 64 to 74 kilometers from the Golden Gate. For the past few years, the State Water Project and the Federal Central Valley Project have been operated to maintain this outflow.

The water quality impact of diversions is not limited to TDS and EC. It can affect D.O. concentration as well. For example, the pumping of water from Tracy and Cliffton Court Forebay can lower the water levels in the Old River. A hydraulic gradient is created to force the water from the San Joaquin River into the Old River. The flow of the San Joaquin River at Stockton is reduced. Since the San Joaquin River is tidally influenced, the reduced flow can cause slack flows or a flow reversal toward the Old River junction. Reduced flows and flow reversals diminish the ability of the San Joaquin River to assimilate the oxygen demands from various sources.

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The Lower San Joaquin River and its tributaries serve as habitat for fish and other aquatic species. The D.O. objectives for the San Joaquin River are as follows: 5.0 mg/l; and 6.0 mg/l in the months of September through November in the reach from Tunner Cut to Stockton. The better objective is partly based on concern that up-migration of adult salmon may be blocked by low dissolved oxygen and/or high temperature in the Lower San Joaquin River.

In developing the Bay-Delta plan, the Board is considering ways to achieve D.O. objectives. Since the D.O. in the San Joaquin River can be affected by the entire Bay-Delta operation, the alternatives, to be considered, must also be wide in scope.

To evaluate alternatives, it is necessary to have a model that accounts for all the influencing factors including river flow, meteorology, temperature, point source waste discharge (BOD and ammonia nitrogen), nonpoint source discharge (including sediment oxygen demand) and algae. The City of Stockton has developed and calibrated such a model during their application for the NPDES permit of their upgraded Regional Wastewater Control Facility (RWCF). The Board has requested and the City has agreed to perform the evaluation of alternatives to meet the dissolved oxygen objectives of the Lower San Joaquin River, with the model.

SCOPE AND OBJECTIVES

The purpose of this model study is to help identify and evaluate alternatives to meet the dissolved oxygen objectives of the Lower San Joaquin River. The model, which was previously calibrated with 1991 data, was upgraded and verified with 1993 and 1996 data. Sensitivity analyses were performed to evaluate how the dissolved oxygen in the San Joaquin River is affected by flows, temperatures, waste discharge from the City of Stockton, and nonpoint source load including sediment oxygen demand.

The dissolved oxygen levels were then simulated for five hydrologic year types (above normal, below normal, dry, wet, and critically dry). For these simulations, the river flows of the San Joaquin River at Stockton were obtained from the output of DWRDSM (the dynamic estuary simulation model of Department of Water Resources). The DWR's river flows reflected the upstream reservoir operations and the operations of barriers. The 1996 waste load from Stockton's RWCF was used in the simulation, except where varied to show alternatives.

Information about the sensitivity of dissolved oxygen to various interacting factors was used to illustrate the effects of those factors and help develop alternatives to meet the D.O. objectives of the Lower San Joaquin River. Some of the alternatives discussed included a combination of flow management (through the operation of Old River barrier), waste management, and side stream aeration. The effectiveness of some specific alternatives was evaluated by the model.

2. SAN JOAQUIN RIVER MODEL

GENERAL DESCRIPTION

The model was adapted from an estuary link-node model (Chen and Orlob 1975). The model divided the river into nodes which were connected by links to form a computational network. Figure 1 shows the model domain from Old River junction to Light 18 of the Stockton Ship Channel. Within this domain, there are 25 nodes represented in the main stem of the San Joaquin River. R1 through R8 shows the locations of monitoring stations where observed water quality data are available.

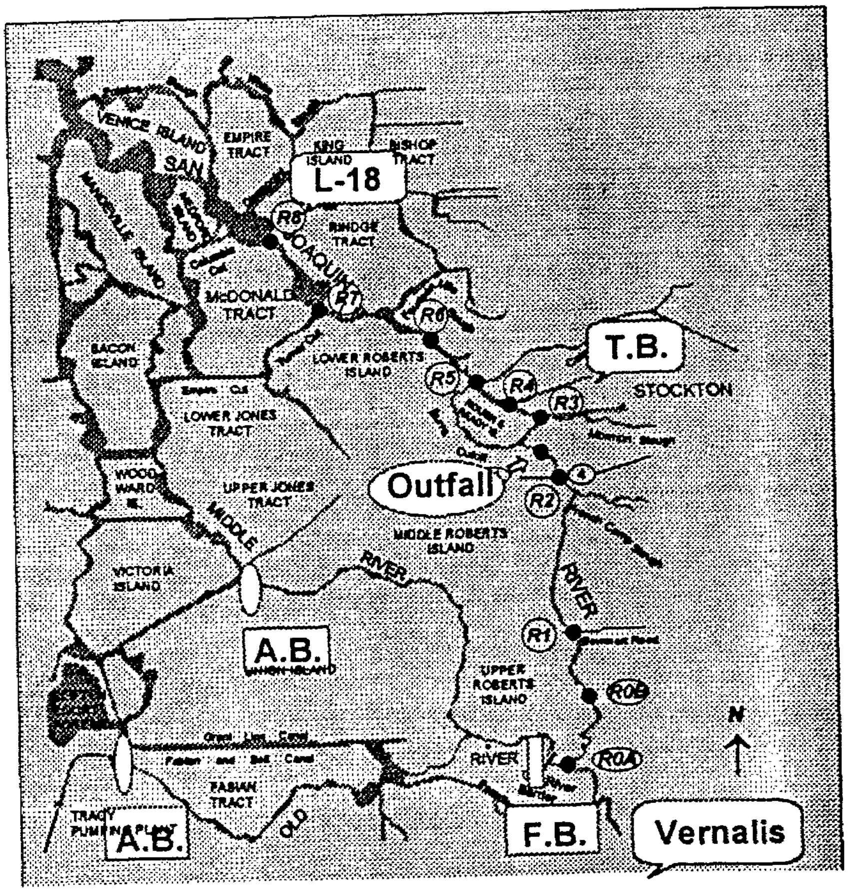

Figure 1. Lower San Joaquin River

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The model has two modules: hydrodynamic and water quality. The hydrodynamic module simulates the tidal movements of water, calculates flows from node to node and determines the water elevations at each node (tidal stage), every minute. The simulated flows are integrated to hourly values for input to the water quality module. The water quality module performs the hourly mass balance calculations to determine the water quality concentrations. The model simultaneously tracks multiple constituents, including temperature, coliform, BOD, ammonia, nitrate, chlorophyll, and dissolved oxygen. The simulation results are averaged to daily values for comparison to the measured concentrations for R1 to R8 stations. Figure 2 presents the flow chart of the Water Quality Model of the San Joaquin River.

To calculate dissolved oxygen concentration for each node, the model accounts for various sink and source terms. The sink terms include BOD decay, ammonia nitrification, sediment oxygen demand, and algal respiration. The source terms include reaeration and photosynthesis of algae. A more detail description of the model is provided in the documentation report (Schanz and Chen 1993).

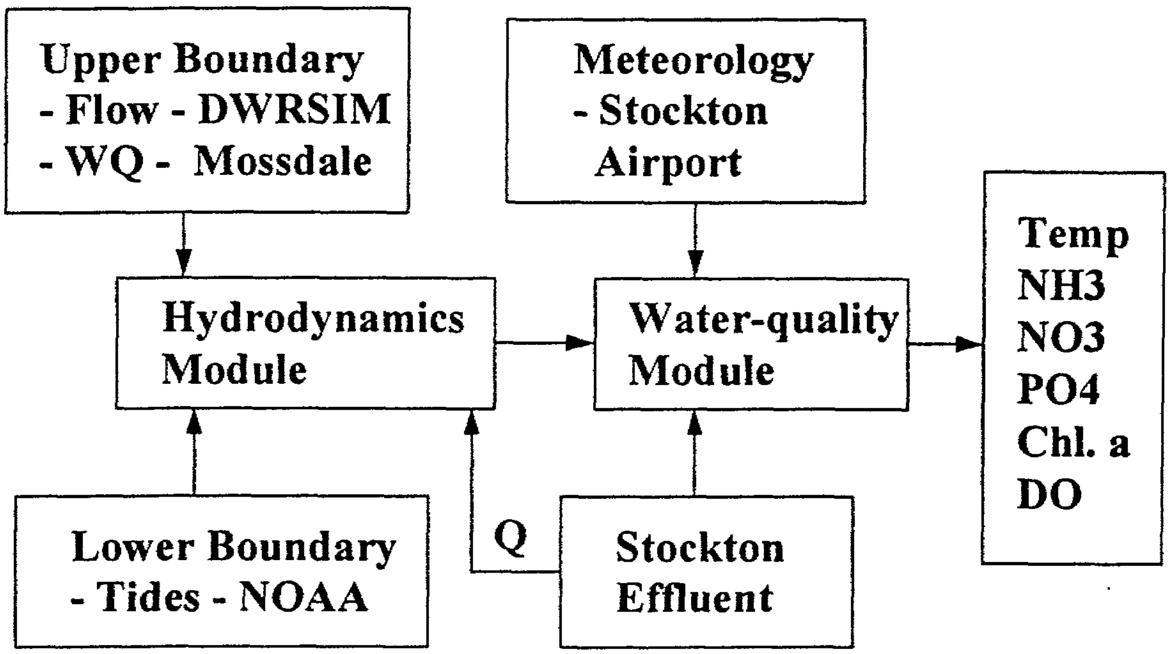

Figure 2. Flow Chart of San Joaquin River Water Quality Model

The original model has the capability to simulate temperature, nutrients (ammonia, nitrate, and phosphorus) and algae-nutrient interactions. In the previous work for the City of Stockton, the heat budget calculation was turned off, in favor of using the observed temperatures directly. For this work, the heat budget calculation was turned back on. The model was also made to read meteorological data of Stockton Airport to drive the model. The simulation results were compared to the observed data.

In the previous work for the City of Stockton, the portion of algal growth and algae-nutrient interactions was also turned off. The model has been modified to accept monthly algal productivity data for the calculation of photosynthesis oxygenation. For every gram of algae produced, 1.6 grams of oxygen was added to and 0.07 gram of nitrogen was extracted from the water. For this study, the portion for algal growth and algae-nutrient dynamics was turned back on. The model computed algal productivity as a function of temperature, light, and nutrient concentrations. Simulated concentrations of nutrients (ammonia, nitrate, and phosphorus) and algae (chlorophyll) were compared to the observed data.

INPUT DATA

Appropriate input data must be prepared for each simulated condition. There were four simulated conditions: calibration and verification, sensitivity analysis, hydrologic year type, and management alternative.

Calibration and Verification

The purpose of calibration and verification is to determine whether the model simulates what happens in the San Joaquin River. This is accomplished by showing how the model results match the observed data. For calibration and verification, it is necessary to use the actual concurrent data of meteorology, waste discharge, river flow at the upper boundary, and tide at the lower boundary. The model results can then be compared to the water quality data observed in the river under such input conditions.

The meteorological data of Stockton Airport for the specific year was downloaded from the home page of National Climatic Data Center of the National Oceanic and Atmospheric Administration (NOAA). The tide tables of the specific year were also compiled from NOAA to set up the condition at the lower boundary. The actual tides included the bi-weekly neap tide and spring tide cycle.

Waste discharge records were obtained from the City of Stockton. To determine the river flow, the record of the rock barrier operation was obtained from the California Department of Water Resources. The DWR's empirical equation was used to calculate the river flow at Stockton as a function of river flow at Vernalis and operating record of the rock barrier at the Old River junction, as described in the documentation report (Schanz and Chen 1993).

The actual water quality data at station ROA, the upper boundary of the San Joaquin River, was monitored in 1991 by the City of Stockton. The data was compiled from the City of Stockton and used directly for the calibration year 1991. For 1993 and 1996 verifications, the actual water quality data at station ROA was not available. It was estimated from water quality data at Mossdale bridge, located upstream of ROA. The data was downloaded from the home page of the Interagency Ecological Program (IEP), which contained the discrete water quality sampling and the continuous water quality sampling, both collected under D1485.

Sensitivity Analysis

Purpose of sensitivity analysis is to reach some understandings on how the dissolved oxygen concentration in the San Joaquin River responds to changes in such variables as river flow, temperature, waste discharge, and nonpoint source load. Such an understanding may help formulate alternatives to meet the dissolved oxygen objective of the San Joaquin river.

For these simulations, only the variable, whose sensitivity is being evaluated, is altered in a prescribed manner. Everything else is kept the same. The sensitivity is measured by the simulated changes in dissolved oxygen with respect to the change of the variable from the base condition.

Hydrologic Year Types

The purpose of simulations for hydrologic year types is to determine how the dissolved oxygen concentration in the San Joaquin River would be in various hydrologic years of wet, above normal, below normal, dry, and critically dry. The simulated conditions are all hypothetical and are useful only for the planning purpose.

For these simulations, the California Department of Water Resources used its dynamic estuary model (DWRDSM) to simulate the flows in the Delta channels, under various operating conditions. Three operating conditions were simulated. The first was for the base case to operate under D1485 and 1995 level of demand (variable 2.6 to 3.6 MAF). The second was for the 1995 Bay-Delta plan, which includes a temporary fish barrier at the Old River junction, operated in October and November. The third was for the Interim South Delta Program with permanent fish barrier at the Old River junction, permanent agriculture barriers at the interior of the Middle River, Grant Line Canal, and the Old River, and operating in conjunction with pulse flows in the spring and fall.

The DWR performed the DWRDSM simulations from 1922 to 1994, a time span of 73 years. From these, five characteristic hydrologic year types were selected for this study. For each of the selected hydrologic year, the meteorological data was compiled from the National Climatic Data Center of NOAA and the tidal data was obtained from NOAA. Waste load from the Stockton's RWCF was assumed to equal the 1996 waste load. The nonpoint source waste loads were accounted for by the sediment oxygen demand

Management Alternatives

The purpose of simulations under this category is to evaluate what engineering solutions can help meet the dissolved oxygen objectives of the Lower San Joaquin River. The alternatives will focus on single factors and combinations of things, i.e. some waste load reduction, some control of river flows, and some in-stream aeration.

For these simulations, the first step is to formulate management alternatives. The idea of management alternatives comes from the understandings on how dissolved oxygen concentrations in the San Joaquin River responds to various controllable variables. Such understandings are obtained from sensitivity analyses.

OUTPUT EVALUATION

The basic output of the model is time series of flows and concentrations of water quality constituents at various nodes. These can be the daily values throughout the years.

From the basic output, it is possible to select a time period and plot the water quality profile along the San Joaquin River. It is also possible to select a station (node) and plot the time-concentration of water quality parameter throughout a year. Since the dissolved oxygen concentrations vary seasonally, it is important to know when the dissolved oxygen drops below the objectives and whether the time period is important to fish migration. For that reason, the time-concentration plot is used most often for output evaluation in this report.

3. CALIBRATION AND VERIFICATION

1991 CALIBRATION

Since the algorithm for heat budget and algal dynamics have been turned on in the model for this report, the first step was to revisit the model calibration made previously.

Appendix A presents the time series plots of river flow, water temperature, ammonia nitrogen, nitrate nitrogen, total phosphorus, chlorophyll-a, and dissolved oxygen. The plots were made for station ROA, and R1 through R8, where observed data were available. The results for station ROA were the headwater conditions, based on the observed data of 1991. There was no distinction between the simulated and observed values. For other stations, the simulated results were plotted in solid line and the observed values were plotted in circles.

The water year 1991 was classified as critically dry. Persistent positive flow occurred only in October and November of 1990 and the latter part of September of 1991. Table 1 presents the number of days with negative flow and the average daily flow of each month.

Table 1. Summary Statistics of River Flows in the San Joaquin River for 1991 Hydrology

Month	Days with (-) Flow	Average Flow, cfs
Oct 90	0	415
Nov 90	0	472
Dec 90	20	- 16
Jan 91	25	- 42
Feb 91	18	- 49
Mar 91	18	- 40
Apr 91	20	- 95
May 91	1	179
Jun 91	23	-28
Jul 91	29	-73
Aug 91	30	-118
Sep 91	8	163
Annual	192	65

For the critical dry year of 1991, the annual average daily flow in the Lower San Joaquin River at Stockton was only 65 cfs. Negative flows occurred in 192 days out of 365. When the river flow is negative, the water was pushed upstream by tides coming through the Stockton Ship Channel. This phenomenon is termed flow reversal, and its magnitude is a function of distance from the lower boundary (i.e. Light 18 in Stockton Ship Channel).

The time series plots of temperatures showed a close match between the simulated and observed values. Other than some under-predictions for May and June, the model followed the seasonal variation of river temperature.

Both the model results and field data showed that the river temperatures varied seasonally from 5 degrees Celsius in January to 27 degrees Celsius in July, August, and September. As the temperature goes up from 5 to 27 degrees, the solubility of dissolved oxygen comes down from 12 to 8 mg/l. The natural variation of temperature alone forces 4 mg/l of oxygen out of the water. In addition, warmer temperature causes everything (BOD, ammonia, sediment BOD) to decay faster and consume dissolved oxygen in the process. Thus, it is more difficult to meet a high DO objective in late summer and early fall, when temperature is 25-27 degrees Celsius.

The time series plots of ammonia nitrogen follow the observed data for all monitoring stations. During the rainy season of January through March, the model under predicted the observed ammonia concentrations for stations R2, R3, and R4. The observed ammonia nitrogen concentrations were as high as 5 to 6 mg/l in the San Joaquin River. The model predictions had high values of 4 to 5 mg/l. These results suggest that the nonpoint source load of ammonia nitrogen might have been under estimated for input to the model.

The time series plots of nitrate nitrogen follow the observed data very closely for all monitoring stations. The concentrations of nitrate nitrogen stayed at 1 to 2 mg/l throughout most of the year. Only in the summer month of August, the algal growth would consume nitrate nitrogen to as low as 0.8 mg/l.

There was an incompatibility between the simulated and observed phosphorus. The model tracked total dissolved phosphorus. The observed data was available only for ortho phosphate. Since total phosphorus included ortho phosphate, the simulated total phosphorus was expected to be higher than the observed ortho phosphate.

The time series plots indicates that the simulated total phosphorus was lower than the observed ortho phosphate during the rainy season. The problem can be caused by the under estimate of nonpoint source load, similar to the situation for ammonia nitrogen. For other periods, the simulated total phosphorus was higher than the observed ortho phosphate. The model predicted lower concentrations of total phosphorus. But, the observed ortho phosphate was reported near zero.

The time series plots of chlorophyll-a concentration indicate a reasonably close match between the simulated and observed values for all monitoring stations. It is said to be "reasonably close", because chlorophyll-a is very difficult to predict precisely by the model or to measure precisely in the analytical laboratory. It is not only a matter of mass balance, which the model can do well, but also a matter of species composition and their physiological state, both of which can change the chlorophyll-a to biomass ratio.

The model results indicates that algae was mostly transported from the headwater location. The general trend was for the chlorophyll-a level to drop toward downstream. The algal biomass was lost to the tidal exchange at the downstream boundary. However, algal blooms can be triggered by right combinations of temperature, nutrients, sunlight, and calm stagnant water, at a localized area, not accounted for in the model. The model could miss some high values of chlorophyll-a due to localized algal blooms.

The effect of algae on dissolved oxygen depends on the chlorophyll level. At the low chlorophyll level of 10-20 ug/l, algae would not contribute a large net gain or net loss of dissolved oxygen in water column. In the summer when algal density becomes higher, algae would contribute to a net loss of dissolved oxygen.

Time series plots of dissolved oxygen indicate that the model has maintained its good calibration as before. This is not surprising. The simulated temperature was close to the observed temperature and the simulated algae was close to the observed chlorophyll-a level. Therefore, the effects of temperature and algae on dissolved oxygen were properly account for, now as well as before.

The model simulation as well as the observed data showed that dissolved oxygen concentrations, in the critically dry year of 1991, were below 5 mg/l in the lower San Joaquin River from station R1 to station R4, in most of June, July, August, and September. Persistent negative river flow drove the dissolved oxygen concentration down to 3 mg/l. The low DO situation also occurred occasionally in February through May when the river flow was persistently low or negative.

1993 VERIFICATION

For 1993 verification, the model coefficients used in the 1991 calibration were not changed. The meteorology, river flow, and waste discharge data of 1993 were input to the model. The model results are plotted for comparison to the observed data. The comparisons are made only for temperature and dissolved oxygen, due to a lack of observed data for chlorophyll-a and other water quality parameters.

Appendix B presents the time series plots of river flow, temperature, and dissolved oxygen. The plots were made for stations ROA and R1 through R8. Station ROA represents the headwater conditions, which was estimated from the monitoring data of Mossdale station, upstream of ROA. In 1993, the water quality data at station ROA was not collected.

The hydrology of 1993 was classified as above normal. The annual daily average flow was 398 cfs. There were more days with a positive flow in the above normal year of 1993 as compared to the critically dry year of 1991. Table 2 presents the number of days with negative flow and the monthly average flow.

Table 2. Summary Statistics of River Flows in the San Joaquin River for 1993 Hydrology

Month	Days with (-) Flow	Average Flow, cfs
Oct 92	0	358
Nov 92	0	394
Dec 92	15	91
Jan 93	8	638
Feb 93	1	411
Mar 93	0	544
Apr 93	0	836
May 93	0	1167
Jun 93	0	437
Jul 93	30	-146
Aug 93	27	-120
Sep 93	4	170
Annual	85	398

For the above normal year of 1993, the annual average daily flow at Stockton was 398 cfs. The total number of days with a negative flow was reduced to 85 days as compared to 192 days in the critical dry year of 1991.

The time series plots of temperature show that the model tracked the seasonal variations of temperature for all stations. On top of the major seasonal change of winter low (approximately 7 degrees Celsius in January 1992) and summer high (approximately 27 degrees Celsius in August 1993), the temperature appears to rise as the flow drops and vise versa. For example, the temperature rose when flow dropped in the beginning of March and in June and July of 1993. When the flow increased in January, March, and May of 1993, there were a time-delayed drop of temperature, against the seasonal rising trend of temperature.

The time series plots of dissolved oxygen show that the model tracked the seasonal variation of dissolved oxygen for all stations. Both the model and observed data show that the dissolved oxygen was below 5 mg/l in the summer and fall. The observed low DO was 2 mg/l. The simulated low DO was 3 mg/l. These low dissolved oxygen concentrations were found in the above normal hydrologic year of 1993, due in part to the negative flows which occurred in December of 1992 and January and July through early September of 1993.

1996 VERIFICATION

For 1996 verification, the model coefficients used in the 1991 calibration were not changed. The meteorology, river flow, and waste discharge data of 1996 were input to the model. The model results are plotted for comparison to the observed data. The comparisons are made only for temperature and dissolved oxygen, due to a lack of observed data for chlorophyll-a and other water quality parameters.

Appendix C presents the time series plots of river flow, temperature, and dissolved oxygen. The plots were made for stations ROA and R1 through R8. Station ROA represents the headwater conditions, which was estimated from the monitoring data of Mossdale station, upstream of ROA. In 1996, the water quality data at station ROA was not collected.

The hydrology of 1996 was classified as wet. Table 3 presents the number of days with negative flow and the monthly average flow.

Table 3. Summary Statistics of River Flows in the San Joaquin River for 1996 Hydrology

Month	Days with (-) Flow	Average Flow, cfs
Oct 95	0	1640
Nov 95	0	429
Dec 95	0	450
Jan 96	22	40
Feb 96	0	4140
Mar 96	0	5920
Apr 96	0	2670
May 96	0	3520
Jun 96	0	1210
July 96	0	460
Aug 96	0	375
Sep 96	0	475
Annual	22	1770

Total number of days with a negative flow is 22, all occurred in January 1996. The annual daily average flow was 1770 cfs.

Time series plots of simulated temperature match the observed data throughout the season for all stations. The lowest temperature of approximately 10 degrees Celsius occurred in January. The highest temperature of approximately 28 degrees Celsius occurred in August.

Time series plots of simulated dissolved oxygen match the observed data throughout the season for all stations. A significant drop of dissolved oxygen, to as low as 5 mg/l, was found in cold January of 19996, when the average river flow was negative for 22 days out of 31. This drop in dissolved oxygen was simulated by the model, but the magnitude was not as large. In late summer and early fall, both model results and observed data showed the dissolved oxygen to drop to low 3 mg/l in late August of 1996. During this period, the river flow was below 500 cfs, even for the 1996 wet years.

DISCUSSION

The results presented in this chapter show a close match between the simulated curves and the observed data. This is remarkable, considering that the model made the predictions with data from so many different sources, i.e. meteorology from National Climatic Center, tides from National Atmosphere and Oceanography Administration, flows and headwater water quality for Mossdale from California Department of Water Resources, and waste loading and water quality data from the City of Stockton.

All data sets, including the measured water quality concentrations, had their uncertainties. The model itself has uncertainty due to its simplified assumptions. A perfect match between the model and observed data therefore cannot be expected. The discrepancy between the simulated and observed data is infrequently more than 1 mg/l of DO.

It is significant that the model was calibrated with 1991 data and verified with 1993 and 1996 data. The year 1991 is a critically dry year. The year 1993 is an above normal year and the year 1996 is a wet year. Thus, the model is shown capable of simulating for a wide range of hydrology conditions.

4. BAY-DELTA OPERATIONS

OPERATING CONDITIONS

The San Joaquin River flow is controlled in two stages. In the first stage, the upstream reservoir releases are balanced with irrigation diversions and irrigation drainage to determine the flow entering the Bay-Delta at Vernalis. In the second stage, the flow at Vernalis, as it traveled toward Stockton, is diverted to the Old River. Pumping of water at Clifton Court in the South Delta lowers the water level in the Old River, which forces a portion of water to flow from the San Joaquin River to the Old River. The magnitude of the diversion and the flow remained in the San Joaquin River depends on the operations of a temporary rock barrier at the Old River junction and also on the pumping at the Clifton Court. If the barrier is up or if exporting is small, less flow is diverted to the Old River and more water is left in the San Joaquin River.

The DWR used their models to predict the flow of the San Joaquin River at Stockton under three operating conditions:

D1485
1995 Bay-Delta Plan with existing temporary rock barrier
1995 Bay-Delta Plan with new permanent fish barrier

D1485 means that the reservoirs will be operated to satisfy the EC and salinity standards at Vernalis, as stipulated by the State Water Resources Control Board. No rock barrier operation was assumed.

1995 Bay-Delta Plan means that the reservoirs and export pumping will be operated to meet the X2 criteria in the Suisun Bay and Carquinez Strait, in addition to the requirement of D1485 at Vernalis. For this case, it was assumed that there was a temporary rock barrier at the Old River junction, as it is currently practiced.

1995 Bay-Delta Plan with a permanent fish barrier means that there will be the operation of a series of barriers to prevent the de-watering of channels in the South Delta. This will be done in addition to the restrictions on reservoir operations and export pumping to meet the X2 and D1485 requirements. For this case, pulse flows to aid fish migration are also included.

The operations of barriers to prevent de-watering is commonly referred to as the Interim South Delta Program (ISDP). Under ISDP, a series of agriculture barriers will be built at the interior of Middle River, Grant Line Canal, and Old River. The temporary rock barrier at the Old River junction will be replaced by a permanent fish barrier. The Interim South Delta Program (ISDP) is basically the operation schedule of fish barrier at the head of Old River and agriculture barriers. The monthly operation schedules of ISDP are:

October -	fish barrier up and agriculture barriers up
November -	fish barrier up and agriculture barriers down
December -	fish barrier and agriculture barriers down
January -	fish barrier and agriculture barriers down
February -	fish barrier and agriculture barriers down
March -	fish barrier and agriculture barriers down
April 1-15	fish barrier down and agriculture barriers up
April 16-30	fish barrier up and agriculture barriers up
May -	fish barrier up and agriculture barriers up
June -	fish barrier down and agriculture barriers up
July -	fish barrier down and agriculture barriers up
August -	fish barrier down and agriculture barriers up
September -	fish barrier down and agriculture barriers up

According to the ISDP, there is no operation of both fish and agriculture barriers from December to March. From June to September, there is no fish barrier to restrict the flow from San Joaquin River to Old River. During this period, the agriculture barriers will create a hydraulic head at the Old River junction. This head may reduce somewhat the flow of water from San Joaquin River to the South Delta.

In addition to ISDP, there were two pulse flows:

Fall pulse flow in October for immigration of adult salmon.
Spring pulse flow in April and May for out migration of juvenile salmon

Based on the three operating conditions described above, the DWR used their models to project the monthly river flow of the San Joaquin River at Stockton. Appendix D presents the complete flow data furnished by the DWR. Three tables were included. They were:

SJR-467 for D1485
SJR-469A for 1995 Bay-Delta Plan with temporary rock barrier
SJR-469 B for 1995 Bay-Delta Plan with ISDP.

In each table, the first line describes the simulation case. Thus, table SJR-467 is for D1485. The second line is "Average Flow DWRDSM Channel 8", which means that the data was based on the results for channel 8 of the DWRDSM model. Channel 8 is the river segment for the San Joaquin River near Stockton.

The first column is for year, which goes from 1922 to 1994. A hydrologic year is divided into 18 time periods of T01, T02, etc. The average river flow for each time period is provided in the table. At the bottom of the table, the time periods for T01, T02 etc. are described. The DWR called the time periods as tides, because different tides were used throughout the year.

From the flow data of 1922 to 1994, five years were selected to represent different hydrologic year types. They are:

Water year 1957 - above normal
Water year 1966 - below normal
Water year 1981 - dry
Water year 1982 - wet
Water year 1991 - critically dry

The flows of these five hydrologic year types were used to drive the DO model.

D1485 PLAN

Table 5 presents the selected flow data provided by the DWR. The table shows the data for critically dry (CD), dry (D), below normal (BN), above normal (AN), and wet (W) years.

Operating under the D1485 restriction, the annual average river flow of the San Joaquin River at Stockton would increase from 535 cfs in the critically dry year of 1991 to 3,558 cfs in the wet year of 1982. However, the trend was not definitive. The flow for the above normal year of 1957 was 810 cfs, which was lower than the flow for the below normal year of 1966.

It must be noted that the DWR's hydrologic year classification is based on unimpaired flow which is controlled by the rainfall data. The flow at Stockton is so regulated that one cannot expect all critical dry years to have a flow pattern similar to that of 1991. The prior years' reservoir storage can allow the release of more water than the rainfall of that year.

Regardless of hydrologic year types, there were two low flow periods: one in the winter months of December to February and the other in the summer months of June to August. The flow during the summer dry period was often below 200 cfs. In the dry year of 1981, the flow went negative to -138 cfs. Even in the wet year of 1982, the low flow in August was -1 cfs. As stated earlier, this low flow condition could cause a flow reversal, which reduced the waste assimilative capacity of the San Joaquin River.

Figure 3 graphs the data shown in Table 4. According to the DWR, only the wet year of 1982 would have substantially different hydrology. During this wet year, the river flows from spring to early summer (January to June) exceeded 3,300 cfs. For other hydrologic years, the river flows were substantially lower during the same period.

Table 4. San Joaquin Flow Data Under D1485 Provided by California Department of Water Resources

Times	Year types				
	1991 (CD)	1981 (D)	1966 (BN)	1957 (AN)	1982 (W)
Oct 1-15	1094	1807	3125	2174	1271
Oct 16-31	1094	1807	3125	2174	1271
Nov 1-10	1059	1543	2508	1456	1207
Nov 11-30	1059	1543	2508	1456	1207
Dec 1-15	132	271	1570	196	151
Dec 16-31	132	271	1570	196	151
Jan 1-20	304	749	1590	184	3382
Jan 21-31	304	749	1590	184	3382
Feb 1-28	104	617	1963	858	7652
Mar 1-31	325	693	1040	757	5843
Apr 1-15	365	565	394	512	10786
Apr 16-30	365	565	394	512	10786
May 1-31	1542	1693	1741	2319	5769
Jun 1-4	117	102	121	198	3625
Jun 5-30	117	102	121	198	3625
Jul 1-31	88	-108	-92	-38	829
Aug 1-31	256	-138	-116	-91	-1
Sep 1-30	1003	1144	1156	1207	2713
Average	535	745	1246	810	3558

Note:

CD - critically dry
D - dry
AN - above normal
BN - below normal
W - wet

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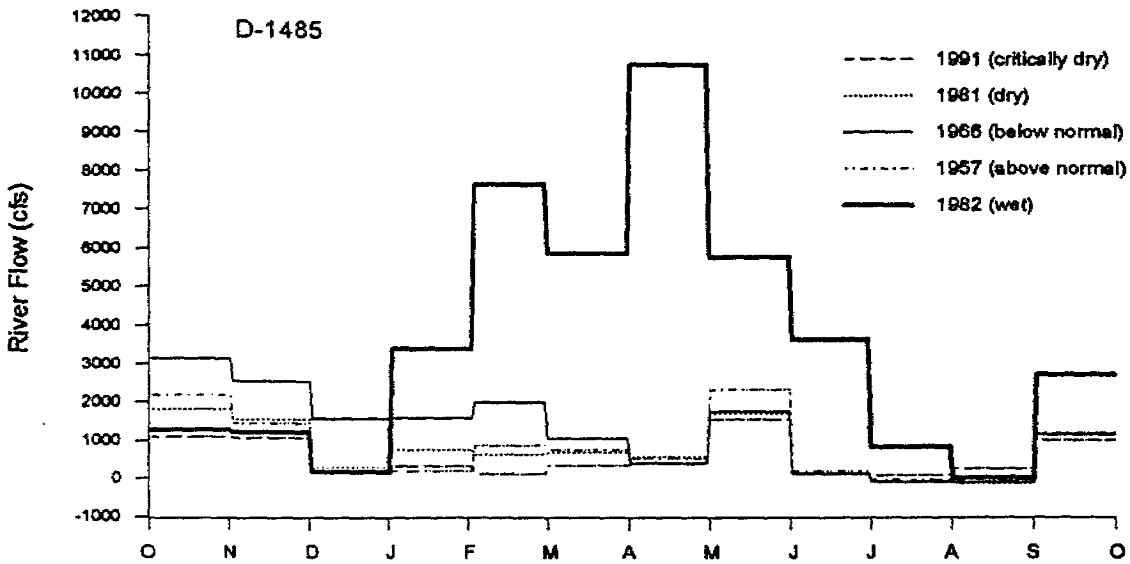

Figure 3. Monthly Average Flows in the San Joaquin River at Stockton, the DWR Projection for D1485

The figure also showed no pattern of higher monthly flows for the above normal year as compared to the flows for the dry year. As described earlier, the upstream reservoirs could have dampened the variations of runoff between above normal and dry years. The figure clearly indicated that the low periods were in December, April, and between June and August.

1995 BAY-DELTA PLAN

Table 5 presents the flow data of the San Joaquin River operated under 1995 Bay-Delta Plan with a temporary rock barrier at the Old River junction. The 1995 Bay-Delta Plan provided a higher annual average flow in the San Joaquin River, but not by much. The comparison was 569 vs. 535 for 1991 hydrology, 875 cfs vs. 745 cfs for 1981 hydrology, 1398 cfs vs. 1246 cfs for 1966 hydrology, and 1039 cfs vs. 810 cfs for 1957 hydrology. For the 1982 wet year, the flow under 1995 Bay-Delta Plan was slightly lower than the flow under D1485.

Figure 4 presents the monthly flows of the San Joaquin River shown in Table 5. The flow pattern is only slightly different from the pattern for D1485. It has the same low flow condition in December, April, and from June to August, which can lead to low DO in the San Joaquin River near Stockton.

D-041441

Table 5. San Joaquin Flow Data Under 1995 Bay-Delta Plan
Provided by California Department of Water Resources

	Year types				
Times	1991 (CD)	1981 (D)	1966 (BN)	1957 (AN)	1982 (W)
Oct 1-15	961	1667	3008	3196	1496
Oct 16-31	961	1667	3008	3196	1496
Nov 1-10	926	1555	2447	1222	1210
Nov 11-30	920	1546	2447	1210	1210
Dec 1-15	95	313	1536	88	137
Dec 16-31	94	307	1530	83	137
Jan 1-20	175	741	1605	130	3378
Jan 21-31	175	741	1605	126	3378
Feb 1-28	298	666	1737	438	6339
Mar 1-31	303	737	1040	756	5843
Apr 1-15	594	1133	1292	1251	10784
Apr 16-30	594	1133	1292	1251	10784
May 1-31	1864	2548	2838	3714	5739
Jun 1-4	236	117	184	369	3578
Jun 5-30	236	115	182	364	3578
Jul 1-31	205	-99	-59	-20	754
Aug 1-31	226	-12	6	58	136
Sep 1-30	936	1144	1161	1216	2723
Average	569	875	1398	1039	3475

Note:
- CD - critically dry
- D - dry
- AN - above normal
- BN - below normal
- W - wet

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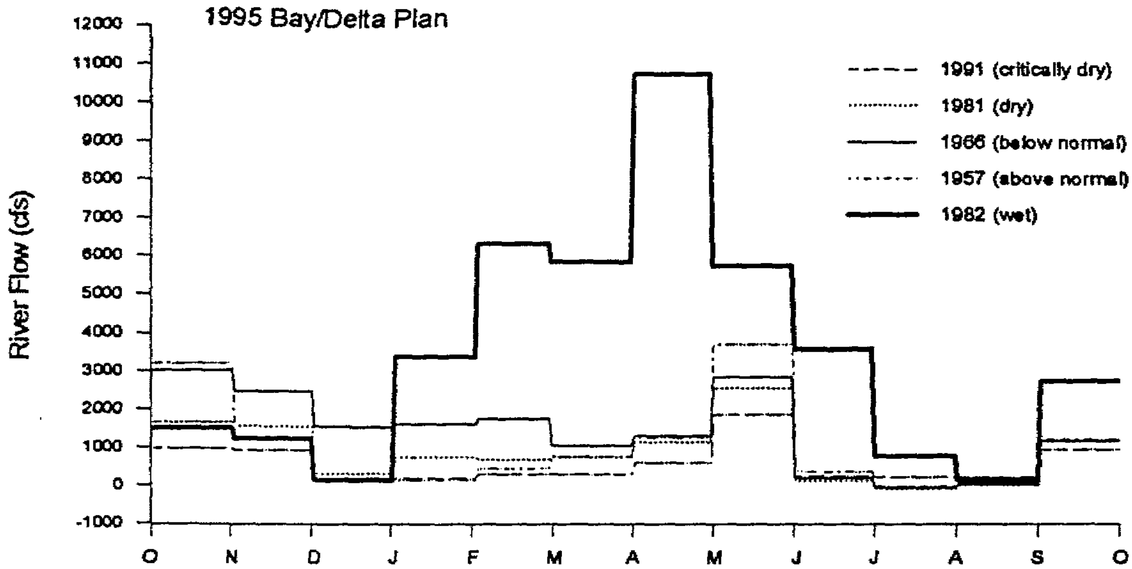

Figure 4. Monthly Average Flows in the San Joaquin River at Stockton, the DWR Projection for 1995 Bay-Delta Plan

INTERIM SOUTH DELTA PROGRAM

Table 6 presents the flow data of the San Joaquin River operated under Interim South Delta Plan. The differences between ISDP and Bay-Delta Plan are the permanent barriers and pulse flows. Therefore, there are slightly more flows in the San Joaquin River under ISDP than under Bay-Delta Plan.

Figure 5 presents the monthly flows of the San Joaquin River shown in Table 6. The flow pattern is similar to that of D1485 and 1995 Bay-Delta Plan, with the exception of pulse flows in October and latter half of April, when the river flow was raised to about 4500 cfs or higher.

Low flow conditions in December, and June through August remain a concern for causing low DO in the San Joaquin River.

Table 6. San Joaquin Flow Data Under Interim South Delta Program
Provided by California Department of Water Resources

Tides	Year types				
	1991 (CD)	1981 (D)	1966 (BN)	1957 (AN)	1982 (W)
Oct 1-15	1244	5048	4376	4694	1973
Oct 16-31	1244	5048	4376	4694	1973
Nov 1-10	1189	2064	3462	1613	1621
Nov 11-30	1189	2064	3462	1613	1621
Dec 1-15	101	313	1528	89	136
Dec 16-31	100	306	1521	84	136
Jan 1-20	180	737	1597	134	3360
Jan 21-31	179	737	1597	130	3360
Feb 1-28	301	663	1728	436	6300
Mar 1-31	300	733	1034	751	5808
Apr 1-15	680	1207	1361	1327	10709
Apr 16-30	2345	3584	3894	3909	10709
May 1-31	1864	2548	2838	3714	5715
Jun 1-4	528	420	490	755	4500
Jun 5-30	531	420	489	751	4500
Jul 1-31	486	209	264	312	1187
Aug 1-31	544	334	367	419	518
Sep 1-30	1196	1488	1519	1591	3904
Average	788	1417	1817	1432	3775

Note:
- CD - critically dry
- D - dry
- AN - above normal
- BN - below normal
- W - wet

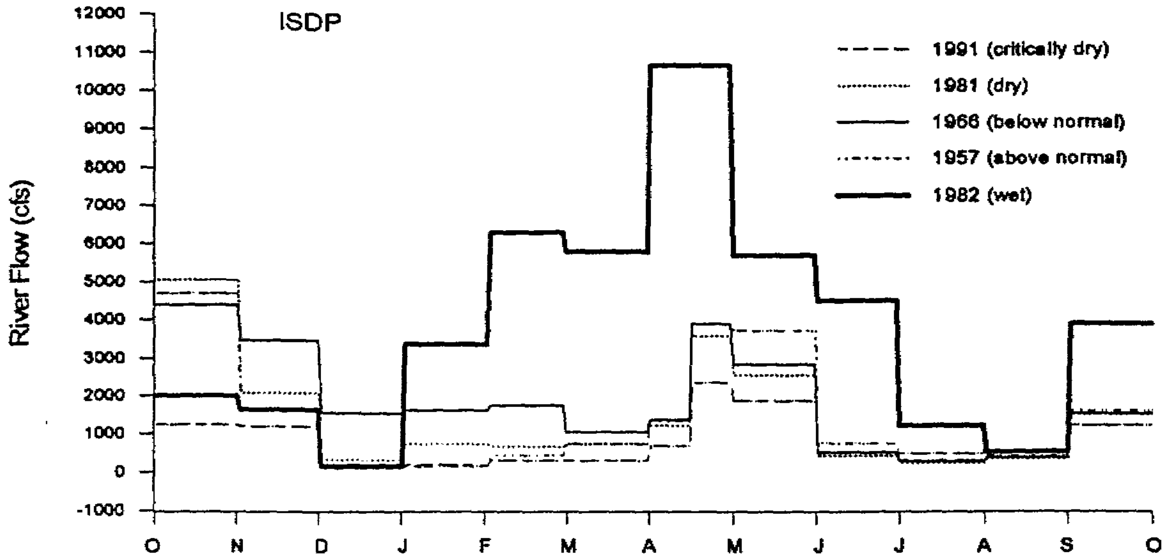

Figure 5. Monthly Average Flows in the San Joaquin River at Stockton, the DWR Projection for ISDP

IMPACT OF OPERATIONS ON FLOW

Figure 6 -10 present the impact of Bay-Delta operations on the flows of the San Joaquin River for various hydrologic years. According to the DWR projection, the ISDP provides higher flow due to pulse flows in October and the last half of April. The river flow from April to September is also raised slightly by the operation of fish and agriculture barriers.

The incremental change of river flow from D1485 to 1995 Bay-Delta Plan was minimal. This is not surprising, because D1485 was designed to meet EC requirement at Vernalis and 1995 Bay-Delta plan was designed to meet X2 criteria at Carquinez Strait. Their purpose was not to increase the flow of San Joaquin River, which might help meet the dissolved oxygen objective of the San Joaquin River.

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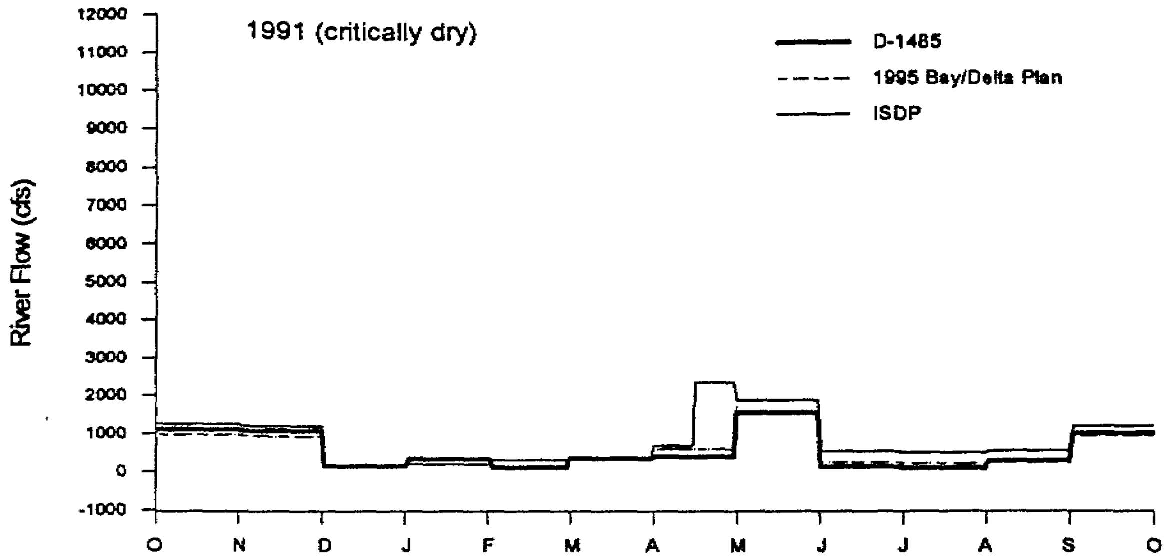

Figure 6. The Average Monthly River Flow of the Critically Dry Year of 1991, Under 3 Operating Conditions

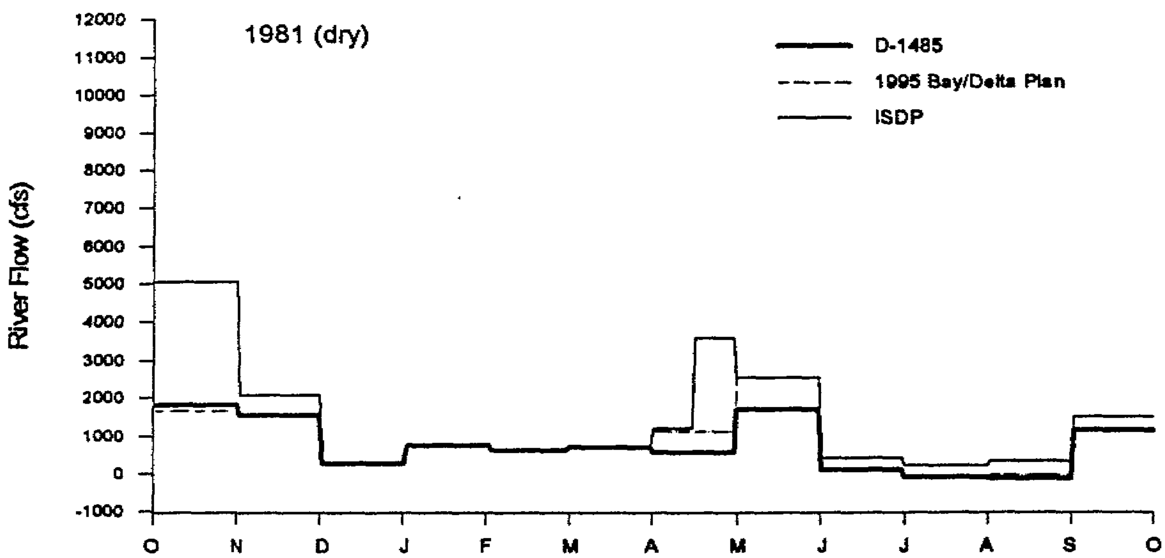

Figure 7. The Average Monthly River Flow of the 1981 Dry Year, Under 3 Operating Conditions

D-041446

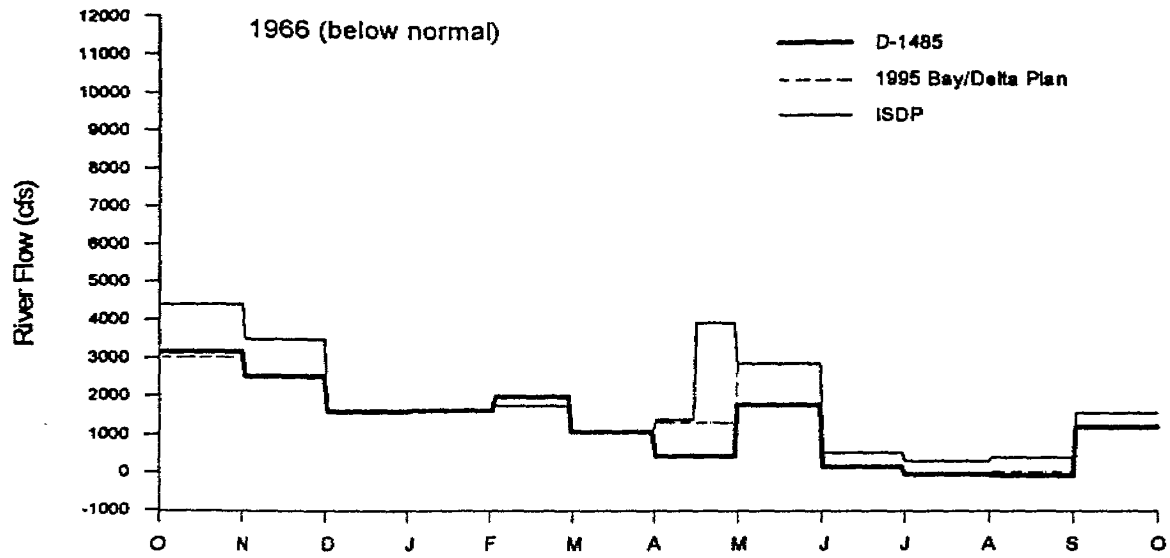

Figure 8. The Average Monthly River Flow of the 1966 Below Normal Year, Under 3 Operating Conditions

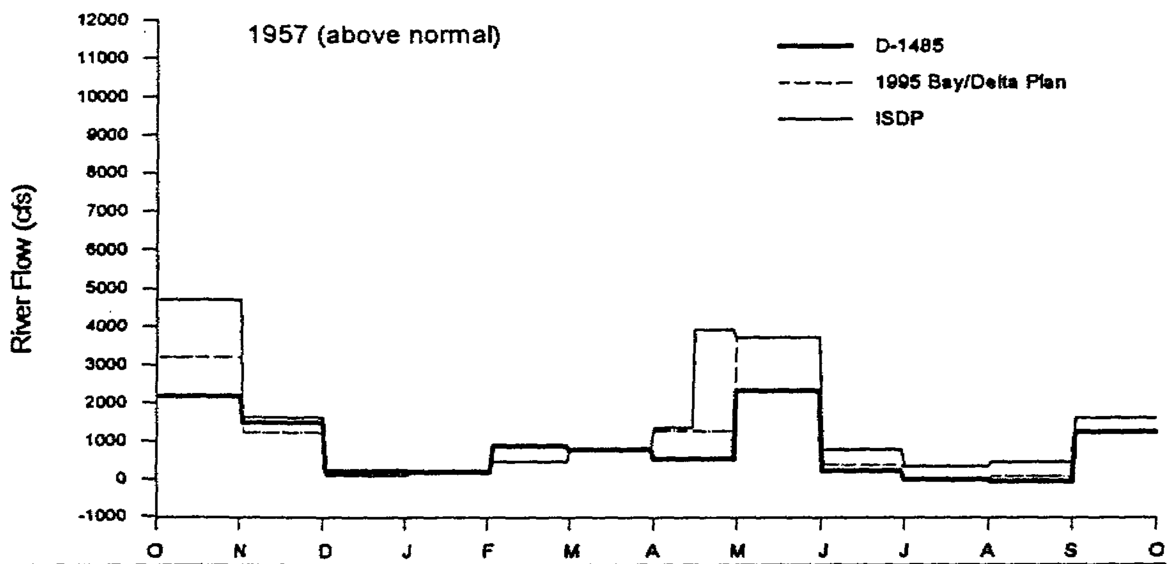

Figure 9. The Average Monthly River Flow of the 1957 Above Normal Year, Under 3 Operating Conditions

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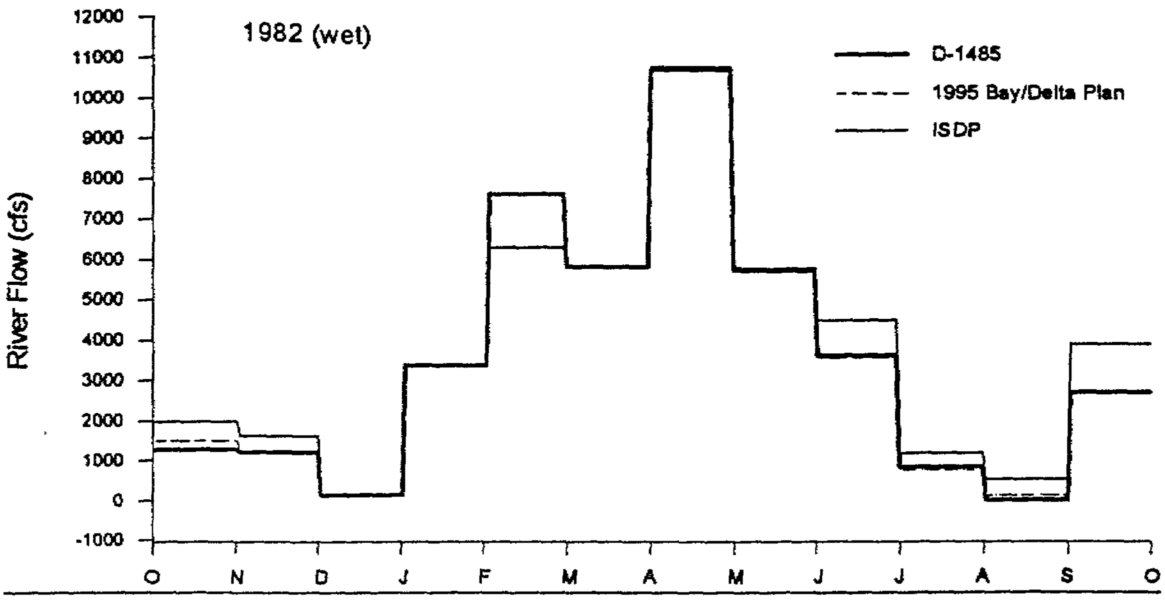

Figure 10. The Average Monthly River Flow of the 1982 Wet Year, Under 3 Operating Conditions

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5. DISSOLVED OXYGEN SIMULATION

SIMULATED CONDITIONS

This chapter describes the DO simulations under the operating conditions of hydrologic runs 467, 469A, and 469B. The flow data of selected hydrological years, provided by the DWR as discussed in Chapter 4, was used as input to the DO model. The tidal data, the meteorological data, and the headwater water quality data of the specific year were used as the boundary conditions.

The simulations were performed with the 1996 loading of Stockton's RWCF. Table 7 presents the monthly average concentrations of CBOD and ammonia nitrogen discharged from the City's RWCF in 1996. The total effluent discharge was 31 MGD of flow, 2,500 pounds per day of CBOD, and 2,000 pounds per day of ammonia nitrogen.

Table 7. The Characteristic of 1996 Effluent From Stockton's RWCF

Month	Flow (MGD)	CBOD(mg/l)	NH3N (mg/l)
Oct., 95	29.5	10.0	18.2
Nov., 95	25.8	11.6	17.4
Dec., 95	35.0	18.0	10.4
Jan., 96	35.0	12.6	13.9
Feb., 96	34.3	17.7	14.0
Mar., 96	31.2	15.4	5.5
Apr., 96	28.3	7.4	2.3
May, 96	36.8	5.7	0.4
June, 96	34.4	6.5	0.1
July, 96	29.0	7.3	0.4
Aug., 96	28.0	11.8	9.9
Sept., 96	31.7	13.5	17.1

Thus, the simulated cases in this chapter are based on projected flows, waste load, tide and meteorological conditions. The results are used to compare various Bay-Delta operational plans for their effects on dissolved oxygen in the San Joaquin River.

CRITICALLY DRY YEAR

Appendix E presents the simulation results for the critical dry year of 1991. Recall that the 1991 condition has been used in the model calibration discussed in Chapter 3. However, the calibration used actual flow, waste load, tide, and meteorology. The actual 1991 flows are different from the DWR projected flows and the 1991 waste loads are slightly different from the 1996 waste loads. For that reasons, the simulation results presented here are similar but different from the calibration results discussed earlier.

The plots are shown in pairs. The first 8 figures compare the simulated DO for Run 467 vs. Run 469A for stations R1, R2, ... R8. The next 8 figures compare the simulated DO for Run 467 vs. Run 469B for stations R1, R2, ... R8. The river flows are also plotted on top of the figure.

From stations R1 to R6, the simulated results show a pattern of seasonal low DO in the summer months, due to higher temperature, lower flow, lower DO solubility, and higher decay rates of CBOD, ammonia nitrogen, sediment BOD, and perhaps higher algae at the headwater (Mossdale). This pattern persists to stations R7 and R8 where the DO sag recovers to the background level.

Table 8 presents the simulated low DO at various stations under three Bay-Delta operations. The lowest DO was 4.0, which occurred at stations R3 and R4. During this period, the minimum river flow was 88 cfs for Run 467, 205 cfs for Run 469A, and 468 cfs for Run 469B. Everything being equal, the change of flow from 88 cfs to 205 cfs did not make any discernible difference in the low DO. When the river flow increased to 468 cfs under Run 469B, the model shows a slight shift of DO sag curve. The DO improves slightly in the upstream stations of R1 and R2. The DO in the downstream stations deteriorates from 6 to 5.5 mg/l at R7 and 6.8 to 6.0 mg/l at R8.

Table 8. Simulated Low DO in the San Joaquin River During the Summer Months For the Critically Dry Year of 1991

Stations	Simulated Low DO, mg/l Run 467	Run 469A	Run 469B
R1	4.5	4.5	4.6
R2	4.5	4.5	4.5
R3	4.0	4.0	4.0
R4	4.0	4.0	4.0
R5	4.0	4.0	4.3
R6	4.5	4.5	4.4
R7	6.0	6.0	5.5
R8	6.8	6.8	6.0
Min flow, cfs	88	205	468

DRY YEAR

Appendix F presents the simulation results for the dry year of 1981. The results are plotted in pairs for comparison, similar to those presented in Appendix E.

For the dry year of 1981, there are also a seasonal low DO in all stations in the summer months of June, July, and August. Table 9 presents the simulated low DO for various stations during these summer months.

For the dry year of 1981, the minimum flow during the summer was -138 cfs under Run 467. Under Run 469A, the minimum flow in the summer was -99 cfs. The minimum flow of the summer under Run 469B was 209 cfs.

Based on the flow information, it is evident that the operating condition of Run 467 for the dry year 1981 would cause a severe flow reversal, which would bring the DO sag upstream to station R1. When the flow increased from -138 cfs under Run 467 to -99 cfs under Run 469A, the DO at the upstream station of R1 would increase from 4.5 to 5.0 mg/l. But, the DO at the downstream stations of R2 through R6 would decrease from 5.0 to 4.5 mg/l. The improvement is negligible because the minimum flow of -138 cfs and -99 cfs are basically the same, as far as flow reversal is concerned. Likewise when the minimum flow increased to +346 cfs under Run 469B, the DO improved only slightly. Because 346 cfs is still a low flow.

Table 9. Simulated Low DO in the San Joaquin River During the Summer Months For the Dry Year of 1981

Stations	Simulated Low DO, mg/l Run 467	Run 469A	Run 469B
R1	4.5	5.0	5.0
R2	5.3	4.8	4.9
R3	5.0	4.5	4.5
R4	5.0	4.5	4.5
R5	5.0	4.5	5.0
R6	6.0	5.0	5.0
R7	6.7	6.6	6.5
R8	6.8	6.7	7.0
Min flow, cfs	-138	-99	209

BELOW NORMAL YEAR

Appendix G presents the simulation results for the below normal year of 1966. The results are plotted in pair for comparison, similar to those presented in Appendix E.

For the below normal year of 1966, there are also a seasonal low DO in all stations in the summer months. Table 10 presents the simulated low DO for various stations during these summer months.

For the below normal year of 1966, the minimum flow was -116 cfs under Run 467. The minimum flow under Run 469A was -59 cfs. The minimum flow under Run 469B was 264 cfs.

For the below normal year of 1966, the flow reversal would be severe under both Run 467 and Run 469A. Under Run 467, the flow reversal was slightly reduced. So, the simulated DO follows the same response pattern as discussed before. There would be improvement of DO at the headwater station of R1 and deterioration of DO in stations R2 through R6. The change would be within 1 mg/l.

Table 10. Simulated Low DO in the San Joaquin River During the Summer Months For the Below Normal Year of 1966

	Simulated Low DO, mg/l		
Stations	Run 467	Run 469A	Run 469B
R1	4.0	5.0	6.0
R2	4.0	4.0	5.0
R3	4.5	4.0	4.0
R4	4.5	4.0	4.0
R5	5.0	4.0	4.0
R6	5.5	5.0	5.0
R7	7.0	6.8	6.3
R8	7.0	6.9	6.0
Min flow, cfs	-116	-59	264

ABOVE NORMAL YEAR

Appendix H presents the simulation results for the above normal year of 1957. The results are plotted in pair for comparison, similar to those presented in Appendix E.

For the above normal year of 1957, there are also a seasonal low DO in all stations in the summer months. Table 11 presents the simulated low DO for various stations during these summer months.

For the above normal year of 1957, the minimum flow under Run 467 was -91 cfs. The minimum flow under Run 469A was -20 cfs. The minimum flow under Run 469B was 312 cfs..

For the above normal year of 1957, the flow reversal was severe under both Run 467 and Run 469A. Under Run 467, the flow reversal would be slightly reduced. So, the simulated DO follows the same pattern as before. There would be improvement of DO at the headwater station of R1 and deterioration of DO in stations R2 through R6. The change would be within 1 mg/l.

Table 11. Simulated Low DO in the San Joaquin River During the Summer Months For the Above Normal Year of 1957

	Simulated Low DO, mg/l		
Stations	Run 467	Run 469A	Run 469B
R1	4.5	5.0	6.0
R2	4.0	4.0	4.5
R3	4.0	3.5	4.5
R4	4.5	4.0	4.5
R5	5.0	4.0	4.5
R6	5.5	5.0	4.5
R7	6.5	6.0	5.5
R8	7.0	6.9	6.0
Min flow, cfs	-91	-20	312

WET YEAR

Appendix I presents the simulation results for the wet year of 1982. The results are plotted in pair for comparison, similar to those presented in Appendix E.

For the wet year 1982, there are also a seasonal low DO in all stations in the summer months. Table 12 presents the simulated low DO for various stations during these summer months.

For the wet year 1982, the minimum flow under Run 467 was -1 cfs. The minimum flow under Run 469A was 136 cfs. The minimum flow under Run 469B was 518 cfs..

For the wet year 1982, the flow reversal was severe under both Run 467 and Run 469A during the critical summer months. Under Run 467, the flow reversal would be slightly reduced. So, the simulated DO follows the same pattern as before. There would be improvement of DO at the headwater stations of R1 and R2 and deterioration of DO in stations R3 through R5. The change would be within 1 mg/l.

Table 12. Simulated Low DO in the San Joaquin River During the Summer Months For the Wet Year of 1982

Stations	Simulated Low DO, mg/l Run 467	Run 469A	Run 469B
R1	4.0	5.5	6.0
R2	3.5	4.0	5.2
R3	3.5	3.4	4.5
R4	3.8	3.5	4.0
R5	4.0	4.0	4.5
R6	3.8	4.0	4.7
R7	4.5	4.5	5.0
R8	5.2	5.2	5.2
Min flow, cfs	-1	136	518

DISCUSSION

The model results show that there is a seasonal low DO in the summer months, especially July and August for all hydrological year types (i.e. critically dry, dry, below normal, above normal, and wet). This low DO can sometimes be extended to early September, depending on meteorological conditions. This low DO can be as low as 3.0 mg/l.

The low DO can be caused by higher temperature, lower DO solubility, higher decay rates of CBOD and ammonia nitrogen, waste discharges, high algal concentration and low flow conditions at the headwater. All these factors are accounted for by the DO model used in this study.

The DWR's flow data shows that the low flow condition would occur even for the wet years, due to reservoirs' operations, irrigation diversions, and export pumping. The minimum flow for the summer months was -138 cfs for the dry year 1981, -116 cfs for the below normal year 1966, -91 for the above normal year 1957, and -1 cfs for the wet year 1982.

There is very little difference between Run 467 and Run 469A on the low summer flow of the San Joaquin River at Stockton. The difference between Run 469A and Run 469B on the low summer flow is less than 200 cfs.

The small change of flow would not lead to a major change in the flow reversals in the Lower San Joaquin River. It only helps shift the DO sag curve slightly toward downstream. As a result, the DO at station R1 and sometimes R2 can increase by up to 1 mg/l under Run 469B as compared to Run 467 or Run 469A. The DO at stations R3 and R4 can decrease by 0.5 mg/l.

6. SENSITIVITY ANALYSIS

INTRODUCTION

The concentration of D.O. in the river is a function of flow, temperature, waste load, algae, sediment oxygen demand, and boundary condition. Flow determines whether there is a flow reversal which traps pollutants in the river reach, moving back and forth by tides. Temperature controls the rates at which D.O. is consumed by decaying CBOD and ammonia nitrogen. It also controls the solubility of D.O. in the water. Waste load contributes CBOD and ammonia nitrogen as D.O. sinks. Algae can either contribute or consume DO depending on whether they are doing more photosynthesis or respiration in the river reach. Sediment oxygen demand , which includes nonpoint source loads, will decay and consume D.O. in the process. The boundary condition provides the water quality, brought into the river reach from the upstream

Since all these factors are included in City of Stockton's water quality model, it is possible to perform sensitivity analyses and determine their relative importance. The knowledge gained from the analyses can help formulate alternatives to raise D.O. in the San Joaquin River.

The sensitivity analyses have been performed, one parameter at a time, with the calibrated model. The results are discussed as follow.

FLOW

Actual river flows in the San Joaquin River vary daily and seasonally. Classical sensitivity analysis would simply increase or decrease the flow from the base case by a fixed percentage or amount. The model would then be used to simulate D.O. with those changes and keeping everything else the same as in the base case. The sensitivity would be measured by the degree of change in D.O. with respect to change in flow.

In this study, a slight modification of the classical approach was made. The flow was held constant at a given level throughout the year. The modified approach would eliminate the daily fluctuation of flow and their effects on D.O. The results could better reflect the true effects of flow on DO in the San Joaquin River.

Appendix J presents the plots of simulated DO at various stations, when the river flow was maintained at four constant levels of -500 cfs, 0 cfs, +500 cfs, 1,000 cfs and +2,000 cfs. Since the 1996 waste load was used in the simulations, the time axis was plotted as if it was for the 1996 hydrology. Actually, it was the hypothetical hydrology of constant flow.

The results show that there is a seasonal trend of low DO in the summer even at high flow conditions. So, the historical low DO in the summer was not caused exclusively by the historical low flow which occurred from June to August. However, the low flow did accentuate the DO problem.

The river flow provides three main functions. First, it furnishes dilution water for point and nonpoint source discharges. Second, it transports water quality at the upstream boundary into the Lower San Joaquin River. Third, it reduces the flow reversal and therefore pushed the DO sag curve downstream.

To illustrate these points, we prepared Figure 11 to show the D.O. profiles along the river, under difference flow regimes. The data was taken from the model results presented in Appendix J for August 20, 1996. The upstream stations were plotted at the negative distances from the outfall. The corresponding monitoring stations (ROA, ROB, R1..R8) were indicated in the figure. First, we noticed the DO profile had an unusual high at the outfall. We found that it was cauced by the high DO value (12 mg/l) in the RWCF effluent.

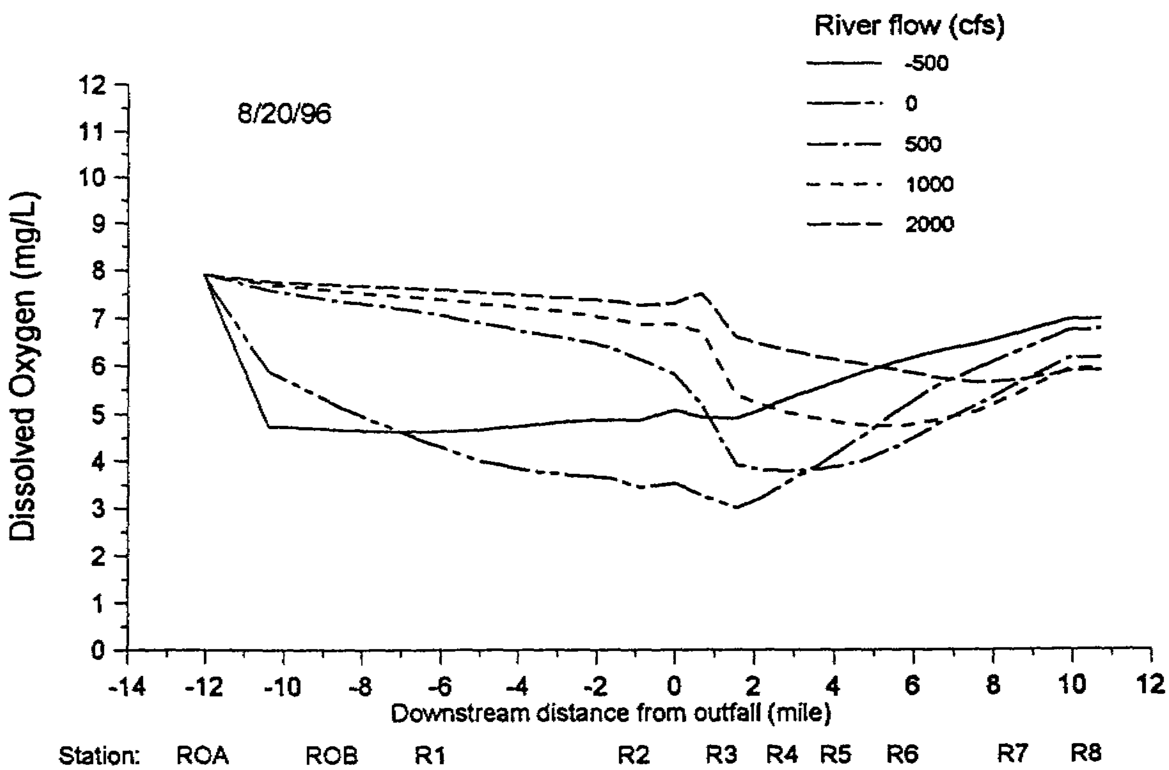

Figure 11. DO Sag Curves Under Various River Flow

The downstream stations (R3 to R8) would have the best DO if the flow was negative. Under a negative flow, the water was pushed upstream from the lower boundary, which had a higher DO concentration. In the negative flow regime, the DO sag curve was also pushed upstream to stations ROA, ROB, R1, and R2. The DO concentrations there were lower.

The plot shows that a zero flow would provide the worse DO for stations ROA, ROB, and R1 to R4. At zero flow, there was no dilution water. The water in the Lower San Joaquin River was transported back and forth by the tide. As a result, the organic pollutants would exert the maximum oxygen demand from the water. The minimum DO dropped to 3 mg/l at station R3, which was close to historic data. Only the very downstream stations (R5 to R8) would have a higher DO due to tides, which brought them the higher quality water from the downstream boundary.

As the flow increased to +500 cfs or higher, the DO sag curve was pushed downstream to stations R3 to R8. The higher the flow, the further the DO sag curve would be pushed. The result indicated that +2,000 cfs of river flow would not push the DO sag curve beyond station R8.

Since the river flow also provided dilution water, the maximum DO sag became smaller at higher flow. At +500 cfs, the minimum DO was 4 mg/l at station R3. At +1,000 cfs, the minimum DO was 5 mg/l at station R6.

Based on the model results, it was estimated that the DO at station R3 increased about 1.0 to 1.3 mg/l per +500 cfs increment of river flow.

TEMPERATURE

The effect of temperature on DO was evaluated by a constant addition or subtraction of temperature from the base case. This was not as easy to do with the enhanced model, because the model now simulates temperature. We have to program a switch to turn off heat budget calculations and to read in the temperature data for direct use as it was done before the model enhancement.

The simulations were performed for the constant flow of -500 cfs, zero flow, +500 cfs, and 1,000 cfs. Appendix K presents all the model results.

Sensitivity of DO with respect to temperature depends on flow and location. The effects are larger for a flow of 500 cfs and smaller for a flow of 1,000 cfs. The effects are larger for stations where the DO sag occurs.

Table 13 presents a summary of results. At a negative flow, a temperature decrease of 2 degrees Celsius led to an increase of DO by 1.0 mg/l. A temperature increase of 2 degrees Celsius led to a decrease of DO only by 0.1 mg/l. The responses were not even. More dissolved oxygen is gained by a colder temperature than lost by a warmer temperature.

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The uneven response of DO with respect to temperature was also found at +500 cfs. The uneven response did not occur when the flow was at 1,000 cfs.

Figure 11 shows the relationship between temperature and solubility of dissolved oxygen. As the temperature goes down, the solubility of DO increases and the rate of oxygen demand decreases, both of which act to raise DO. The opposite is true when the temperature goes up.

At high flow, the waste load is more diluted and the effect of oxygen demand is reduced. As shown in Figure 12, the relationship between solubility and temperature is almost linear. So, the change of solubility is even on both increasing and decreasing temperature by the same amount. At low flow, the effect of oxygen demand is higher on a per unit volume basis. The temperature effect on the oxygen sink is exponential, which leads to an uneven response of DO.

Table 13. Sensitivity of Dissolved Oxygen With Respect to Temperature

	Change in Dissolved Oxygen, mg/l					
Stations	Flow -500 cfs		Flow +500 cfs		Flow +1000 cfs	
	+ 2°C	-2°C	+2°C	-2°C	+2°C	-2°C
R1	-0.1	+1.0	-0.1	+0.1	-0.1	+0.1
R2	-0.1	+1.0	-0.2	+0.2	-0.2	+0.1
R3	-0.1	+1.0	-0.2	+0.5	-0.2	+0.2
R4	-0.1	+0.8	-0.2	+0.5	-0.2	+0.2
R5	-0.1	+0.5	-0.2	+0.5	-0.2	+0.2
R6	-0.1	+0.3	-0.2	+0.5	-0.2	+0.2
R7	-0.1	+0.1	-0.1	+0.3	-0.2	+0.2
R8	-0.0	+0.0	-0.1	+0.1	-0.1	+0.1

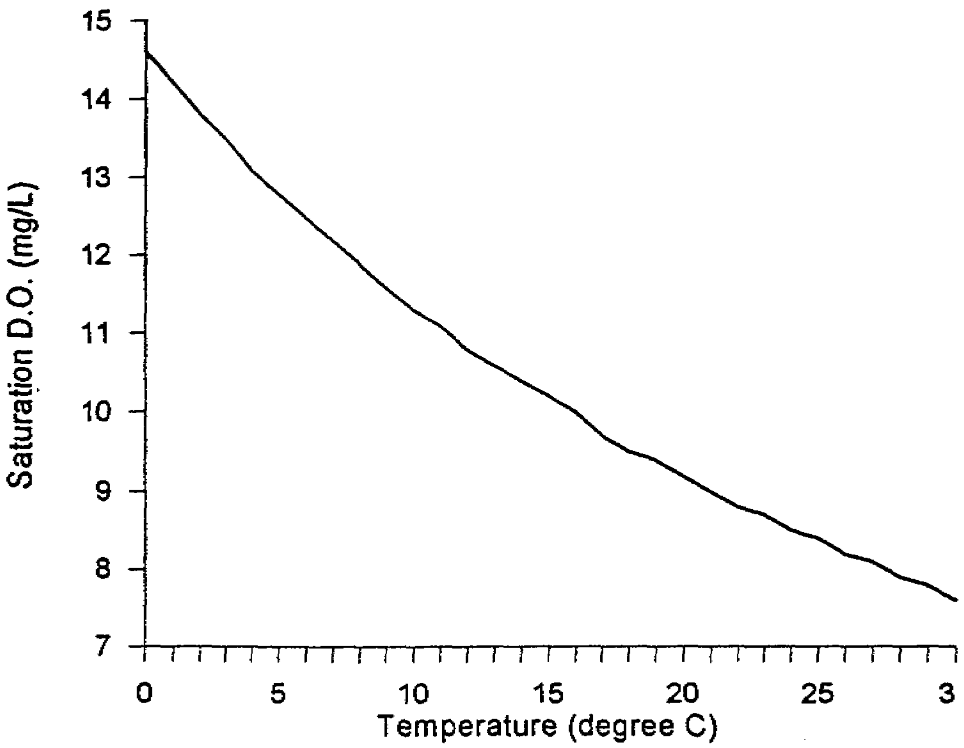

Figure 12. Relatioship Between Temperature and
Solubility of Dissolved Oxygen

SEDIMENT OXYGEN DEMAND

Over the years, the San Joaquin River has accumulated a large amount of organic material at the river bottom. When bacteria decompose the organic matter, they consume oxygen from the overlying water. The model accounts for this oxygen sink by the sediment oxygen demand. The sediment oxygen demand was also made to include all diffused sources of oxygen demand, i.e. nonpoint source pollutants.

The sensitivity analyses were performed by cutting the sediment oxygen demand by 50% and 100%. The results are presented in Appendix L.

Table 14 presents a summary of results. The sensitivity of DO with respect to sediment oxygen demand is a function of flow and locations. At the flow of -500 cfs, a 50% reduction of sediment oxygen demand will raise DO by 1.3 mg/l at R1, R2, and R3. At the flow of +500 cfs, a 50% reduction of sediment oxygen demand will raise DO by 1.2 mg/l at R3, R4, and R5. At the flow of +1,000 cfs, a 50% reduction of sediment oxygen demand will raise DO by 0.9 mg/l at R5, R6, and R7. Clearly, the DO in the San Joaquin River is very sensitive to the sediment oxygen demand.

Table 14. Sensitivity of Dissolved Oxygen to Sediment Oxygen Demand

Stations	Change in Dissolved Oxygen, mg/l					
	Flow -500 cfs		Flow +500 cfs		Flow +1000 cfs	
	50%	100%	50%	100%	50%	100%
R1	+1.3	+2.5	+0.4	+0.8	+0.1	+0.2
R2	+1.3	+2.5	+0.8	+2.0	+0.6	+1.1
R3	+1.3	+2.5	+1.2	+2.5	+0.7	+1.5
R4	+1.0	+2.0	+1.2	+2.5	+0.8	+1.5
R5	+0.9	+1.8	+1.2	+2.5	+0.9	+2.0
R6	+0.8	+1.5	+1.1	+2.5	+0.9	+2.0
R7	+0.2	+0.4	+0.6	+1.5	+0.9	+2.0
R8	+0.1	+0.2	+0.5	+1.0	+0.6	+1.5

ALGAE

Algal blooms occurred often at Vernalis. Agriculture drainage and other point source discharges upstream of Vernalis provide nutrients to promote the blooms. Sensitivity analyses were performed to evaluate the impacts of these algal blooms on the dissolved oxygen in the Lower San Joaquin River. For these analyses, the actual 1991 condition was used as the base case.

Algal blooms mean that there is a substantial increase of algal density at Vernalis and Mossdale. If the base condition has 1X of chlorophyll-a, the algal bloom was assumed to have a five hold (5X) or a ten hold (10X) increase of biomass. Figure 13 shows the chlorophyll-a concentrations imposed at Mossdale (e.g. the headwater station ROA) under 1X, 5X, and 10X of algal density. There was no chlorophyll-a data for September, 1991. For the 5X and 10X simulations, the concentration in September was assumed to be the same as in August.

Appendix M presents the simulation results. The model shows that algal blooms at the headwater would produce a lower DO for the downstream water. Apparently, algae was decaying (respiring) more than growing (photosynthetic oxygenation) in the downstream.

We were surprised that DO depressions occurred in June and early July but did not occur in late July and August, when algal density was high. A more careful analysis indicated that the flow during the period was very low. The model predicted a flow reversal which moved water from R1 to ROA instead of from ROA to R1. For that reason, algae was not transported to R1 to consume oxygen there.

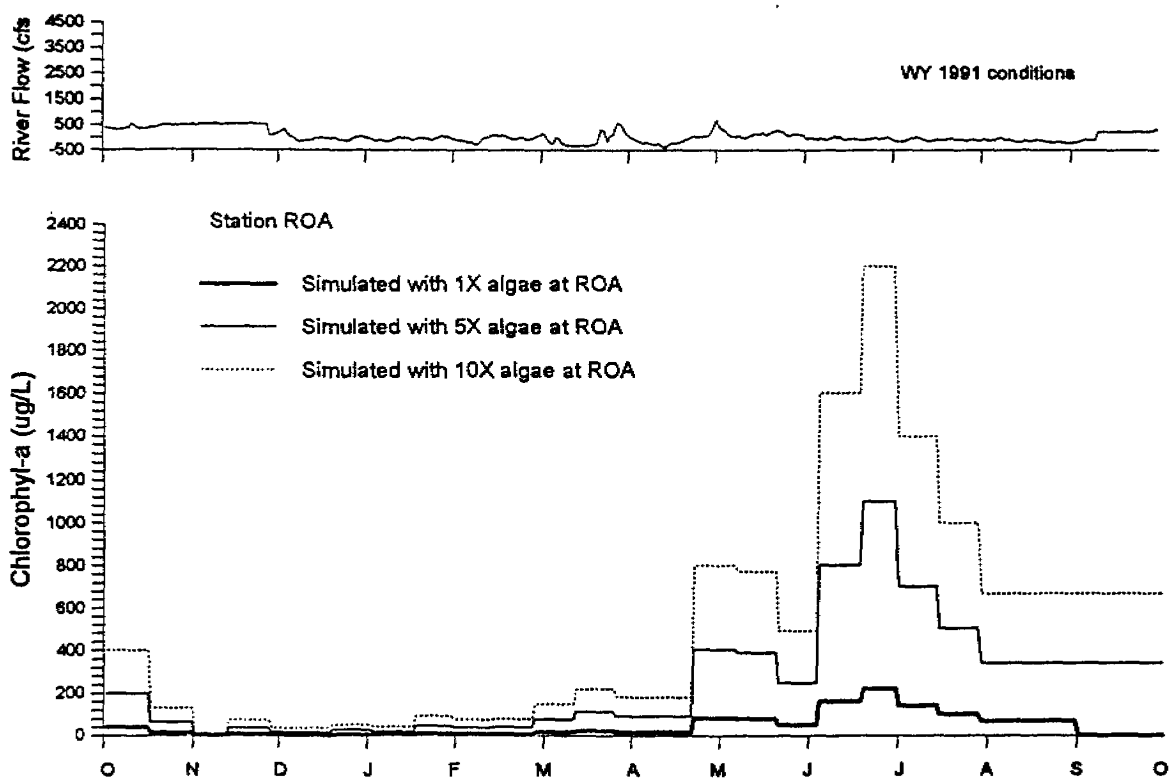

Figure 13. Sensitivity Analysis with 3 Levels of Algae at Mossdale for Headwater Conditions.

For September, 1991, there was no chlorophyll-a data for the headwater. During the model calibration, a zero concentration of chlorophyll-a was used. The simulated DO was above the measured value. During the sensitivity analyses, an estimate of chlorophyll-a data was given to the model. For the month of September, the river flow was higher and the water was expected to carry algae downstream. The model did predict lower DO concentrations closer to the observed values. This is shown in Figure 14, which is reproduced from a figure presented in Appendix M.

The sensitivity analyses showed that algal blooms at Mossdale can depress DO in the San Joaquin River at Stockton. A sudden increase of chlorophyll level by 5 times (i.e. algal blooms) at Mossdale coupled with a positive flow can cause a DO depression at R3 by as much as 3 mg/l. Such incidents, which could occur frequently in the past, were the main reason for the episodic drop of DO to as low as 2 mg/l.

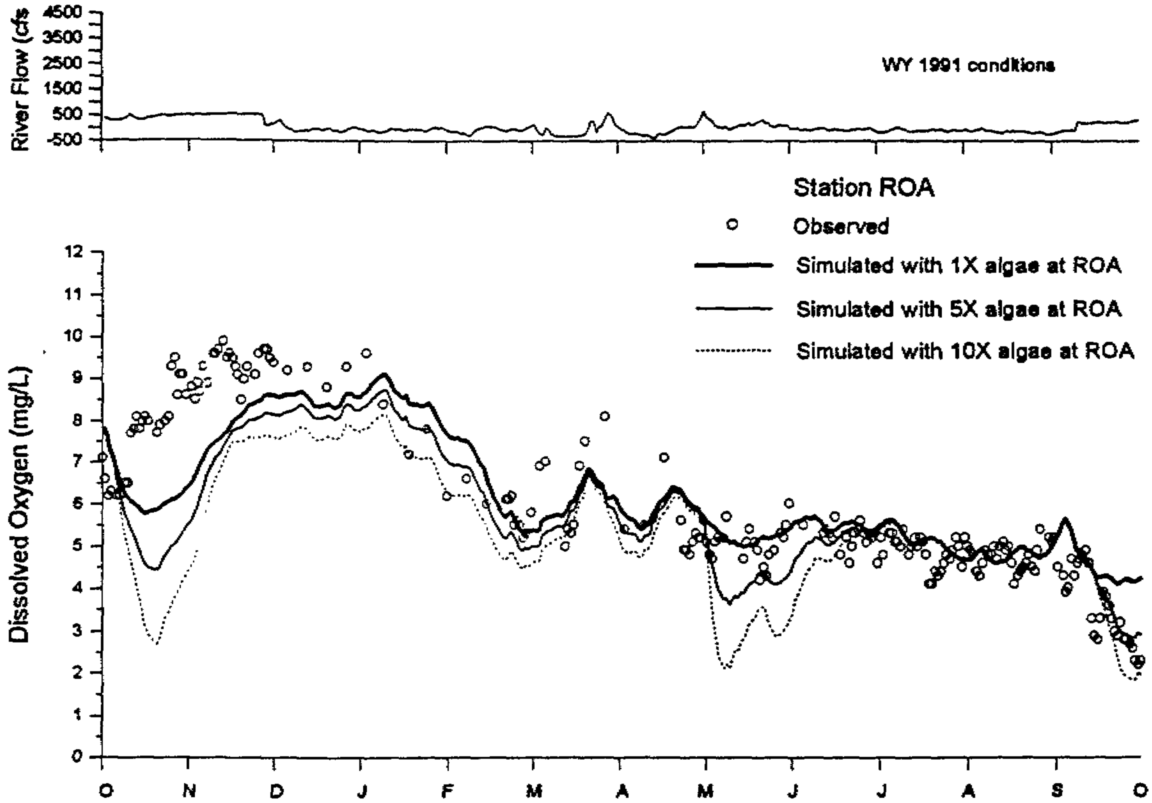

Figure 14. Effect of Algal Bloom at Head Water on the Concentration of Dissolved Oxygen in the San Joaquin River

RWCF WASTE LOAD

Sensitivity of DO to the waste load from Stockton's Regional Wastewater Control Facility was evaluated by comparison of D.O under the 1996 waste load to D.O under the zero discharge condition.

The effluent characteristics of the 1996 waste load was shown in Table 7. Zero discharge was that no waste effluent was emitted from Stockton's RWCF.

The simulations were performed for five types of hydrologic year, using the flow data provided by the DWR. Results are presented in Appendix N.

The sensitivity of DO with respect to waste load is a function of location. The sensitivity is measured by the DO increase in the critical summer months (June to August). Table 15 presents the maximum increases of DO when the 1996 loading is changed to zero discharge.

Table 15. Sensitivity of Dissolved Oxygen to Waste Loads From Stockton's RWCF

Stations	Maximun Change of Summer DO by Zero Discharge				
	1991 (CD)	1981 (D)	1966(BN)	1957(AN)	1982(W)
R1	+0.0	+0.5	+0.6	+0.1	+0.0
R2	+0.2	+1.0	+1.0	+0.6	+0.6
R3	+1.0	+1.0	+1.0	+1.0	+1.0
R4	+1.0	+1.0	+1.0	+1.0	+1.0
R5	+1.0	+1.0	+1.0	+1.0	+1.0
R6	+0.5	+0.6	+0.6	+0.7	+0.8
R7	+0.2	+0.1	+0.1	+0.2	+0.2
R8	+0.0	+0.0	+0.0	+0.1	+0.1

As shown in Table 15, a zero discharge would only improve the DO up to 1 mg/l during the summer months of June through August.

SUMMARY

The sensitivity analysis has revealed a number of important findings regarding the factors influencing DO in the critical summer months. They are:

1. The historical low DO in summer was not caused by the historical low flow alone. The low flow did accentuate the DO problem.

2. A zero flow creates a stagnant water, which is worst for DO. Increasing river flow would provide more dilution to the waste discharge and also push the DO sag curve downstream. It would take more than +2,000 cfs to push the DO sag curve beyond station R8. However, the minimum DO at station R3 would increase 1.0 to 1.3 mg/l per 500 cfs of incremental river flow.

3. Under a low flow condition (e.g. <500 cfs), a temperature decrease of 2 degree Celsius may cause an increase of 1.0 mg/l DO. A temperature increase of 2 degree Celsius will cause a decrease 0.1 mg/l DO. The uneven response disappears when the flow reaches +1,000 cfs.

4. Under the low flow condition, a 50% reduction of sediment oxygen demand can lead to an increase of 1.2 mg/l DO. A 100% reduction can bring the DO up by 2.5 mg/l.

5. Algal blooms at Vernalis and Mossdale coupled with a positive flow will transport algae downstream to respire. A bloom (5 folds increase) will consume 3 mg/l of DO from the water. Such incidents were the reason for the past episodic drops of DO to 2 mg/l in the San Joaquin River near Stockton.

6. When there is an algal blooms at Mossdale and a negative flow in the San Joaquin River, algae would not be transported downstream to cause a DO drop.

7. Going from 1996 waste load at RWCF to zero discharge would raise DO by a maximum of 1 mg/l during the critical summer months of June to August at the critical location of DO sag curve.

Thus, algae is most sensitive. Flow is next, followed by sediment oxygen demand. The temperature and RWCF waste load are at the last.

7. MANAGEMENT ALTERNATIVES

INTRODUCTION

The historical data shows that the dissolved oxygen concentration in the San Joaquin River near Stockton has a seasonal low of 3 mg/l in the critical summer months of June to August, even early September. Episodic drop to 2 mg/l can occur when there is an algal bloom in the headwater (Mossdale and Vernalis).

As discussed earlier in this report, the causes of low DO includes algal blooms at Mossdale, diminishing river flow, high sediment oxygen demand, high temperature, and the discharge of BOD and ammonia from RWCF. Alternatives to meet a high DO standard will require some measures of control on the contributing factors.

Based on the sensitivity analysis, one of the very effective way to raise DO is to prevent or reduce algal blooms at Mossdale. This could help bring DO up by 3 mg/l. It would probably involve a watershed approach, in which farmers adopt best management practice and minimize the nutrients in their drainage water. Such an approach may take sometimes to implement and is not considered in this study, although the on-going activities in the management of agricultural drainages could provide some benefits in this regard.

Second factor is temperature. When temperature increases to 27 degree Celsius, the solubility of DO decreases to 8 mg/l, which is only 2 to 3 mg/l above the DO objective. The sensitivity analysis shows that if the temperature can some how be decreased by 2 degrees, the DO may be raised by 0.5 mg/l. However, temperature would be difficult, if not impossible, to control, without a major manipulation of reservoir operations.

The third factor is sediment oxygen demand (SOD). The sensitivity analysis indicates that the DO can be raised by 1.2 mg/l if the sediment oxygen demand can somehow be reduced by a half. However, this can only be accomplished by the dredging of organic materials that have been accumulated in the sediment over the years. During these years, the low flow condition led to stagnant like water, which promoted the sedimentation of not only algae but also hazardous chemicals (pesticides and metals). Dredging of contaminated sediment is an impossible task.

However, SOD includes nonpoint source pollutants. Majority of nonpoint loadings enter the river in the rainy season. But, there are some dry weather flows occurring in the summer as well. It would be possible to implement best management practice to reduce some nonpoint pollution.

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The remaining controllable factors are river flow and waste load. Since there is a limit to water available to maintaining a minimum flow, the barrier operations should also be included in the management alternatives. To maintain a higher DO in the San Joaquin River, the fish barrier should probably be up during the summer months.

The maximum extent of waste load reduction from RWCF is zero discharge. Zero discharge is ideal, but impractical. Even so, the sensitivity analysis indicates that a zero discharge may not be enough due to other uncontrollable factors. This study will investigate the alternative of direct oxygen addition to the river water.

Because there are limits to what one can do in each controlling factor, a best approach can be doing a little of everything. Such a combination alternative may become most feasible because it may not impose an undue constraint on each individual operation.

MANAGEMENT ALTERNATIVES

The following alternatives were evaluated:

Alternative 1 - no diversion to the Old river
Alternative 2 - waste load reduction
Alternative 3 - direct oxygen addition to the river
Alternative 4 - flow alteration.

No Diversion to Old River

In this alternative, it was assumed that no flow diversion to the Old River occurred. In other words, there was a permanent barrier to seal off the San Joaquin water from entering the Old River. The river flow at Stockton was the same as the flow at Vernalis.

For this analysis, the San Joaquin river flow at Vernalis is needed as input to the DO model. DWR has not provided us with the projected flows at Vernalis. So, we went to the DWR home page in the Internet and retrieved the actual flows at Vernalis for the critically dry year of 1991. Since the year 1991 was used in the model calibration, we have the data of river flows at Stockton. To evaluate the difference that the Old River diversion made, we need to ran the DO model with same waste load. We decided to use the 1996 waste load. The results are presented in Appendix O.

The plot shows that 30% to 80% of flow at Vernalis was diverted to the Old River in the hydrologic year 1991. As discussed in the calibration and verification chapter (3), the flow in the critical dry year 1991 was mostly negative (e.g. -30 to -120 cfs), with an annual average of 65 cfs. By eliminating the diversion to the Old River, the flow would increase to approximately +500 to +600 cfs in the summer.

As discussed earlier in the sensitity analysis chapter (6), a zero flow provided the worse case for DO. A negative flow improved DO by bringing in the higher DO water from the downstream boundary. A +600 cfs flow would push the DO sag curve downstream to deteriorate DO in the downstream stations.

The plots in Appendix O show that DO at stations R1 and R2 was improved by no diversion to the Old River. With a +600 cfs flow, however, the DO sag curve was not pushed too far downstream beyond station R2. For that reason, the DO for stations R3 to R8 was worse off under no diversion scenario than under the diversion scenario.

Unless the river flow can be increased substantially higher than what was left at Vernalis (approximately 600 cfs), increasing the flow by eliminating diversion to the Old River would deteriorate DO for stations R3 to R8. If the flow can be raised above 1,000 cfs, however, the DO sag curve can be pushed further downstream. The DO for stations R3 to R8 can all be improved then.

RWCF Waste Load Reduction

In this alternative, the river flow was based on DWR's projection. The waste load was assumed to vary from 1996 waste discharge to zero discharge. The results are presented in Appendix N, discussed previously in the sensitivity analysis chapter.

The minimum DOs simulated with the 1996 waste load are:

4 mg/l for the critically dry year of 1991.
4.5 mg/l for the dry year of 1981
4 mg/l for the below normal year of 1966
4.5 mg/l for the above normal year of 1957
4.5 mg/l for the wet year of 1982.

A complete elimination of waste discharge from RWCF would raise the minimum DOs by 0.6 to 1.0 mg/l. When there is a algal bloom and a positive flow, the DO would still drop below 3 mg/l. Even if a zero discharge were feasible, the alternative would not provide any assurance to meet the DO objective.

Oxygen Addition

This hypothetical alternative was evaluated for the oxygen addition project. It was designed to preliminary address two questions: how much of oxygen addition and for how long. For the model simulations, it was assumed that the river flow was maintained constant at -500, +500, and +1,000 cfs throughout the year. The oxygen addition was set at 0, 1000, 2000 kg/day. The model was used to simulate two operating conditions: oxygen addition throughout the year and oxygen addition starting in June 1. Simulation results are presented in Appendix P.

For a low flow of either -500 cfs or +500 cfs, 2,000 kg/day of oxygen addition would raise the minimum summer DO from 4 mg/l to 5 mg/l. When the flow is 1,000 cfs, the minimum summer DO would be 4.5 mg/l. To raise it to 5 mg/l, it would require 2,000 kg/day of oxygen addition.

The results also show that the year round operation of oxygen addition may not be needed. The oxygen addition unit can be turned on June 1. In two weeks, the dissolved oxygen will be raised to the same level as the year round operation.

Flow Alteration

This hypothetical alternative was evaluated to illustrate the benefit of flow alterations. For this alternative evaluation, the flow pattern of the hydrologic year 1993 was used as an example.

The hydrologic year 1993 is classified as an above normal. Yet, the DWR's projected flow was zero cfs for December of 1992 and 500 cfs for July and August of 1993. For the pulse flow period of April 15 to May 31, 1993, the DWR projected a high flow of 6,000 cfs (Run 469B).

Under the flow alteration alternative, the pulse flow is scaled down from 6,000 cfs to 3,000 cfs from April 15 to May 31, 1993. The saved water is distributed evenly for the other months. Under this scenario, the river flow would be raised to 1,700 cfs. There is no change in the total annual flow.

The model was used to simulate the DO under these two flow patterns. The results are compared in Appendix Q.

The redistribution of flow is shown to improve the DO substantially. The episodic low of 5 mg/l at station R3 is raised to 6 mg/l.

This modeling exercise shows the benefit of flow redistribution. Whether such a flow redistribution can meet other operational constraints (e.g. EC at Vernalis, X2 at Carquinez Strait) is not known. DWR needs to run its models to find out.

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SUMMARY AND CONCLUSION

The model study shows that DO in the San Joaquin River is controlled by many factors. It may not be possible to control such major factors as algal blooms at Vernalis and Mossdale, high summer time temperatures, and high sediment oxygen demand. The control of the remaining minor factors, individually, may not be enough. A complete elimination of waste discharge from the City of Stockton, for example, would not raise the DO above 5 mg/l.

The combination alternative can have many perturbations. For a more definitive evaluation, the DWR needs to run their models under new constraints (e.g. a minimum flow of 500 cfs for Channel 8). The DO model can then be applied to the newly projected flow together with other control measures. Such an analysis can lead to a best combination alternative to meet the DO objective of the San Joaquin River.

Finally, there is a possibility for real-time water quality mangement of DO in the Lower San Joaquin River. The real time information about river flow (the City of Stockton has already installed a gaging station), tide, fish migration, algal bloom, and DO in the river can be used to coordinate the operations of fish barrier, Stockton's RWCF, and oxygen addition facility. When the condition is bad, Stockton can withhold its discharge and store the water in algae ponds for a week or longer. Such a coordination can help meet the DO objective and protect migrating fish.

REFERENCES

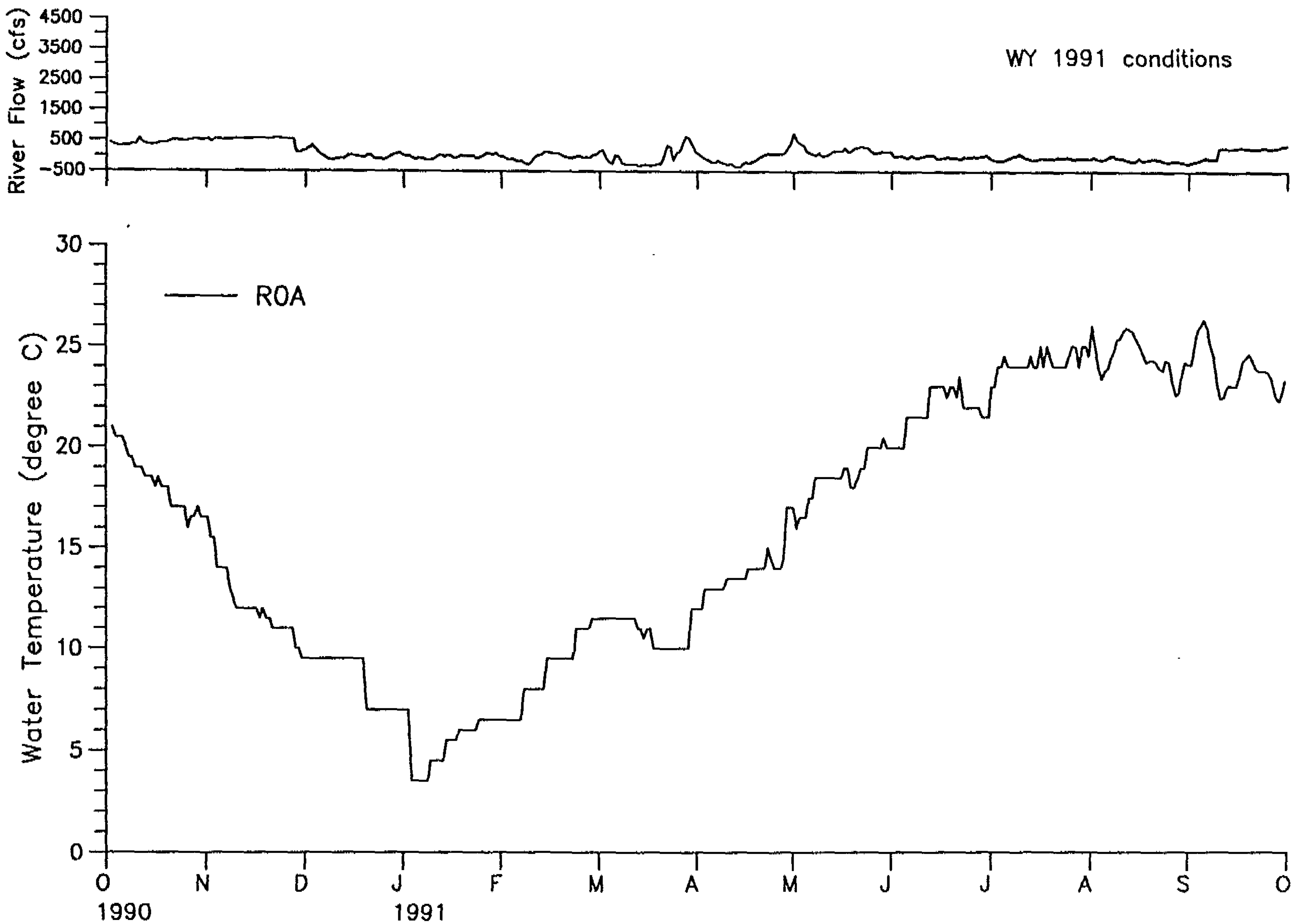
Chen, Carl W. and G.T. Orlob, "Ecologic Simulation for Aquatic Environment" in Systems Analysis and Simulation in Ecology Volume III, Bernard C. Patten, Editor, Academic Press, Inc. New York, NY, 1975.

Schanz, Robert and Carl Chen., "City of Stockton Water Quality Model, Volume I: Model Development and Calibration", Report to City of Stockton, PWA and Systech Engineering, Inc., August, 1993.

Hayes, Steve and Staff of the Compliance Monitoring and Analysis Section, DWR., "Dissolved Oxygen Conditions in the Stockton Ship Channel" in Newsletter, Interagency Ecological Program for the Sacramento-San Joaquin Estuary, Winter, 1995, pp. 8-9.

Appendix A.

1991 Calibration Results for Stations R1 Through R7.


River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Water Temperature (degree C)
30
25
20
15
10
5
0
ROA
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

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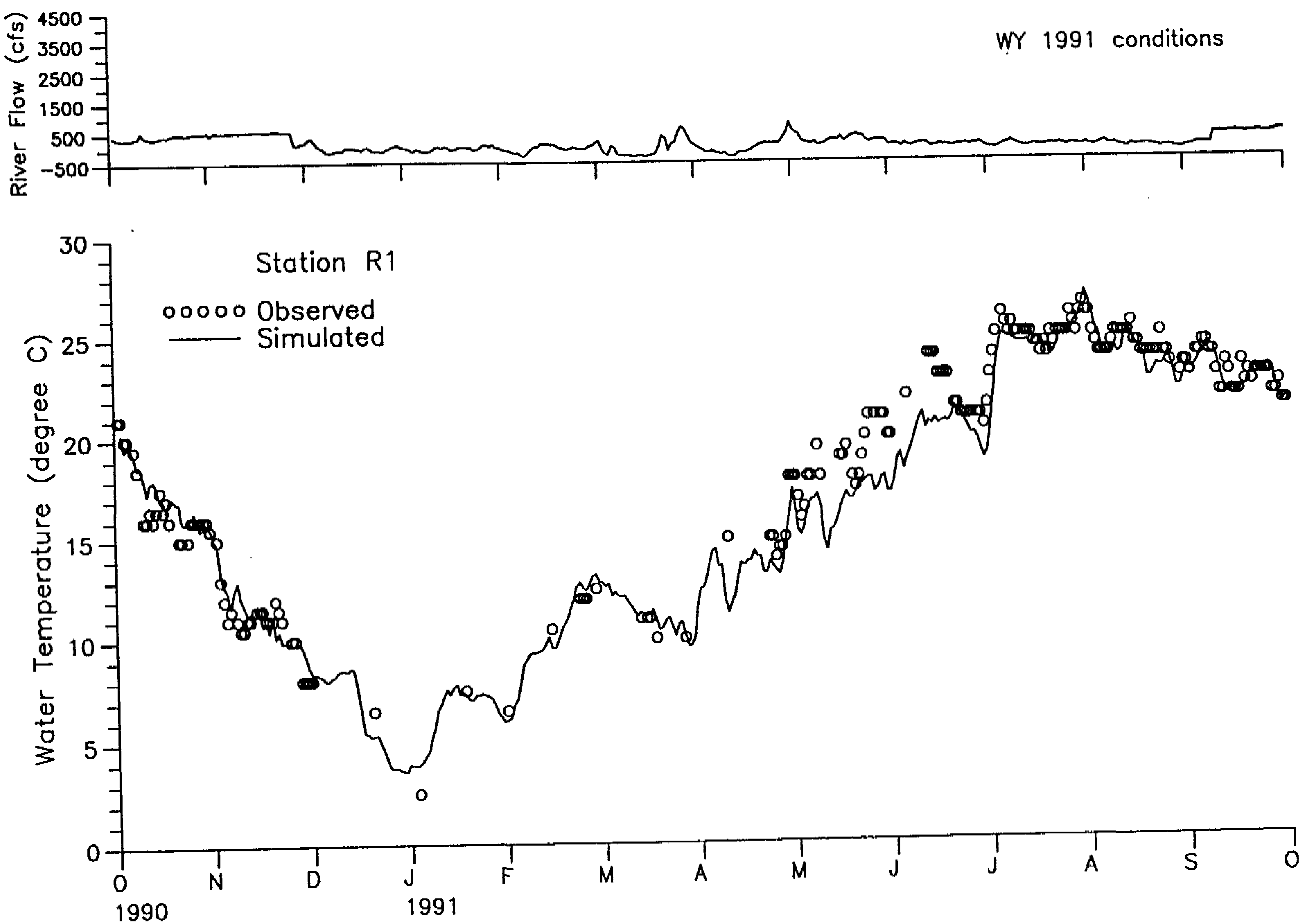
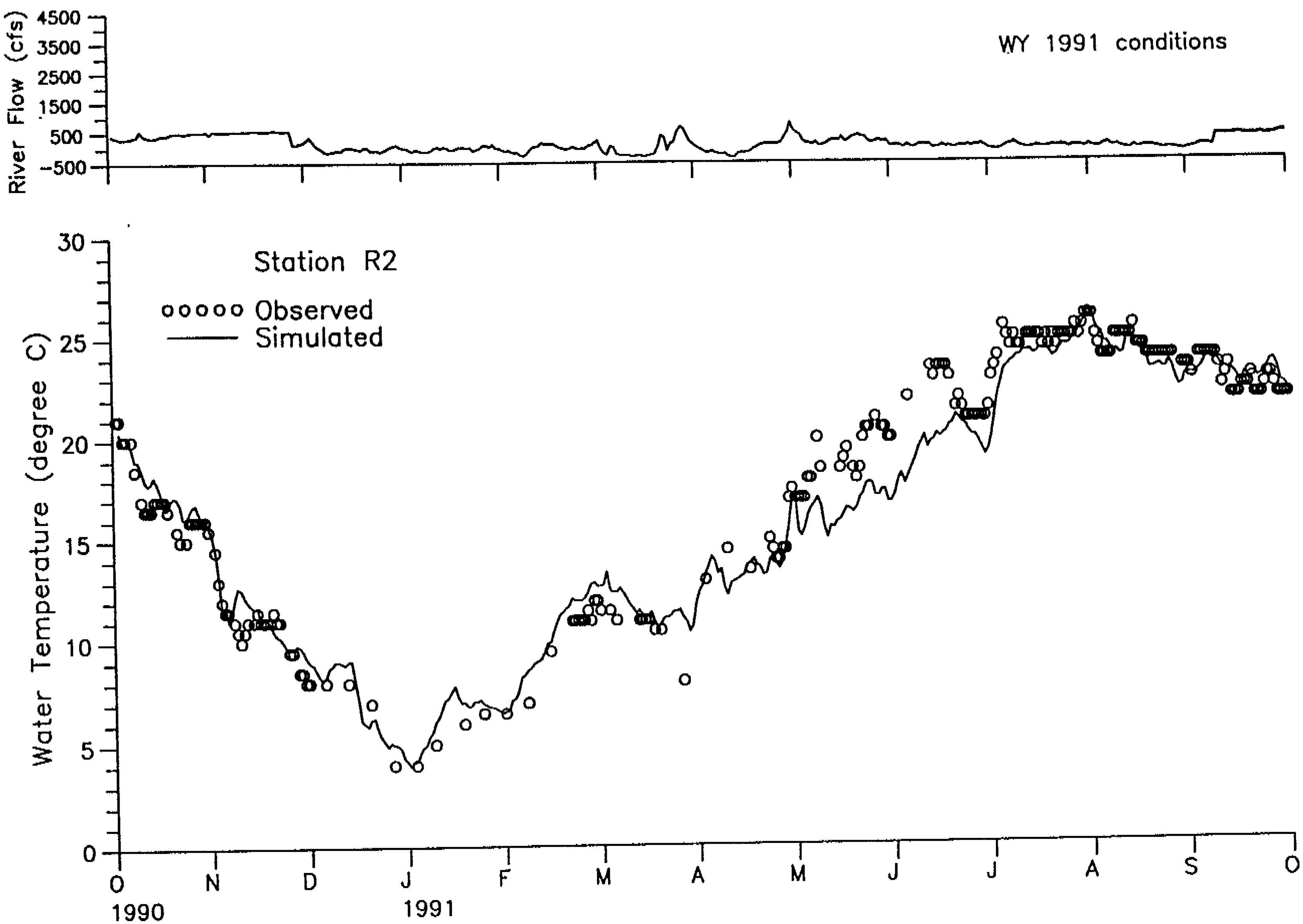


D-041475

D —0 4 1 4 7 5



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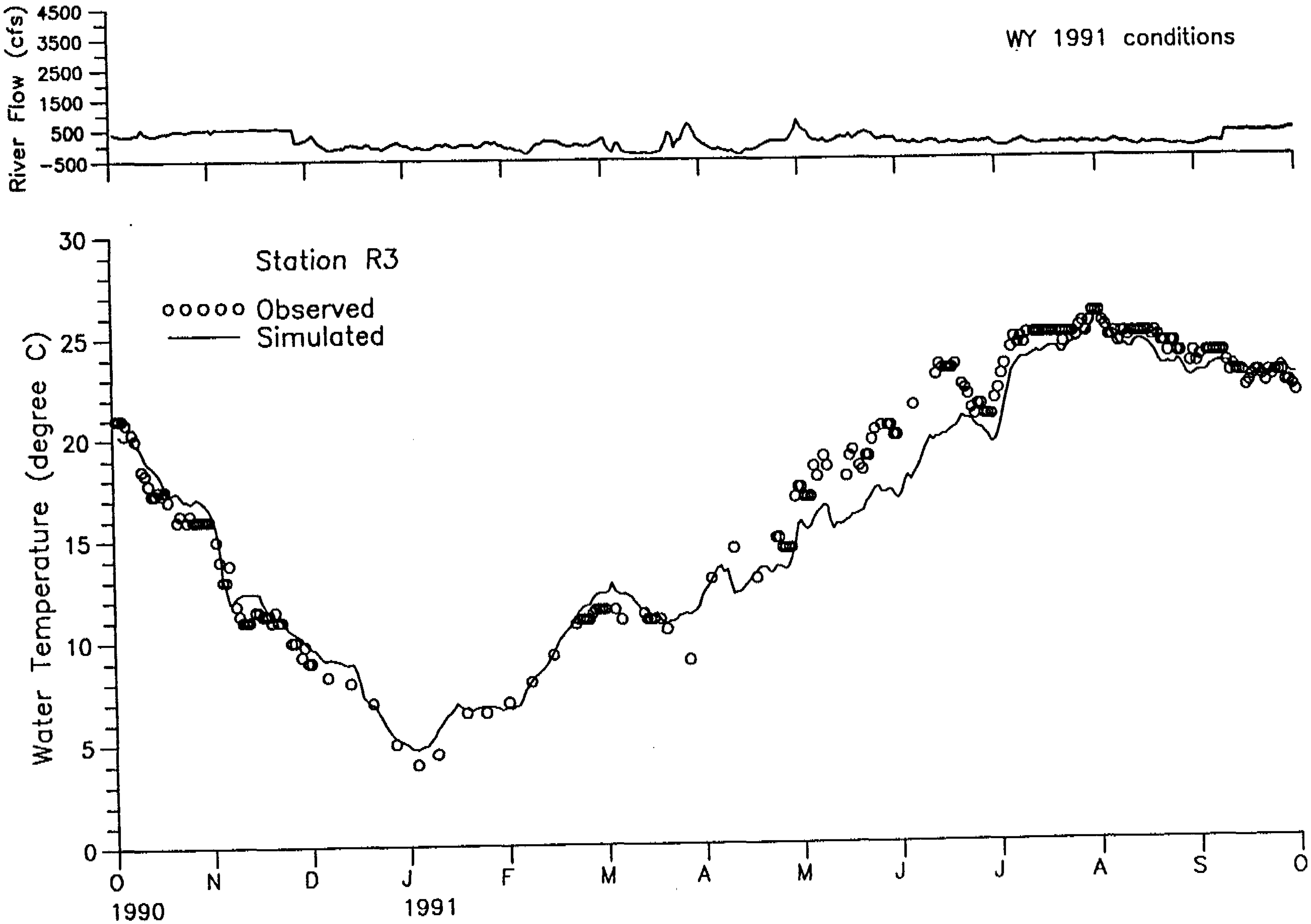
D-041476



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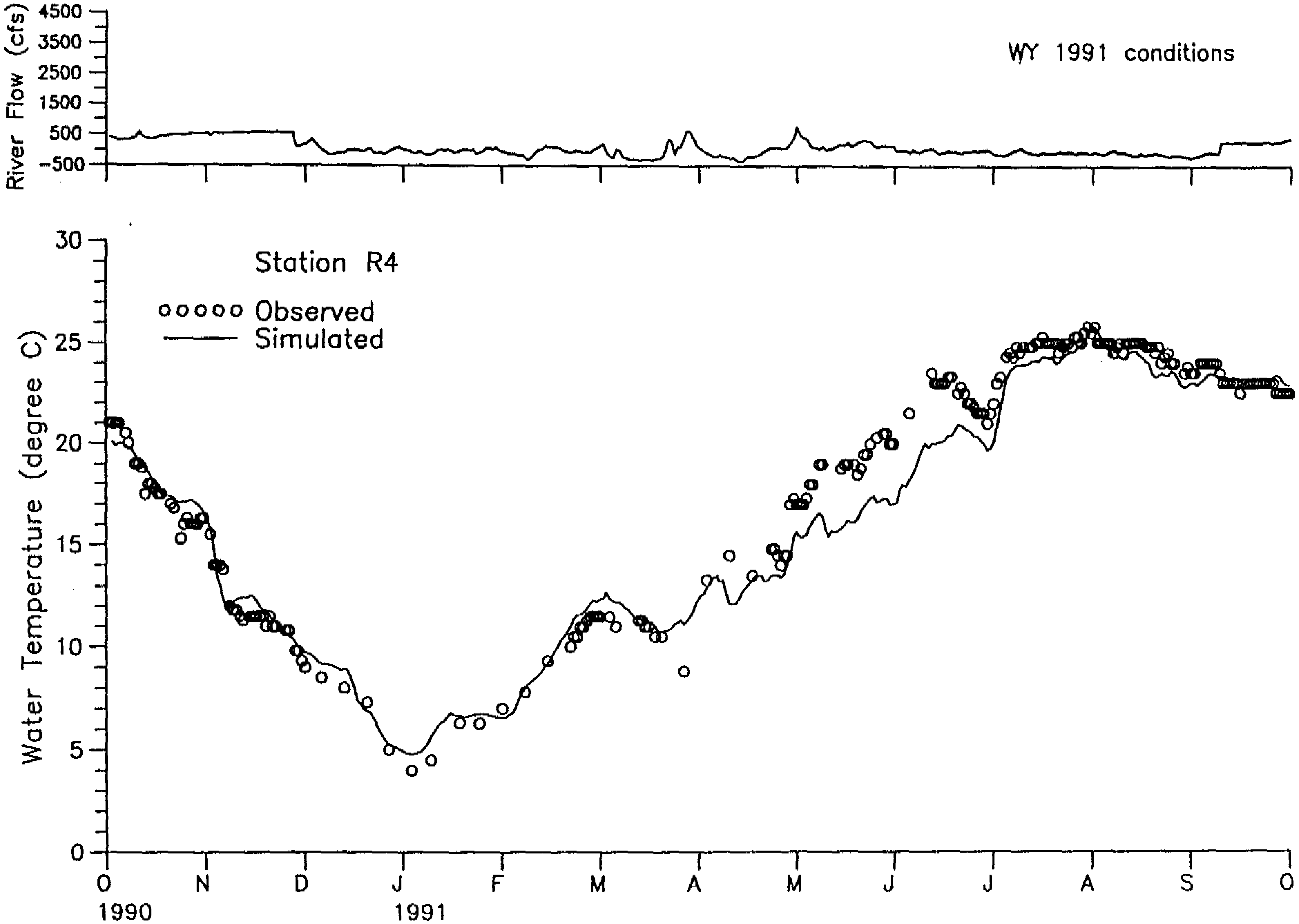
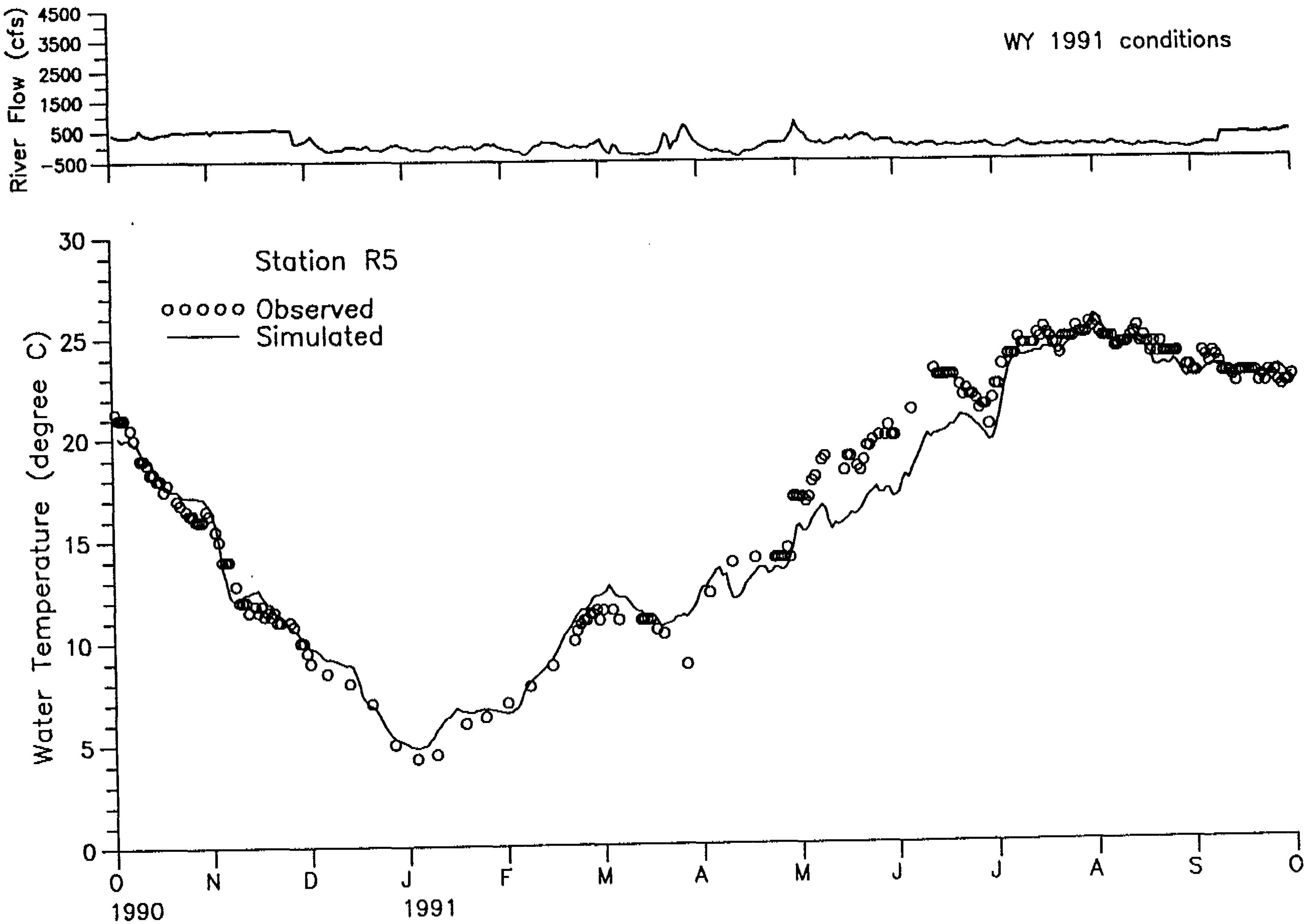
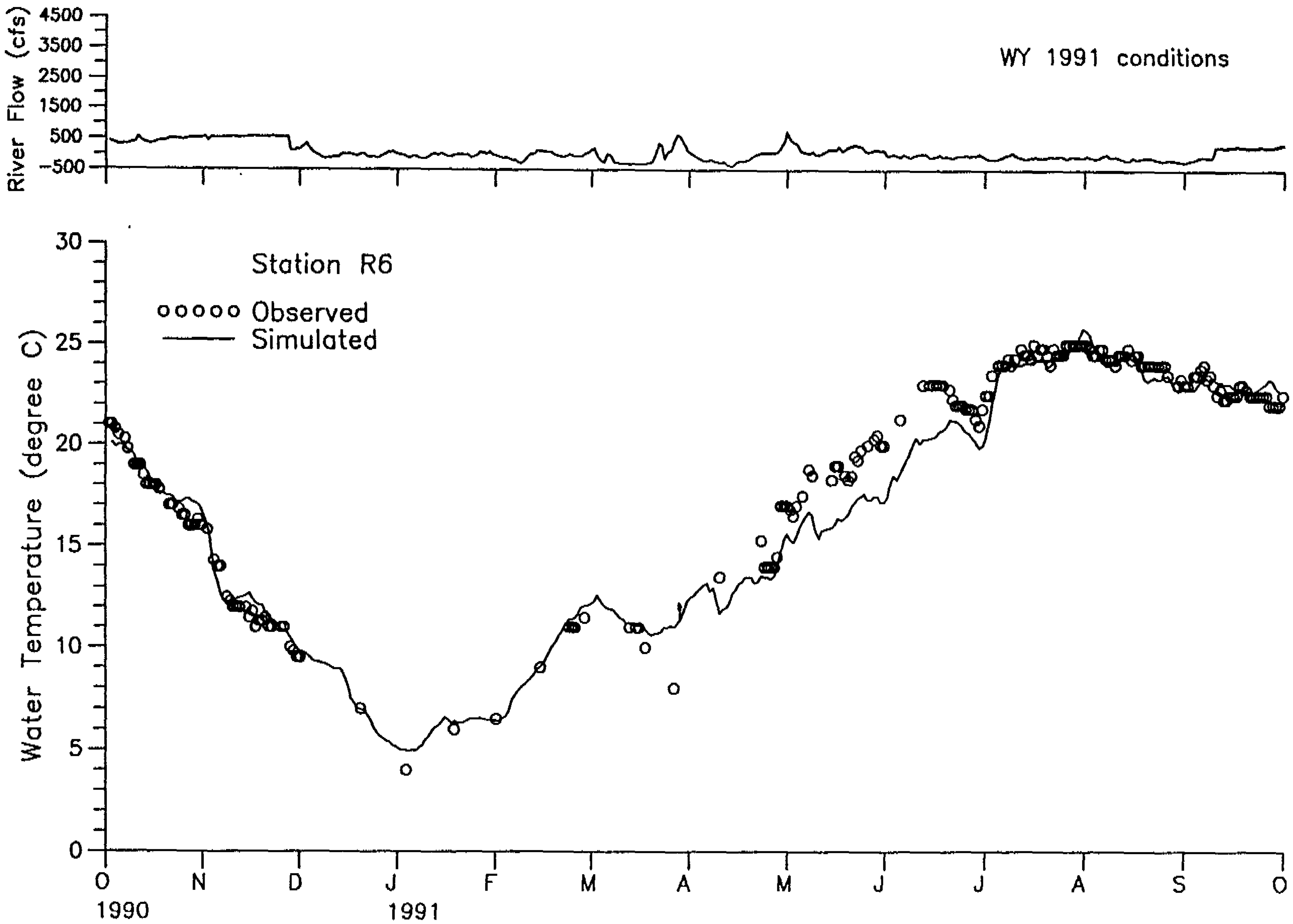


River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Station R4
Observed
Simulated
Water Temperature (degree C)
30
25
20
15
10
5
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

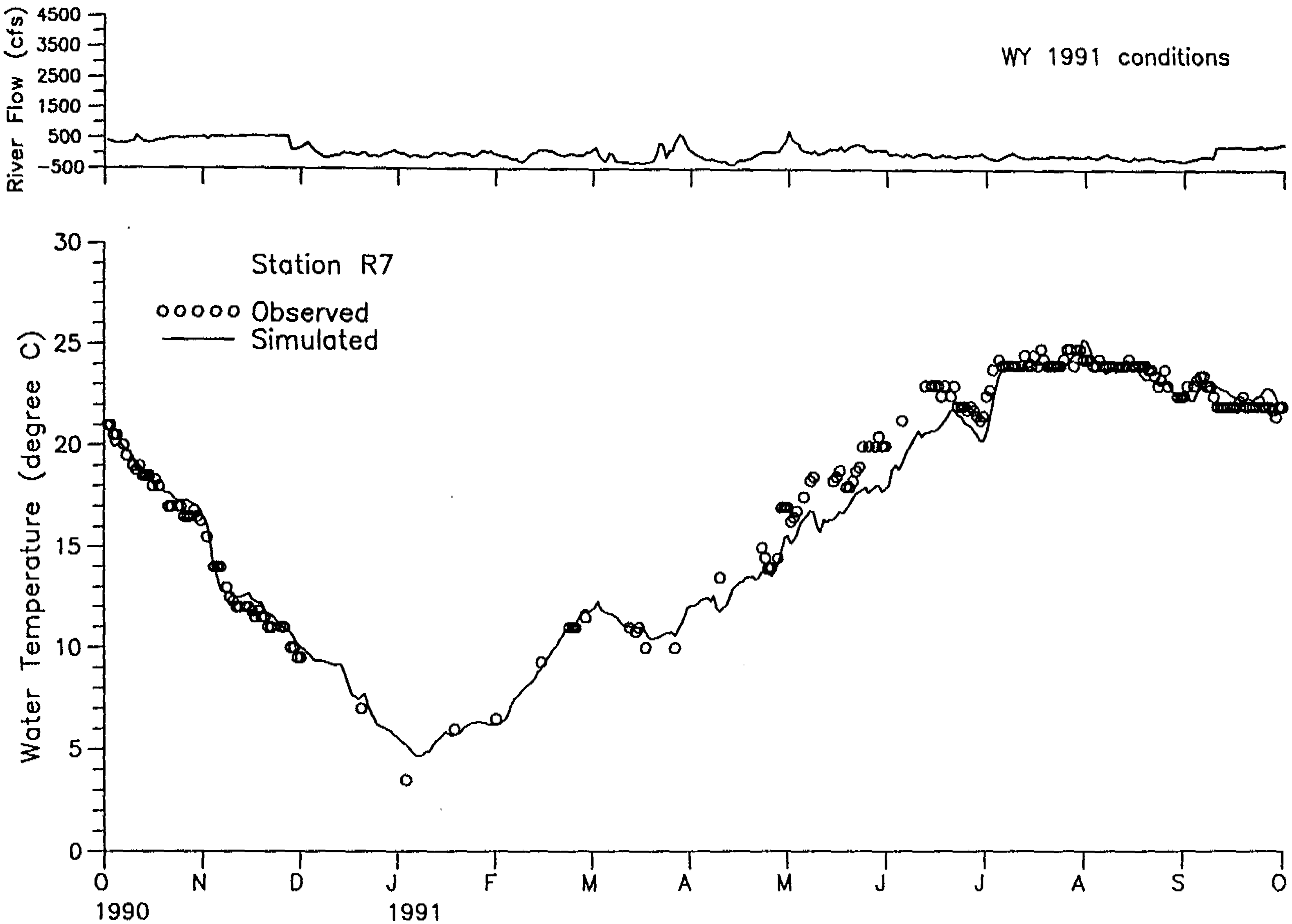
D-041478


River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Station R5
ooooo Observed
Simulated
Water Temperature (degree C)
30
25
20
15
10
5
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

D-041479


River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
30
25
20
15
10
5
0
Water Temperature (degree C)
Station R6
ooooo Observed
Simulated
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

D-041480



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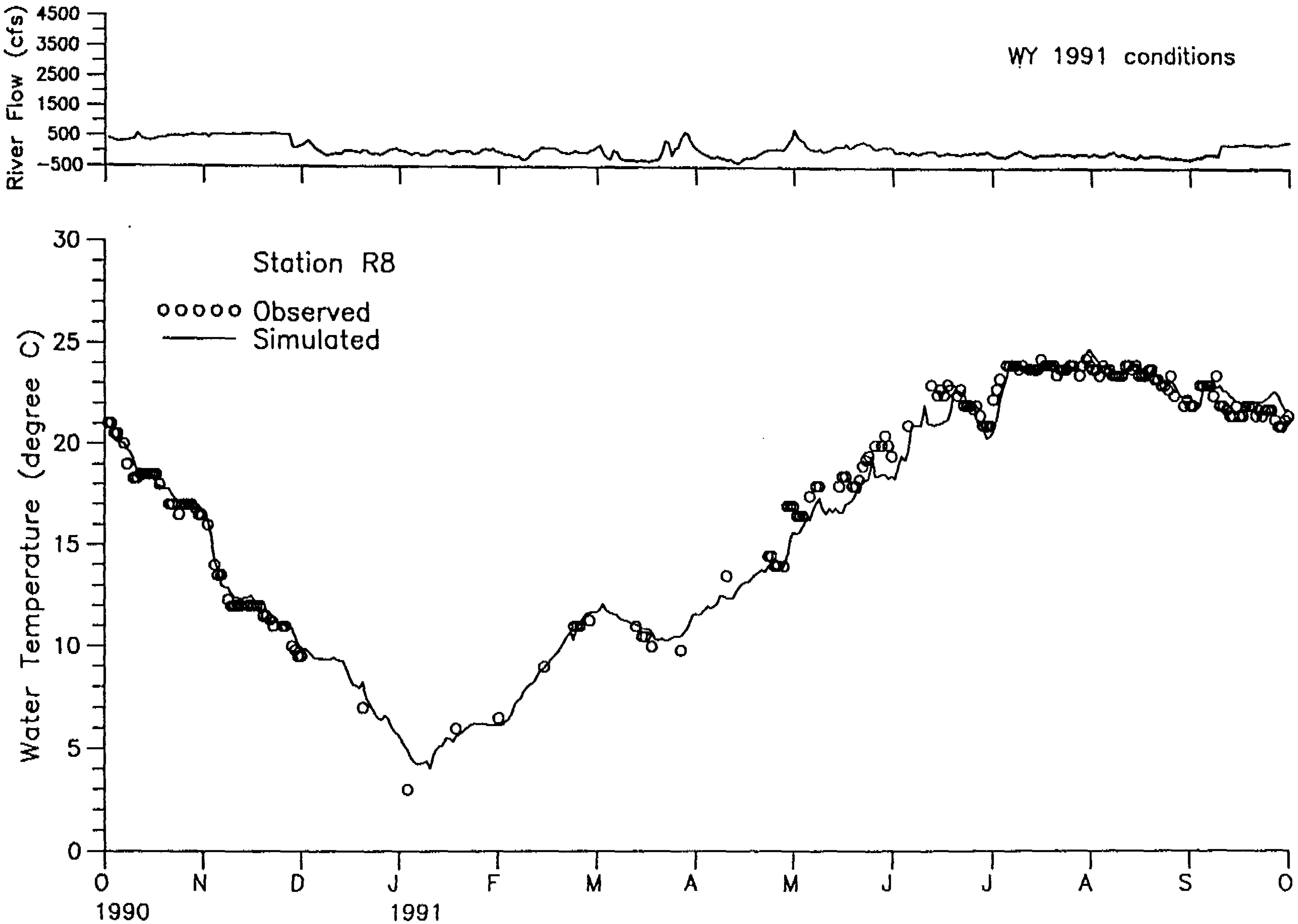
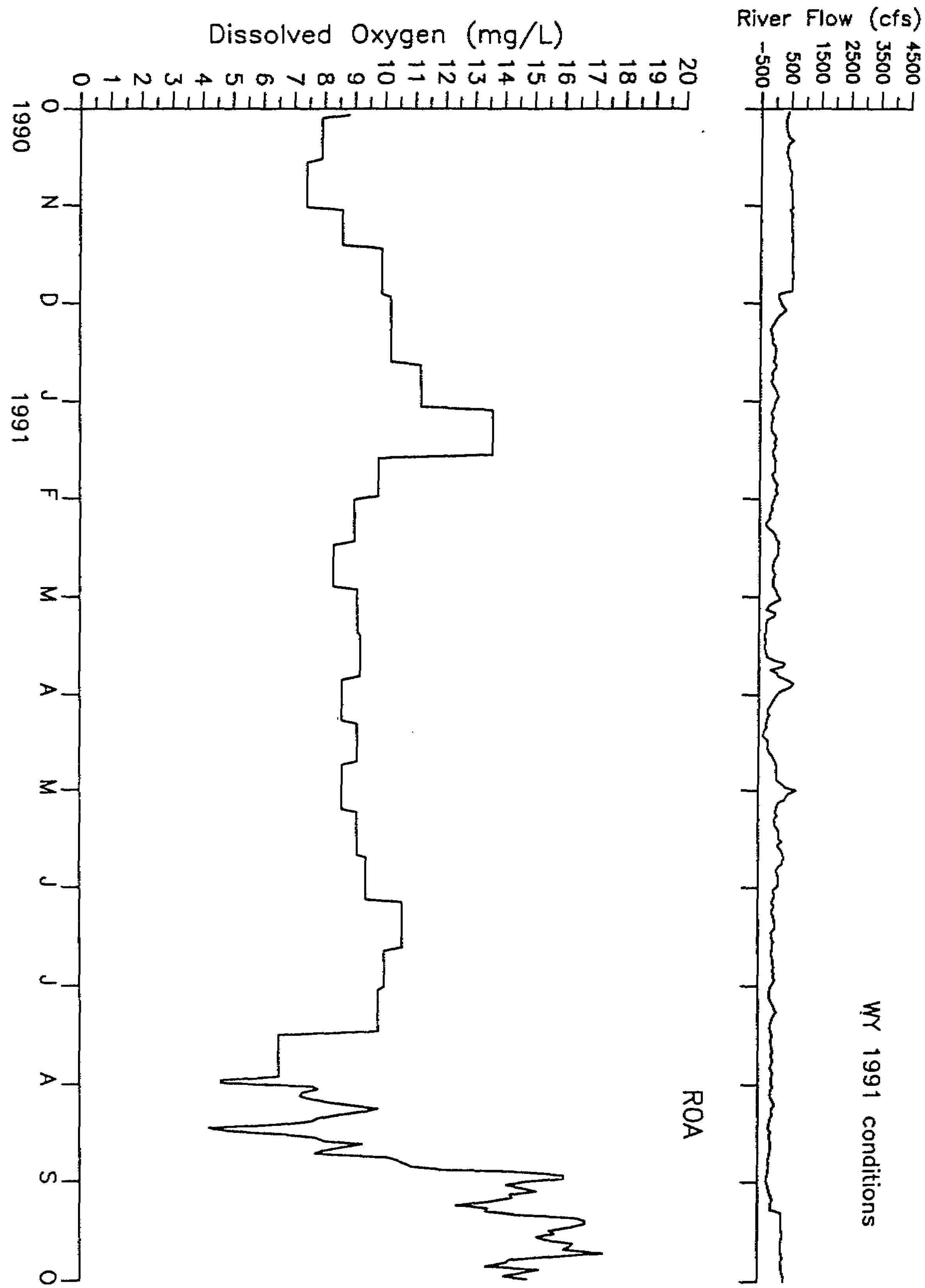
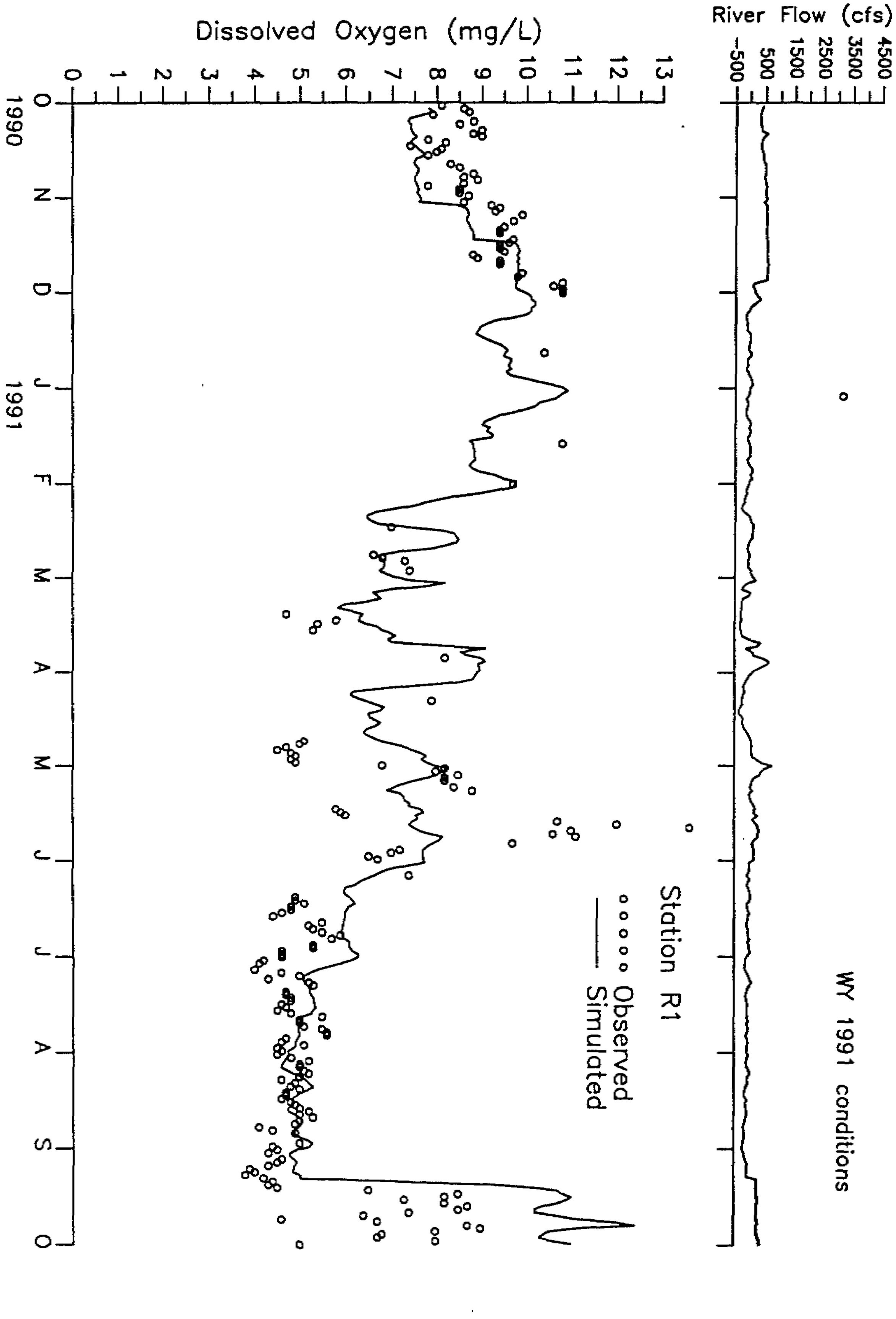
D-041481


River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Water Temperature (degree C)
30
25
20
15
10
5
0
Station R8
oooooo Observed
Simulated
O N D J F M A M J J A S O
1990
1991

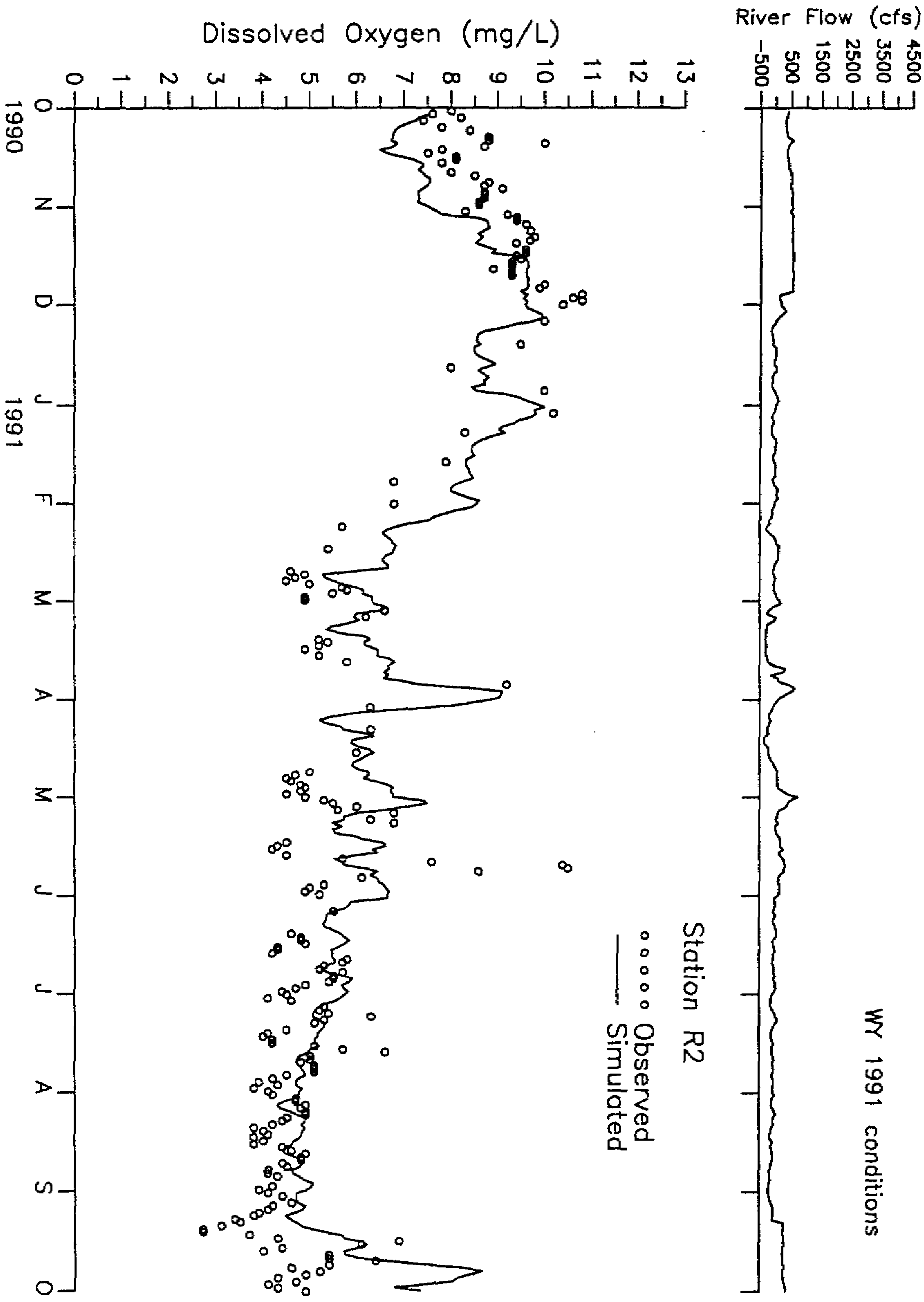

Dissolved Oxygen (mg/L)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
River Flow (cfs)
-500 500 1500 2500 3500 4500
O N D J F M A M J J A S O
1990
1991
ROA
WY 1991 conditions

D-041483

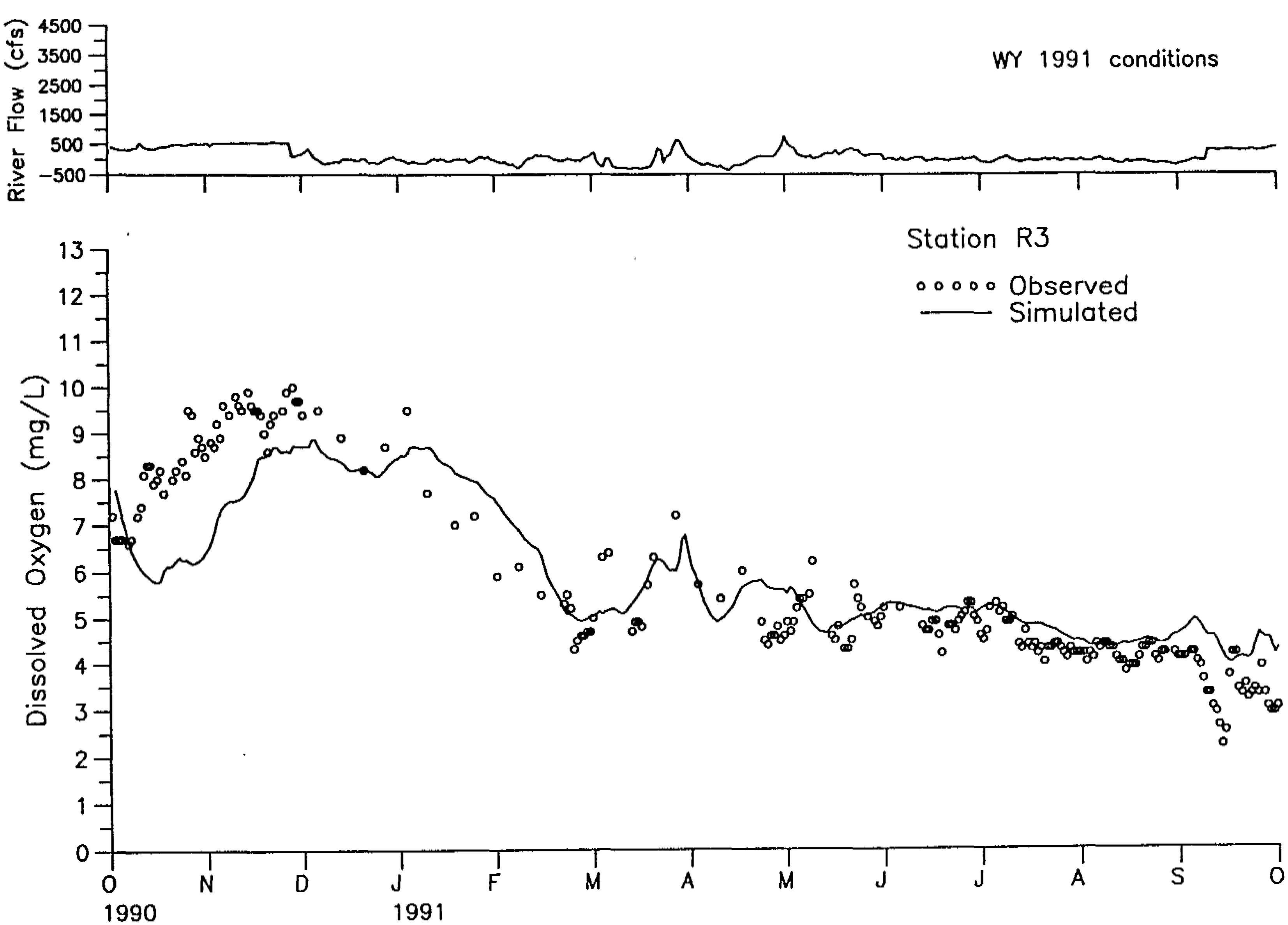


Dissolved Oxygen (mg/L)
River Flow (cfs)
-500
500
1500
2500
3500
4500
0
1
2
3
4
5
6
7
8
9
10
11
12
13
1990
1991
O
N
D
J
F
M
A
M
J
J
A
S
O
WY 1991 conditions
Station R1
Observed
Simulated

D-041484

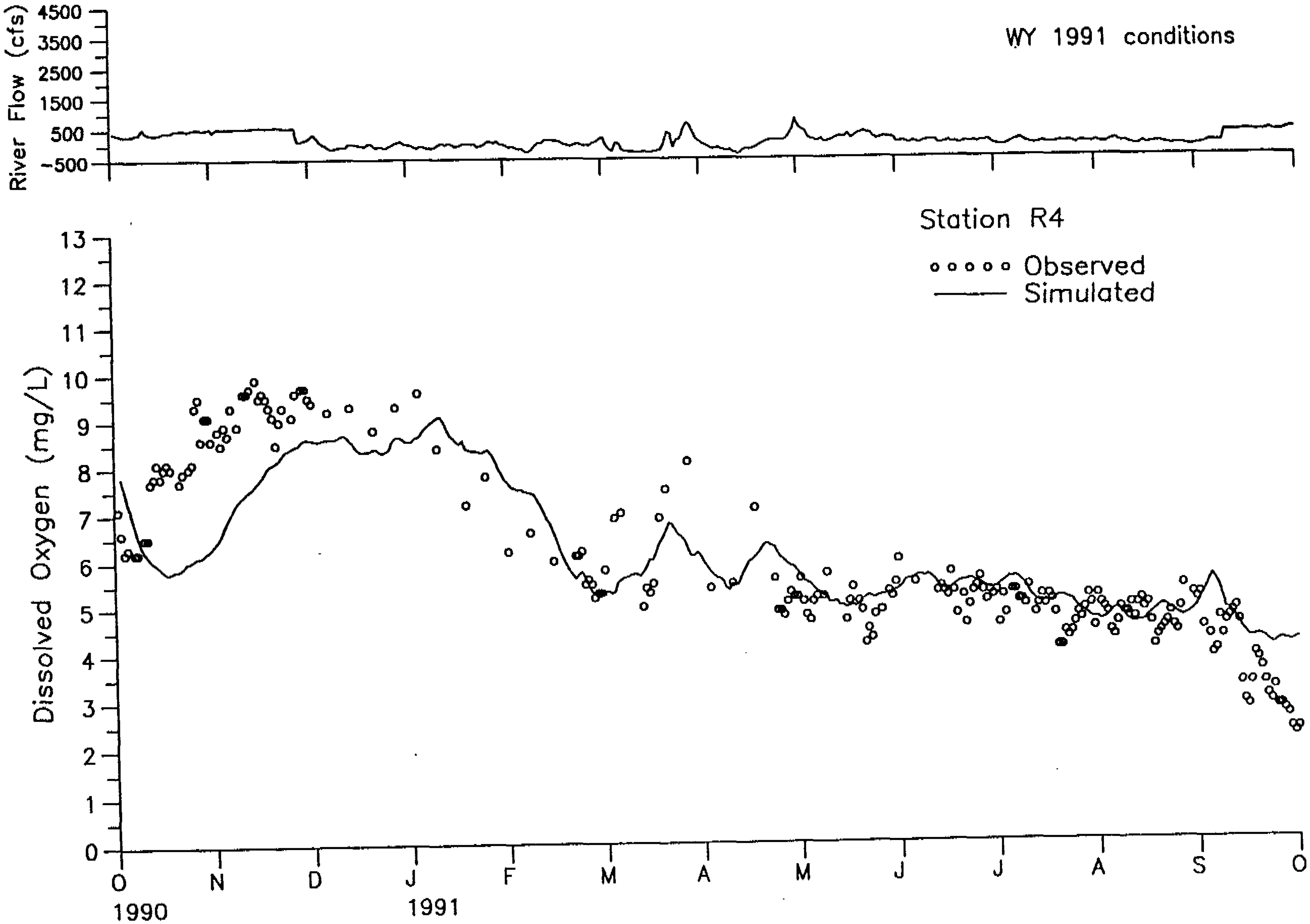


Dissolved Oxygen (mg/L)
River Flow (cfs)
WY 1991 conditions
Station R2
Observed
Simulated
1990
1991
O N D J F M A M J J A S O
0 1 2 3 4 5 6 7 8 9 10 11 12 13
-500 500 1500 2500 3500 4500

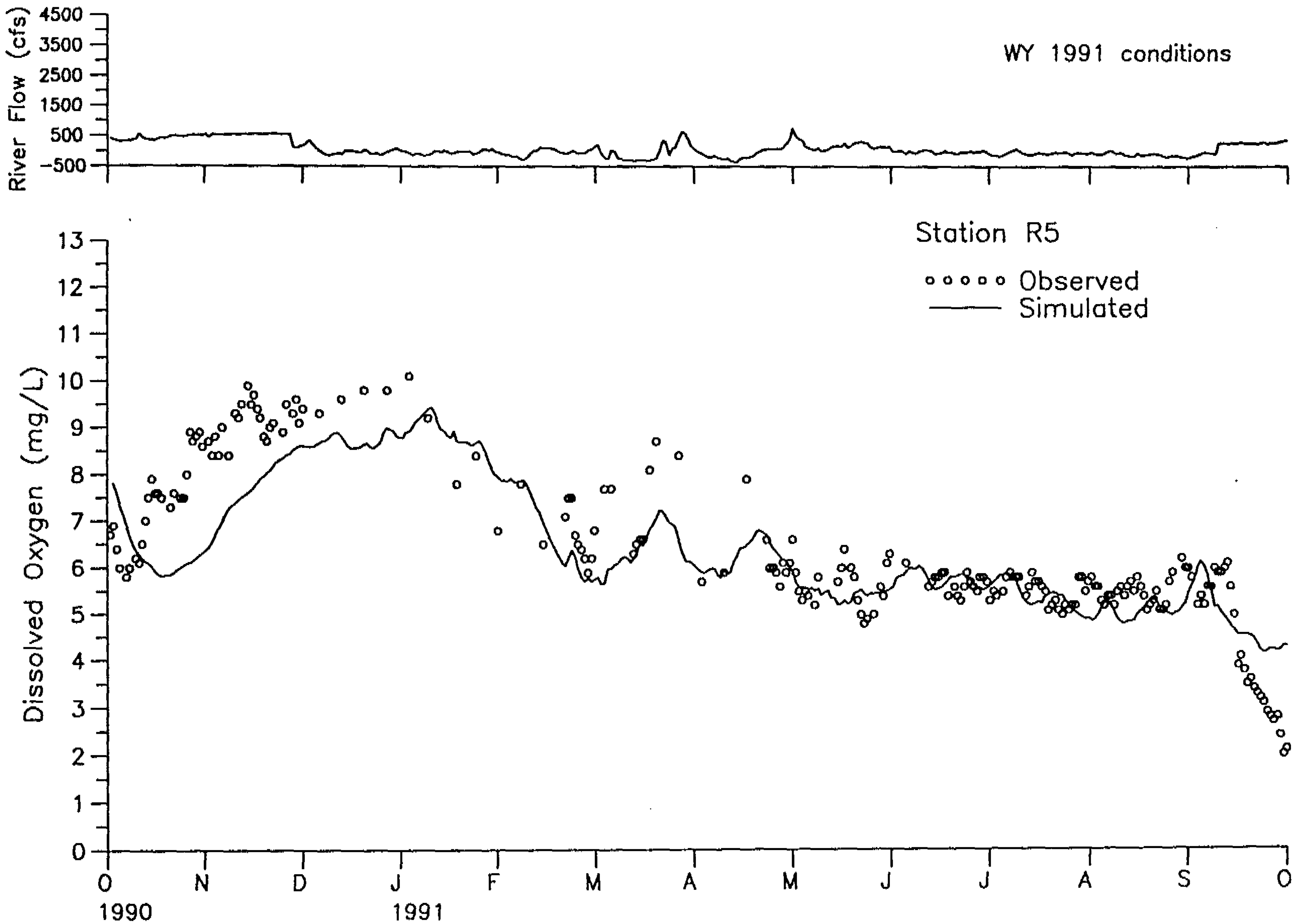


D-041486

D-041486



WY 1991 conditions
River Flow (cfs)
4500
3500
2500
1500
500
-500
Station R4
Observed
Simulated
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1990
1991



River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Station R5
Observed
Simulated
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
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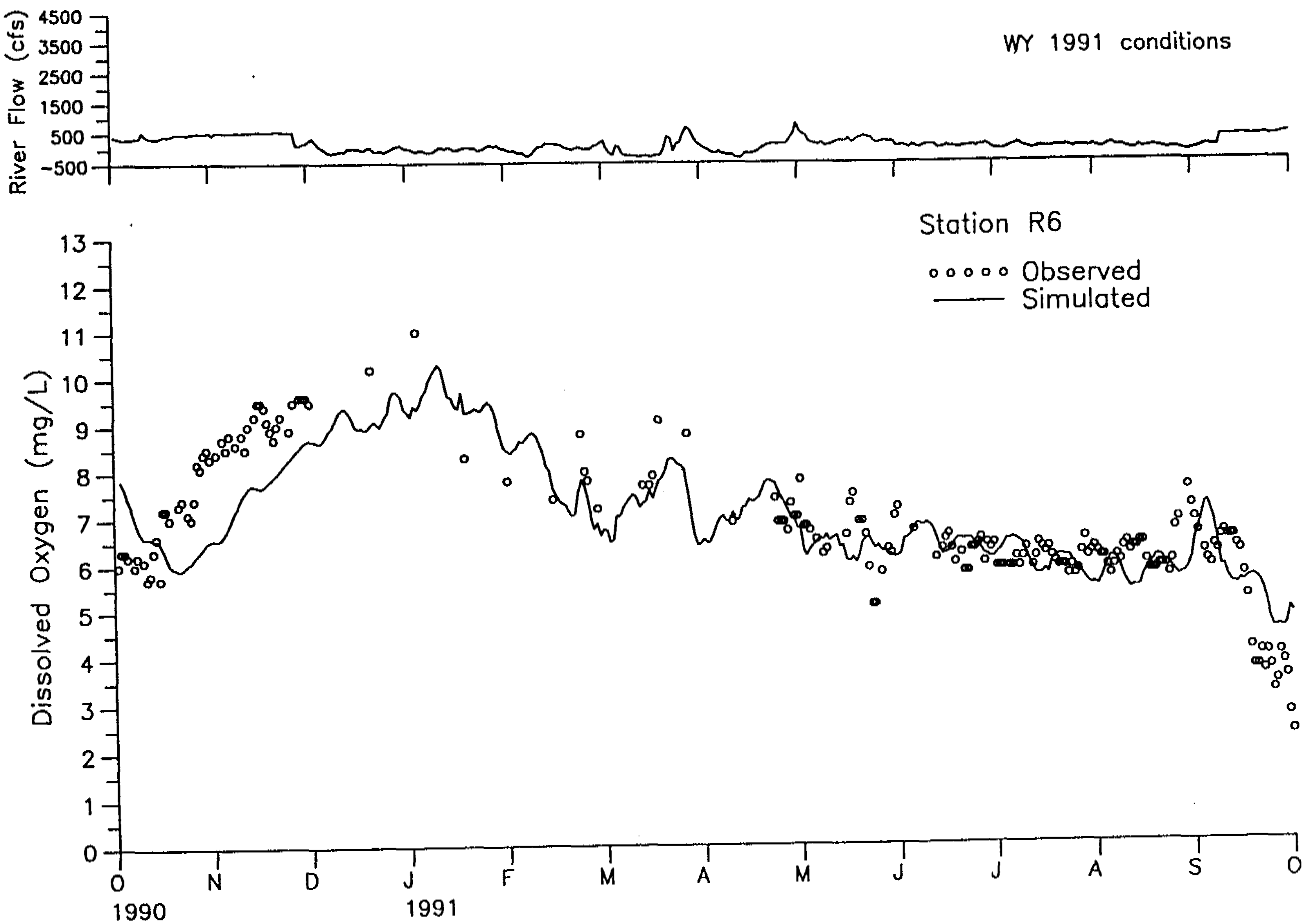
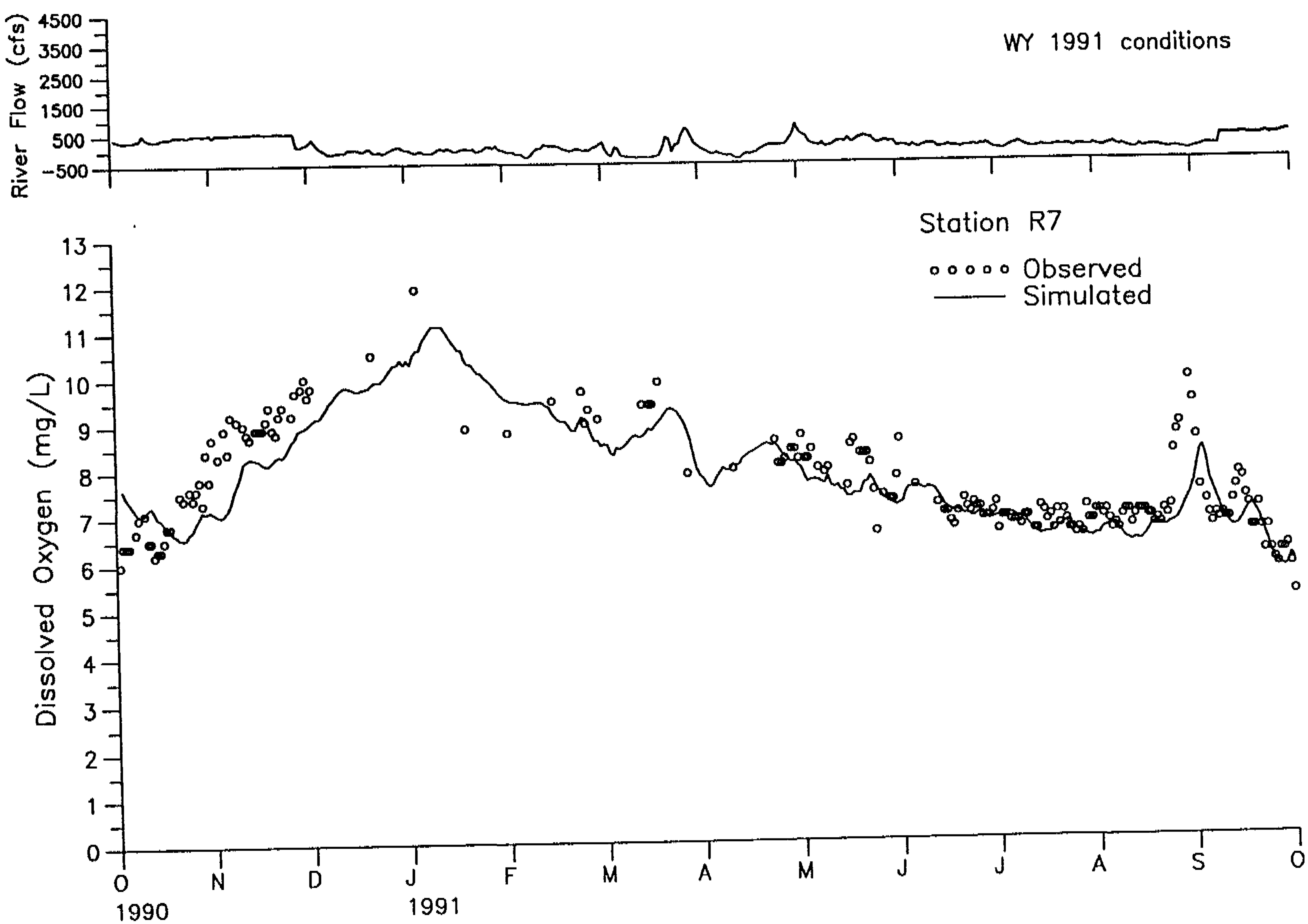
J
A
S
O
1990
1991



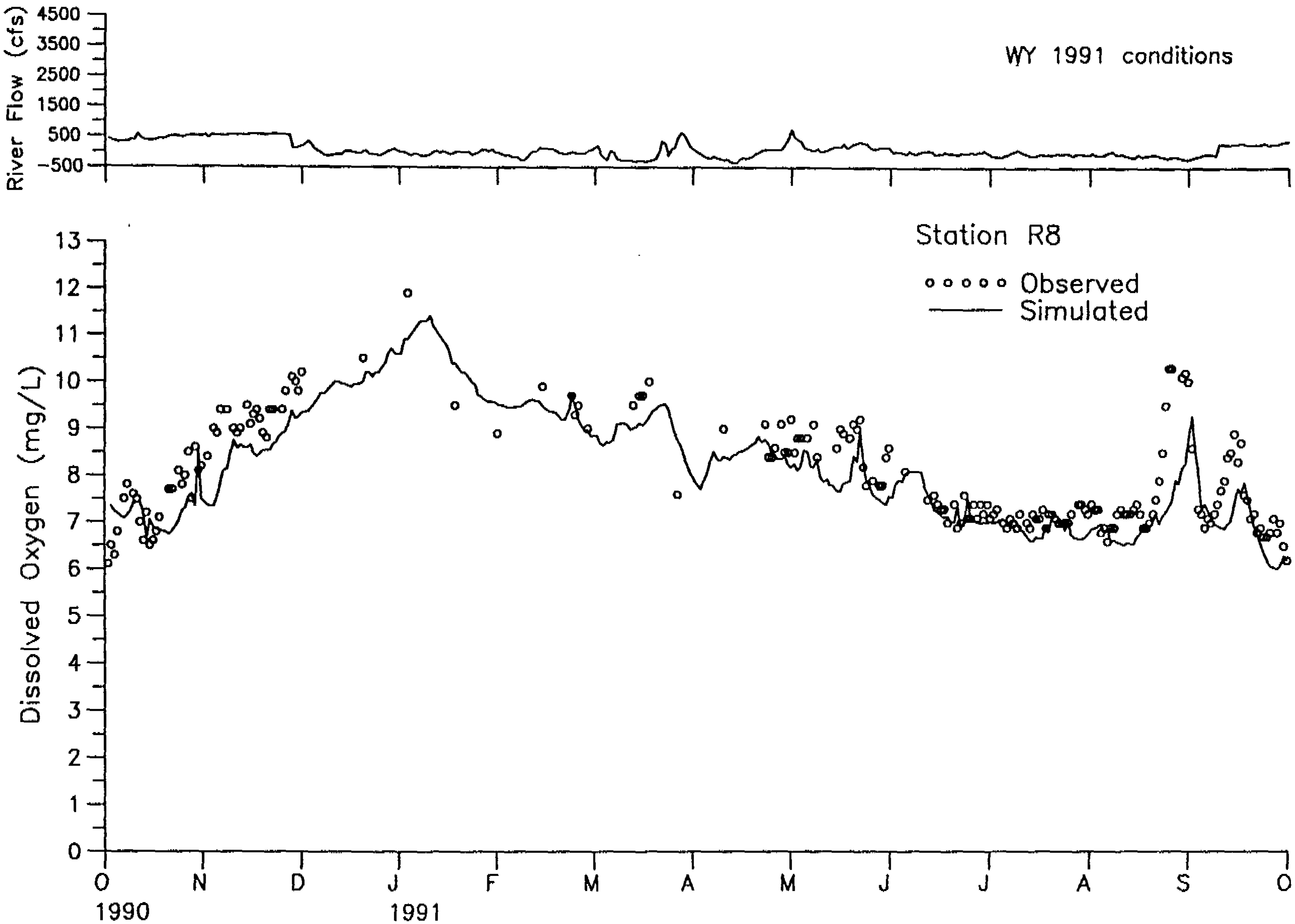
D-041489

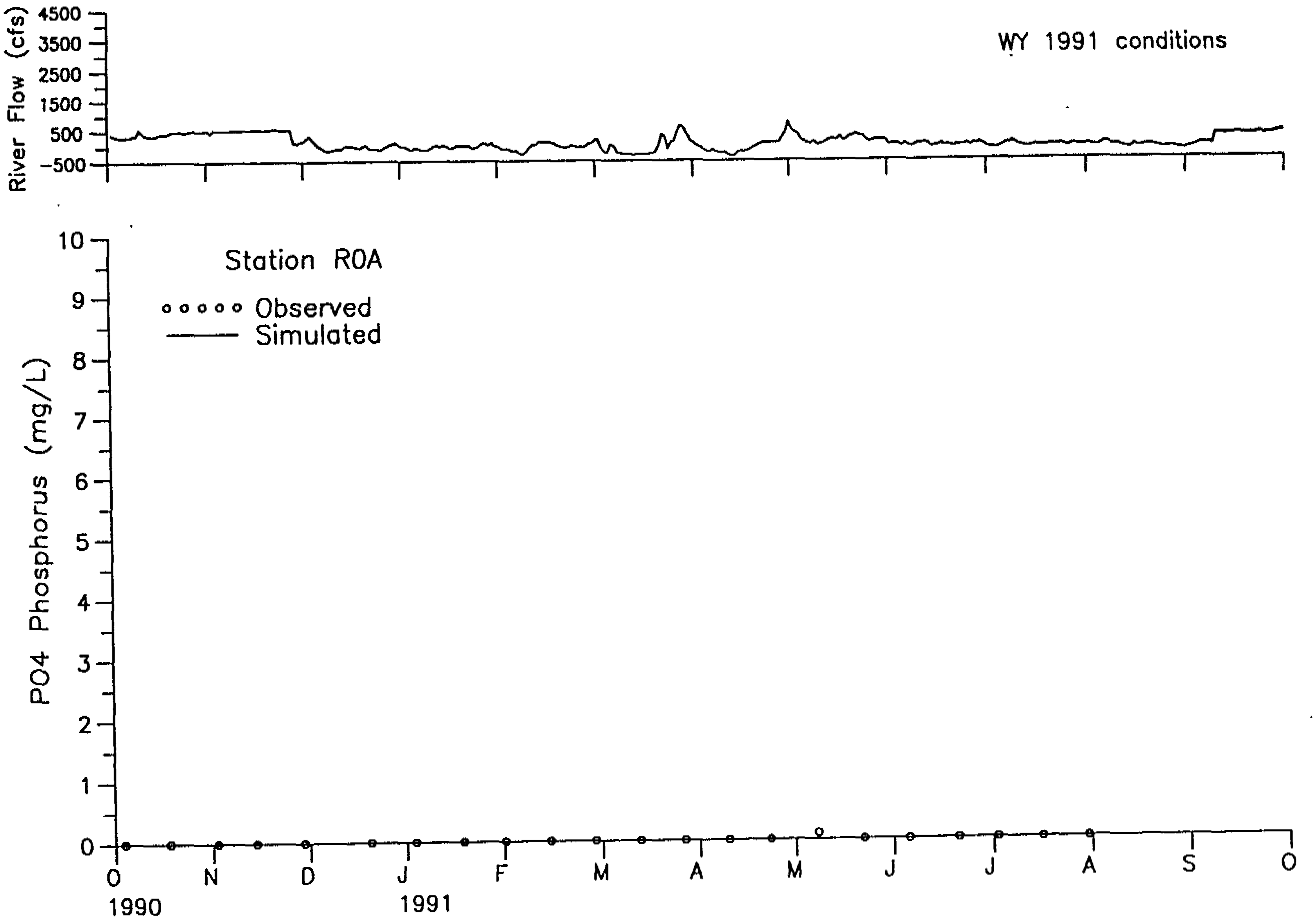
D-041489



WY 1991 conditions
River Flow (cfs)
4500
3500
2500
1500
500
-500
Station R7
Observed
Simulated
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

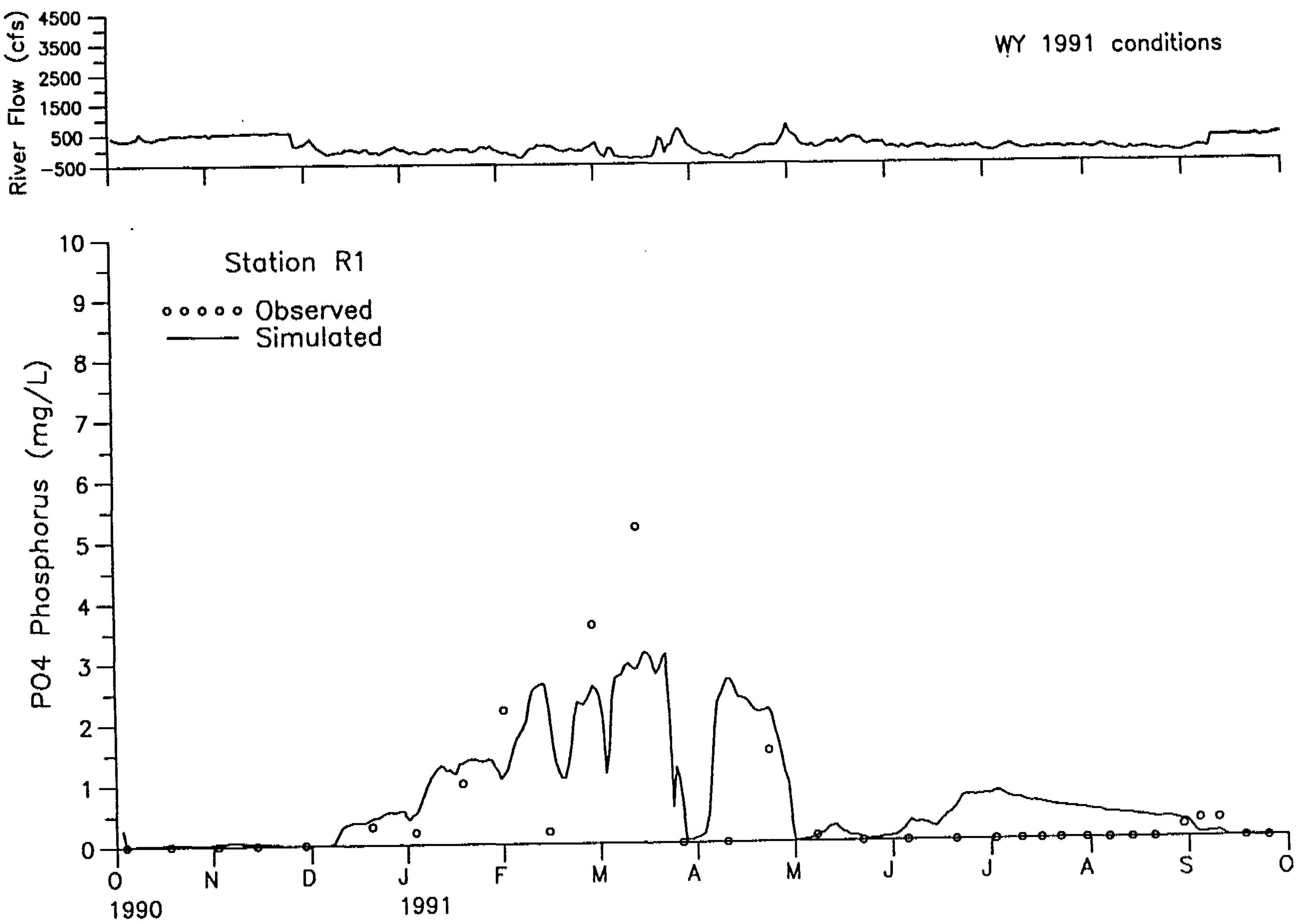
D-041490


River Flow (cfs)
4500
3500
2500
1500
500
−500
WY 1991 conditions
Station R8
Observed
Simulated
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991



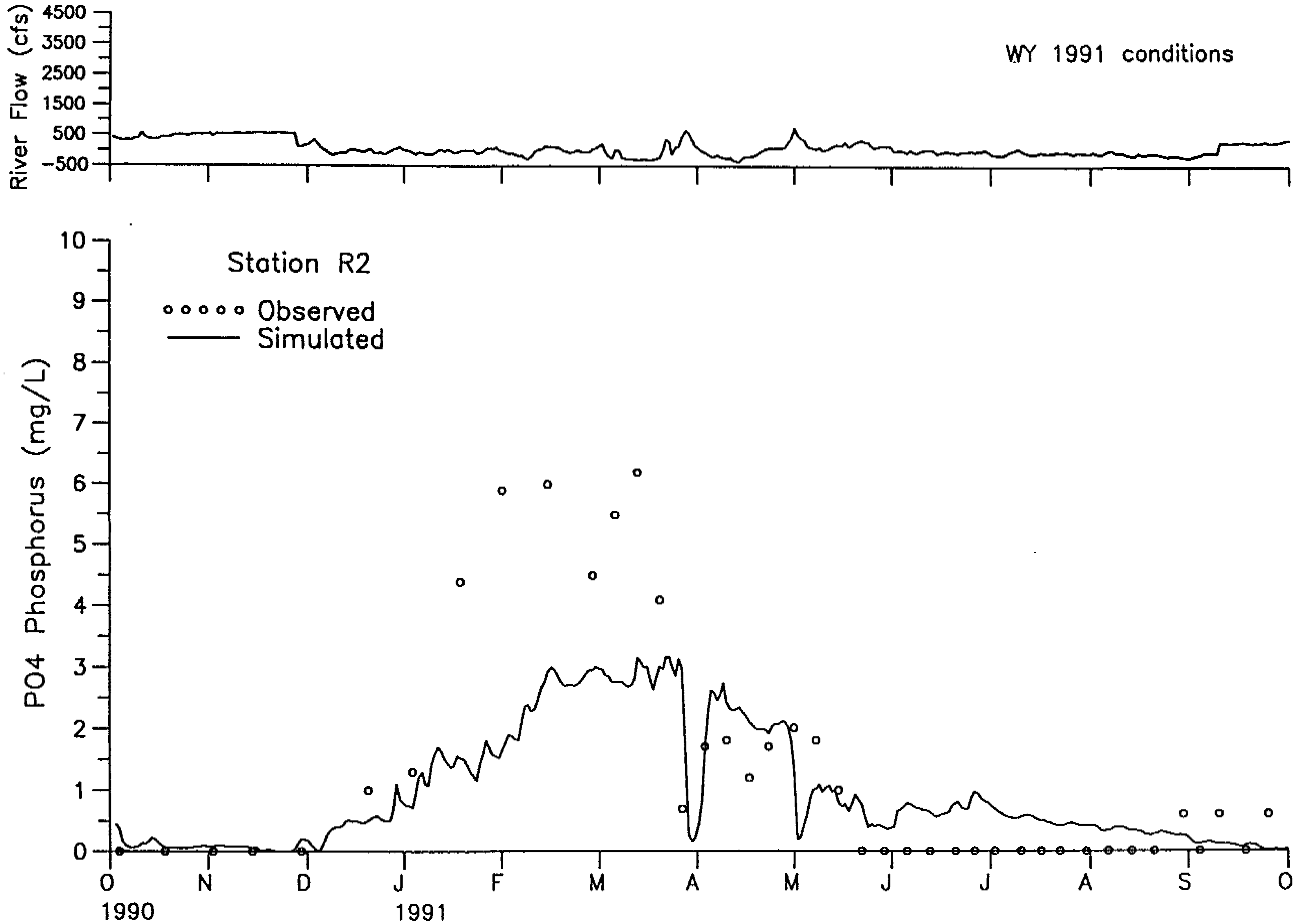
River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Station R0A
Observed
Simulated
PO4 Phosphorus (mg/L)
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

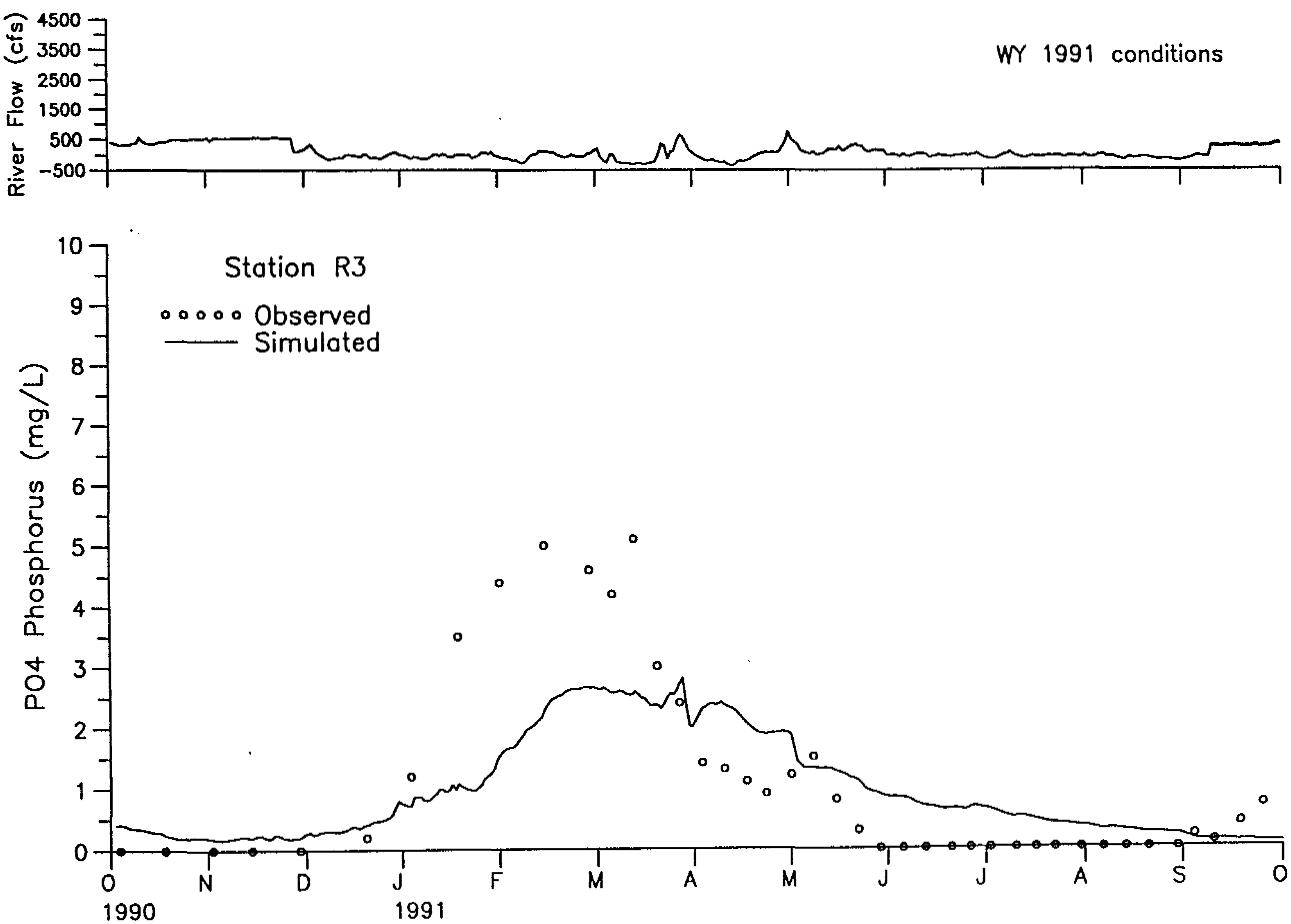
D-041492



WY 1991 conditions
River Flow (cfs)
4500
3500
2500
1500
500
-500
Station R1
Observed
Simulated
PO4 Phosphorus (mg/L)
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

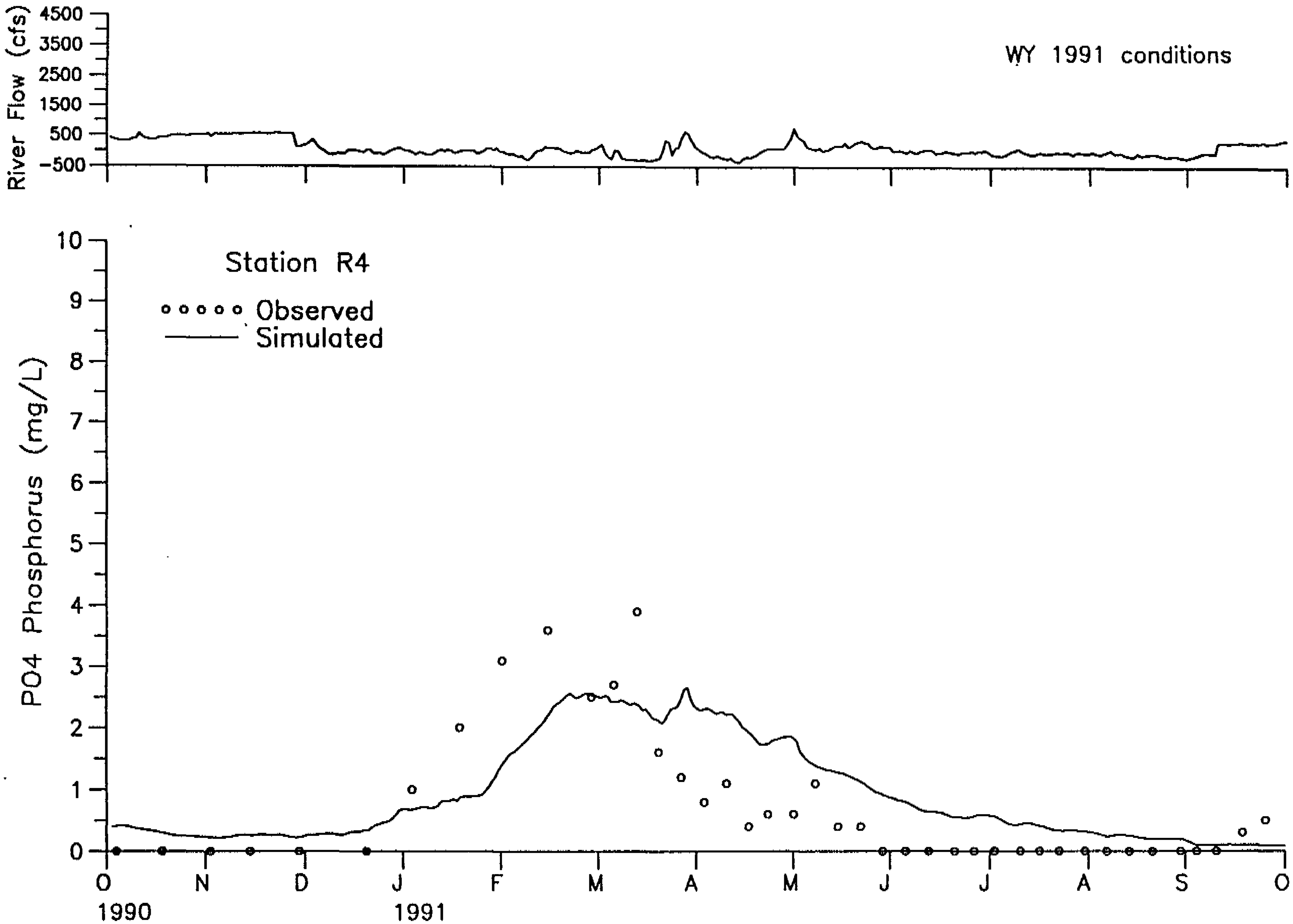
D-041493


River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
PO4 Phosphorus (mg/L)
10
9
8
7
6
5
4
3
2
1
0
Station R2
Observed
Simulated
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991



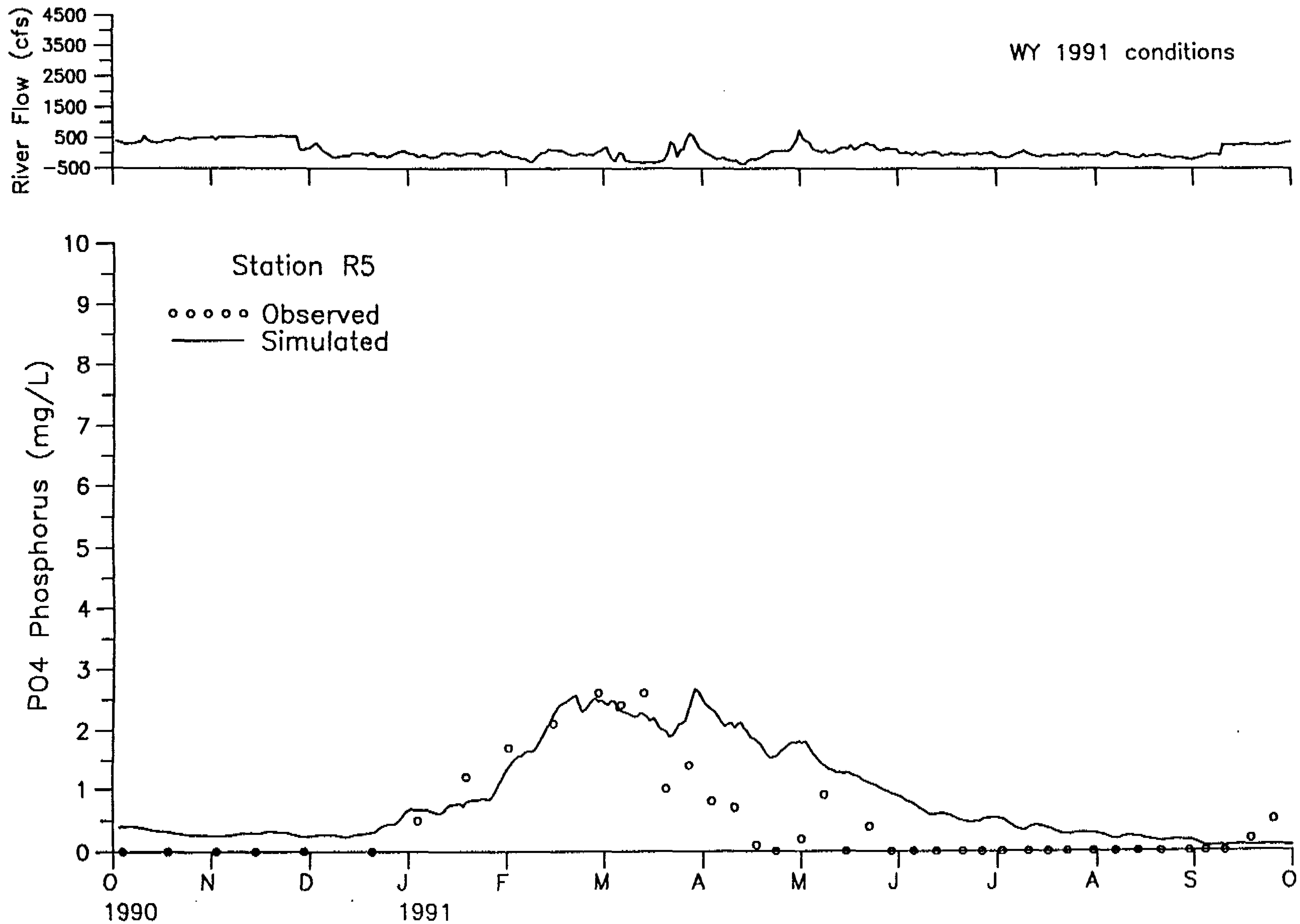
D-041495

D-041495



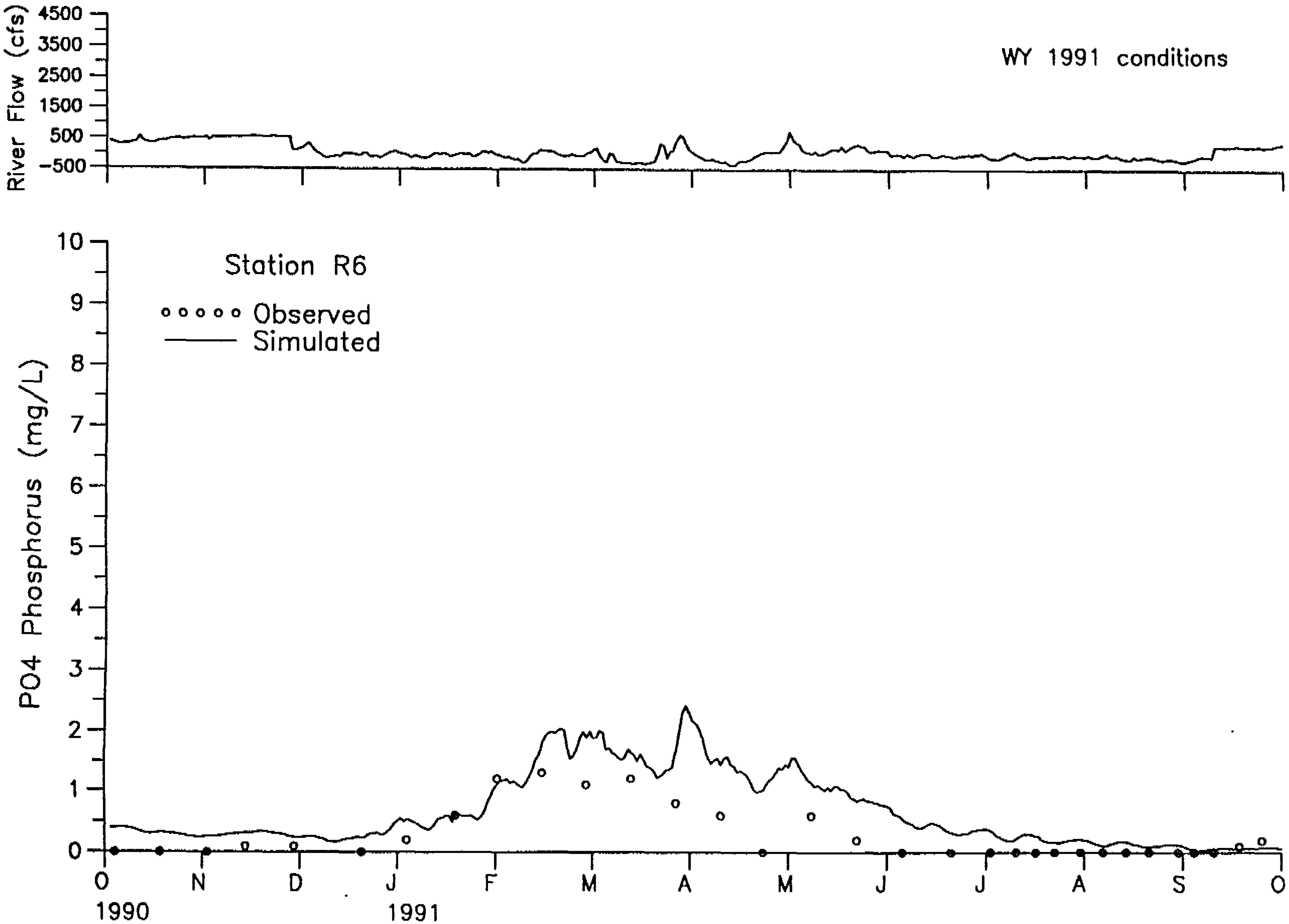
D-041496

D-041496



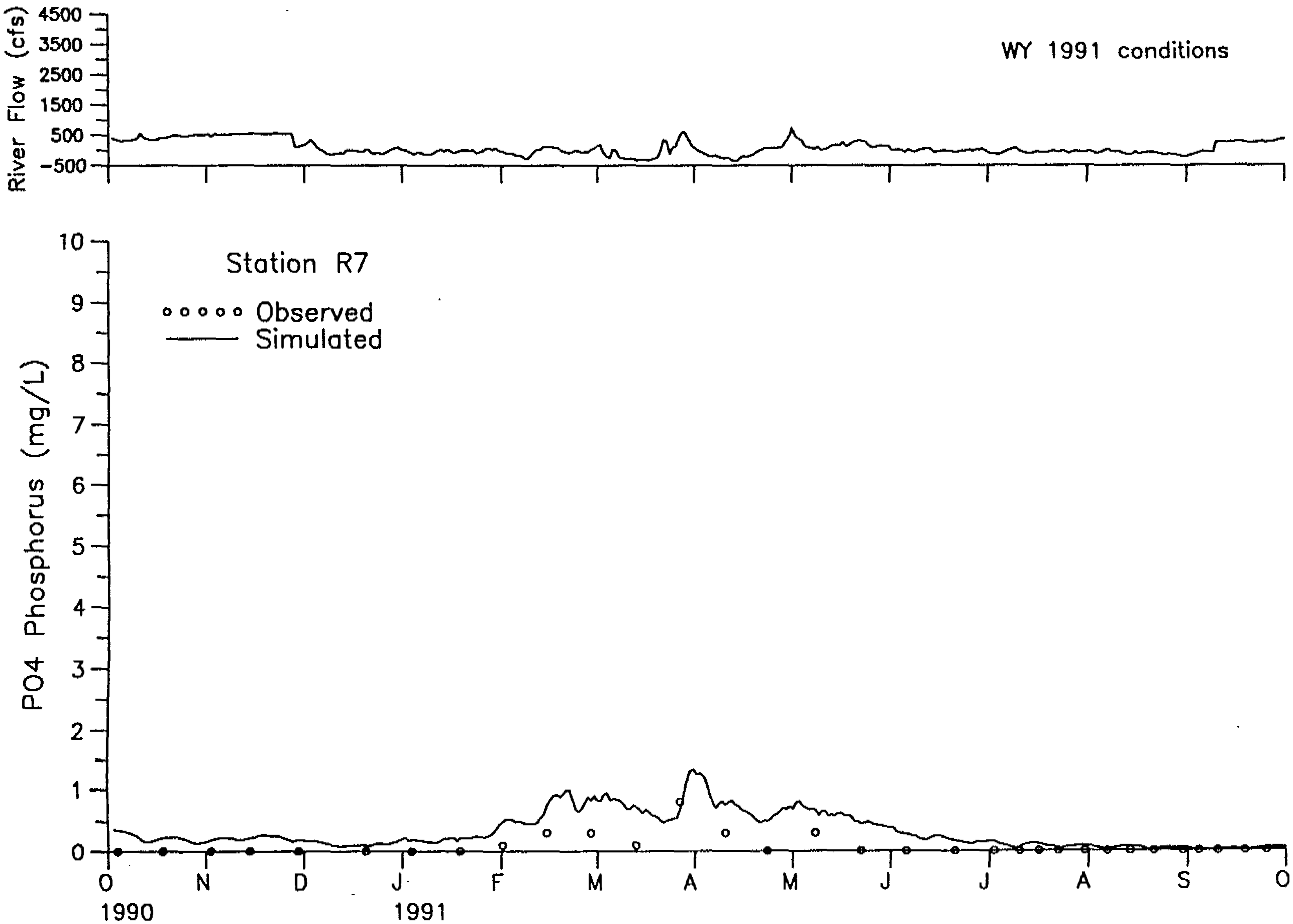
D-041497

D-041497

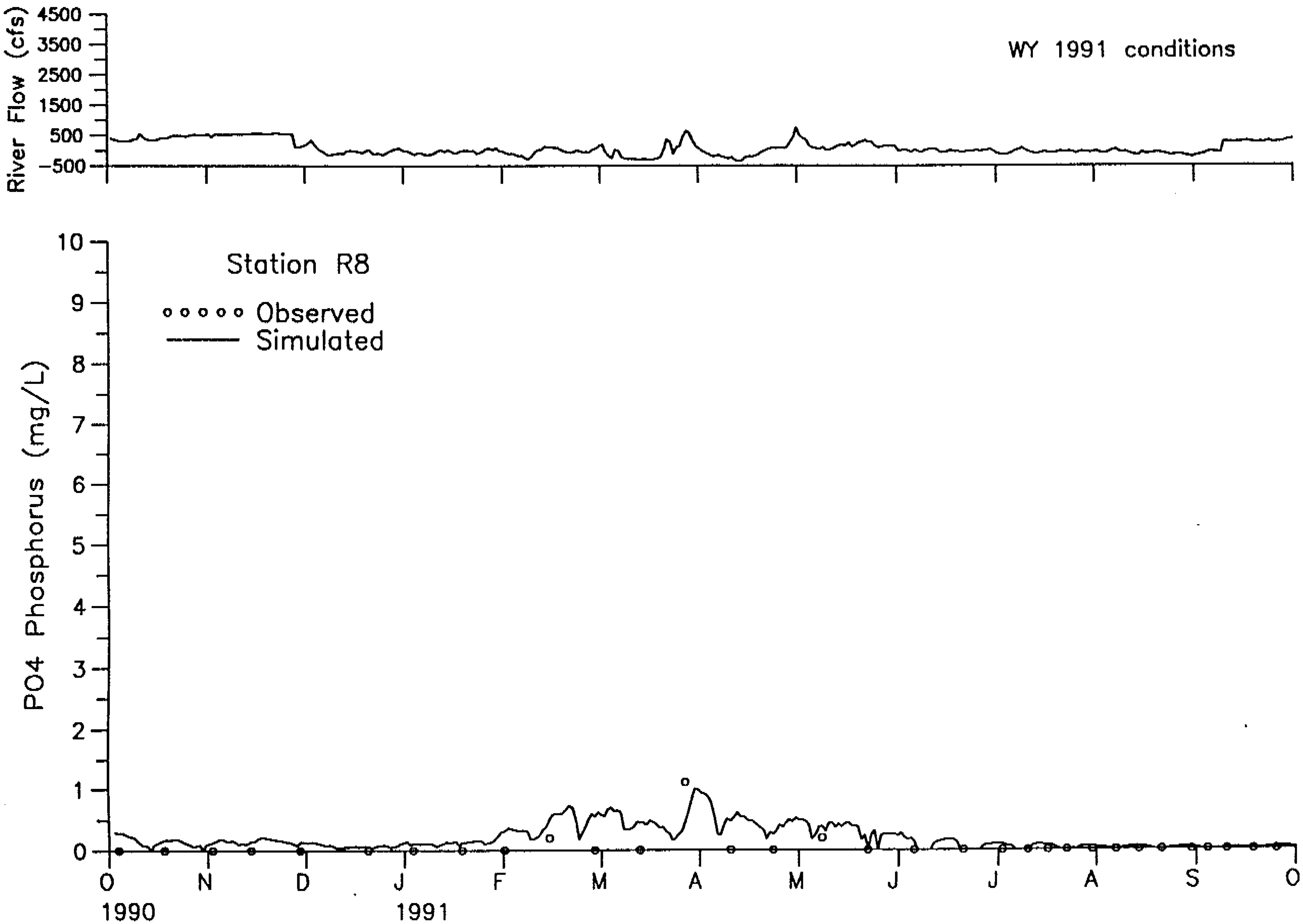


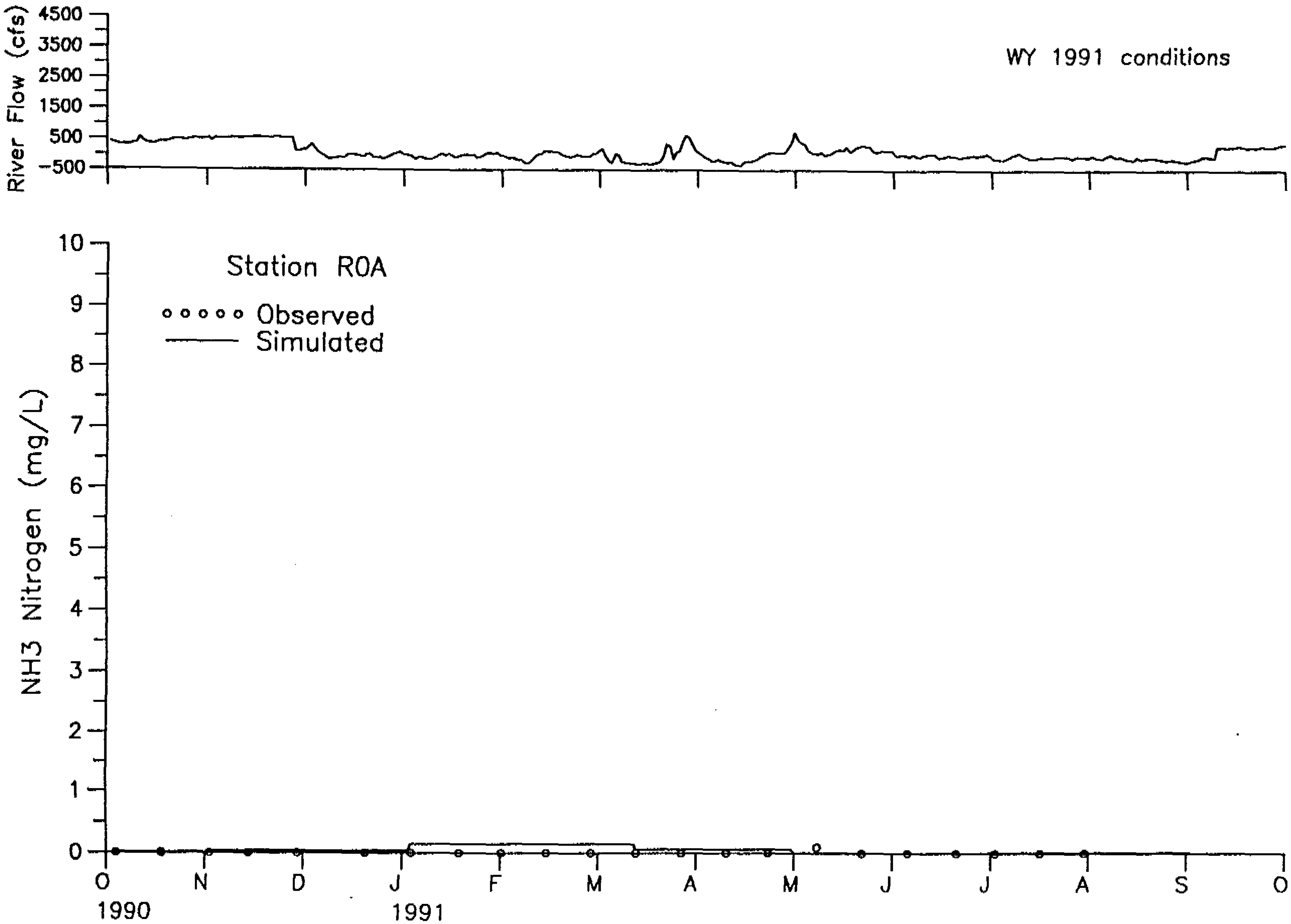
D — 0 4 1 4 9 8

D-041498

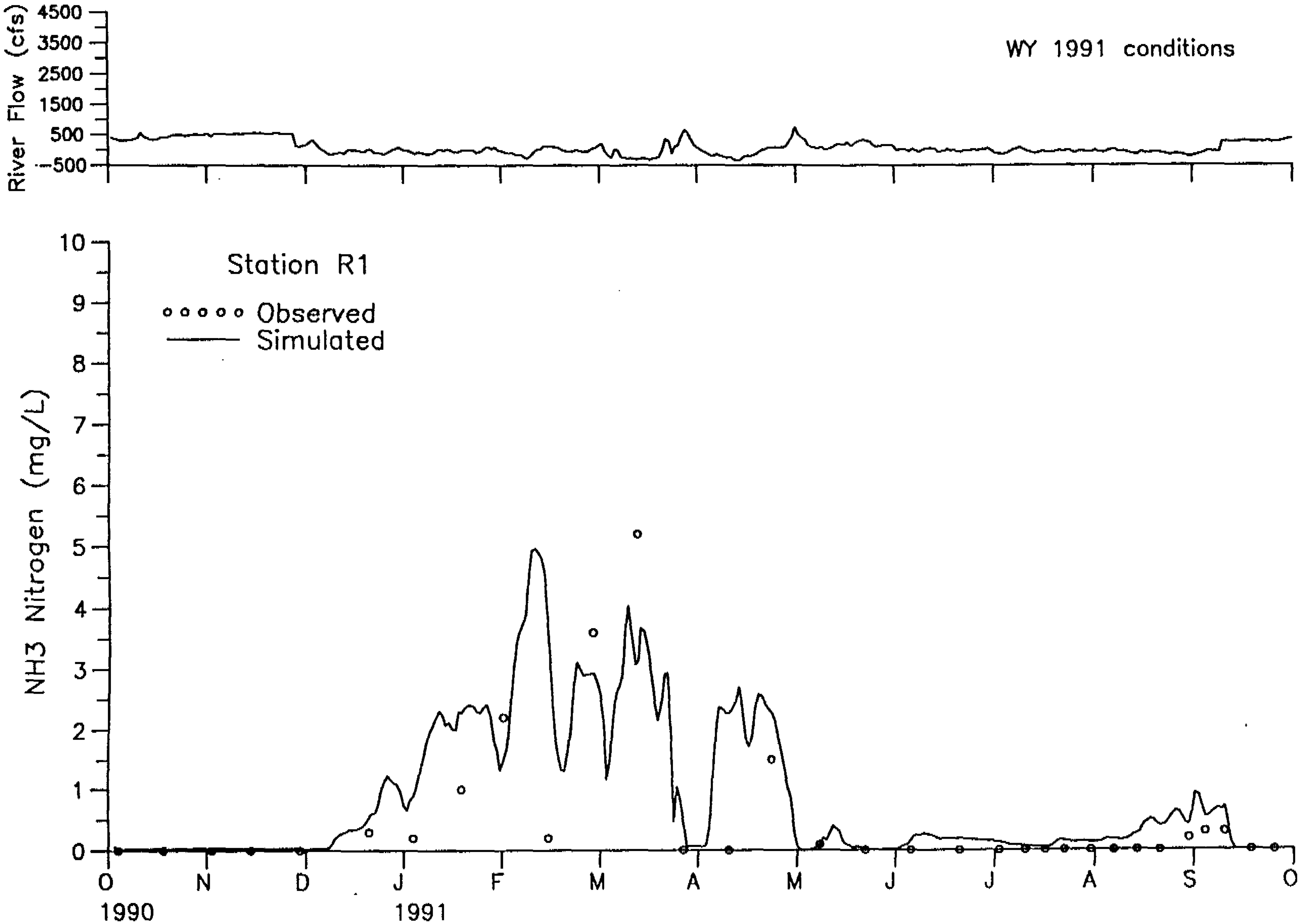


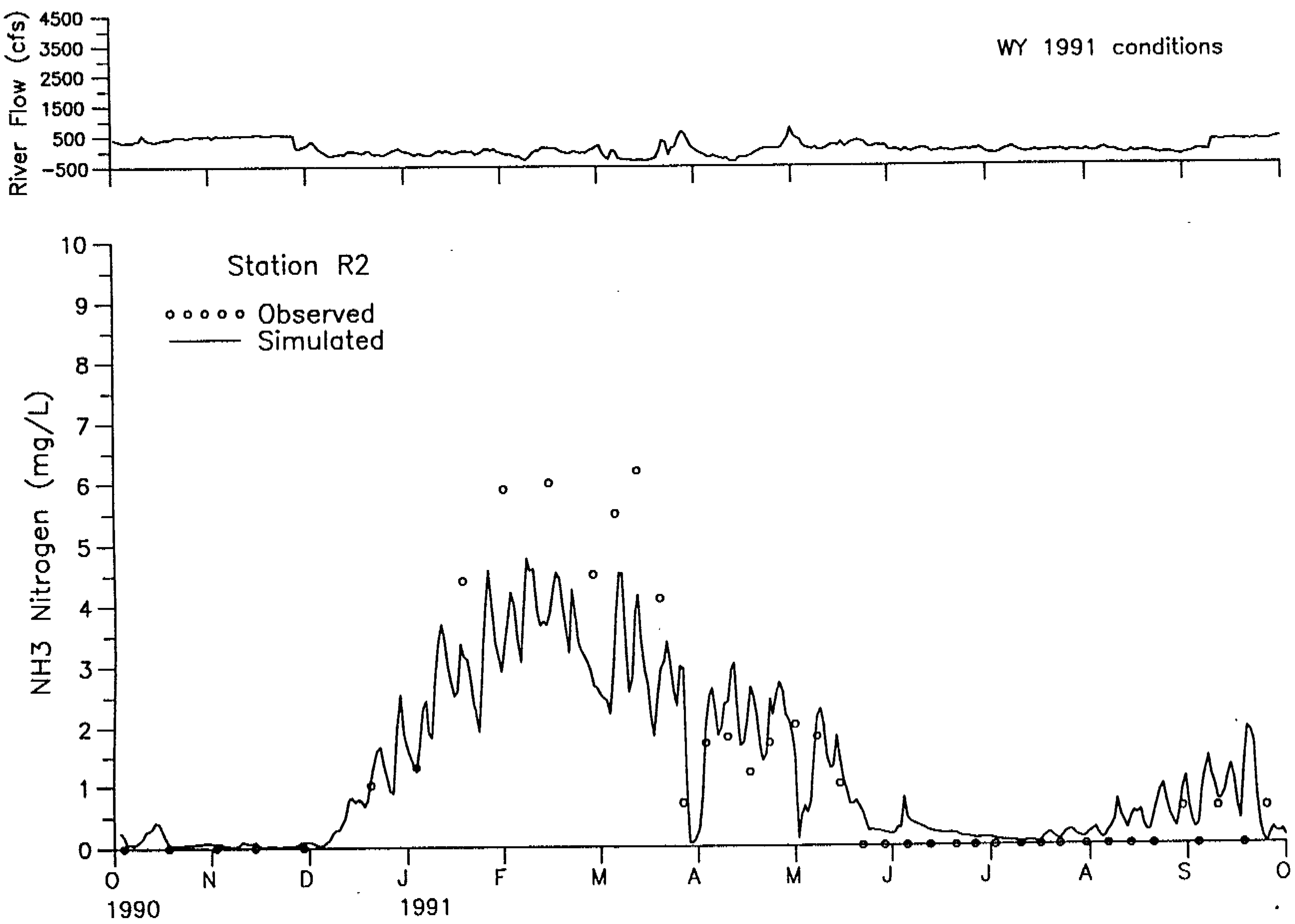
WY 1991 conditions
River Flow (cfs)
4500
3500
2500
1500
500
-500
Station R7
Observed
Simulated
PO4 Phosphorus (mg/L)
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1990
1991


River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Station R8
Observed
Simulated
PO4 Phosphorus (mg/L)
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

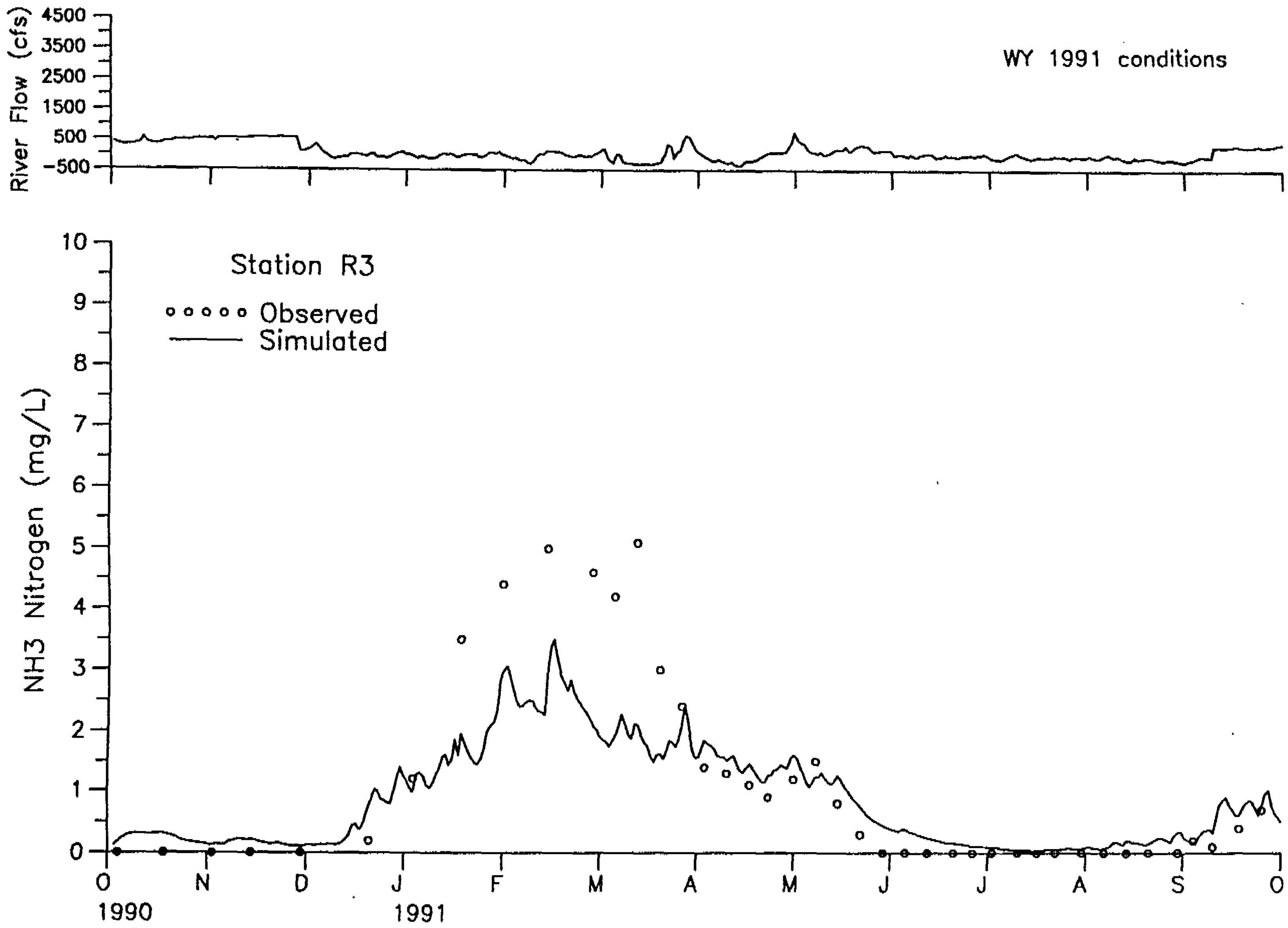

River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
NH3 Nitrogen (mg/L)
10
9
8
7
6
5
4
3
2
1
0
Station R0A
Observed
Simulated
O N D J F M A M J J A S O
1990
1991

D-041501

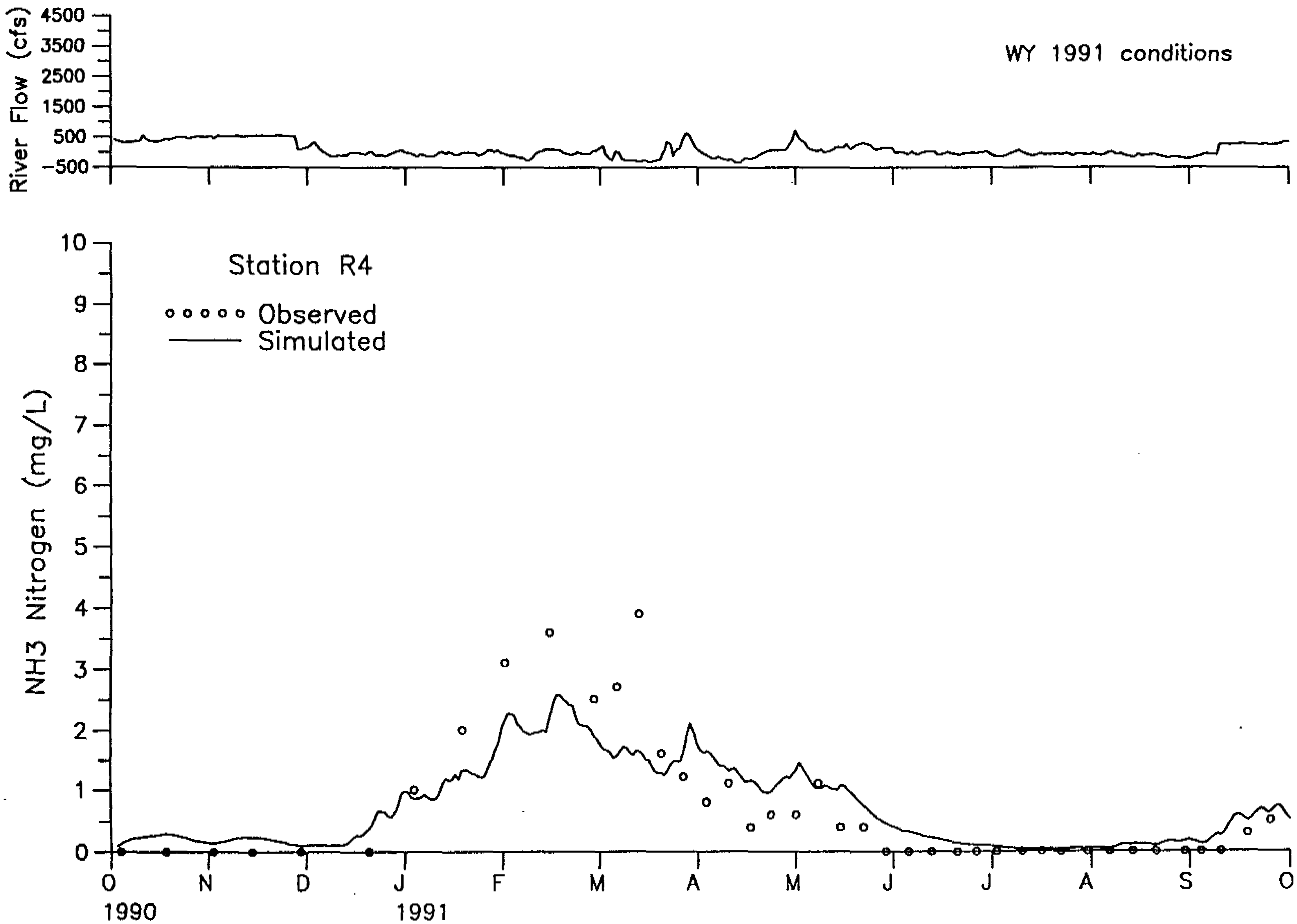

River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
NH3 Nitrogen (mg/L)
10
9
8
7
6
5
4
3
2
1
0
Station R1
Observed
Simulated
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991


River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
NH3 Nitrogen (mg/L)
10
9
8
7
6
5
4
3
2
1
0
Station R2
ooooo Observed
Simulated
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

D-041503

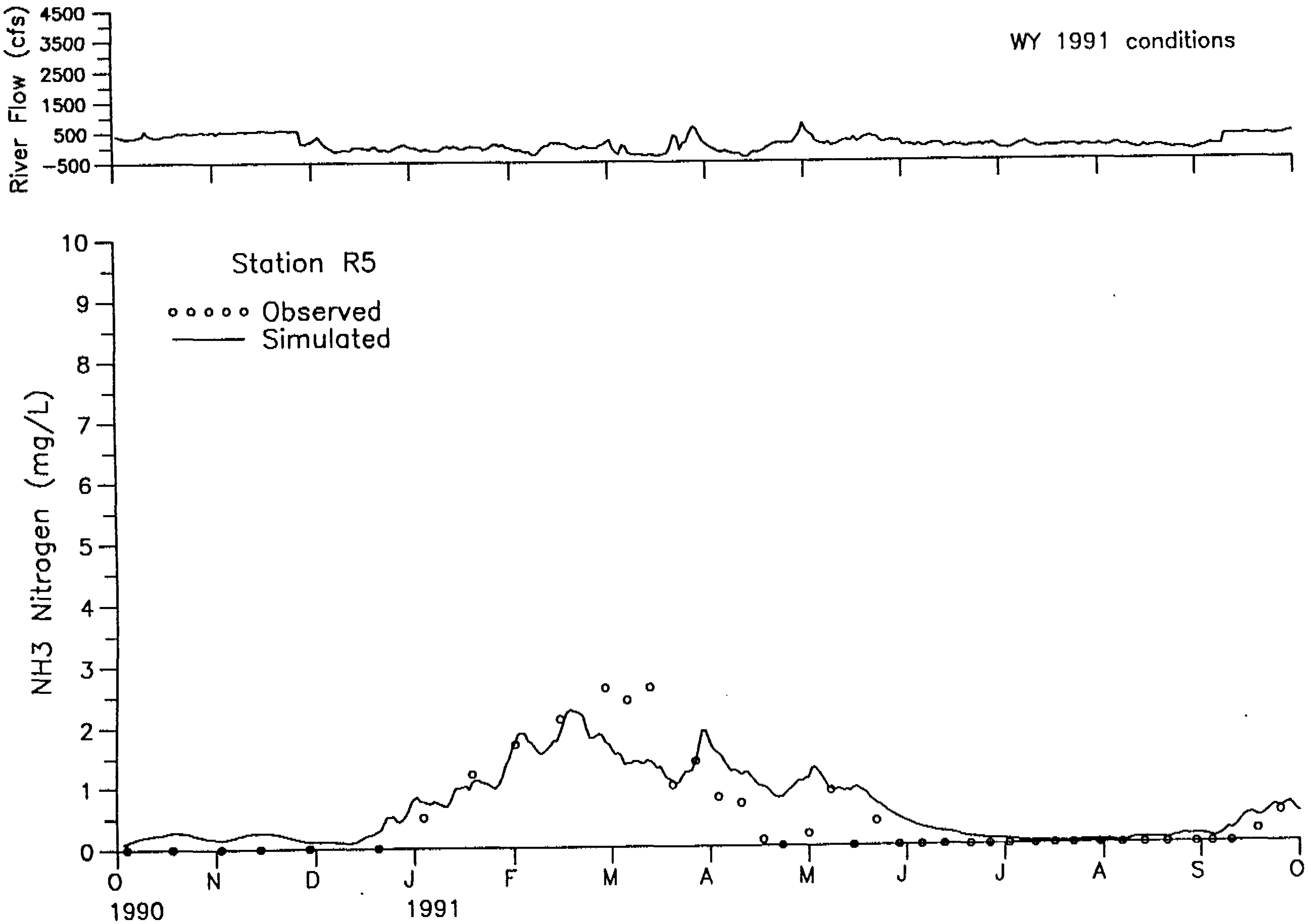

River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
NH3 Nitrogen (mg/L)
10
9
8
7
6
5
4
3
2
1
0
Station R3
Observed
Simulated
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

D-041504

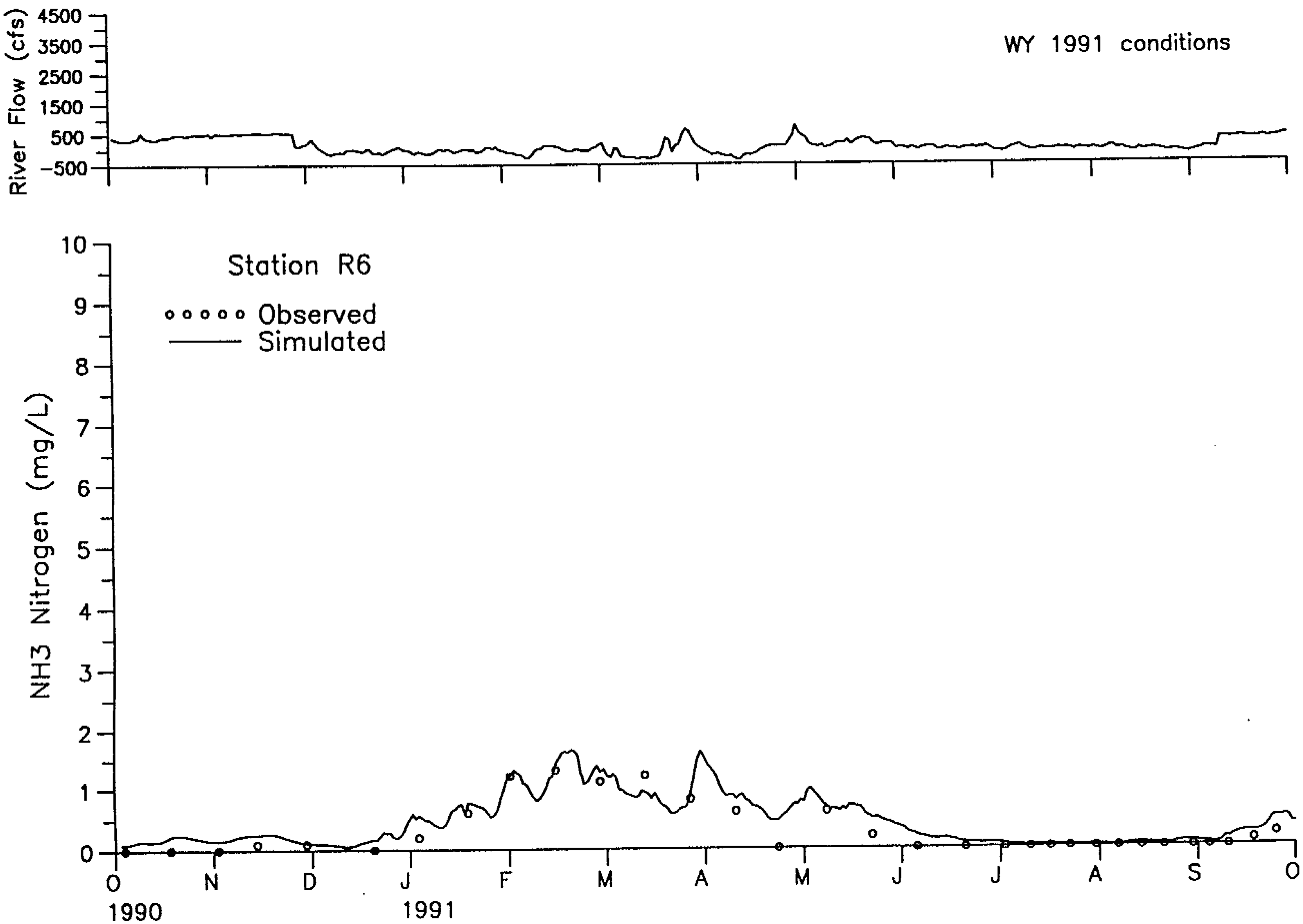


D-041505

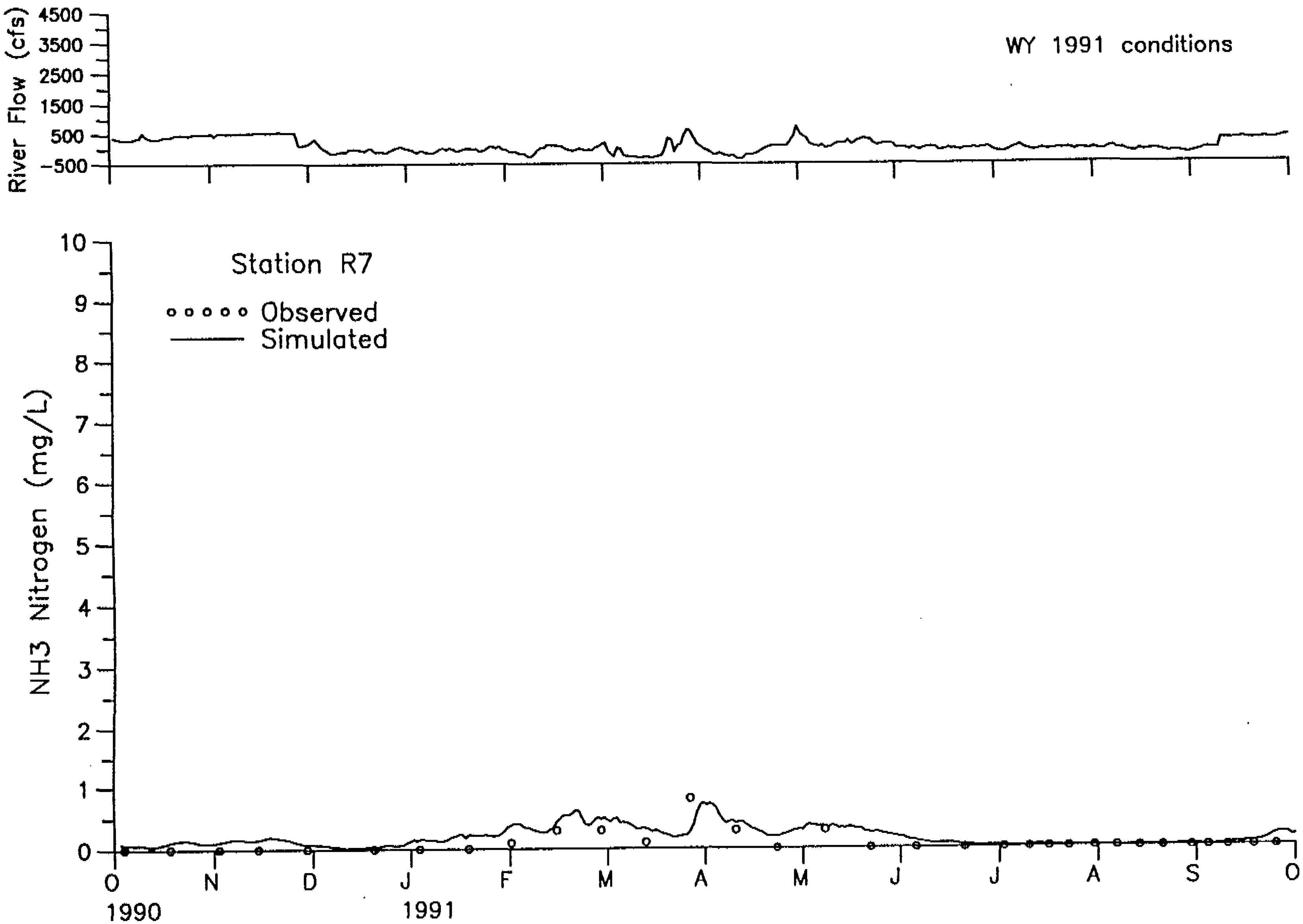
D—041505



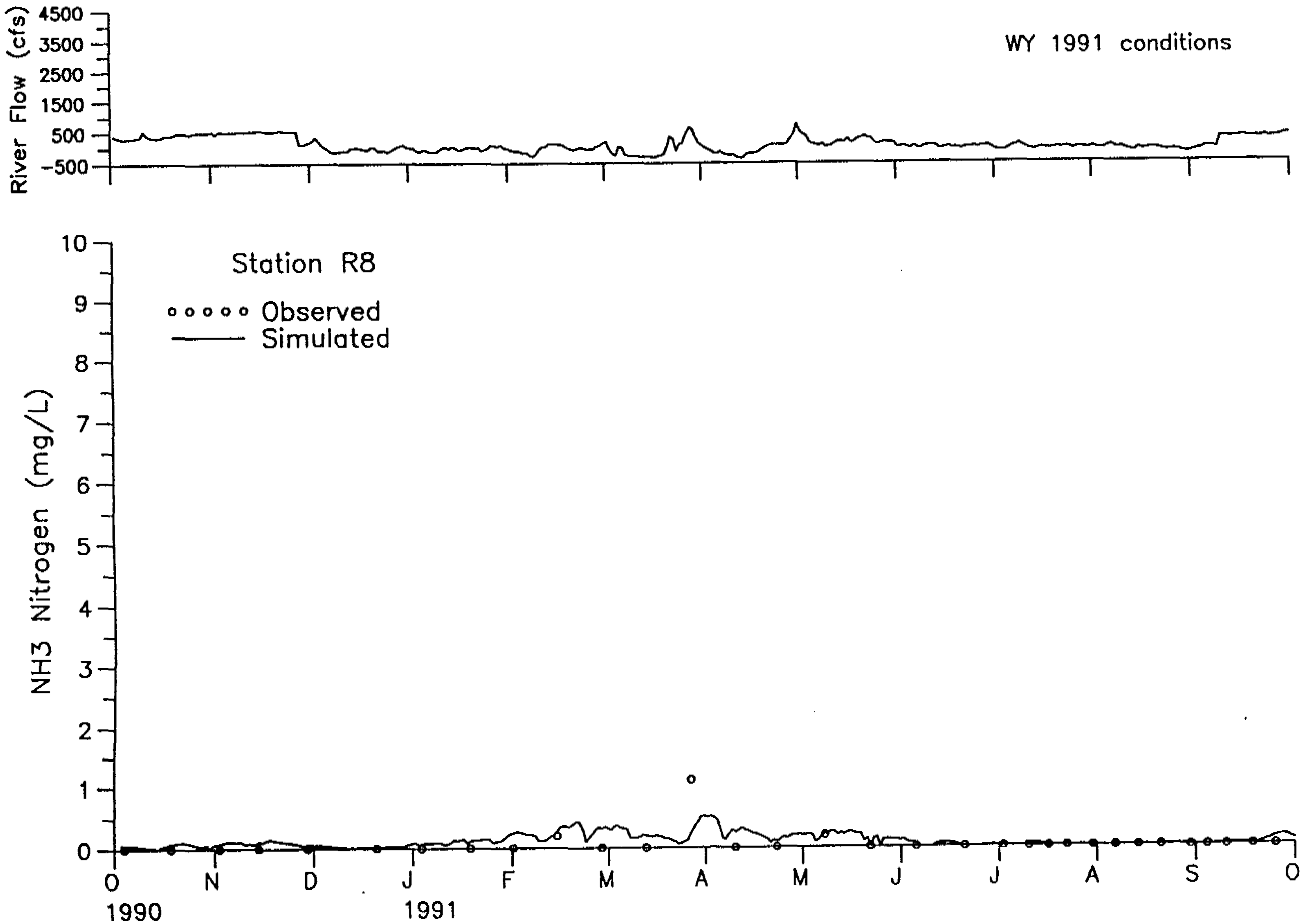
River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
NH3 Nitrogen (mg/L)
Station R5
Observed
Simulated
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991


River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Station R6
Observed
Simulated
NH3 Nitrogen (mg/L)
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

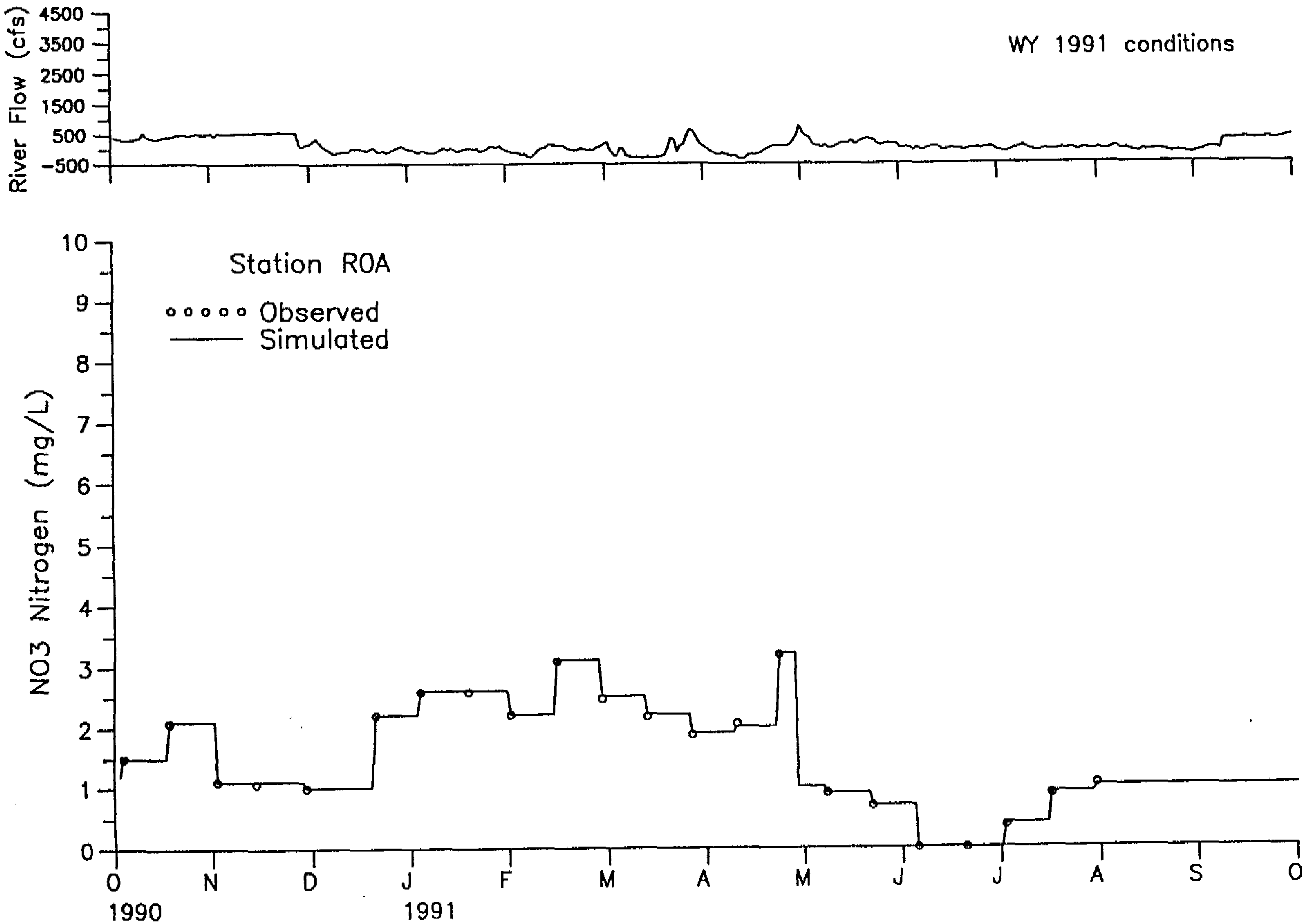
D-041508



D-041508

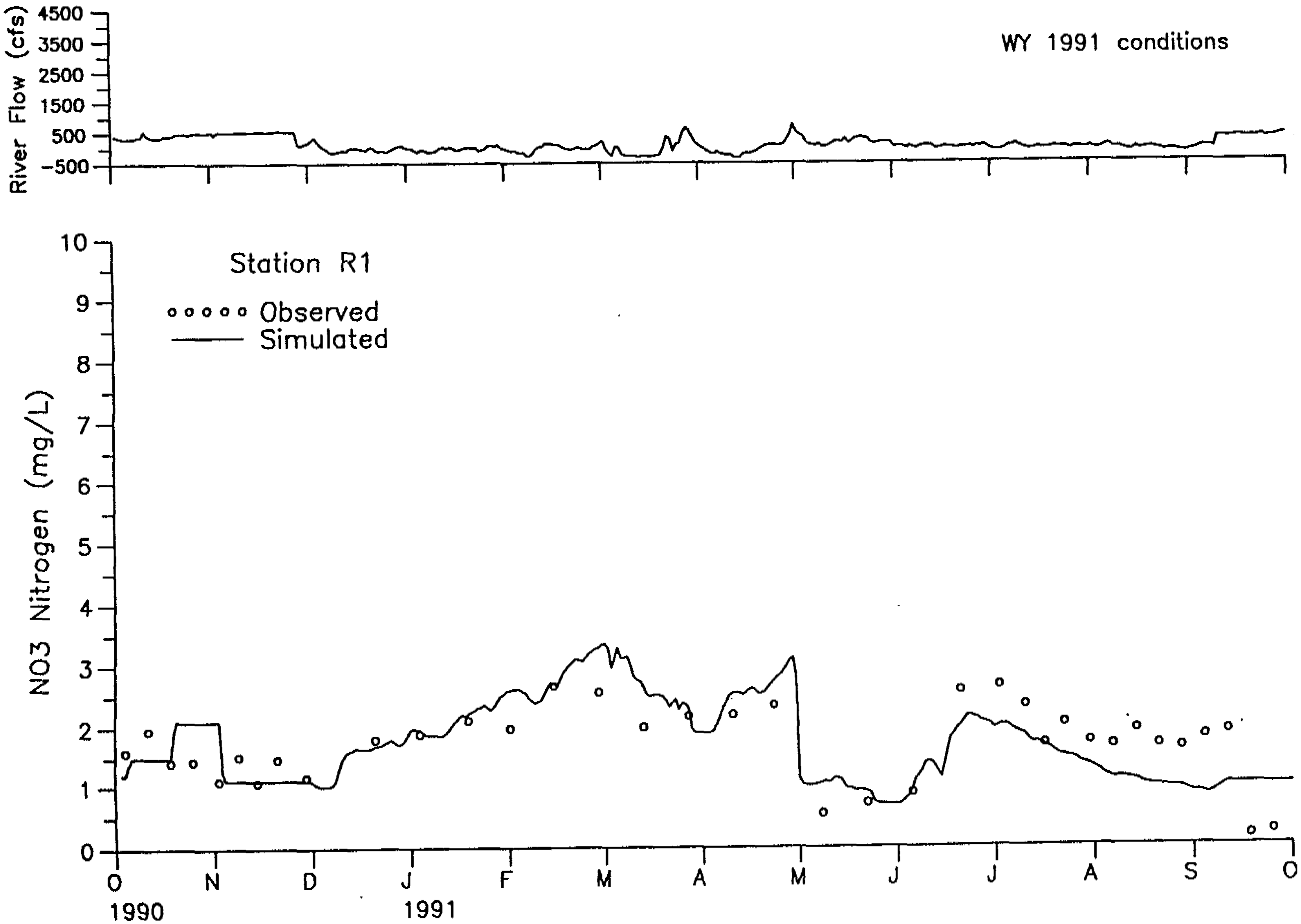


River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Station R8
Observed
Simulated
NH3 Nitrogen (mg/L)
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

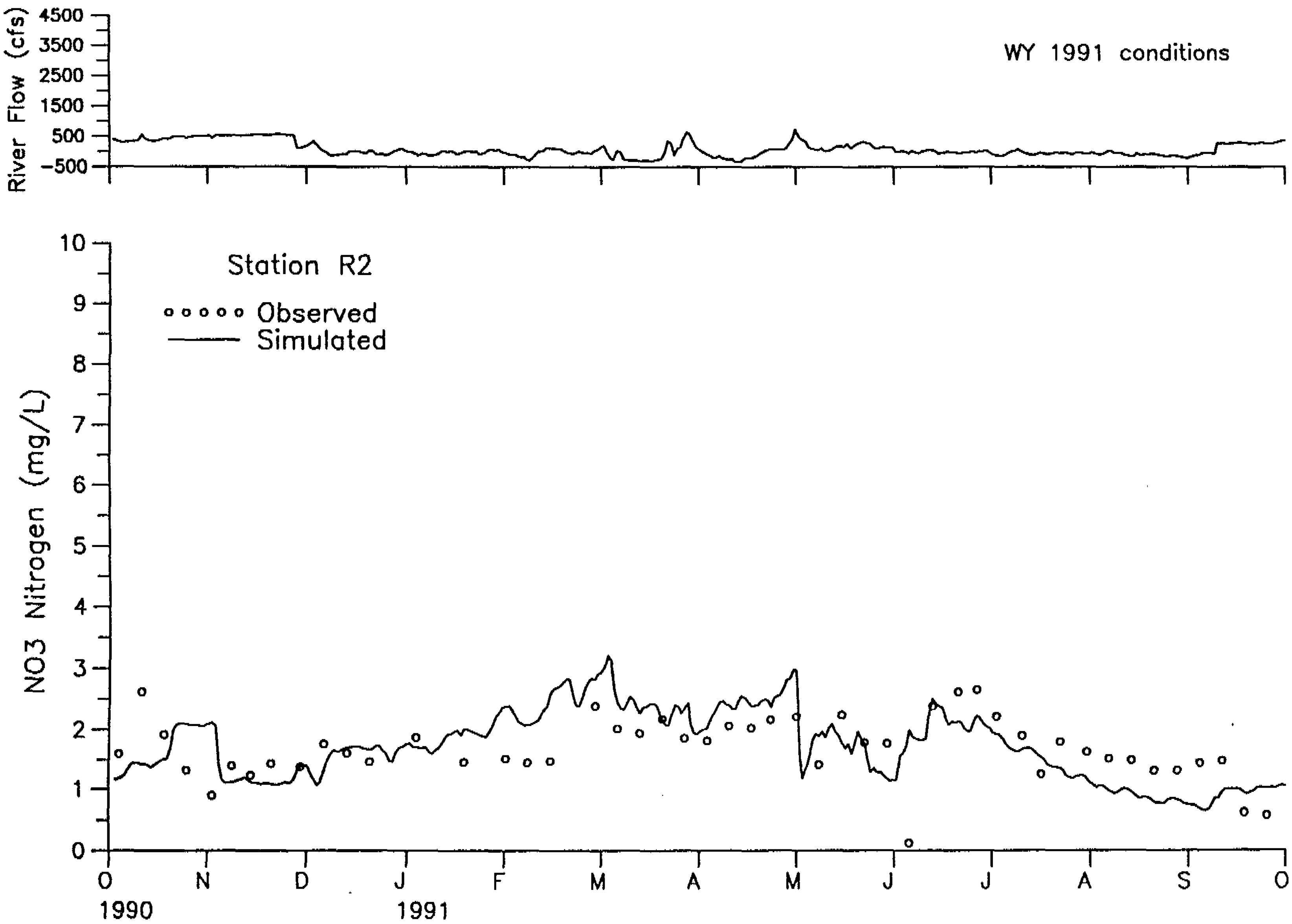


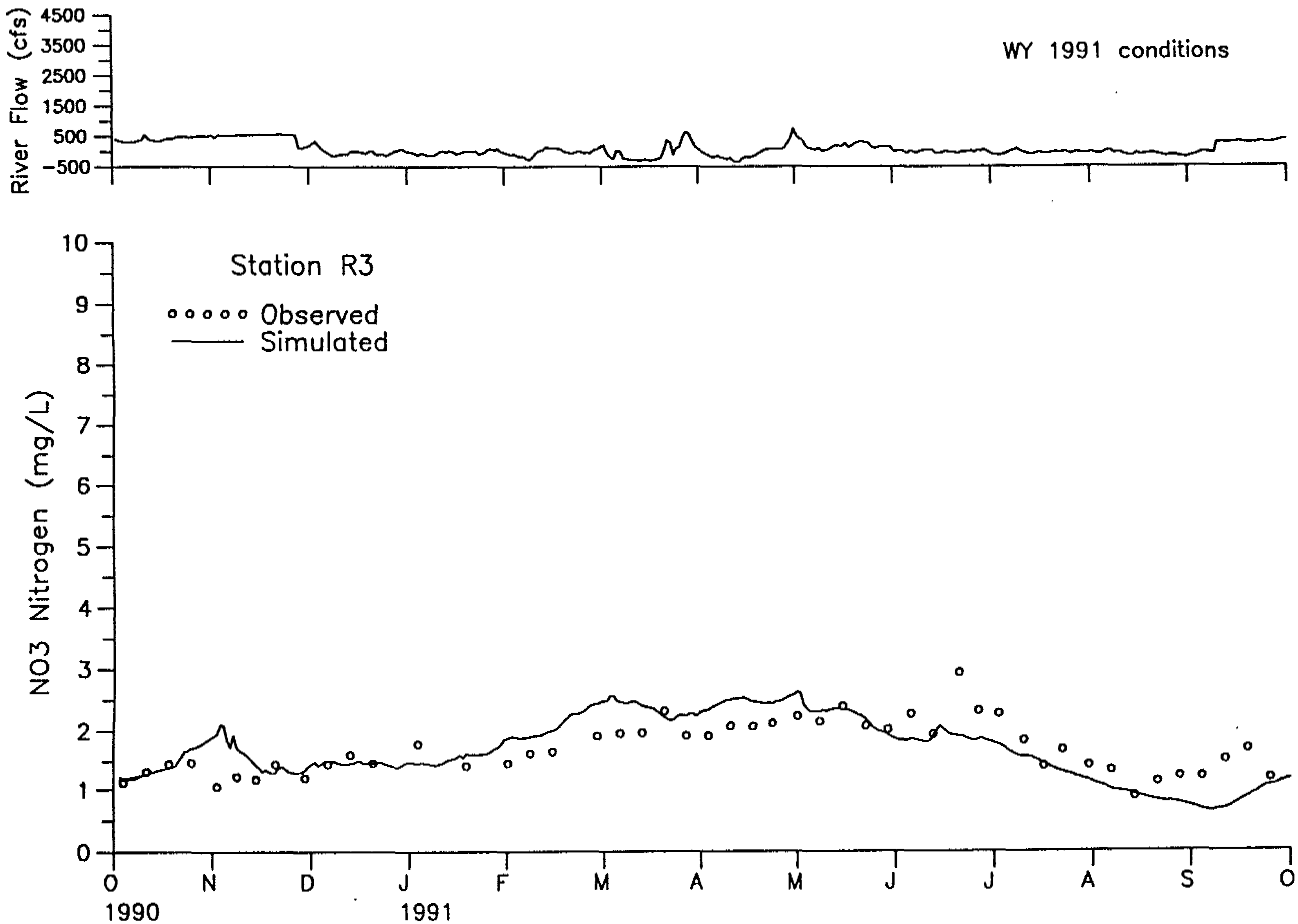
River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Station ROA
Observed
Simulated
NO3 Nitrogen (mg/L)
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

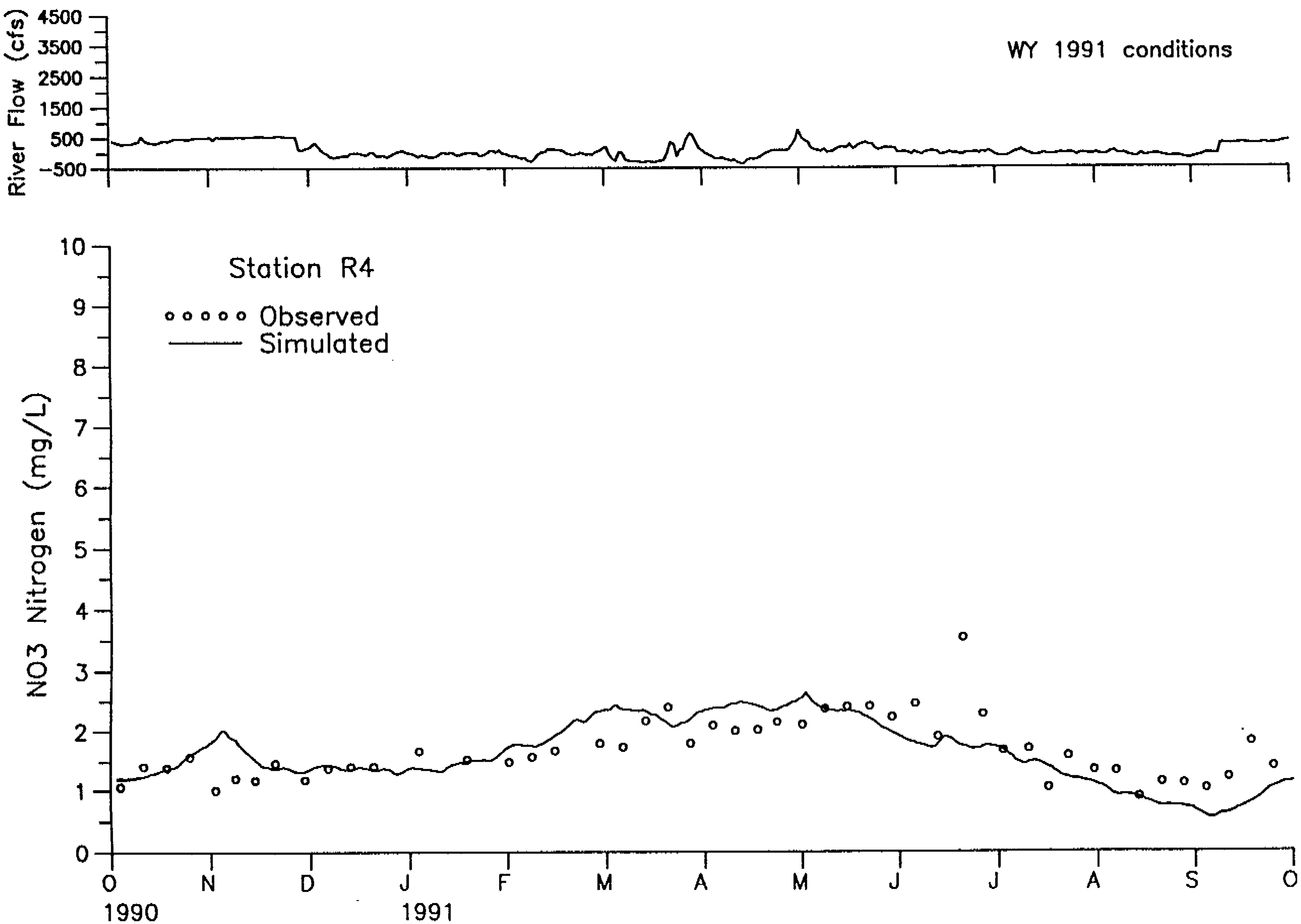
D-041510



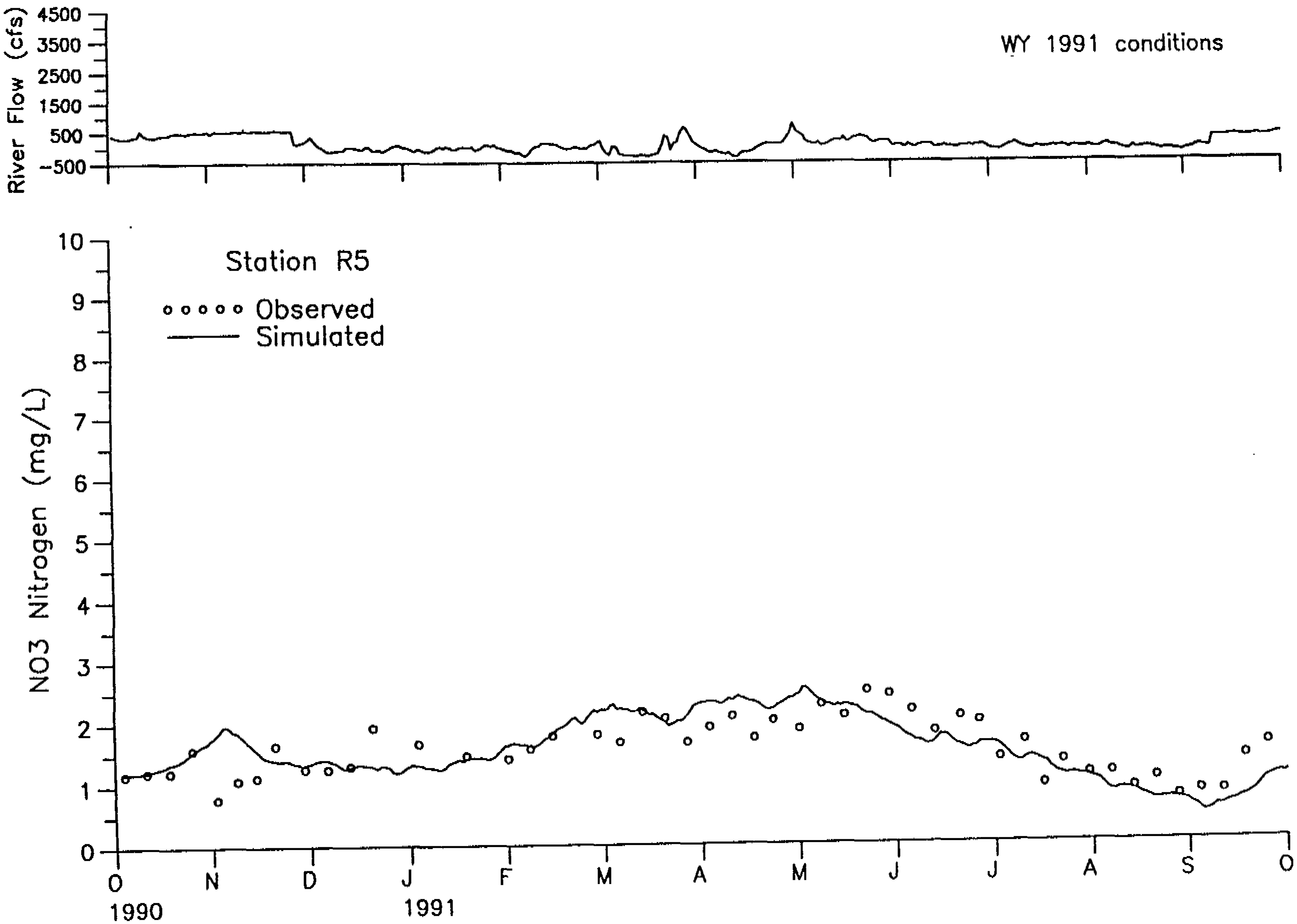
River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Station R1
Observed
Simulated
NO3 Nitrogen (mg/L)
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991


WY 1991 conditions
River Flow (cfs)
4500
3500
2500
1500
500
-500
Station R2
Observed
Simulated
NO3 Nitrogen (mg/L)
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1990
1991


WY 1991 conditions
River Flow (cfs)
4500
3500
2500
1500
500
-500
Station R3
Observed
Simulated
NO3 Nitrogen (mg/L)
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

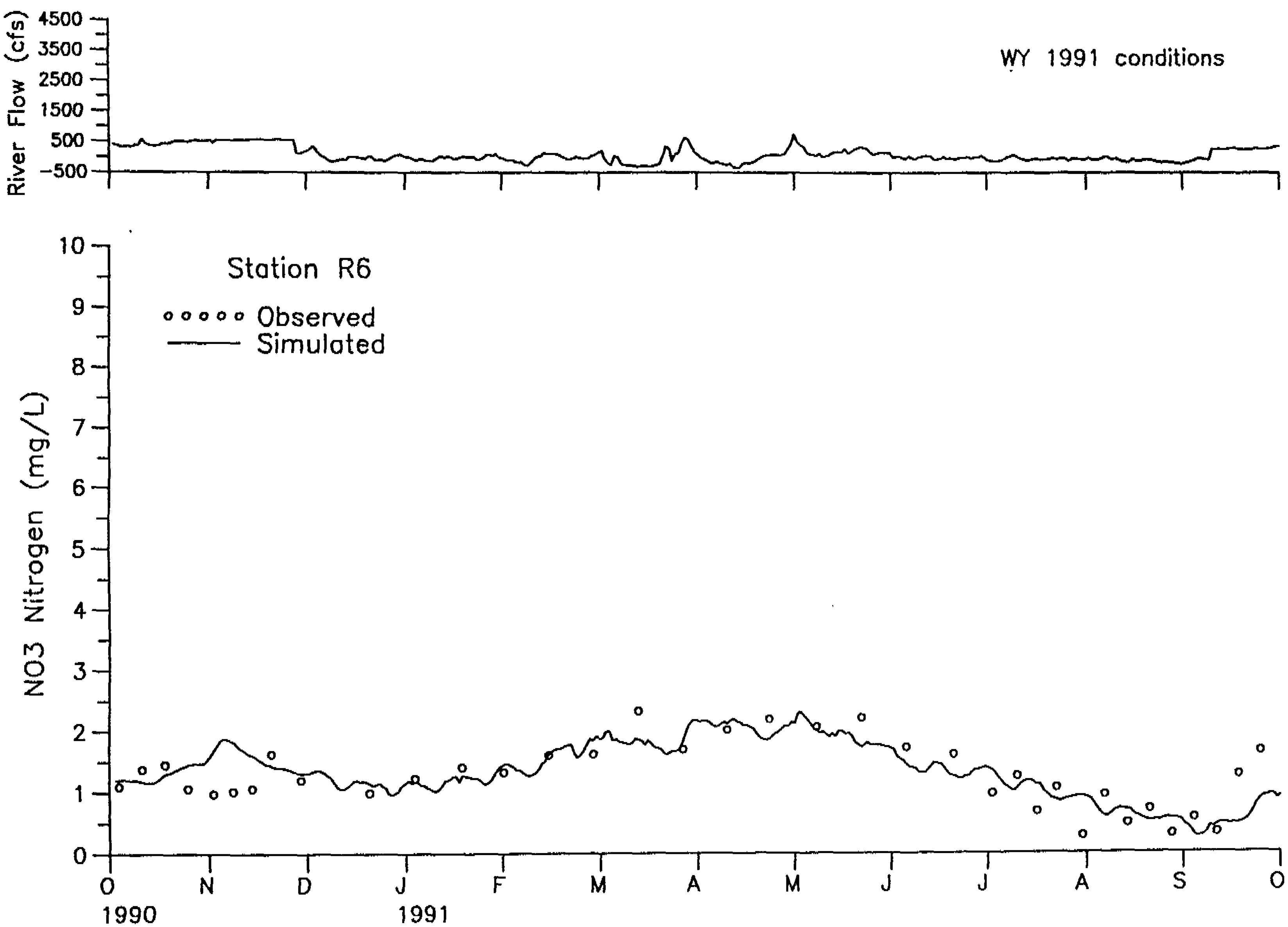


WY 1991 conditions
River Flow (cfs)
4500
3500
2500
1500
500
-500
Station R4
Observed
Simulated
NO3 Nitrogen (mg/L)
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1990
1991



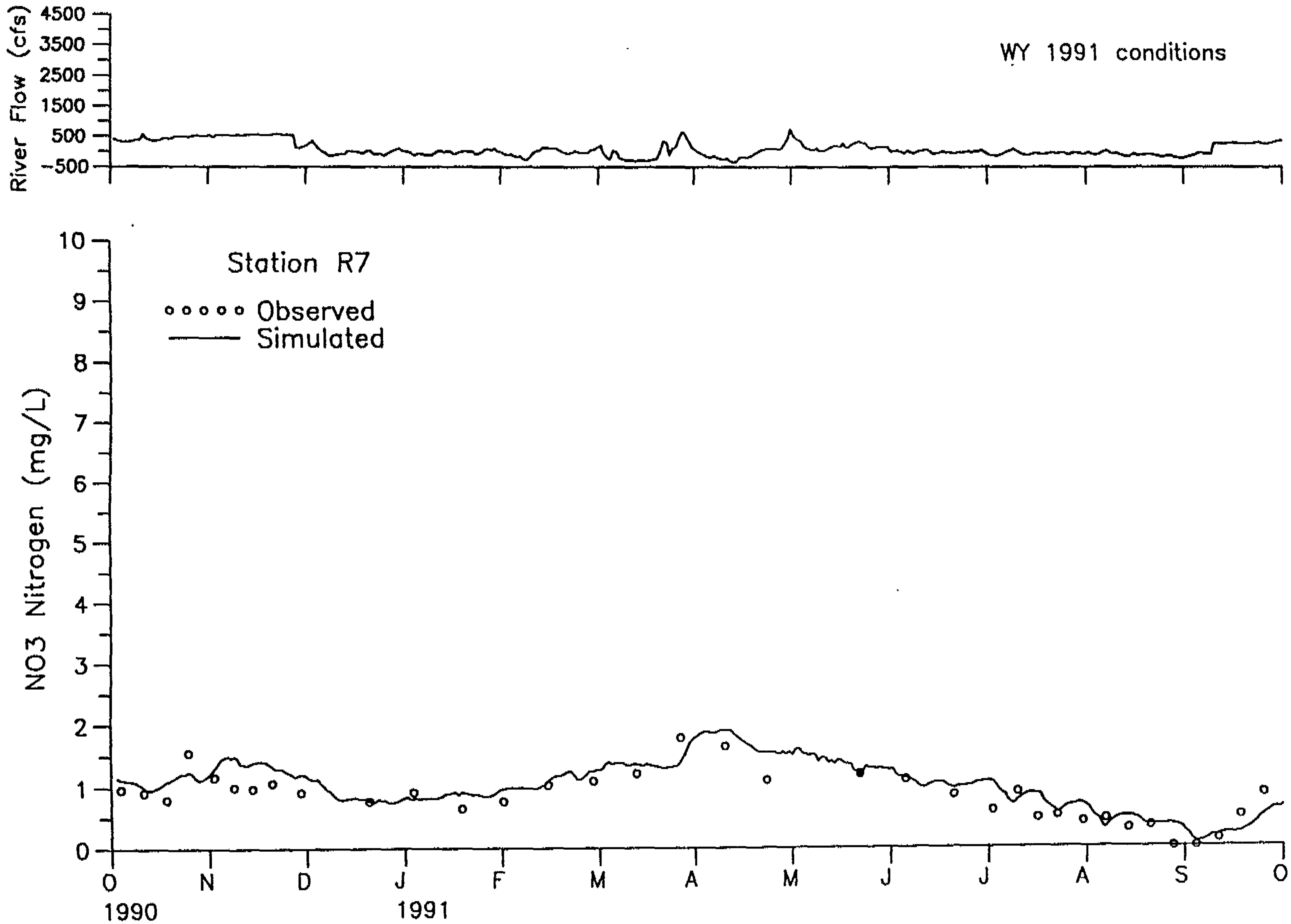
D-041515

D-041515

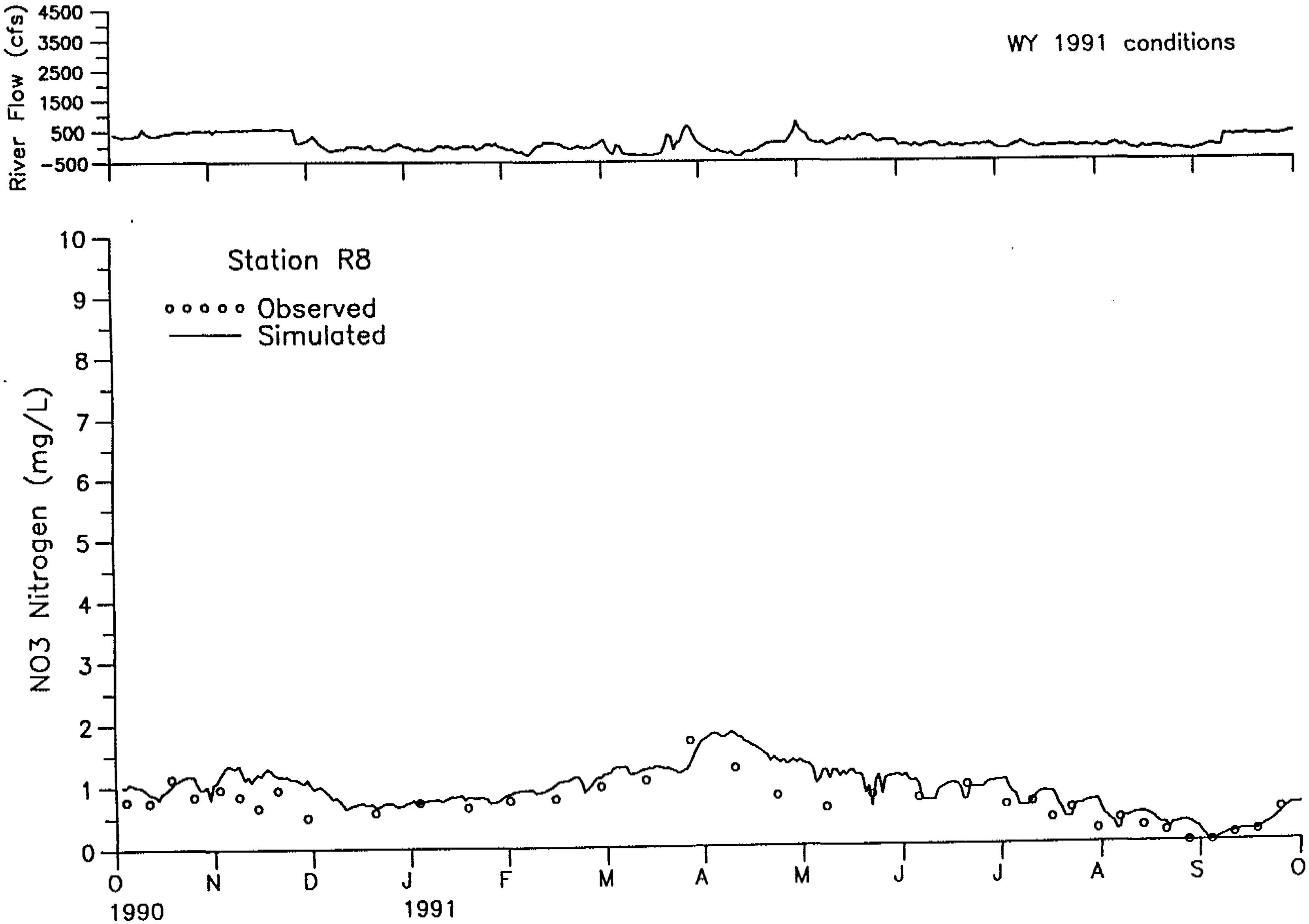


D-041516

D—041516

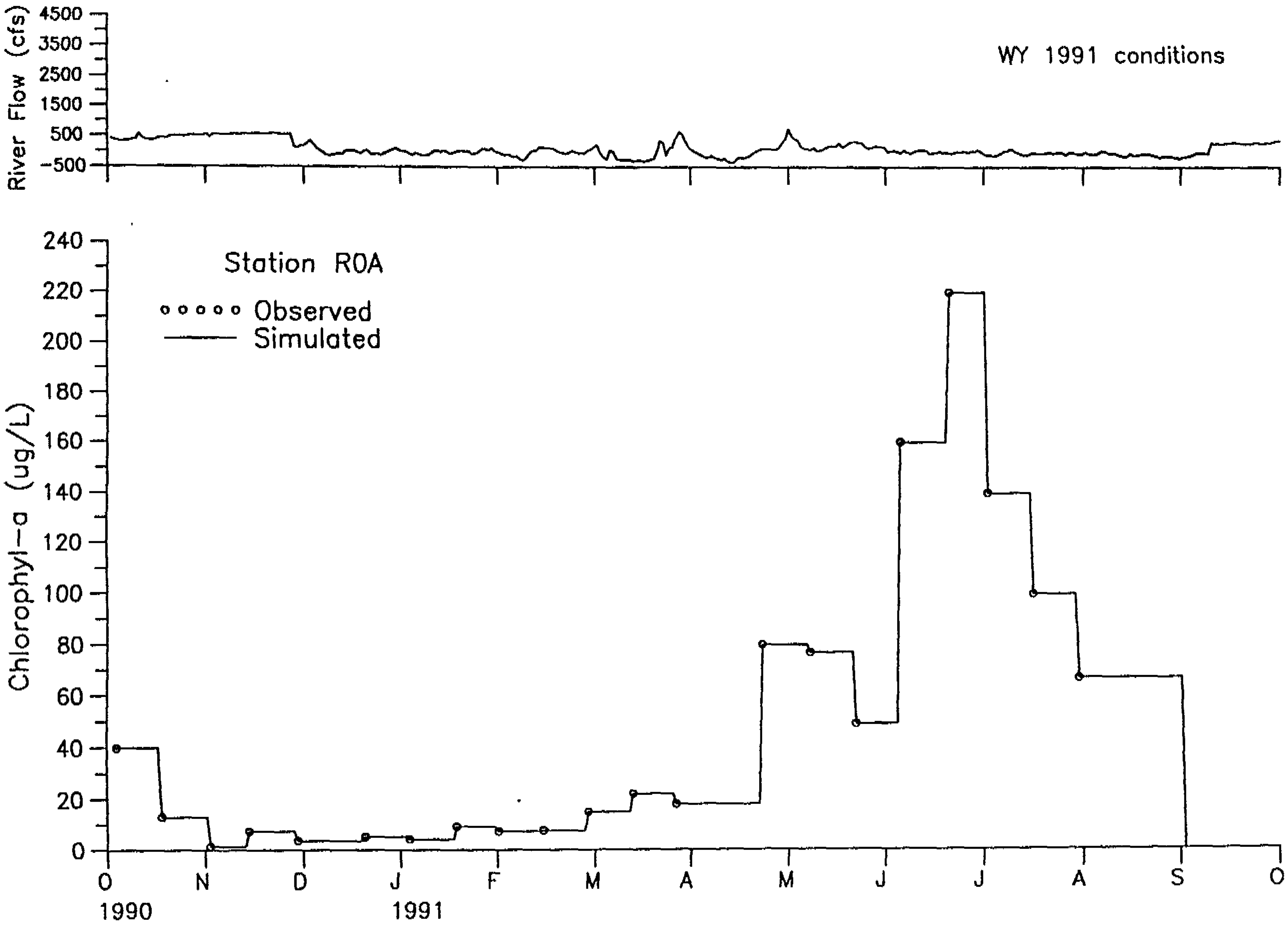


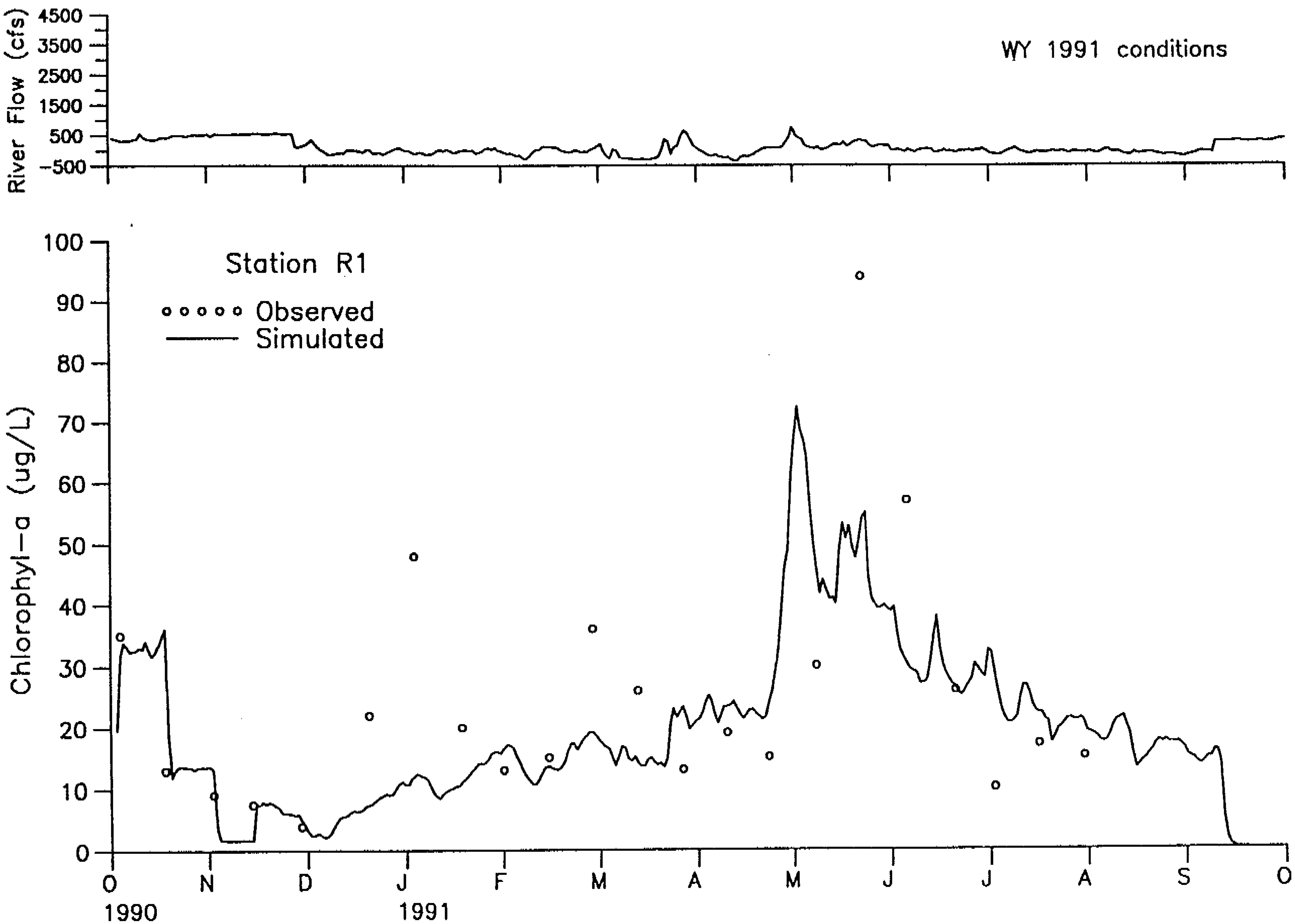
WY 1991 conditions
River Flow (cfs)
4500
3500
2500
1500
500
-500
Station R7
Observed
Simulated
NO3 Nitrogen (mg/L)
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991



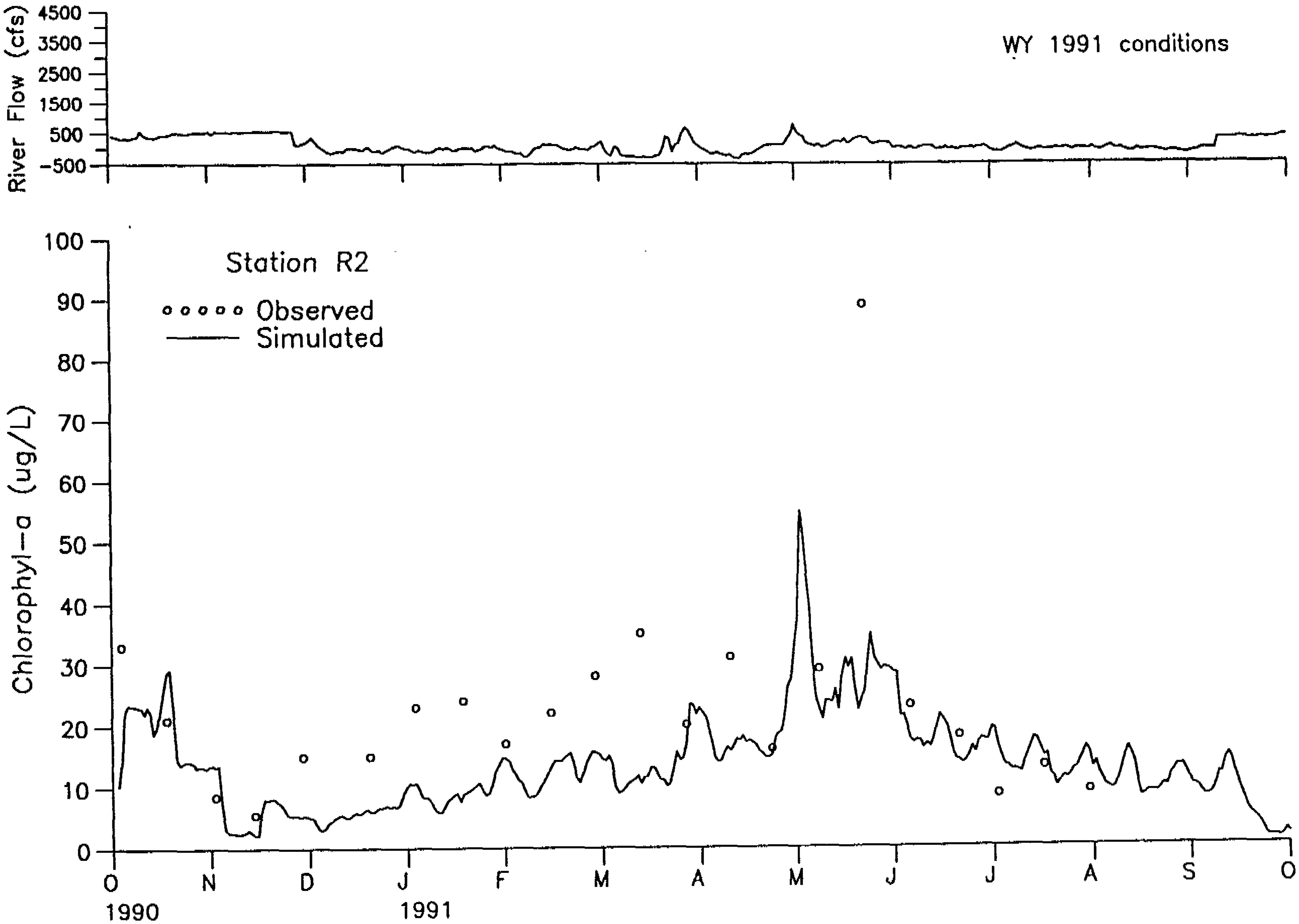
WY 1991 conditions
River Flow (cfs)
4500
3500
2500
1500
500
-500
Station R8
Observed
Simulated
NO3 Nitrogen (mg/L)
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

D-041518


River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Chlorophyl-a (ug/L)
240
220
200
180
160
140
120
100
80
60
40
20
0
Station R0A
ooooo Observed
—— Simulated
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

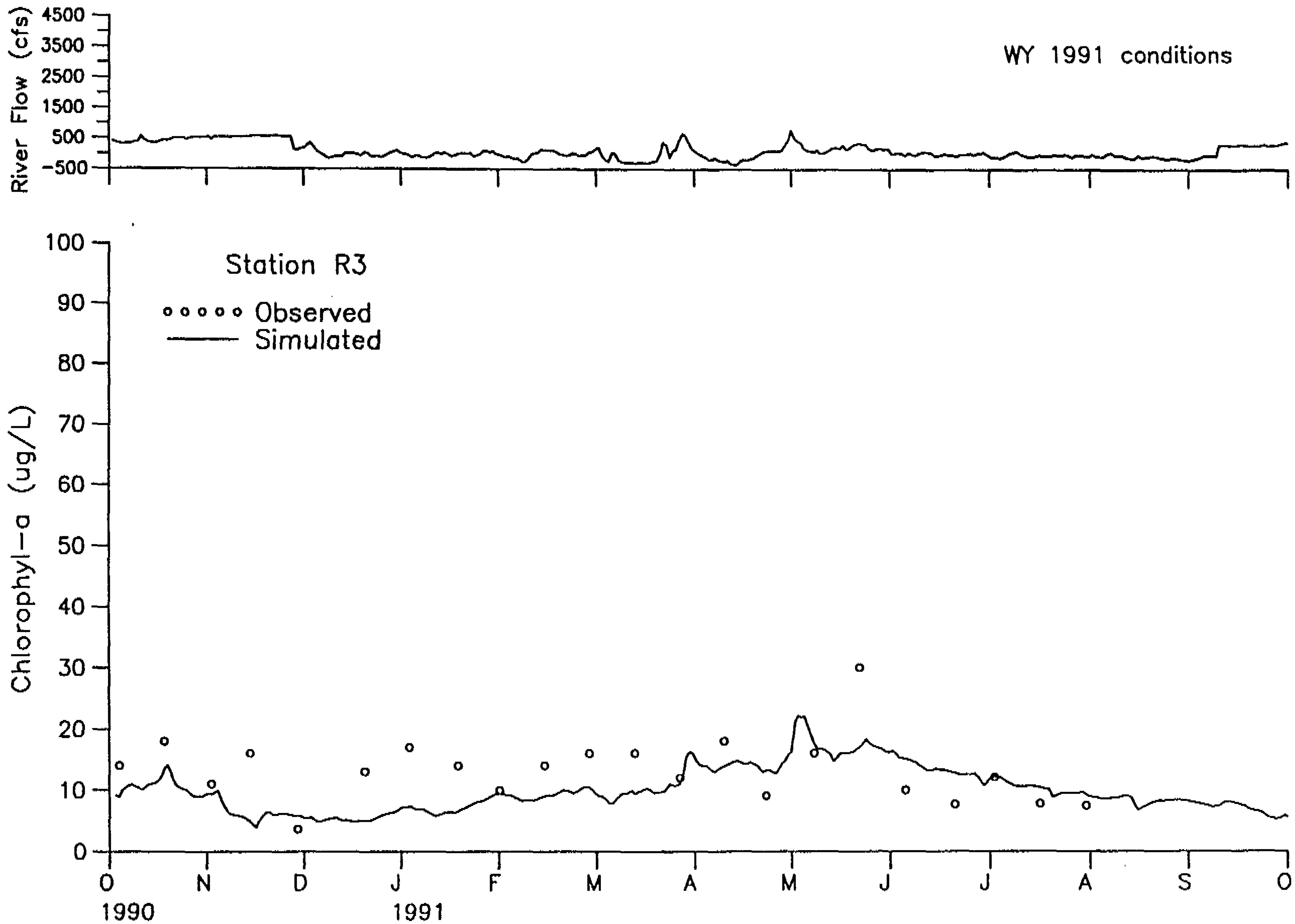

River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Chlorophyl-a (ug/L)
100
90
80
70
60
50
40
30
20
10
0
Station R1
Observed
Simulated
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

D-041520



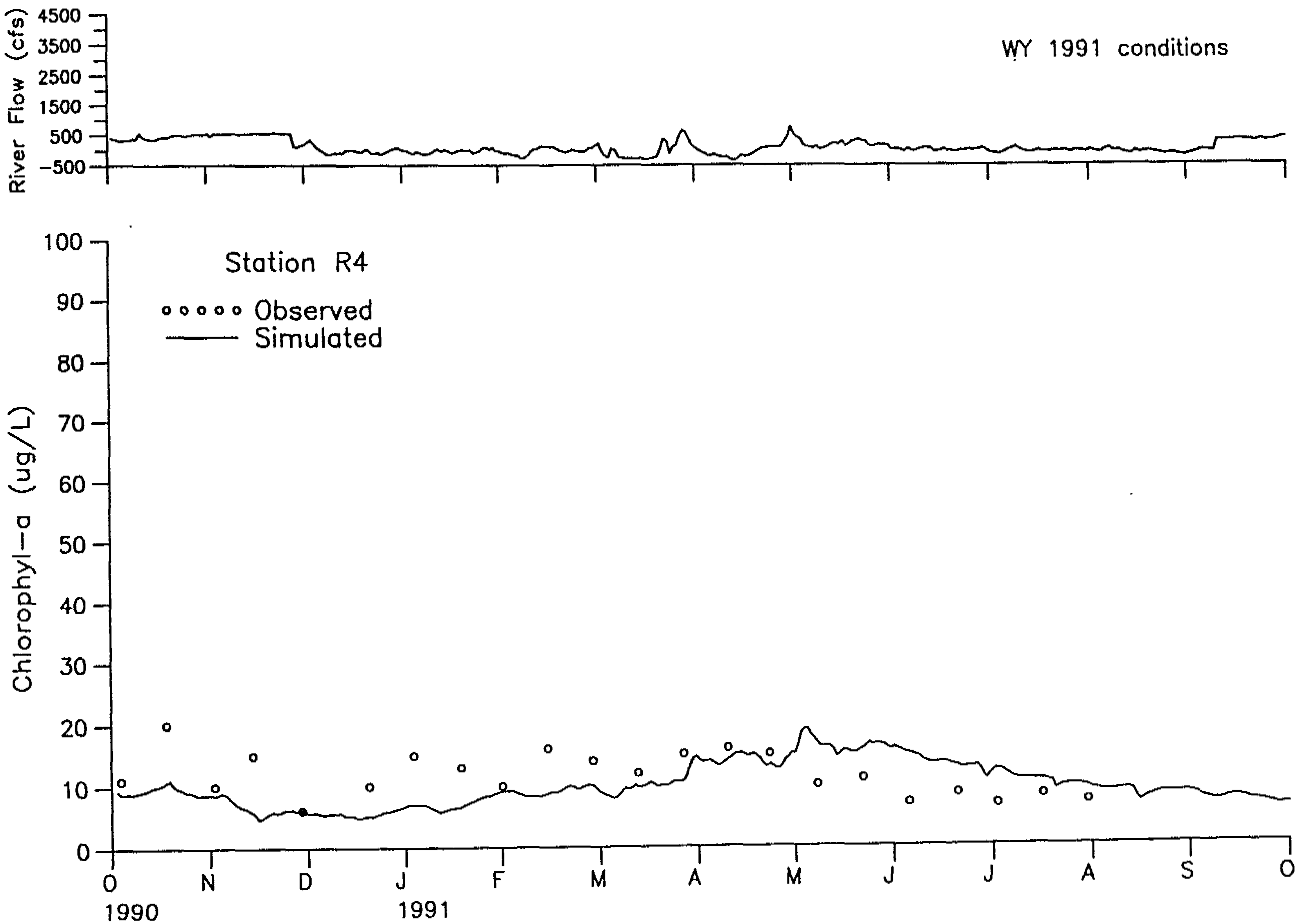
D-041521

D-041521



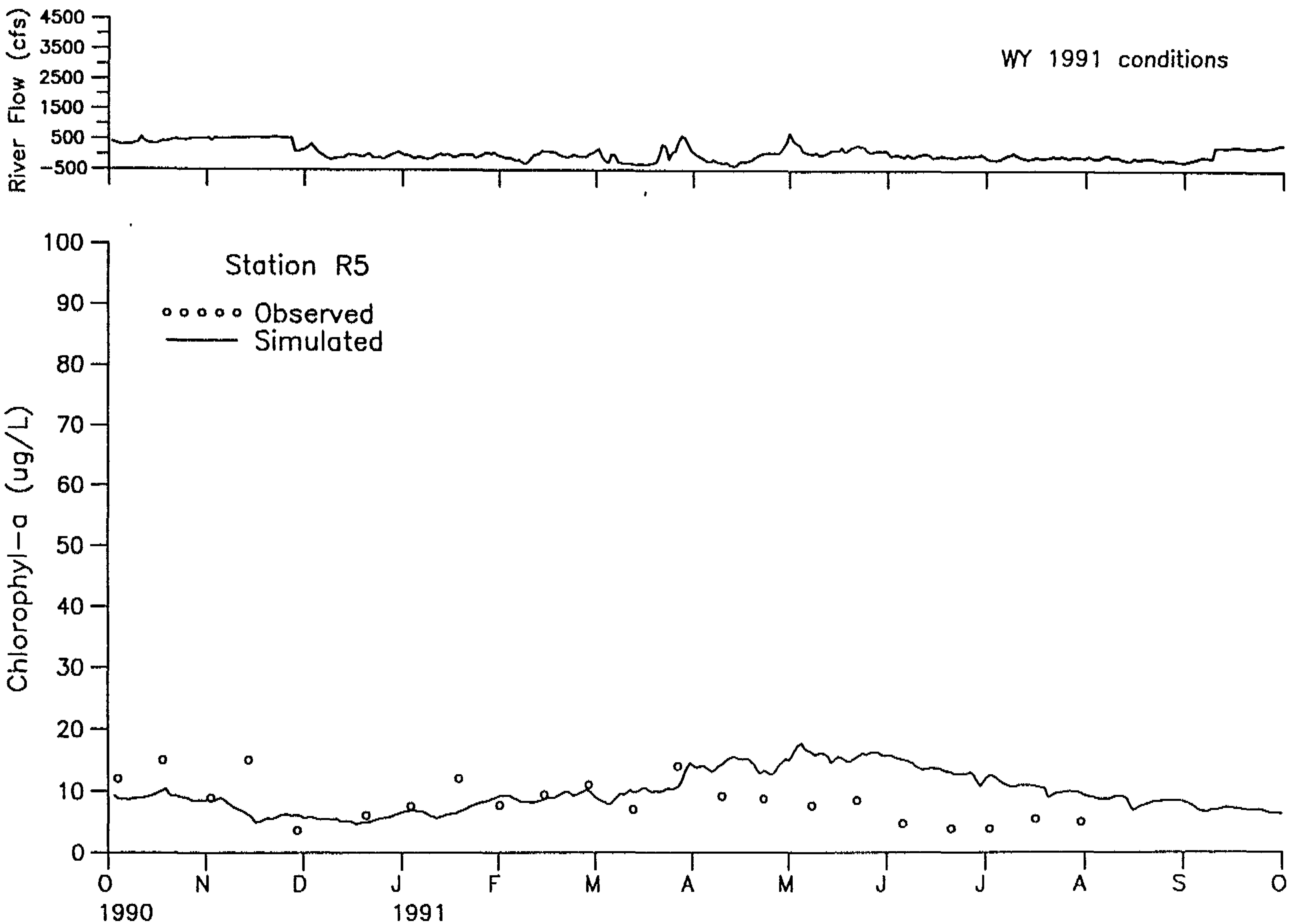
D-041522

D-041522



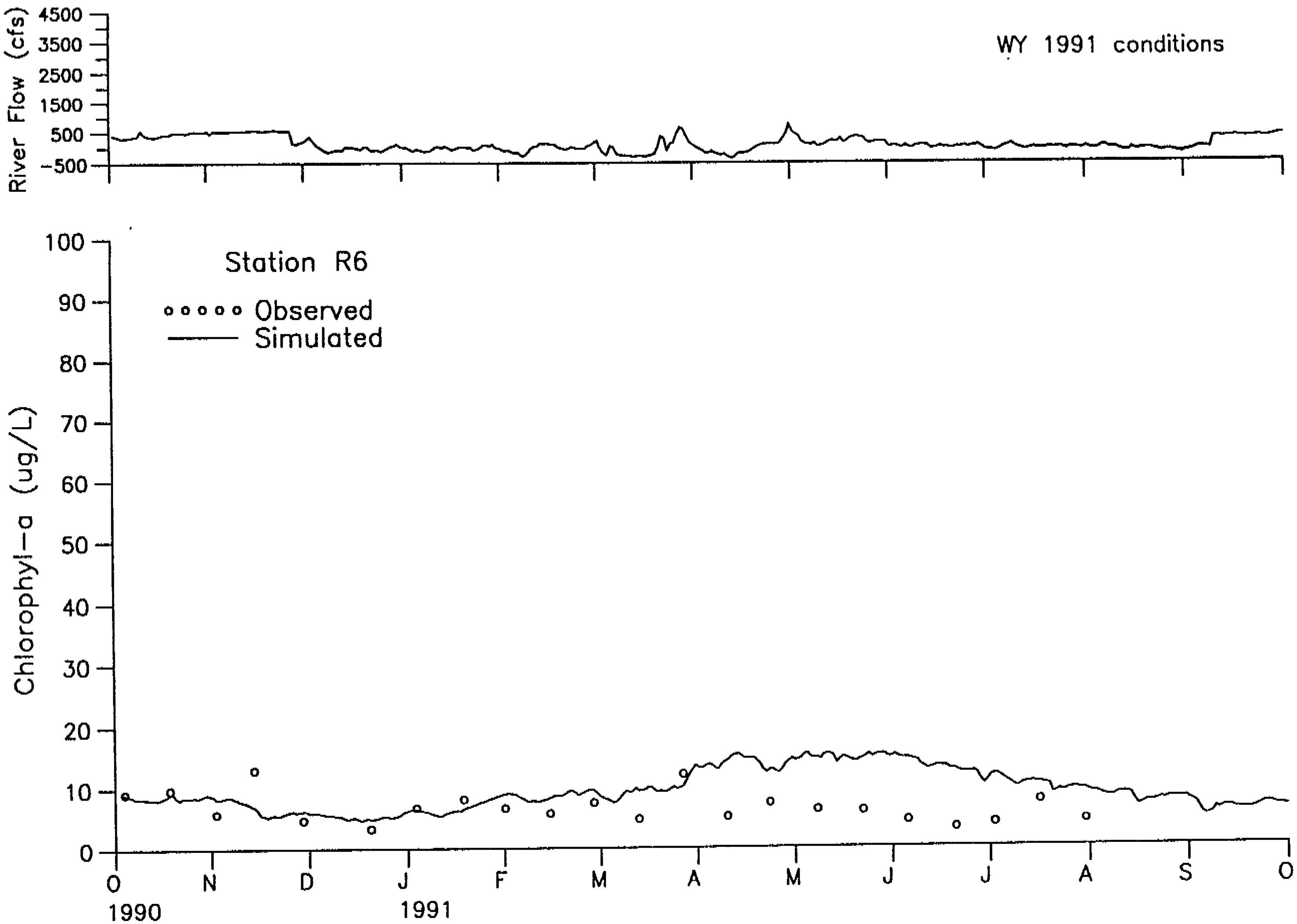
WY 1991 conditions
River Flow (cfs)
4500
3500
2500
1500
500
−500
Station R4
Observed
Simulated
Chlorophyl−a (ug/L)
100
90
80
70
60
50
40
30
20
10
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

D −0 4 1 5 2 3

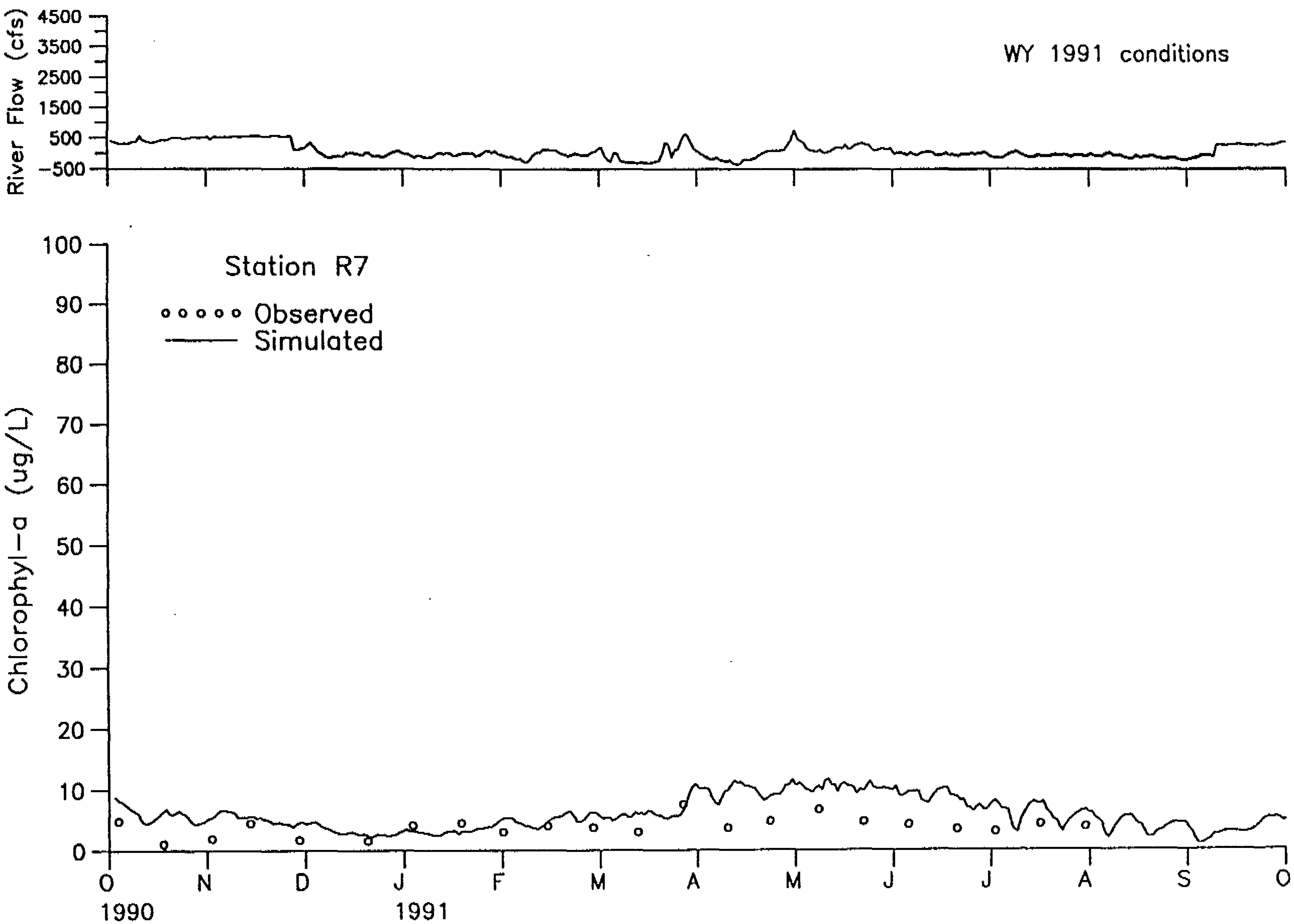


D-041524

D-041524

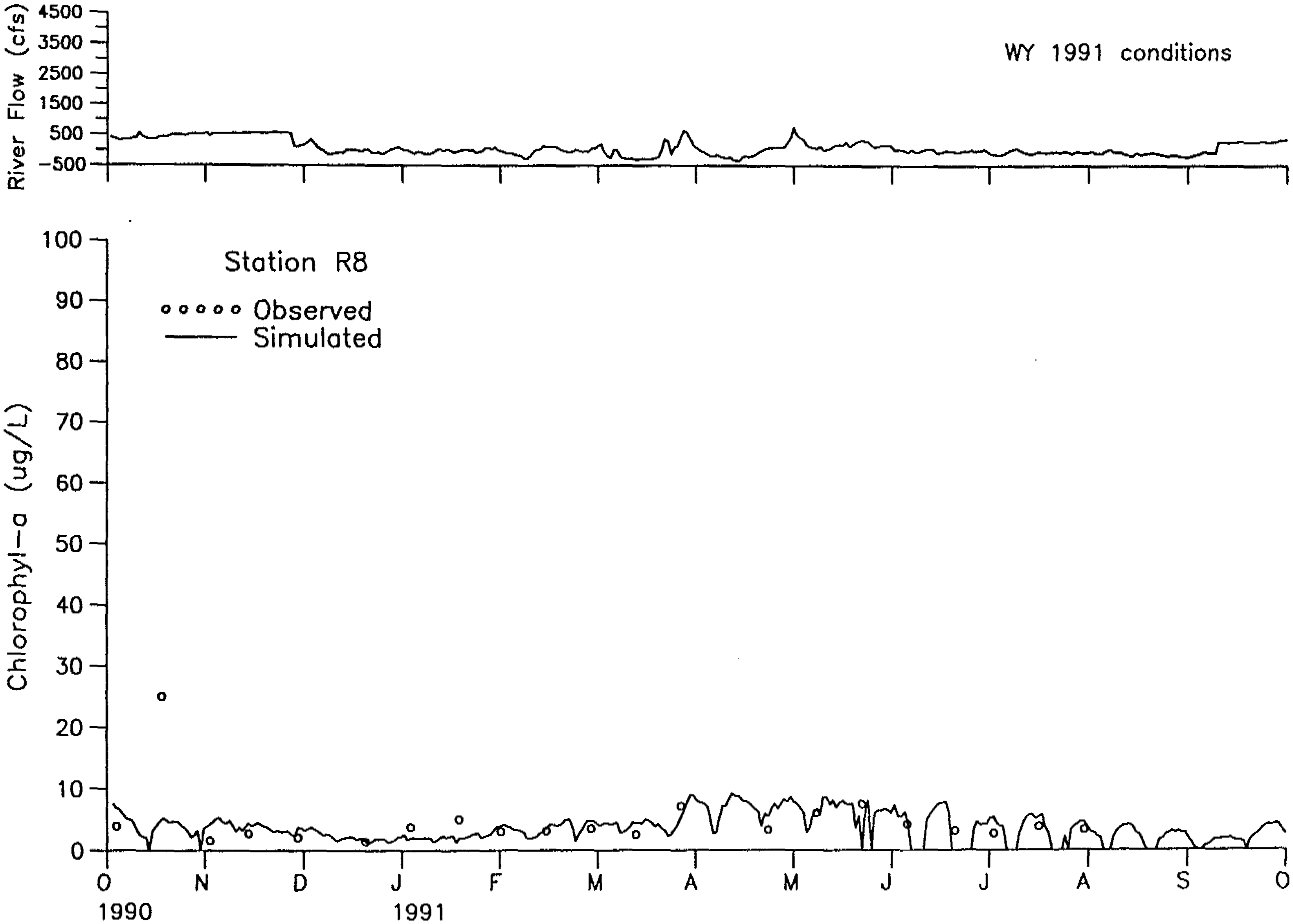


River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Chlorophyl-a (ug/L)
100
90
80
70
60
50
40
30
20
10
0
Station R6
Observed
Simulated
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991



D-041526

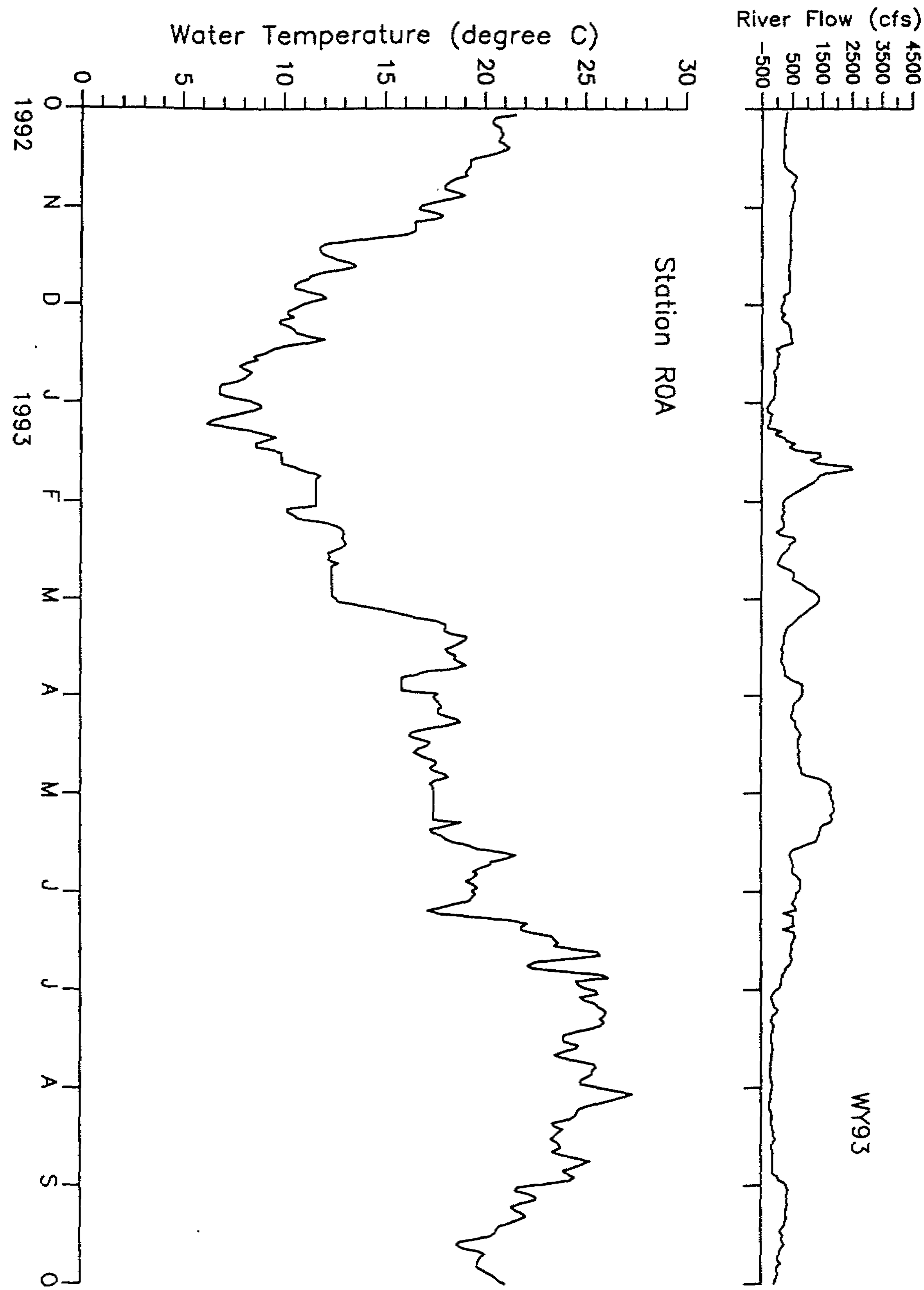
D-041526


River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
100
90
80
70
60
50
40
30
20
10
0
Chlorophyl-a (ug/L)
Station R8
Observed
Simulated
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

D-041527

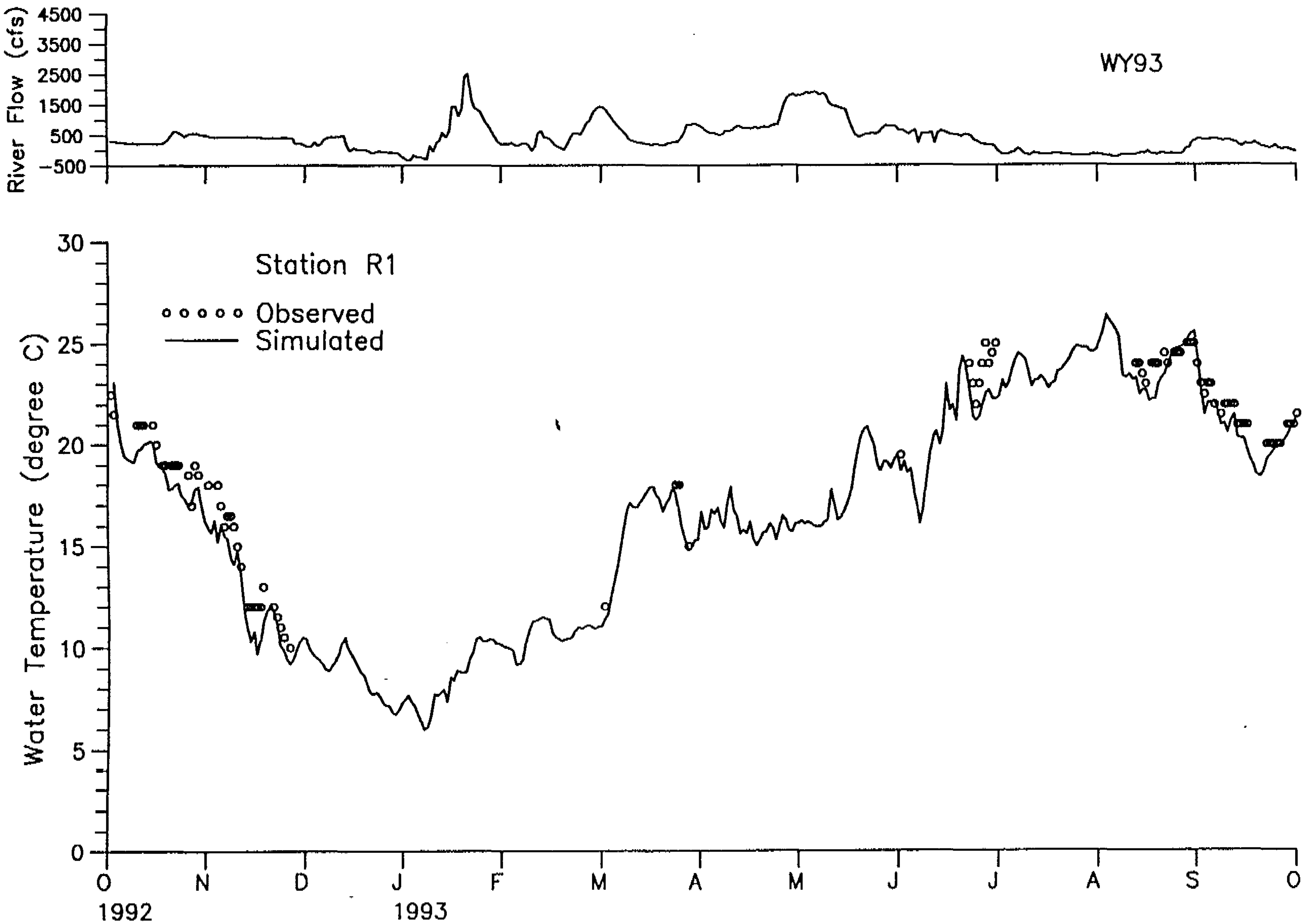
Appendix B.

1993 Verification Results for Stations R1 Through R7.



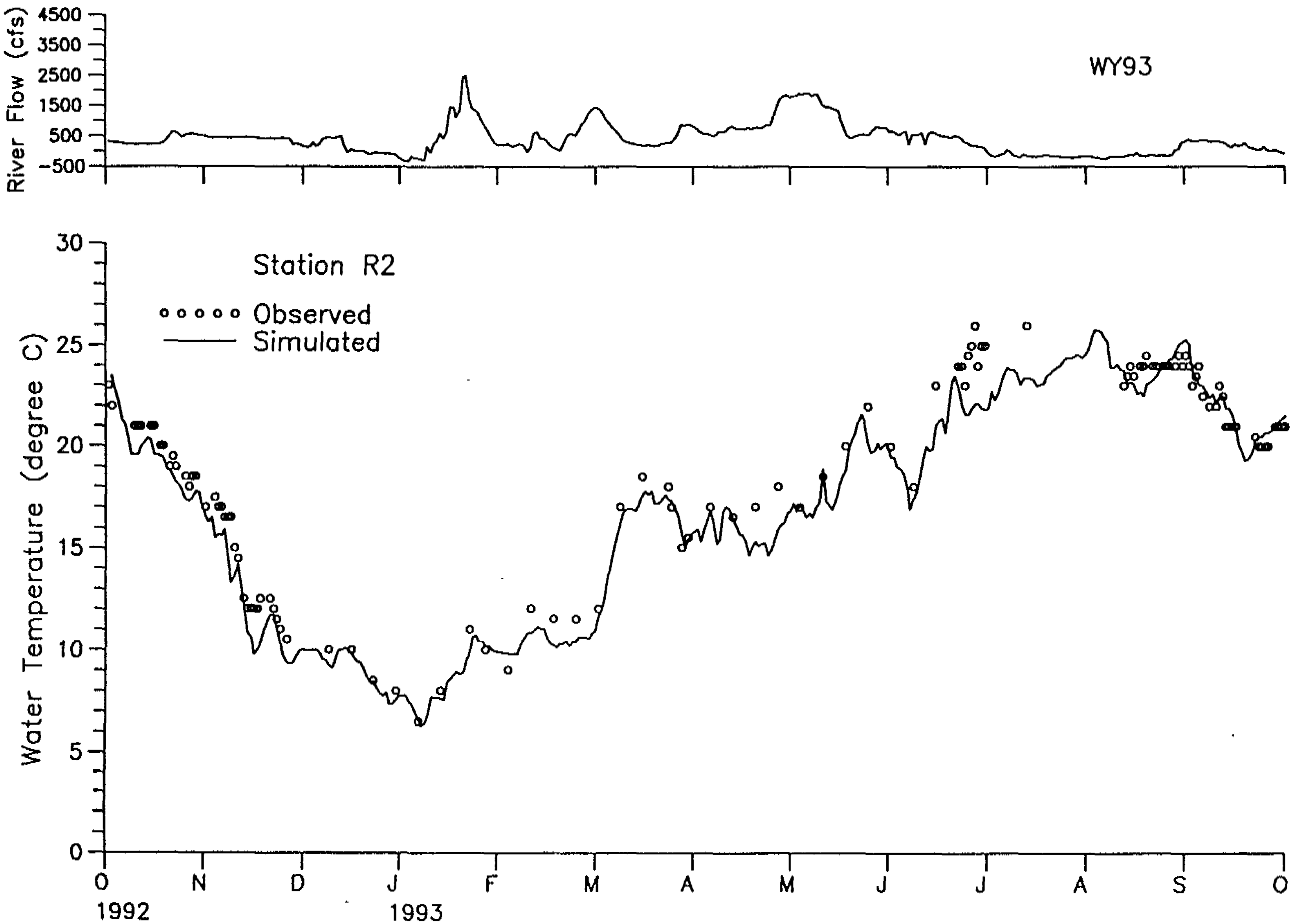
Water Temperature (degree C)
0
5
10
15
20
25
30
River Flow (cfs)
-500
500
1500
2500
3500
4500
Station ROA
WY93
1992
N
D
J
1993
F
M
A
M
J
J
A
S
O

D —0 4 1 5 2 9



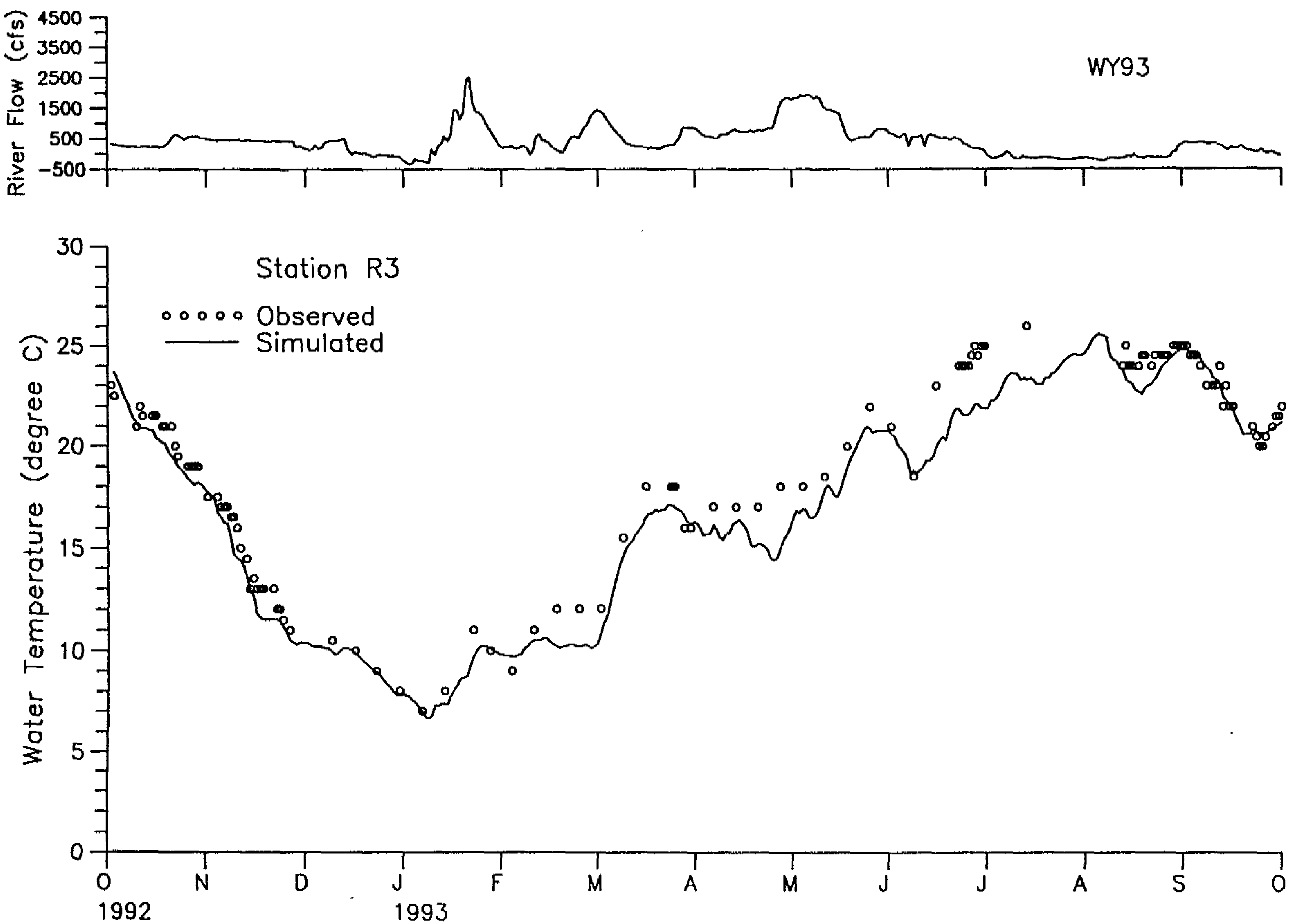
D-041530

D-041530



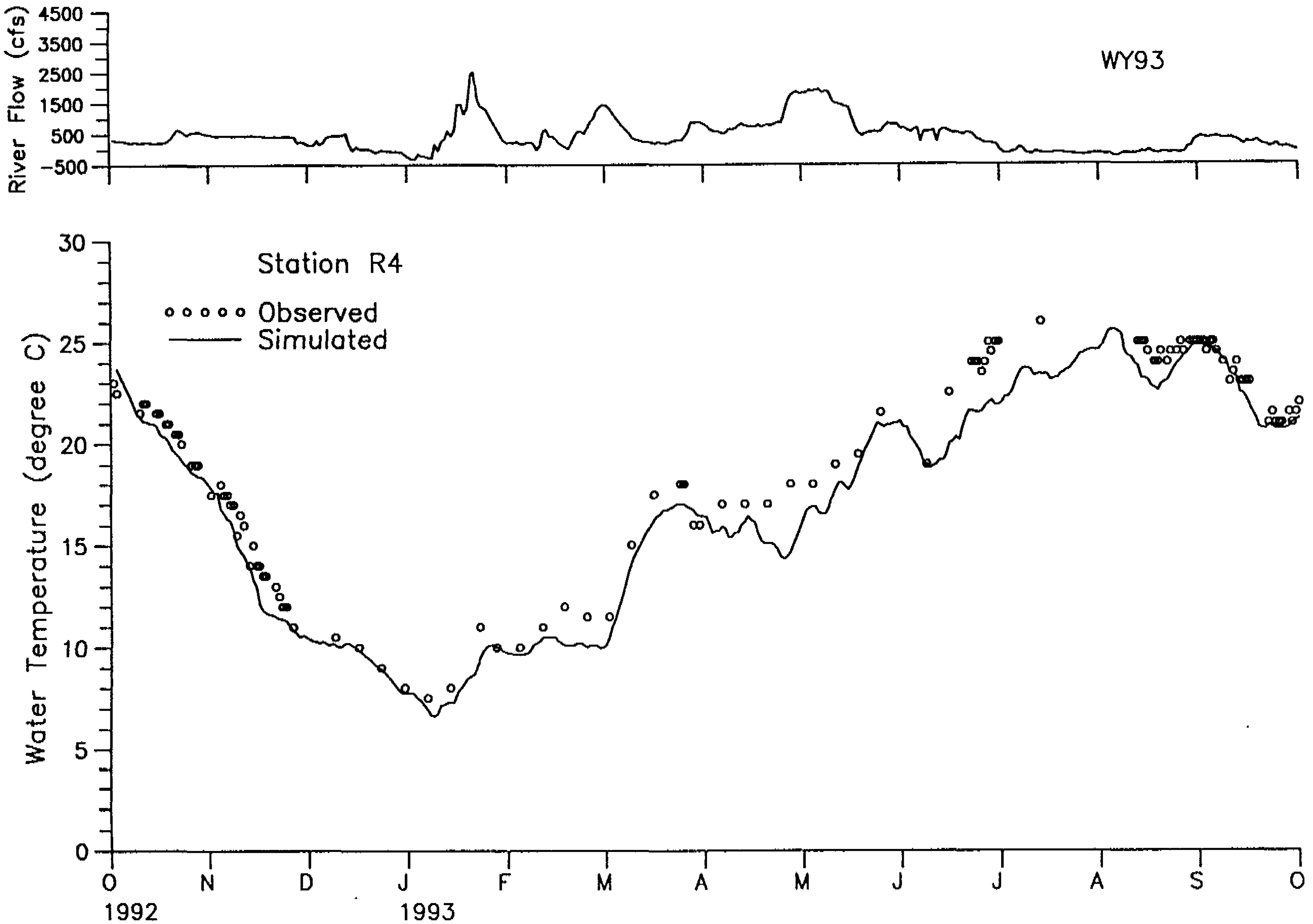
D —0 4 1 5 3 1

D-041531



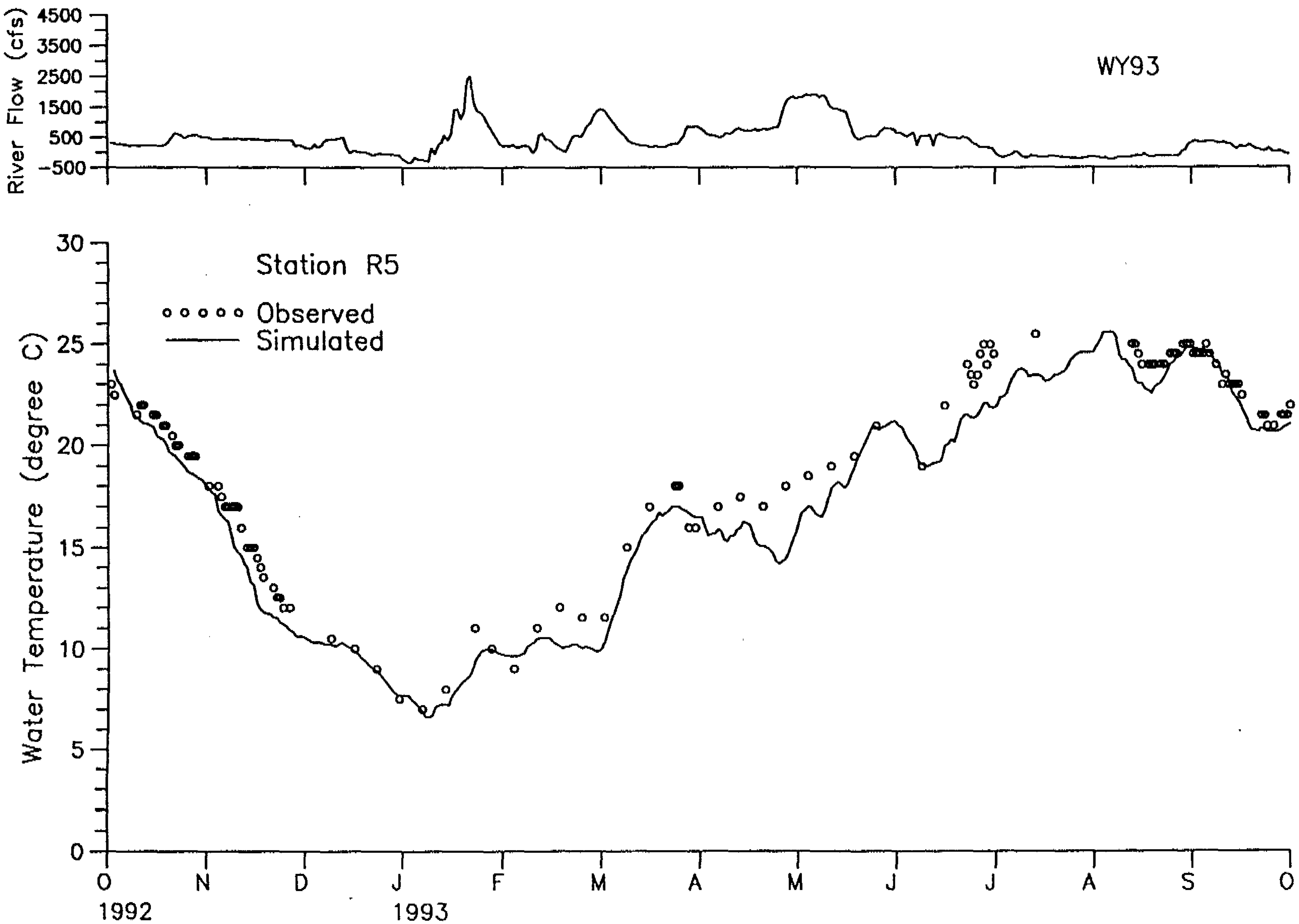
River Flow (cfs)
4500
3500
2500
1500
500
-500
WY93
Water Temperature (degree C)
30
25
20
15
10
5
0
Station R3
Observed
Simulated
O
N
D
J
F
M
A
M
J
J
A
S
O
1992
1993

D-041532



D −0 4 1 5 3 3

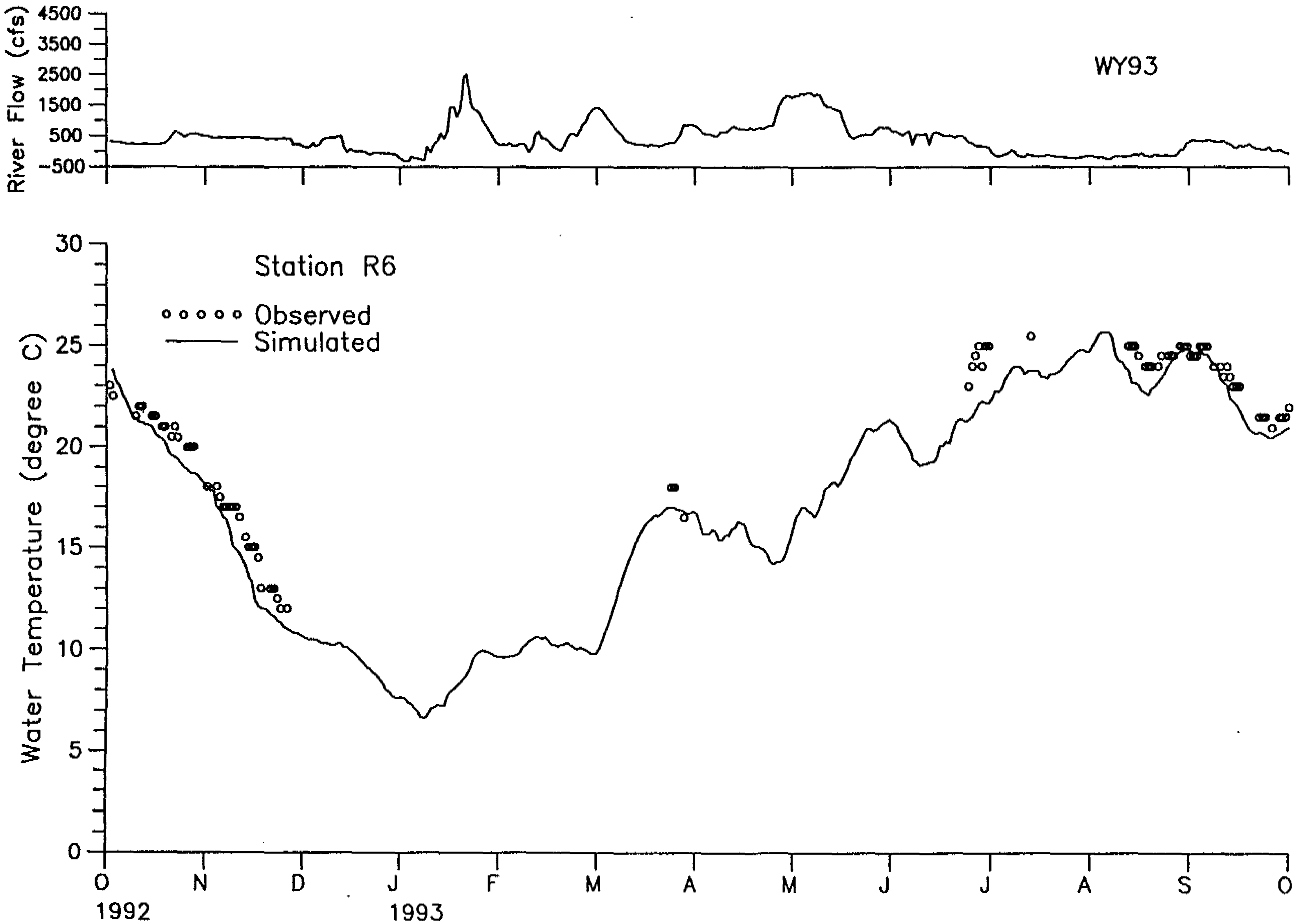
D-041533



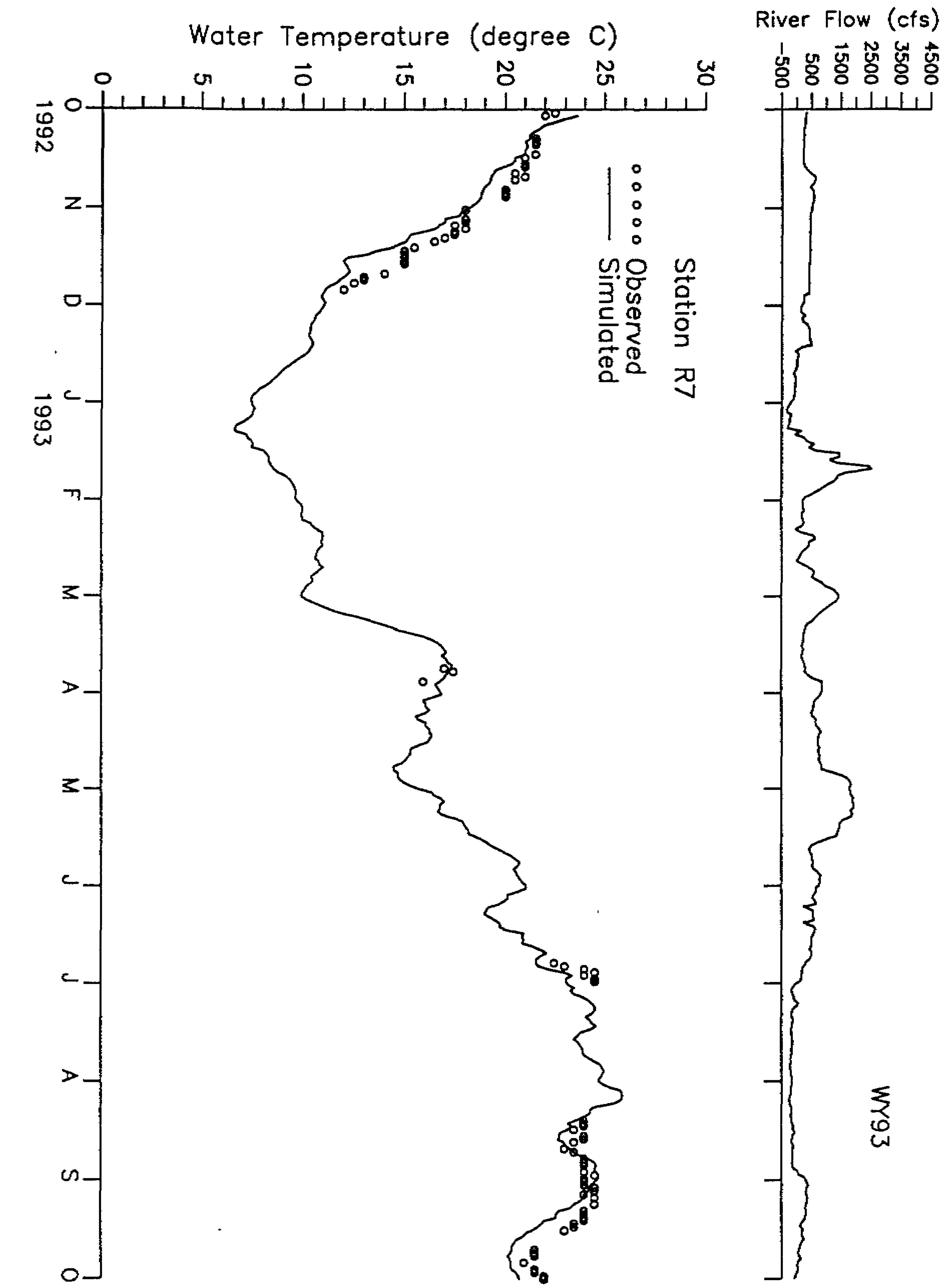
River Flow (cfs)
4500
3500
2500
1500
500
-500
WY93
Station R5
Observed
Simulated
Water Temperature (degree C)
30
25
20
15
10
5
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1992
1993

D-041534

D-041535

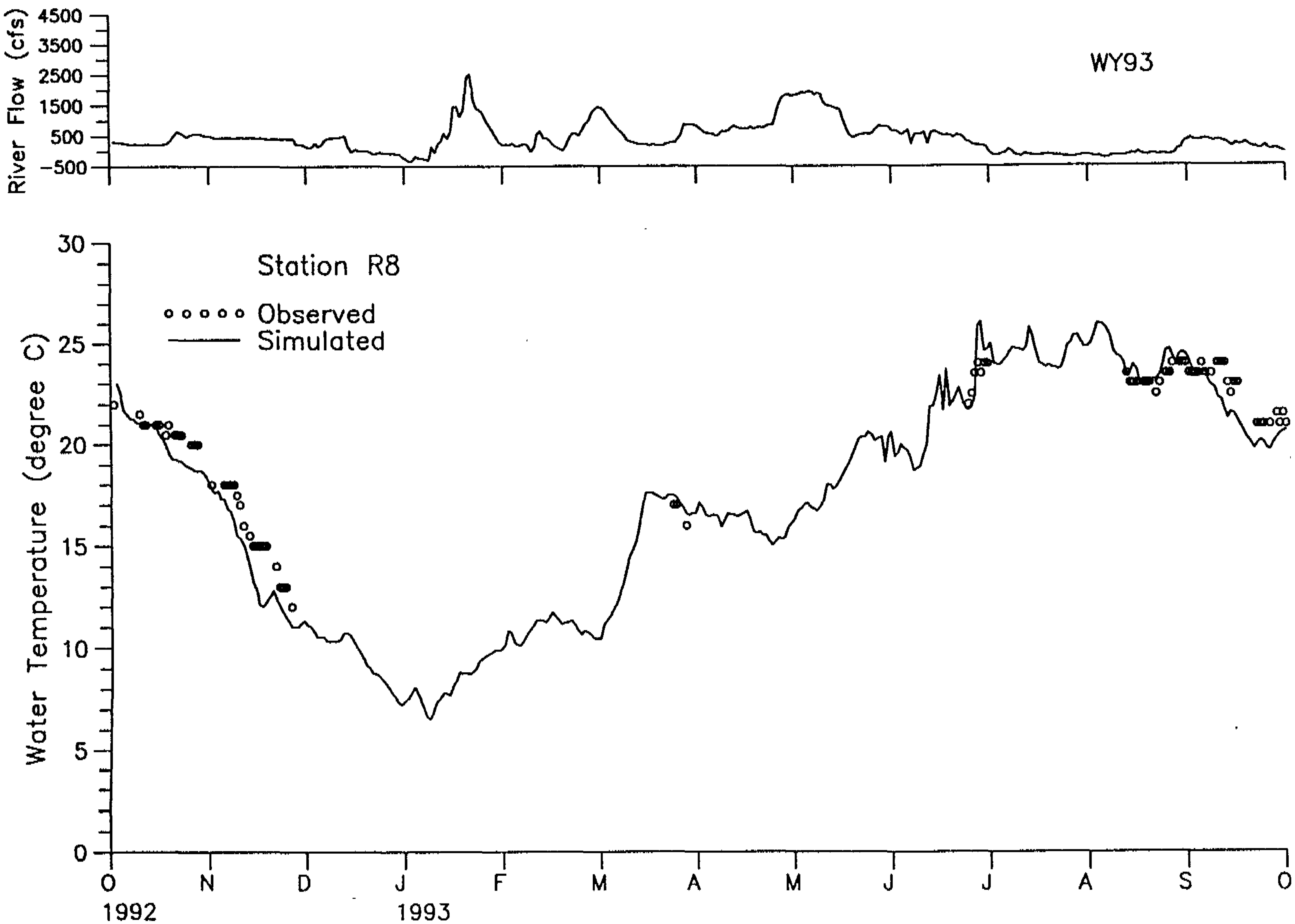


D—041535



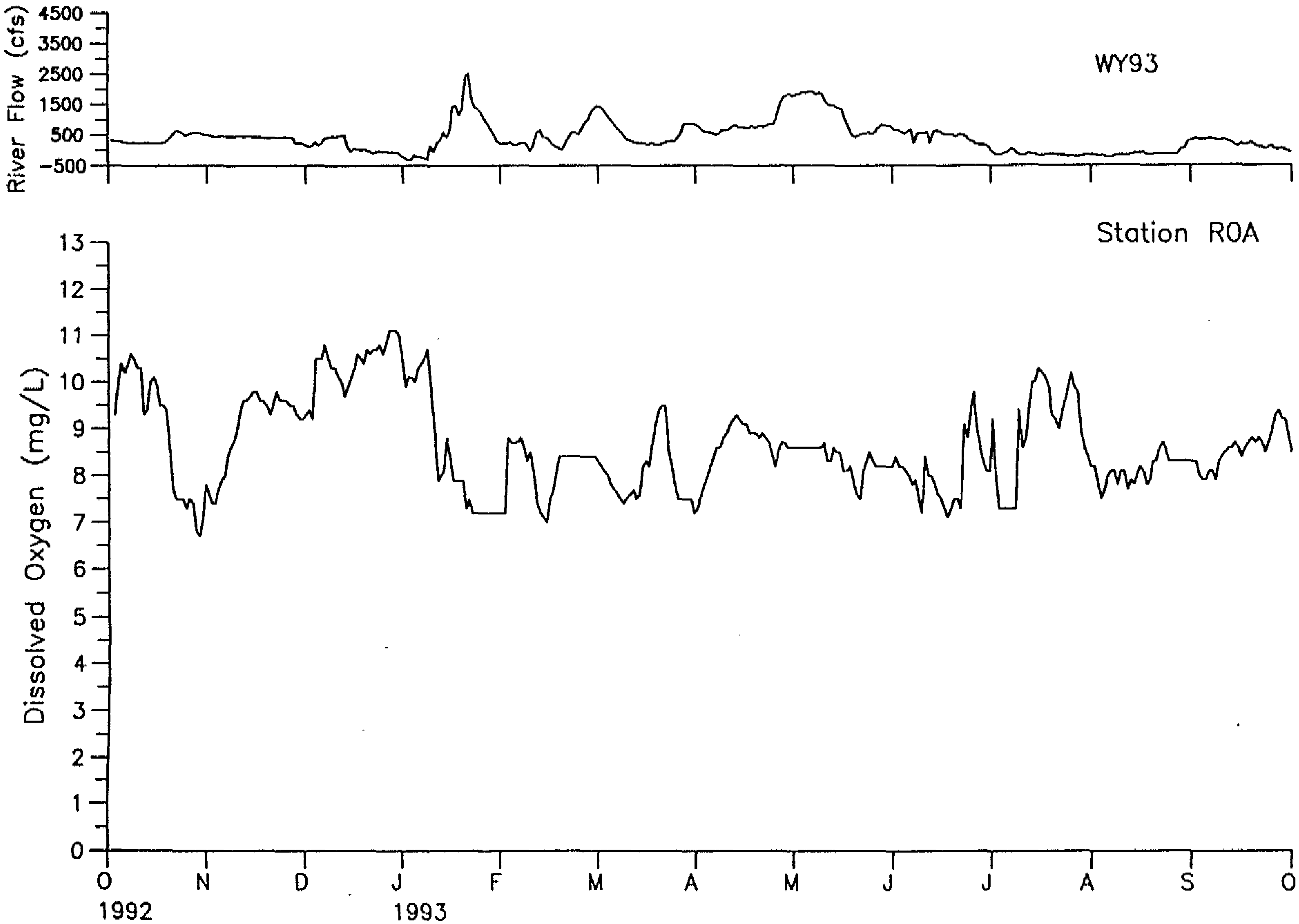
Water Temperature (degree C)
River Flow (cfs)
Station R7
Observed
Simulated
WY93
1992
1993
O
N
D
J
F
M
A
M
J
J
A
S
O
0
5
10
15
20
25
30
-500
500
1500
2500
3500
4500

D-041536



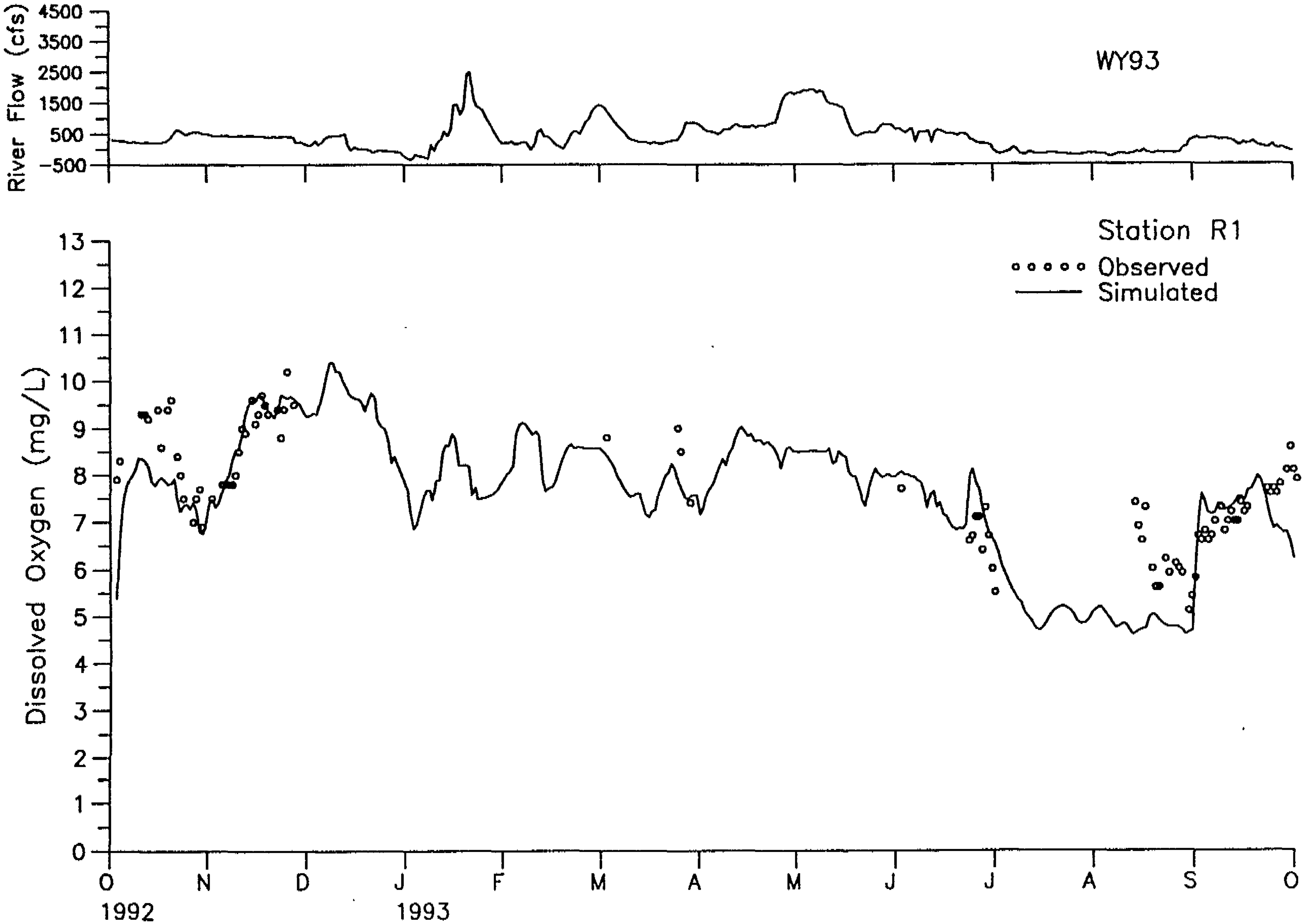
D-041537

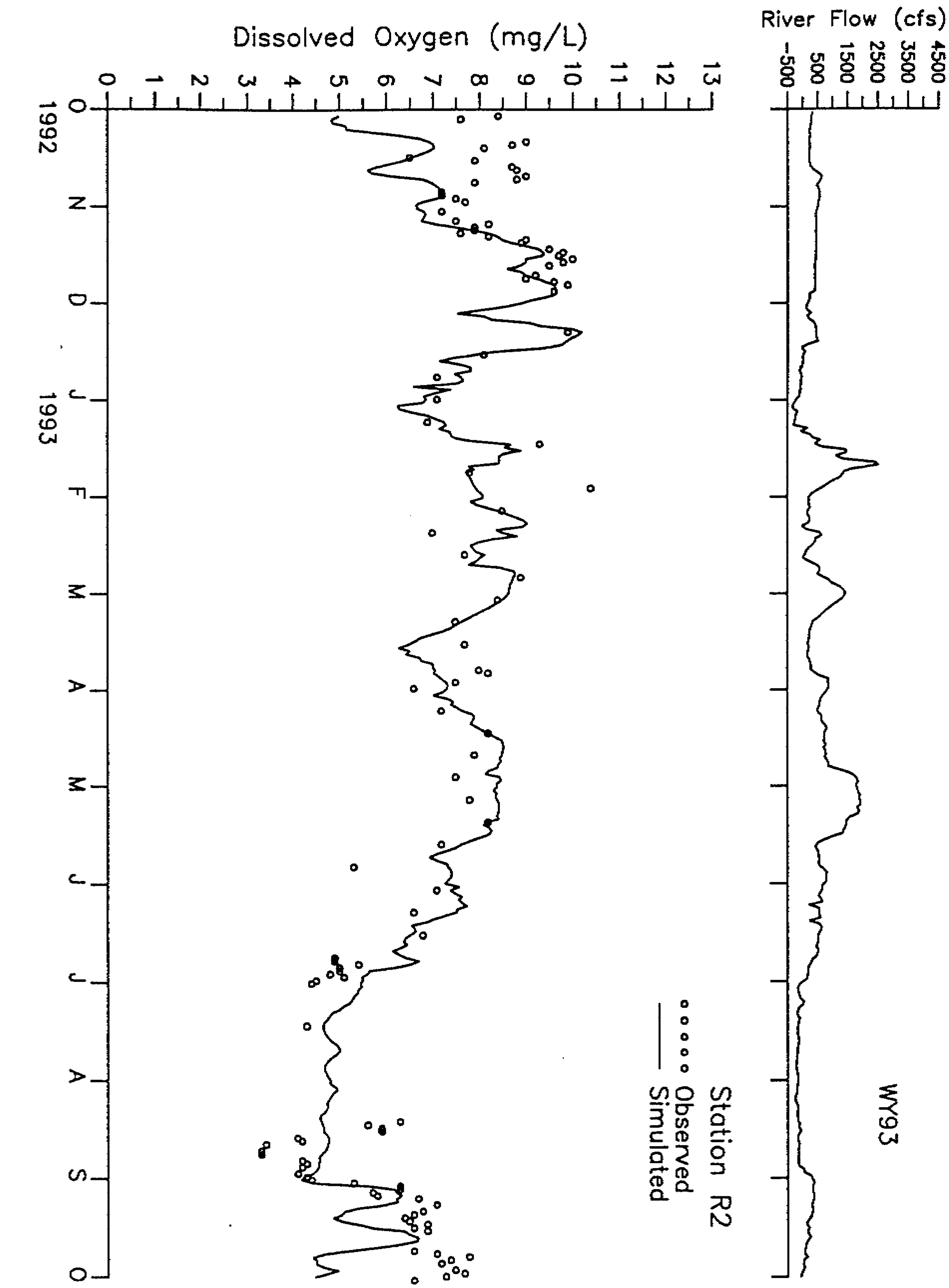
D-041537



D-041538

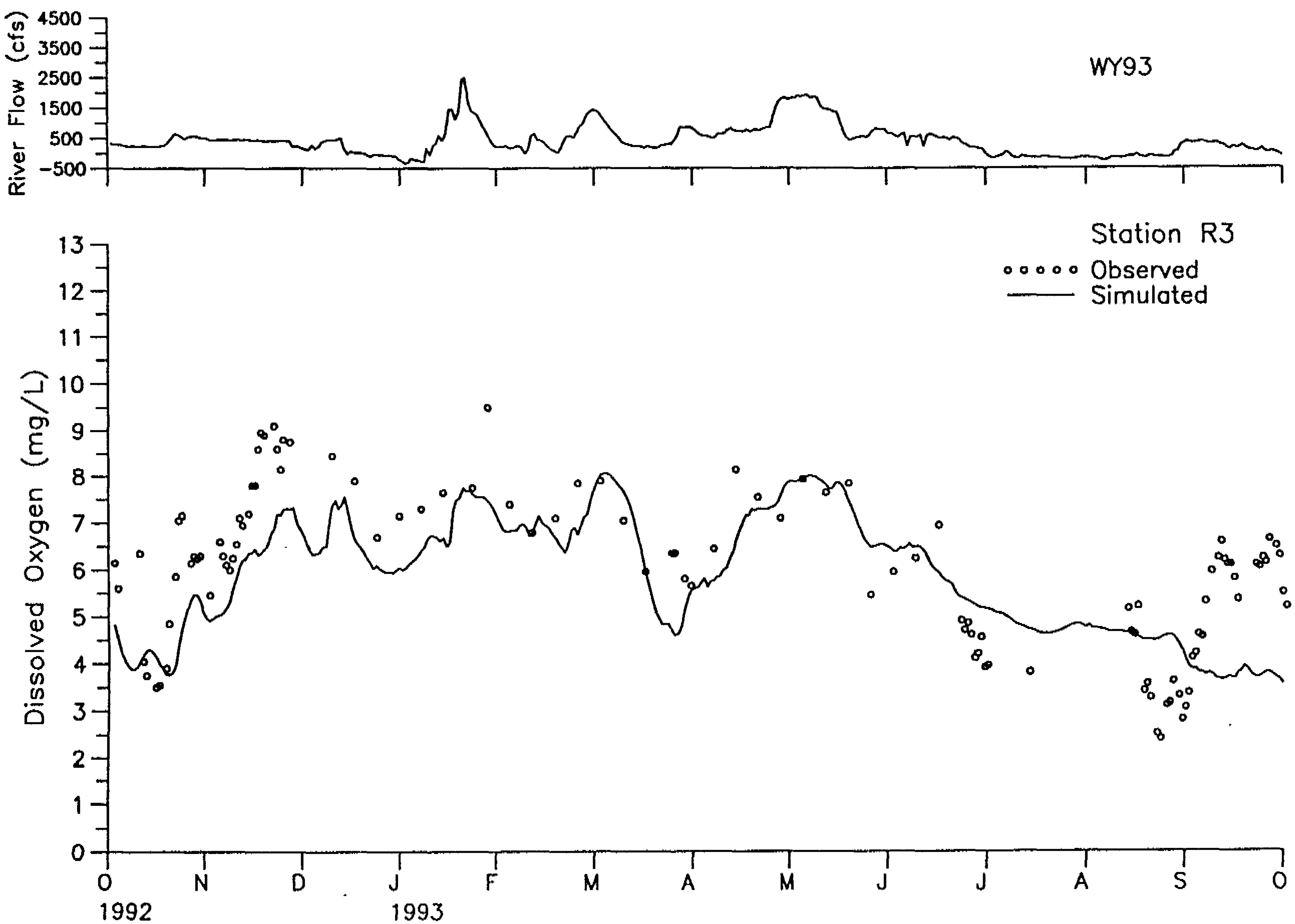
D-041538


River Flow (cfs)
4500
3500
2500
1500
500
-500
WY93
Station R1
Observed
Simulated
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1992
1993

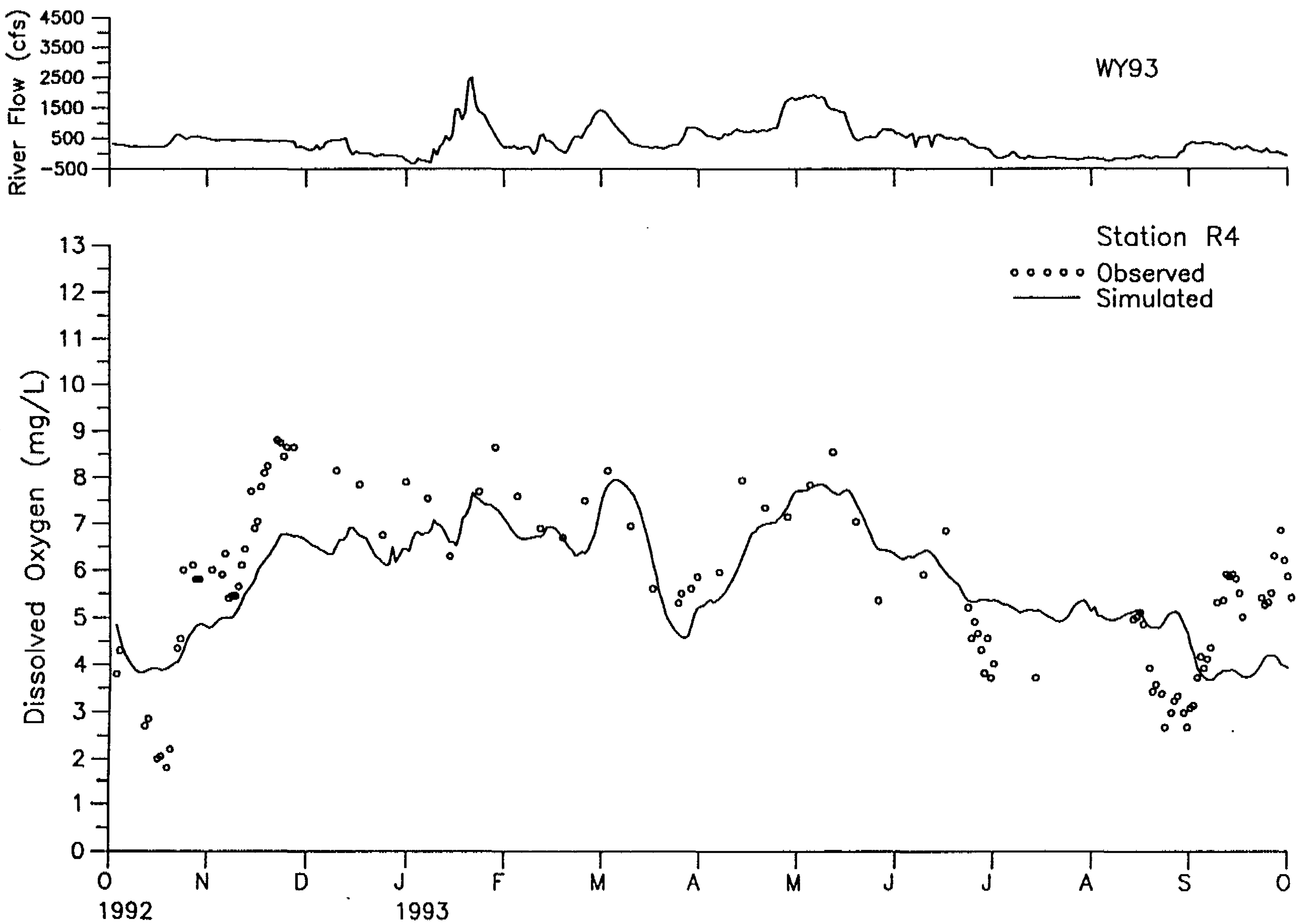

River Flow (cfs)
-500
500
1500
2500
3500
4500
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
O
N
D
J
F
M
A
M
J
J
A
S
O
1992
1993
WY93
Station R2
Observed
Simulated

D —0 4 1 5 4 0

D-041541

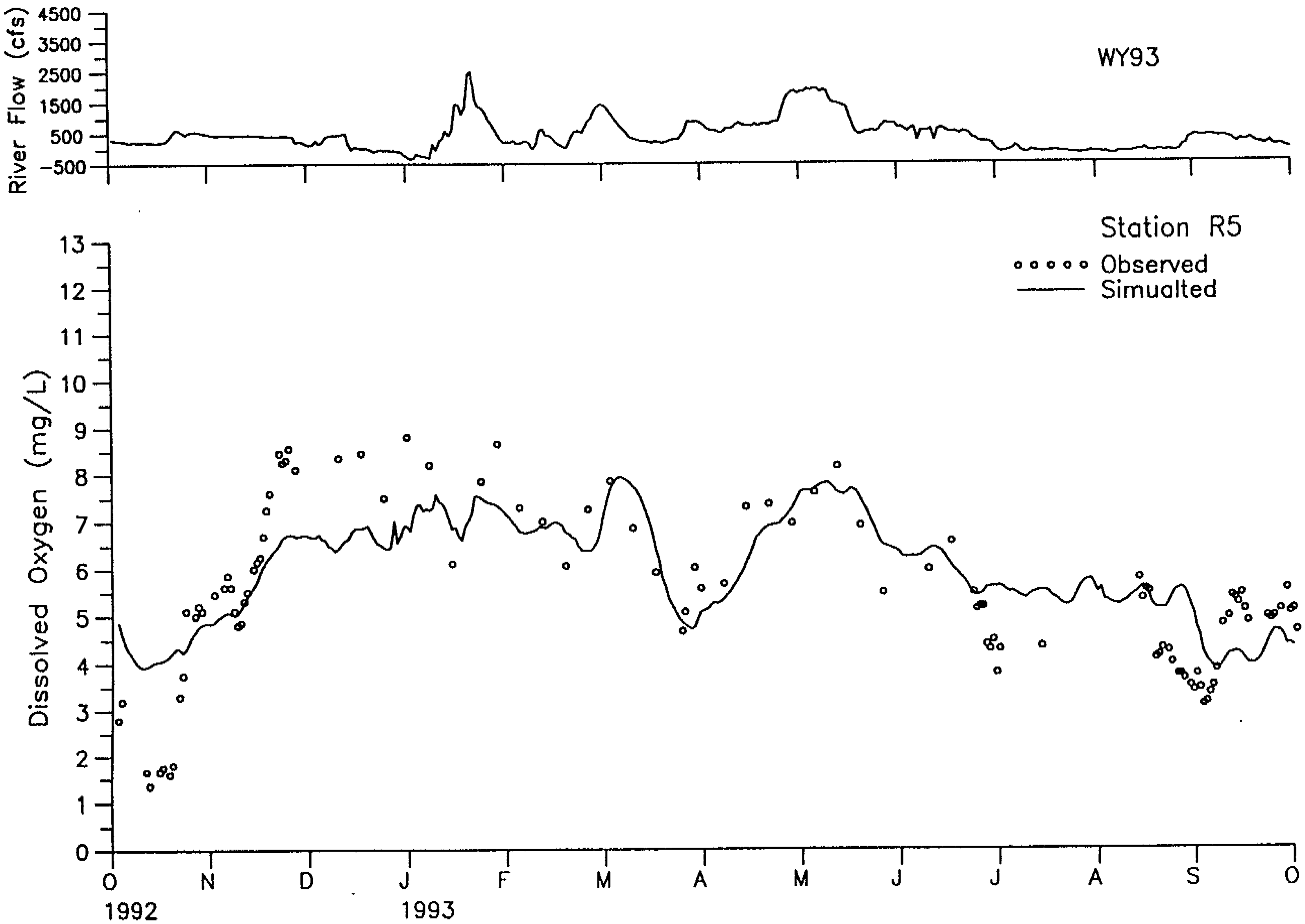


D-041541



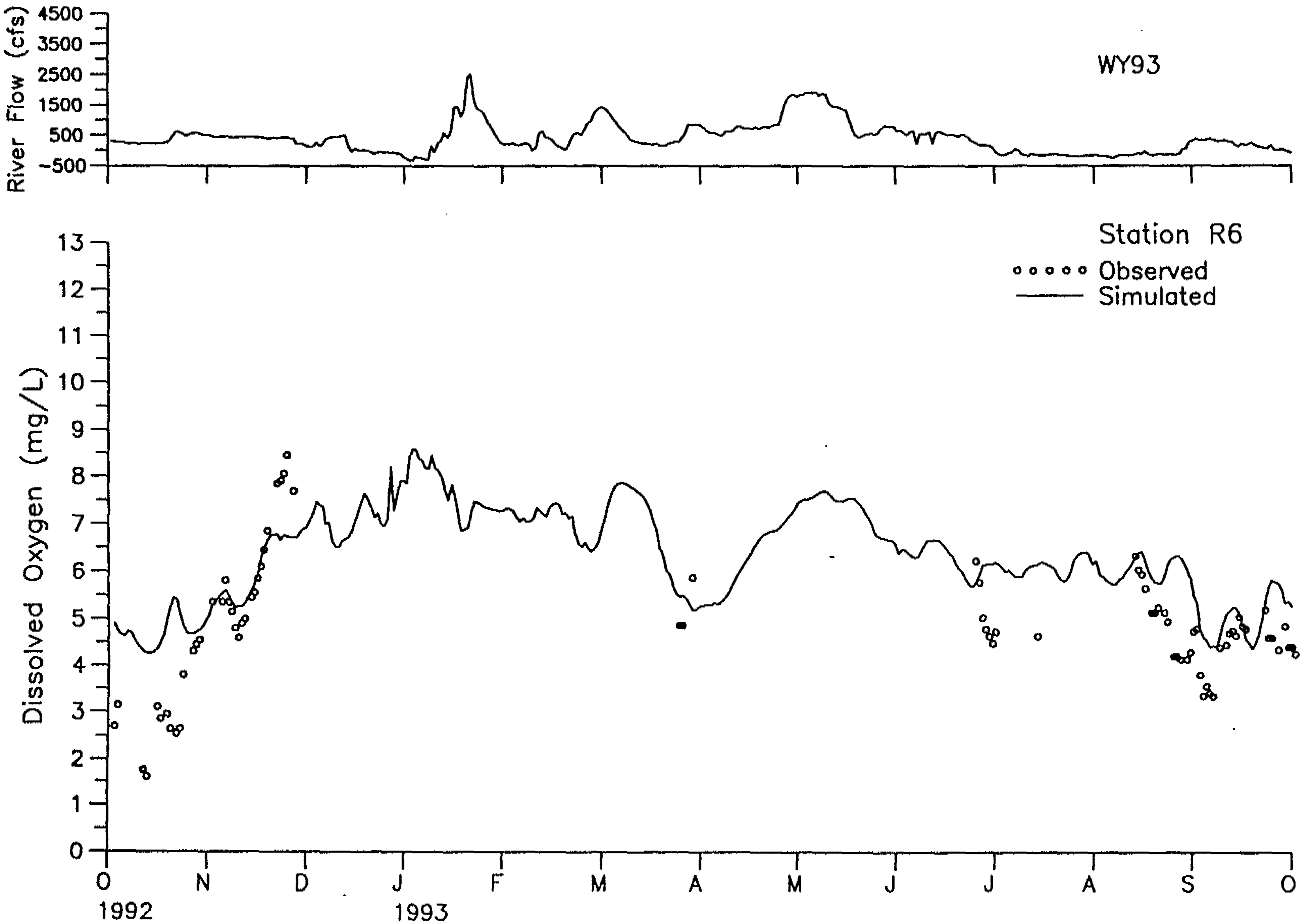
River Flow (cfs)
4500
3500
2500
1500
500
-500
WY93
Station R4
Observed
Simulated
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1992
1993

D-041542



River Flow (cfs)
4500
3500
2500
1500
500
-500
WY93
Station R5
Observed
Simualted
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
O
N
D
J
F
M
A
M
J
J
A
S
O
1992
1993

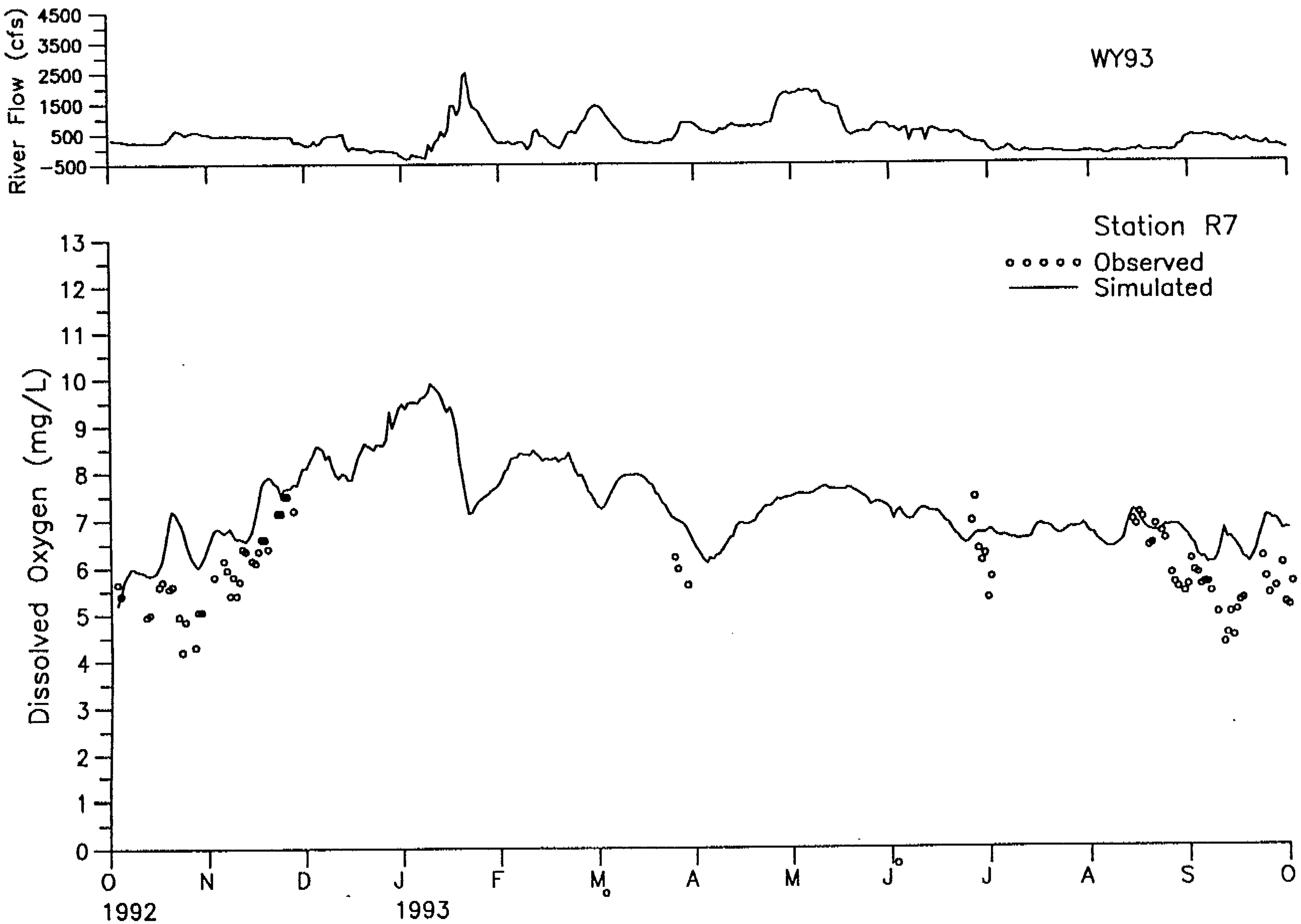
D—041543



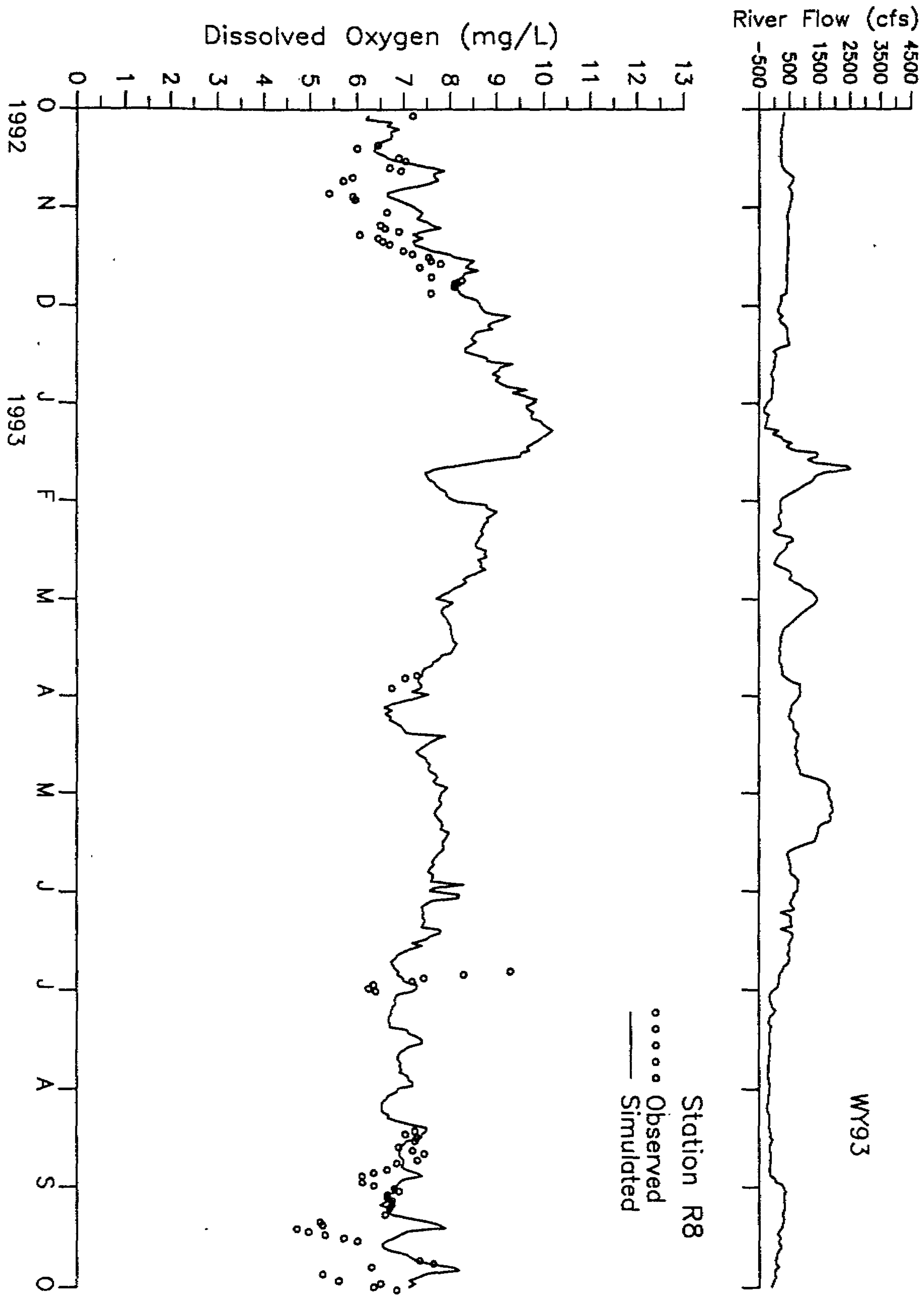
River Flow (cfs)
4500
3500
2500
1500
500
-500
WY93
Station R6
Observed
Simulated
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1992
1993

D-041544

D-041545



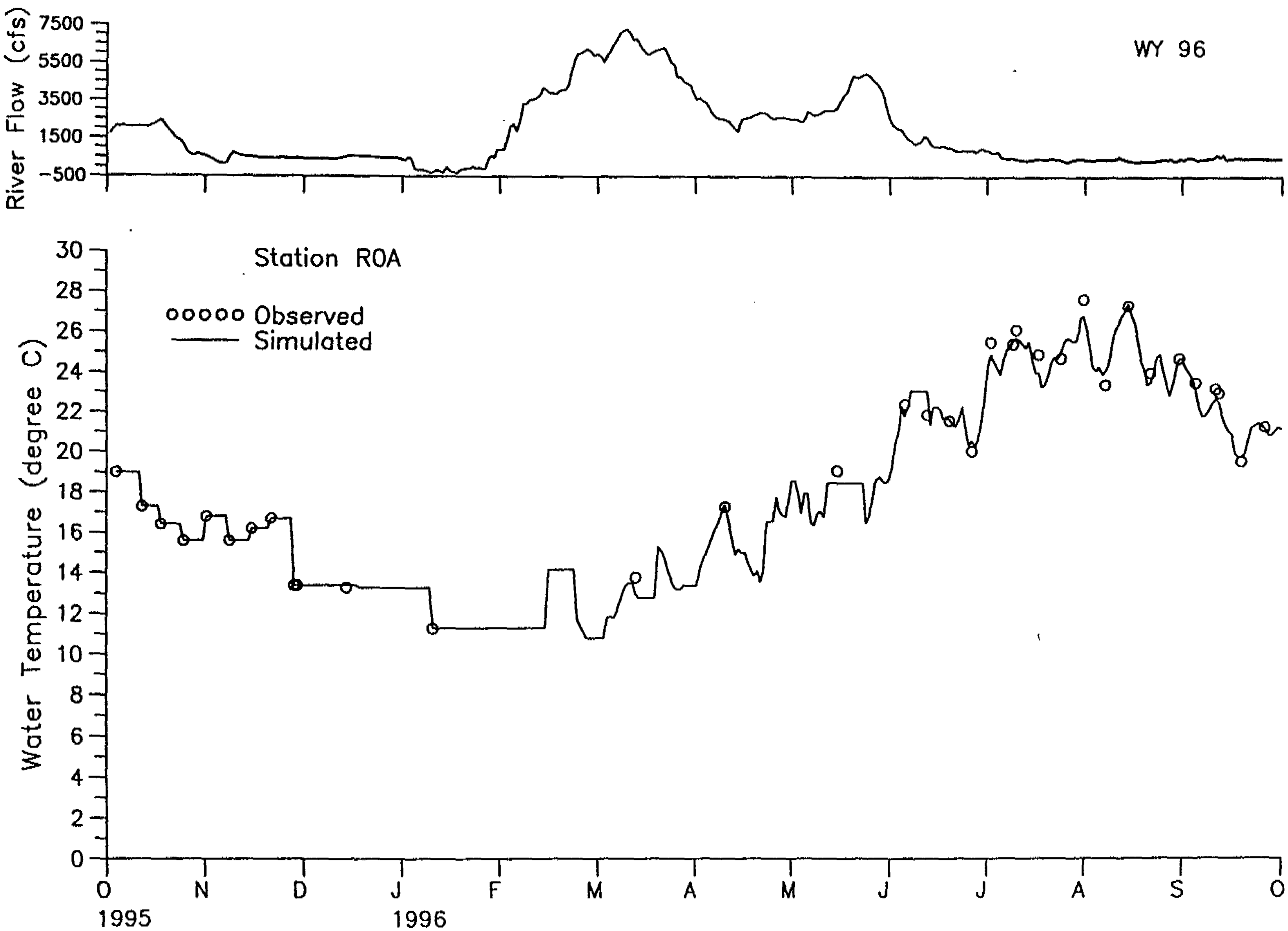
D-041545


River Flow (cfs)
-500
500
1500
2500
3500
4500
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
1992
1993
O
N
D
J
F
M
A
M
J
J
A
S
O
WY93
Station R8
Observed
Simulated

D —0 4 1 5 4 6

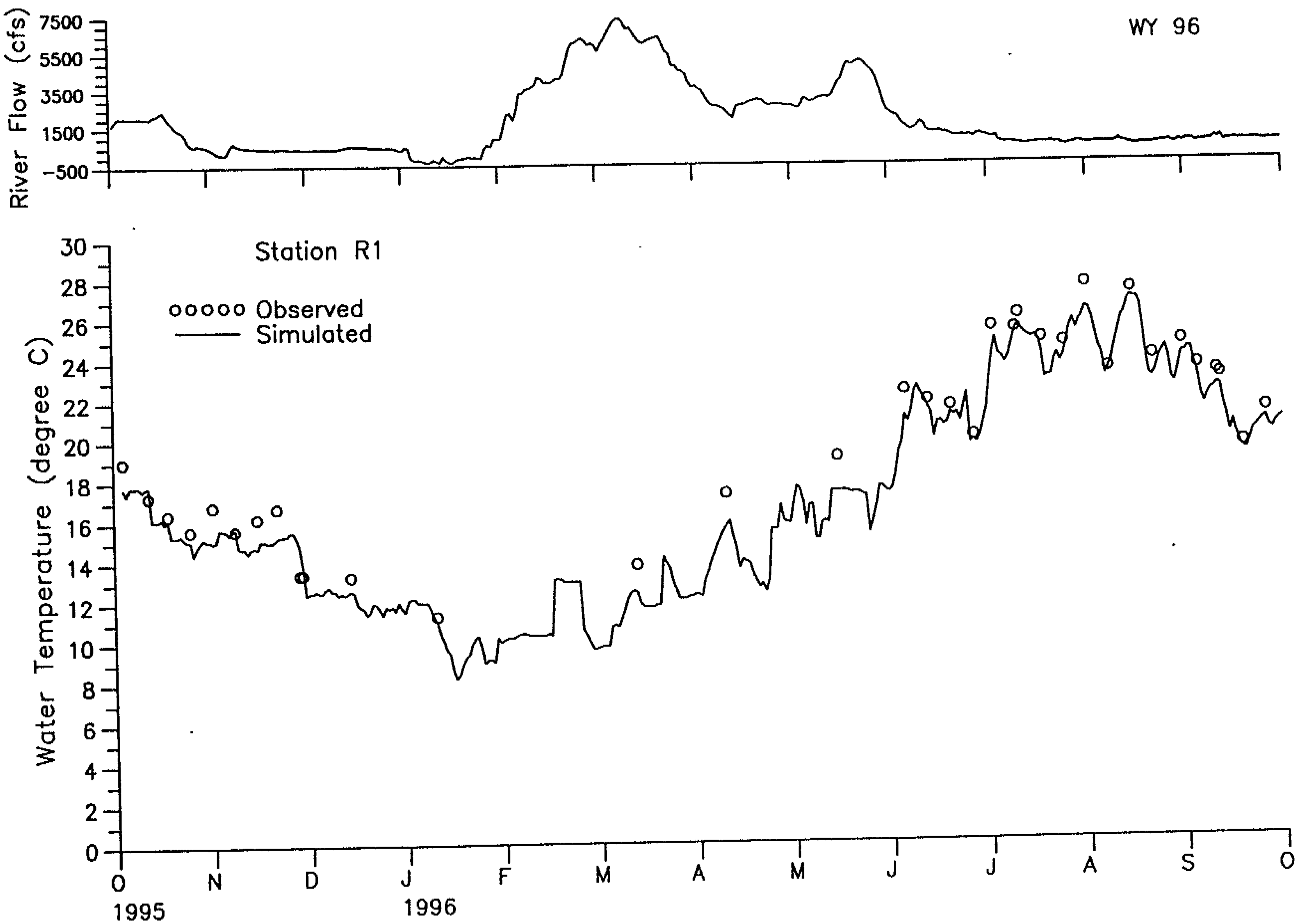
Appendix C.

1996 Verification Results for Stations R1 through R7.

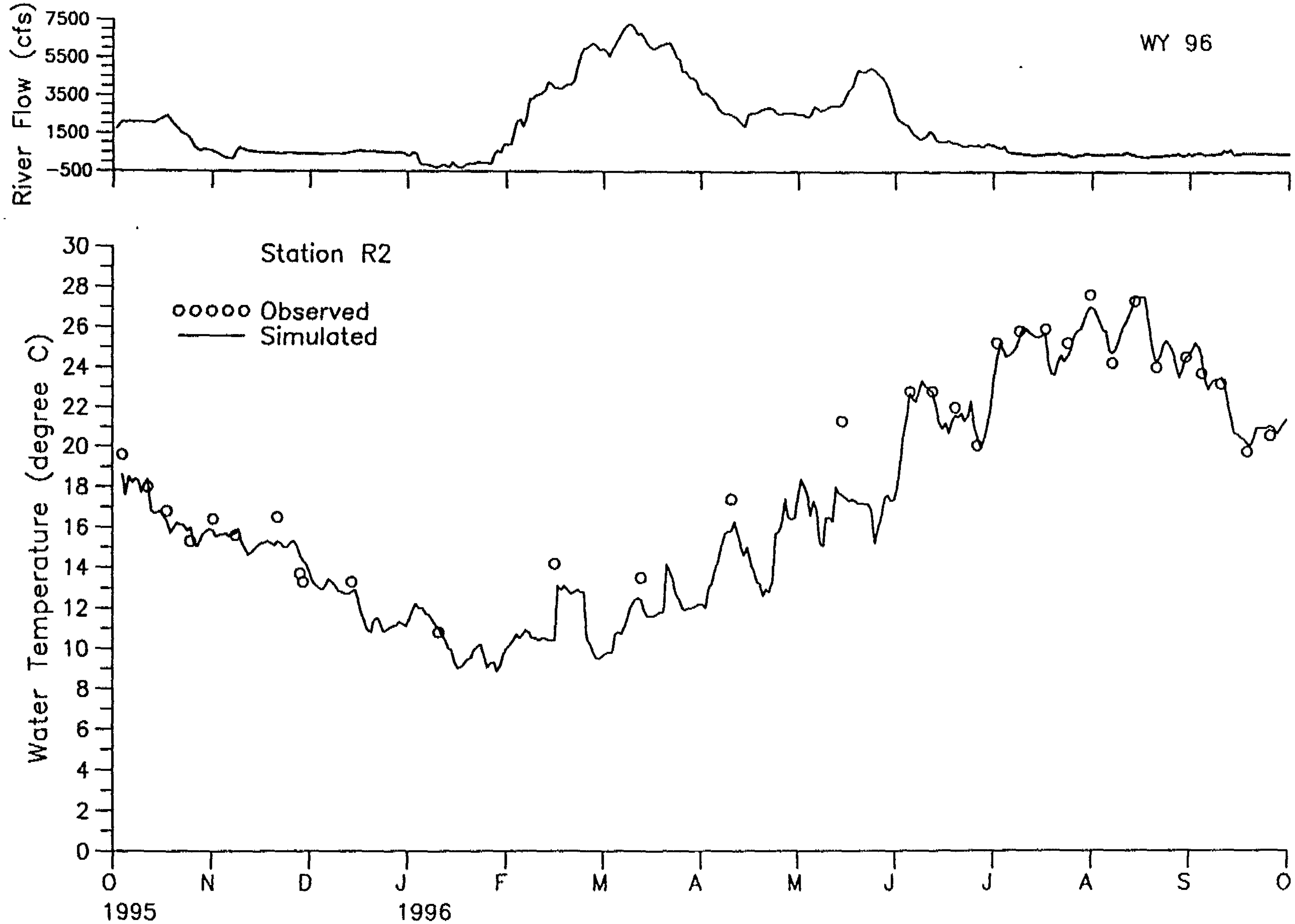


D-041548

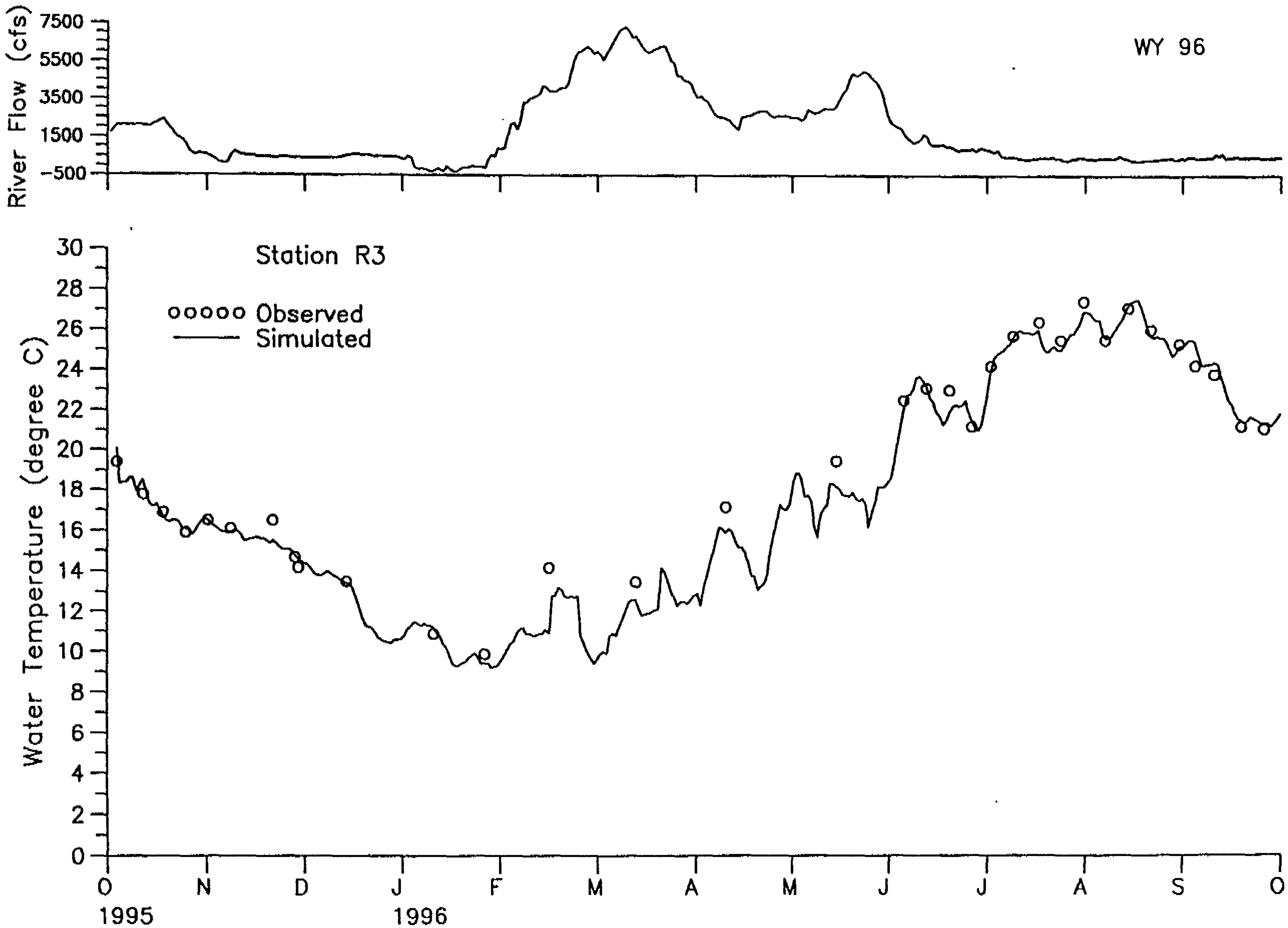
D-041548


WY 96
River Flow (cfs)
7500
5500
3500
1500
-500
Station R1
ooooo Observed
Simulated
Water Temperature (degree C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

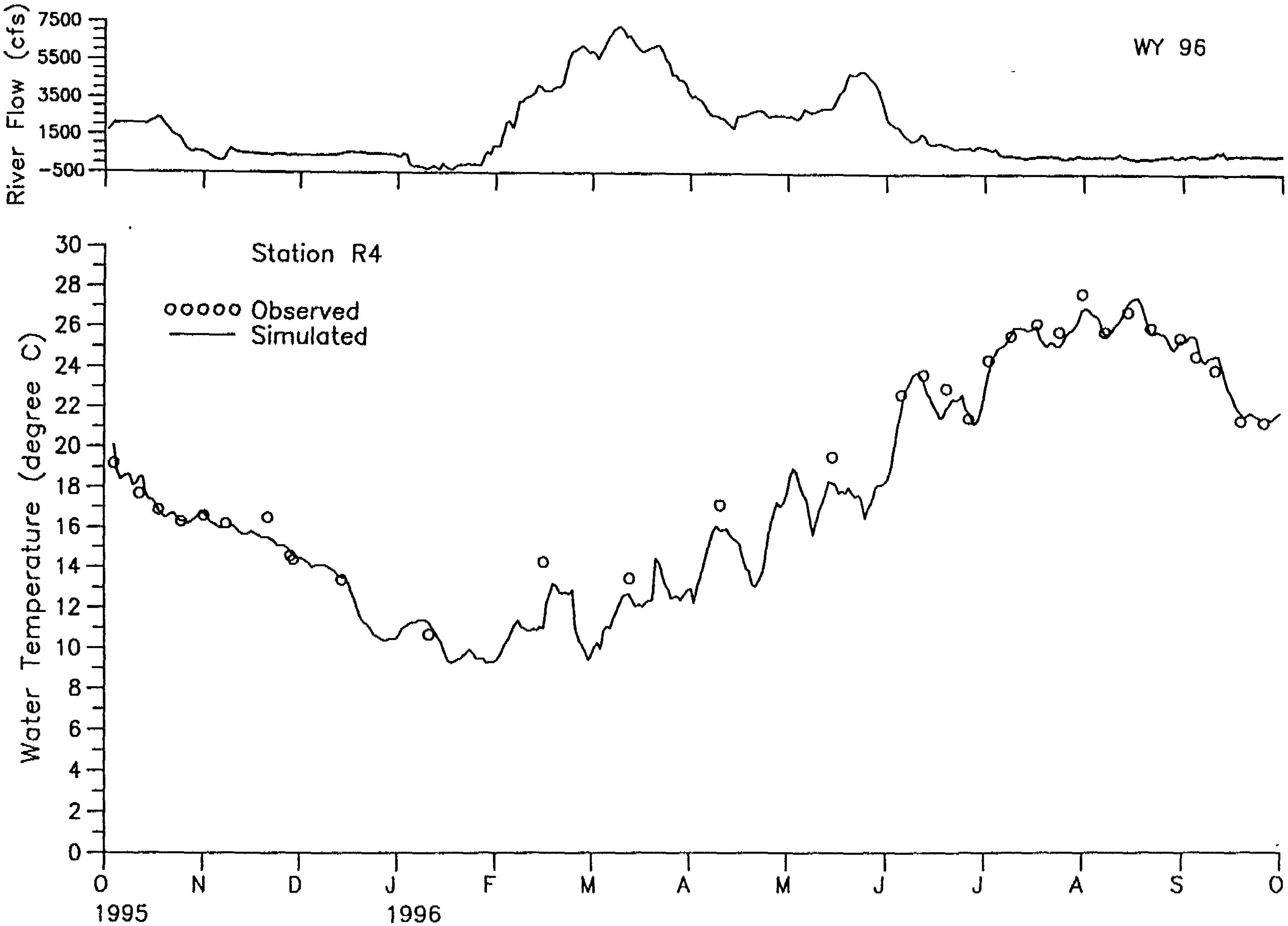
D-041549

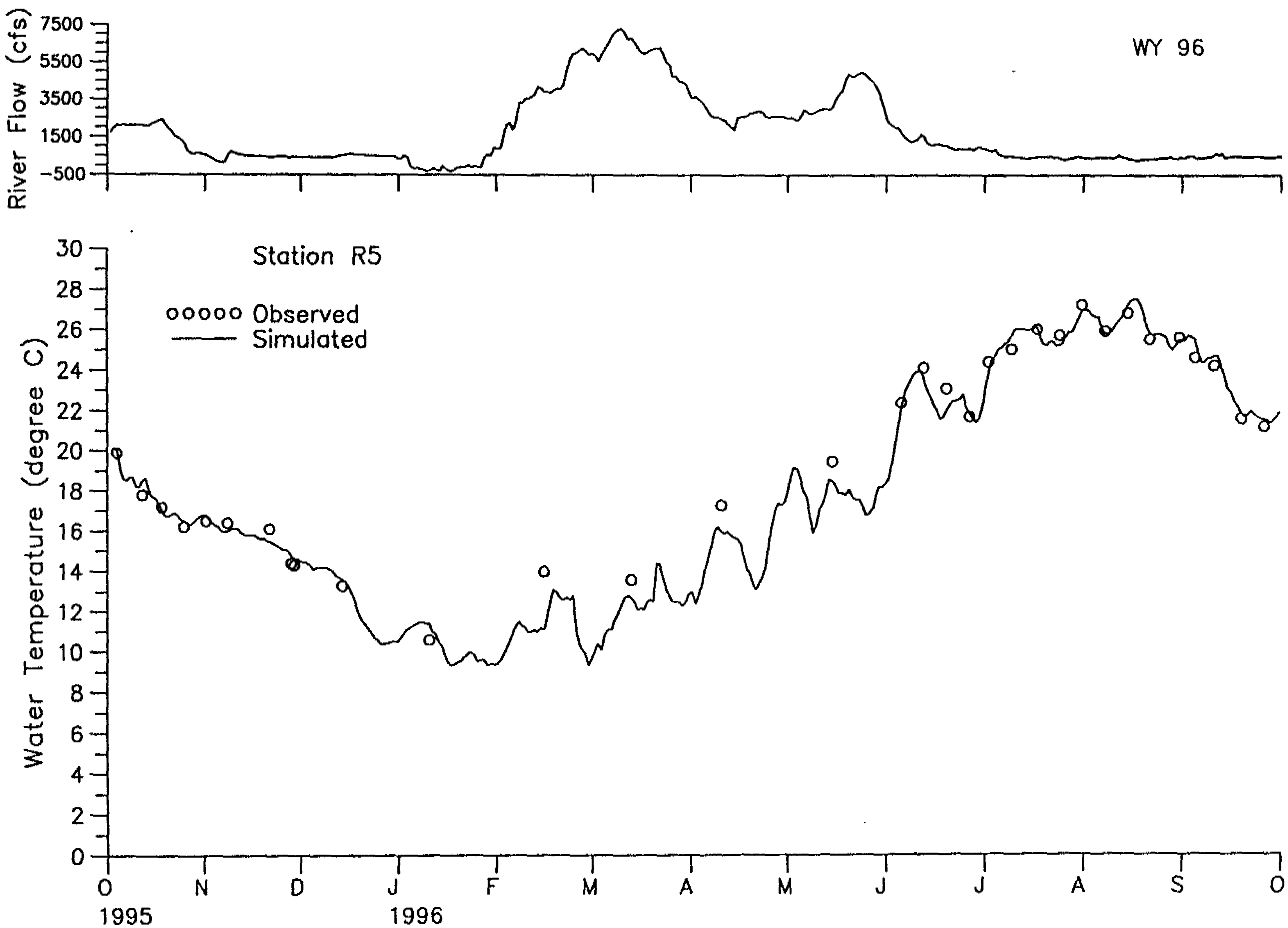

River Flow (cfs)
7500
5500
3500
1500
-500
WY 96
Station R2
ooooo Observed
Simulated
Water Temperature (degree C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D-041550

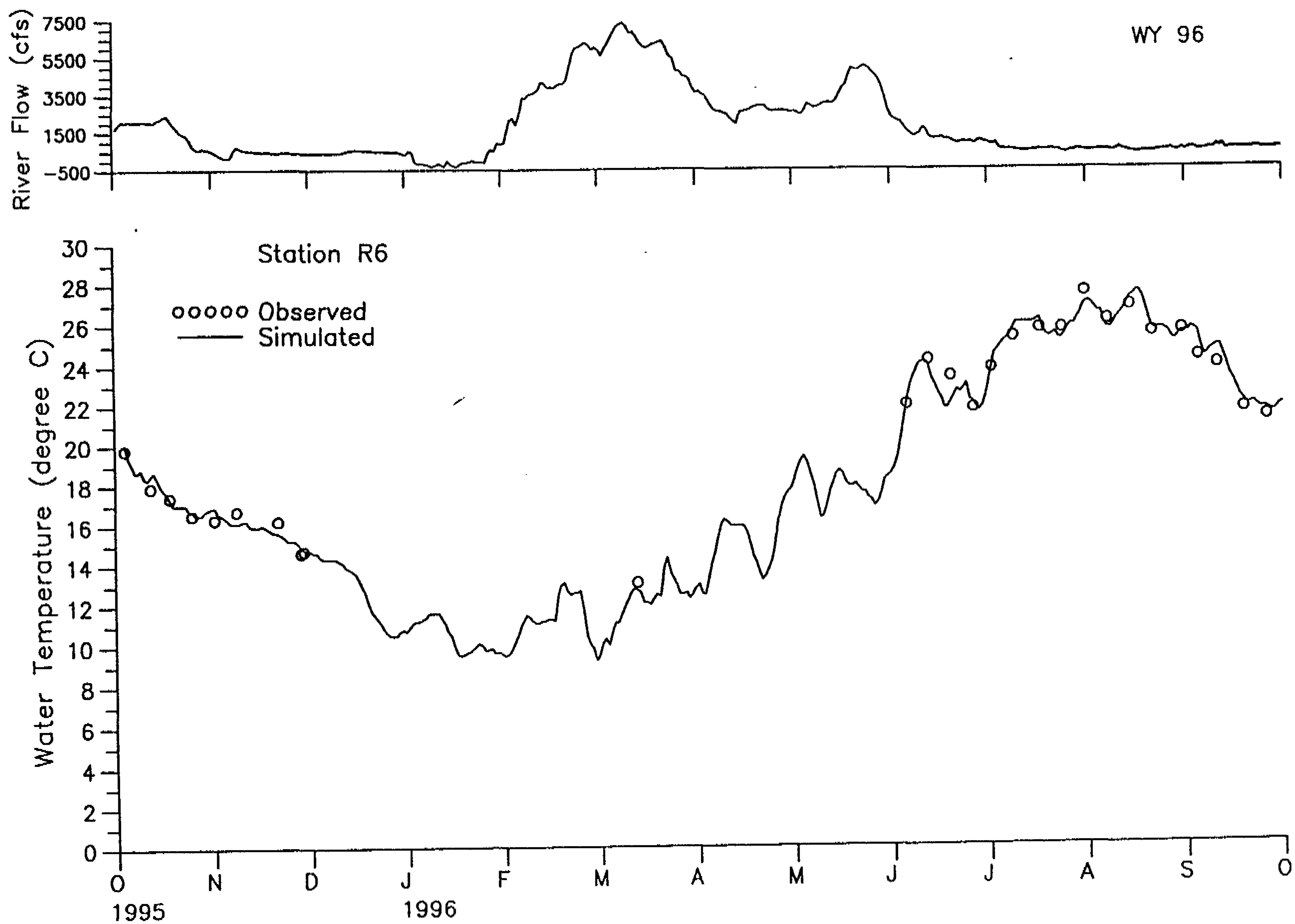


River Flow (cfs)
7500
5500
3500
1500
-500
WY 96
Station R3
oooooo Observed
Simulated
Water Temperature (degree C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

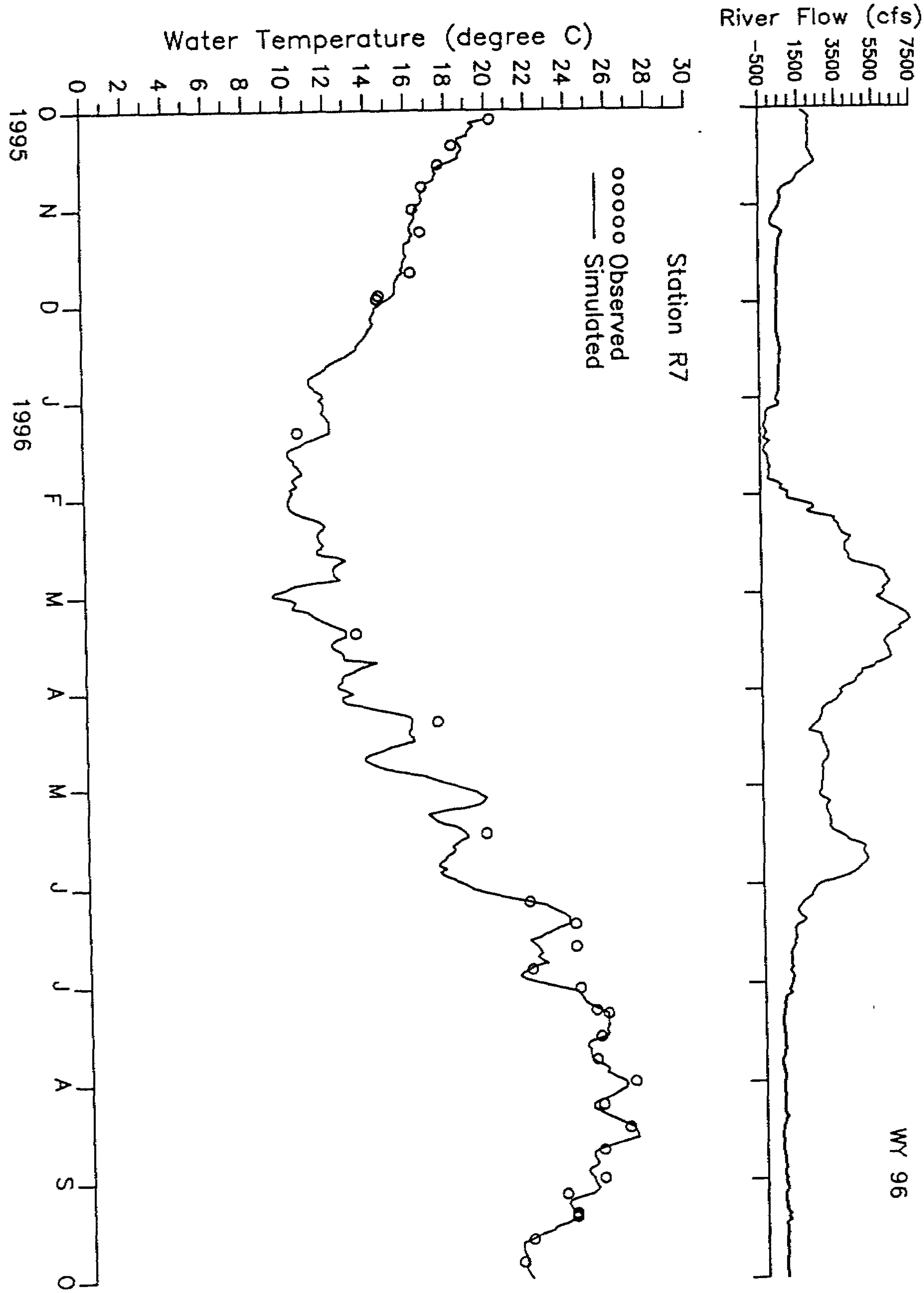

River Flow (cfs)
7500
5500
3500
1500
-500
WY 96
Station R4
ooooo Observed
Simulated
Water Temperature (degree C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
O N D J F M A M J J A S O
1995
1996



WY 96
River Flow (cfs)
7500
5500
3500
1500
-500
Station R5
ooooo Observed
Simulated
Water Temperature (degree C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

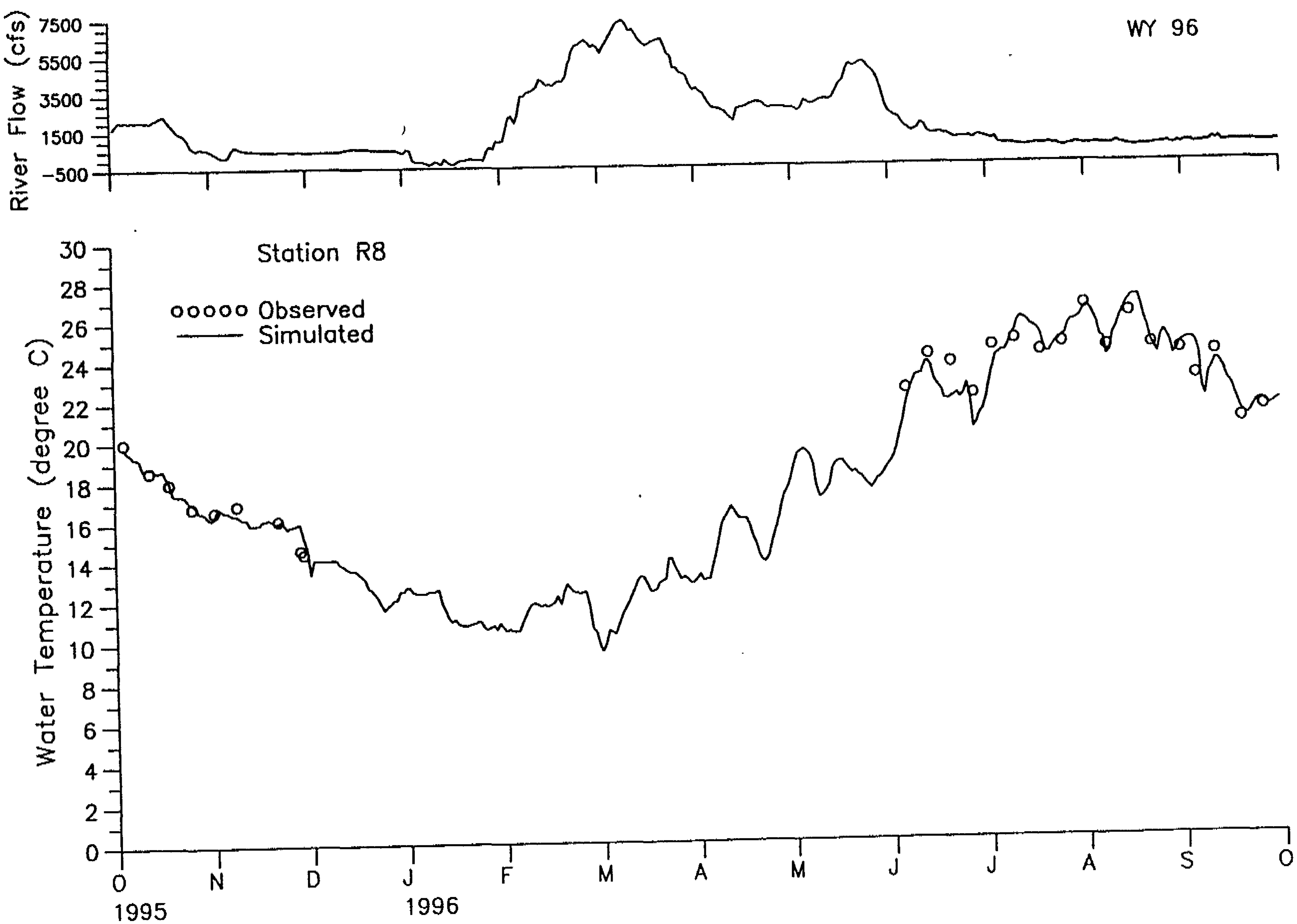


River Flow (cfs)
7500
5500
3500
1500
-500
WY 96
Station R6
ooooo Observed
Simulated
Water Temperature (degree C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

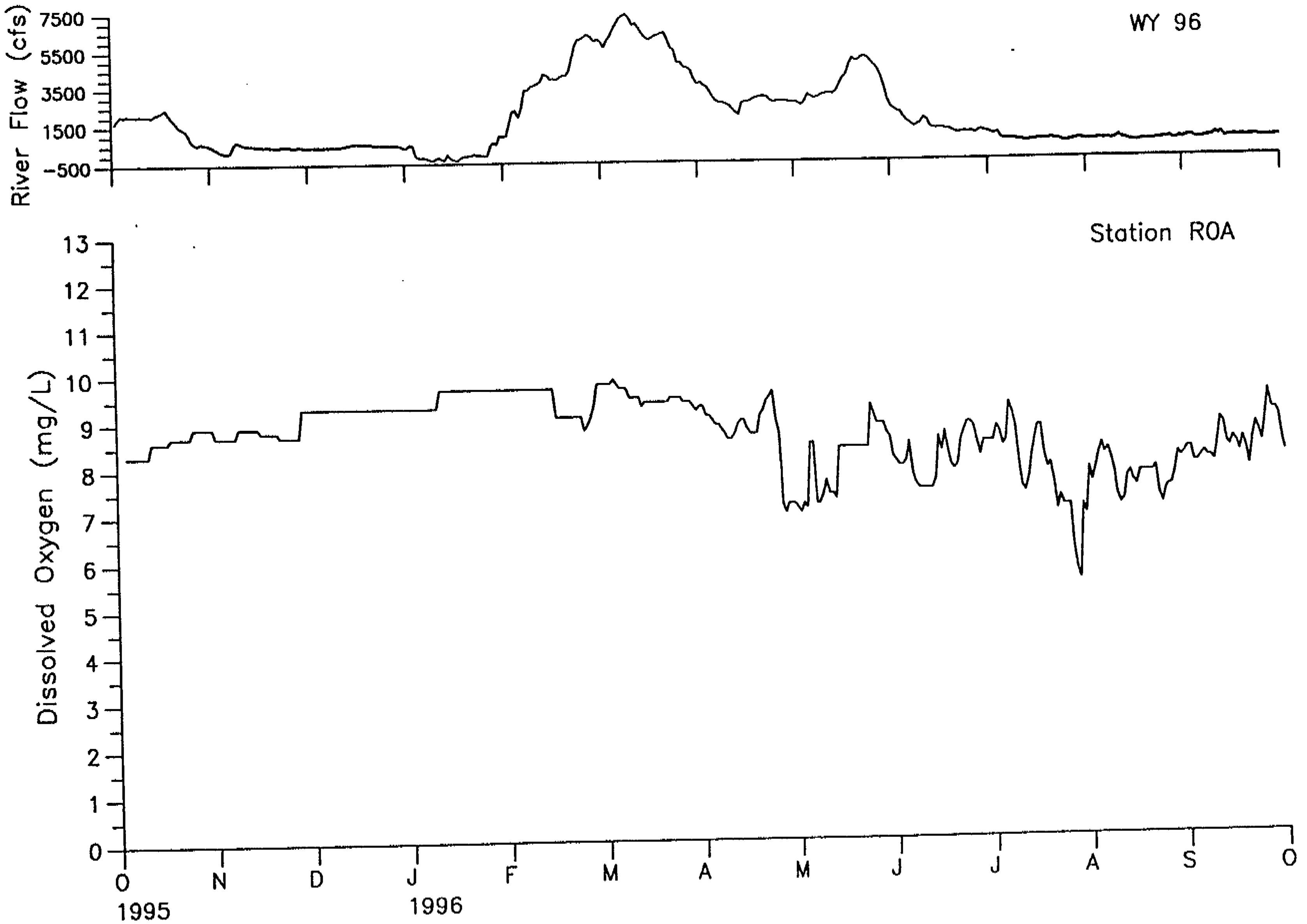


D —0 4 1 5 5 5

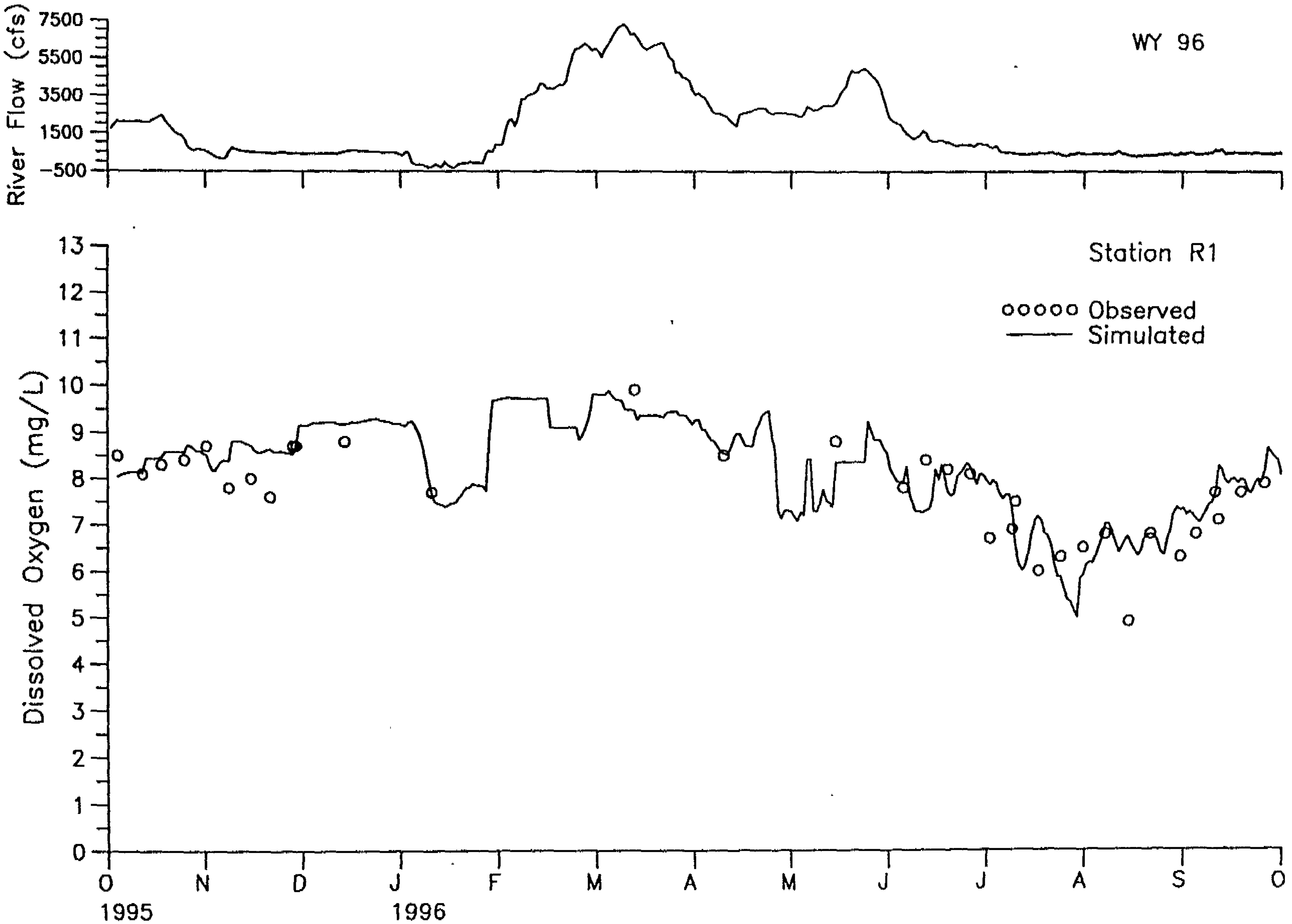
D-041555



WY 96
River Flow (cfs)
7500
5500
3500
1500
-500
Station R8
ooooo Observed
Simulated
Water Temperature (degree C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

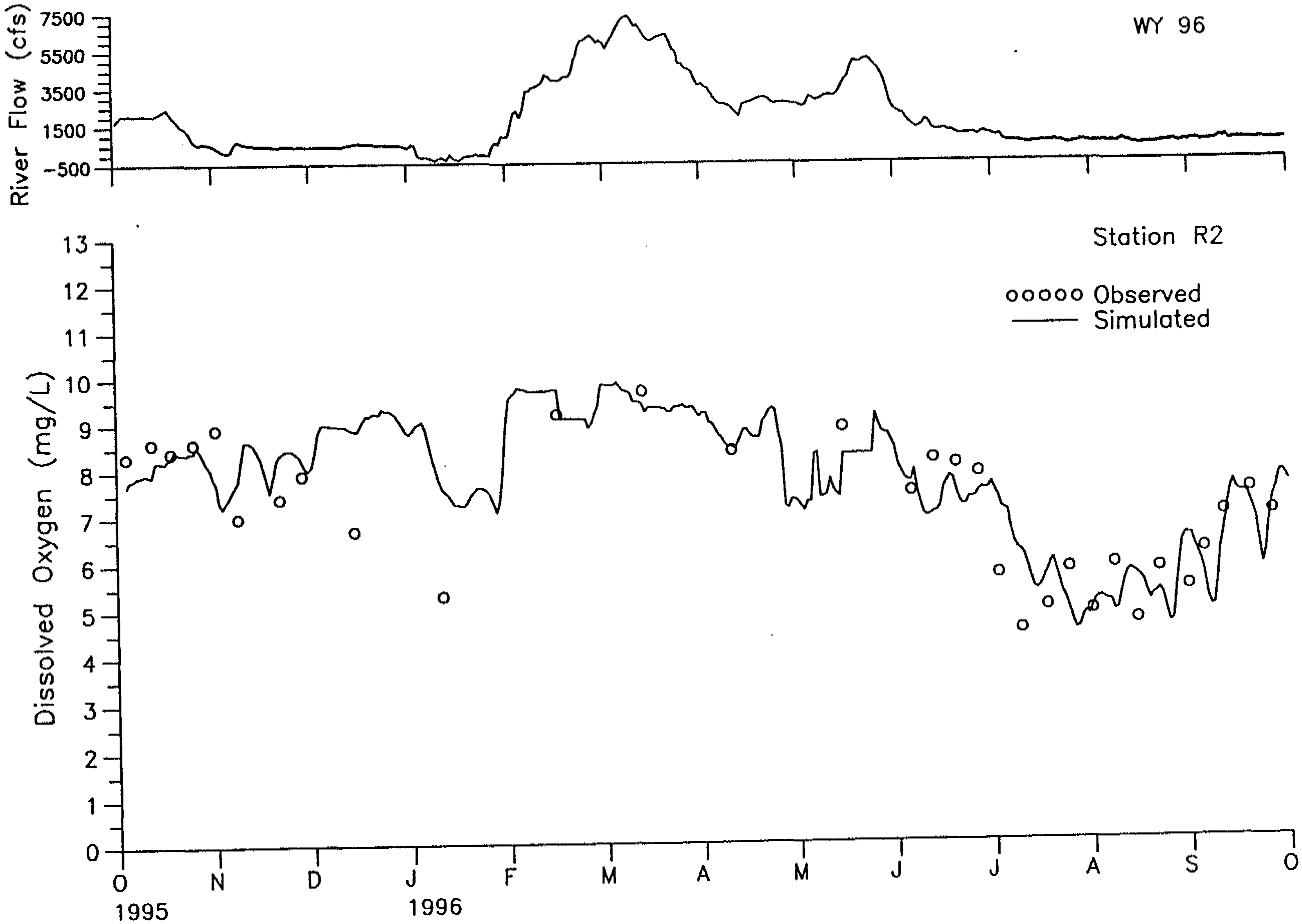


WY 96
River Flow (cfs)
7500
5500
3500
1500
-500
Station ROA
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996



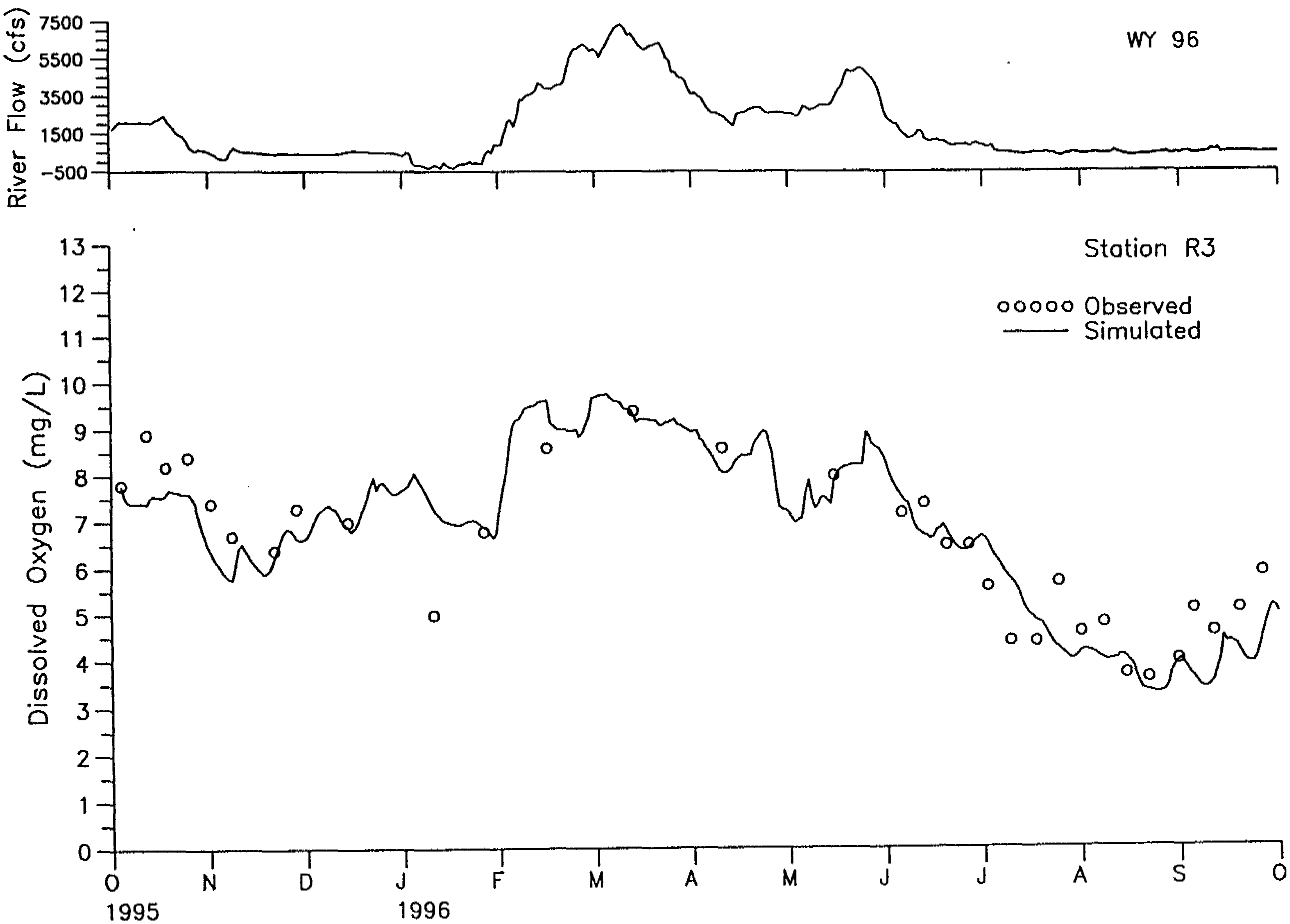
D-041558

D-041558

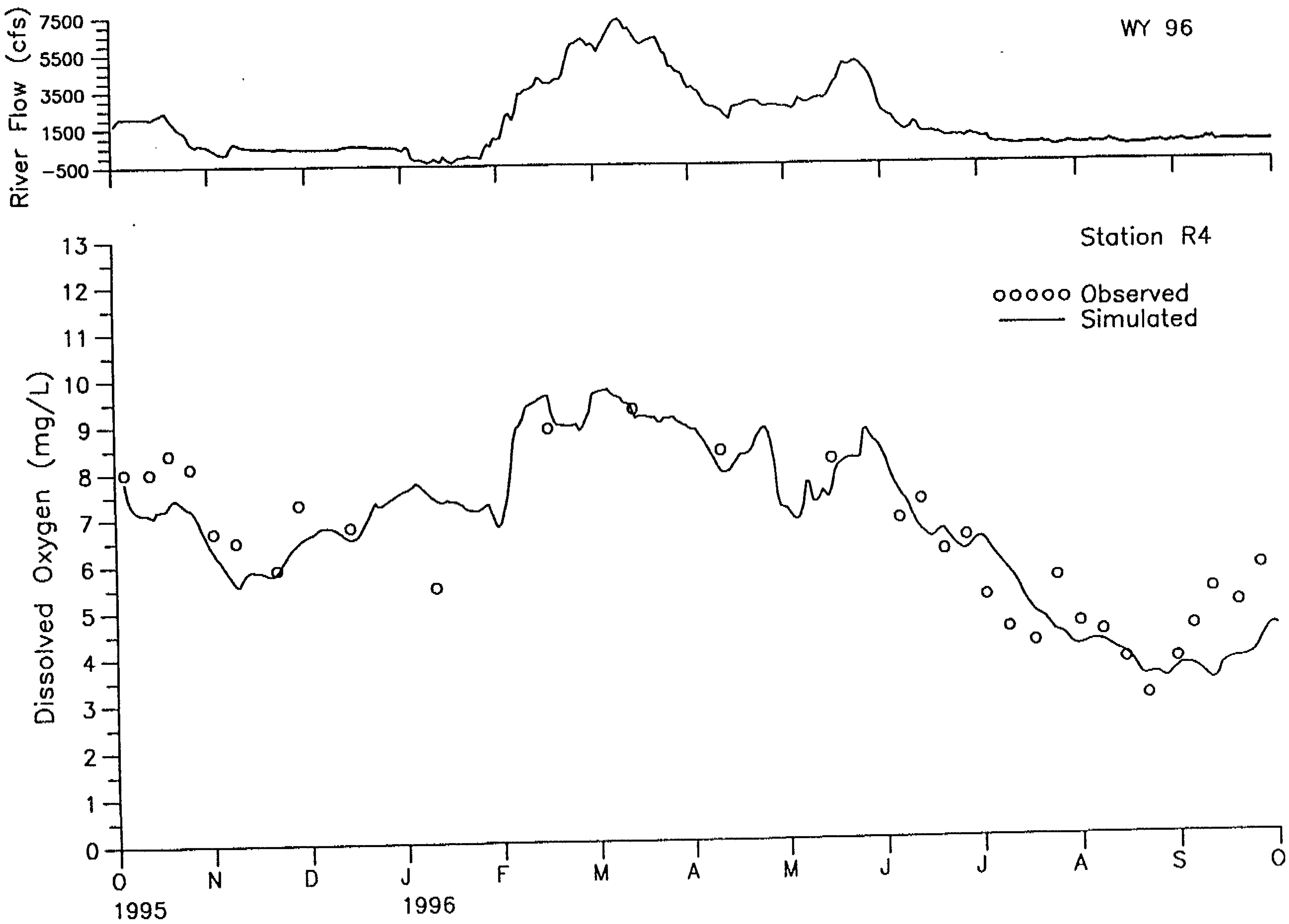


D —0 4 1 5 5 9

D-041559

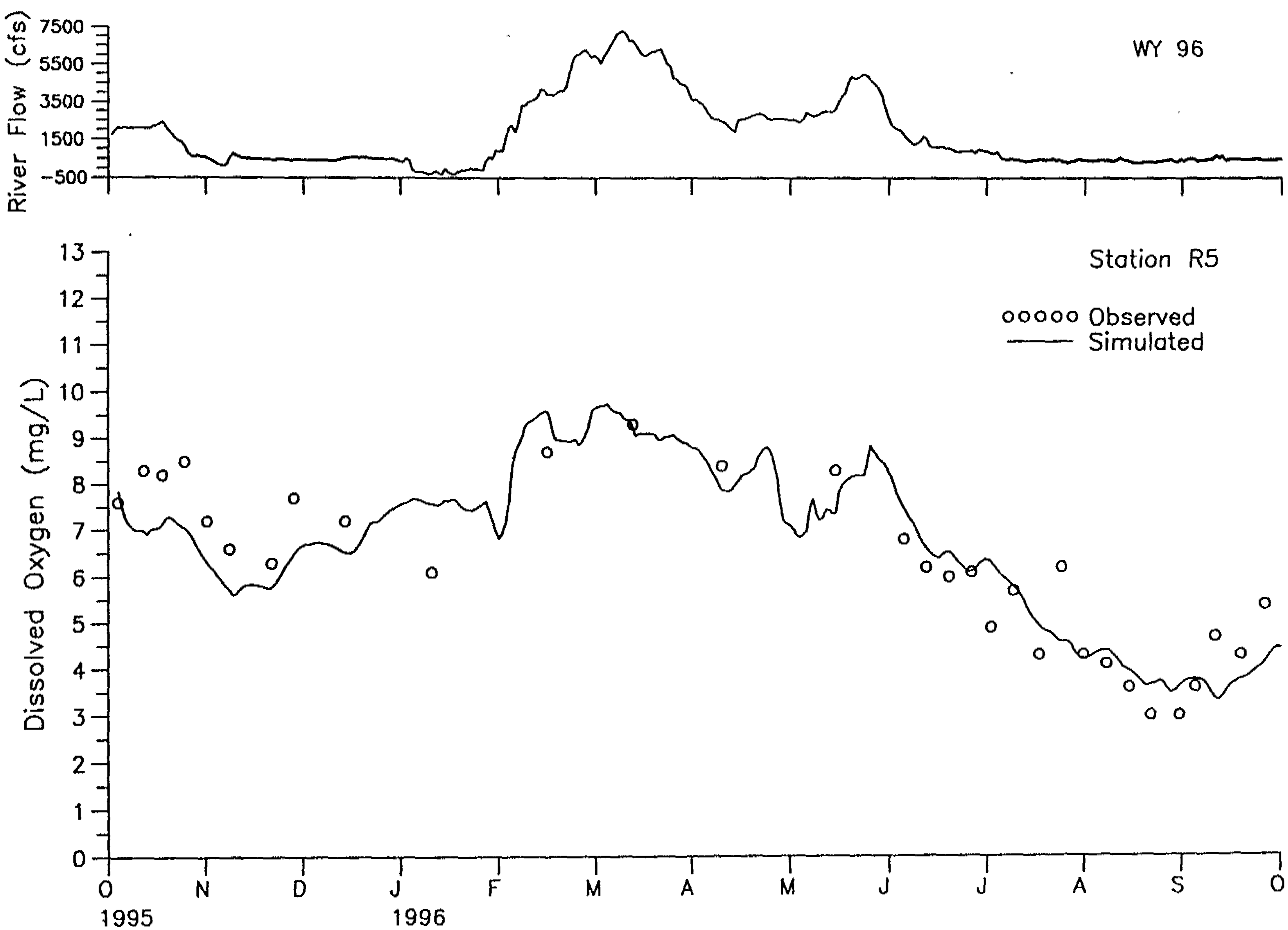


River Flow (cfs)
7500
5500
3500
1500
-500
WY 96
Station R3
ooooo Observed
Simulated
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996



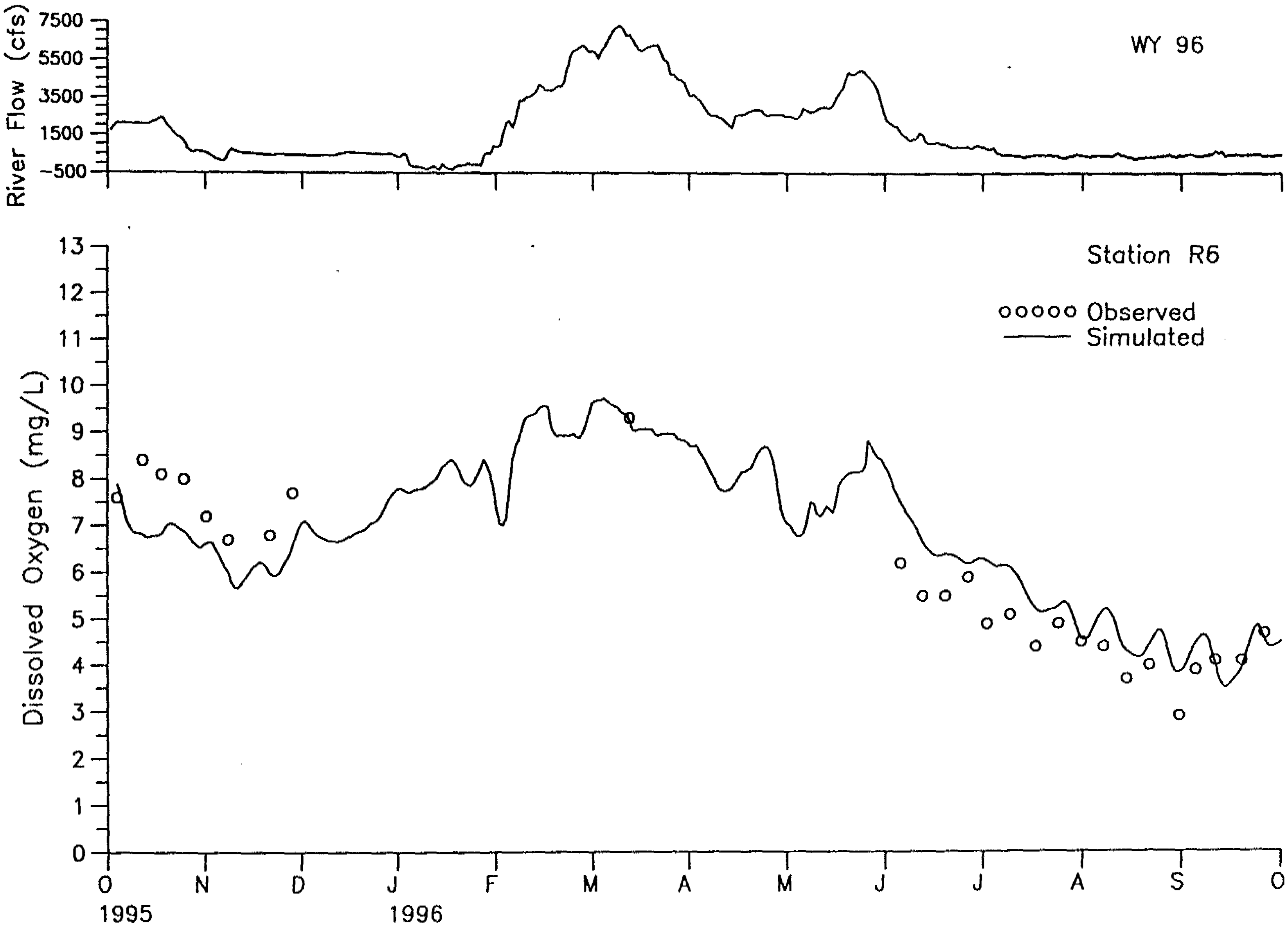
D-041561

D-041561



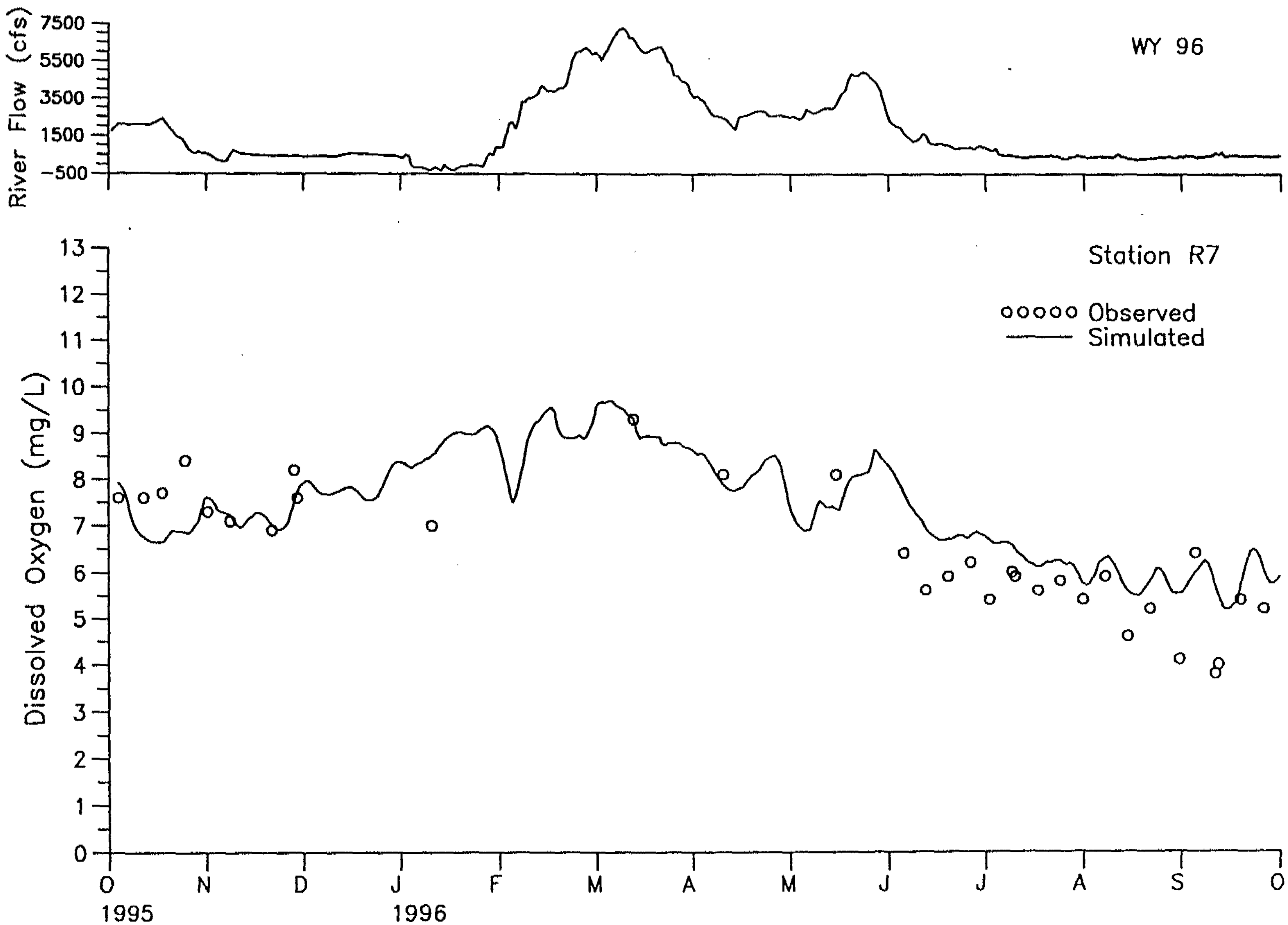
River Flow (cfs)
7500
5500
3500
1500
-500
WY 96
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Station R5
ooooo Observed
Simulated
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D-041562

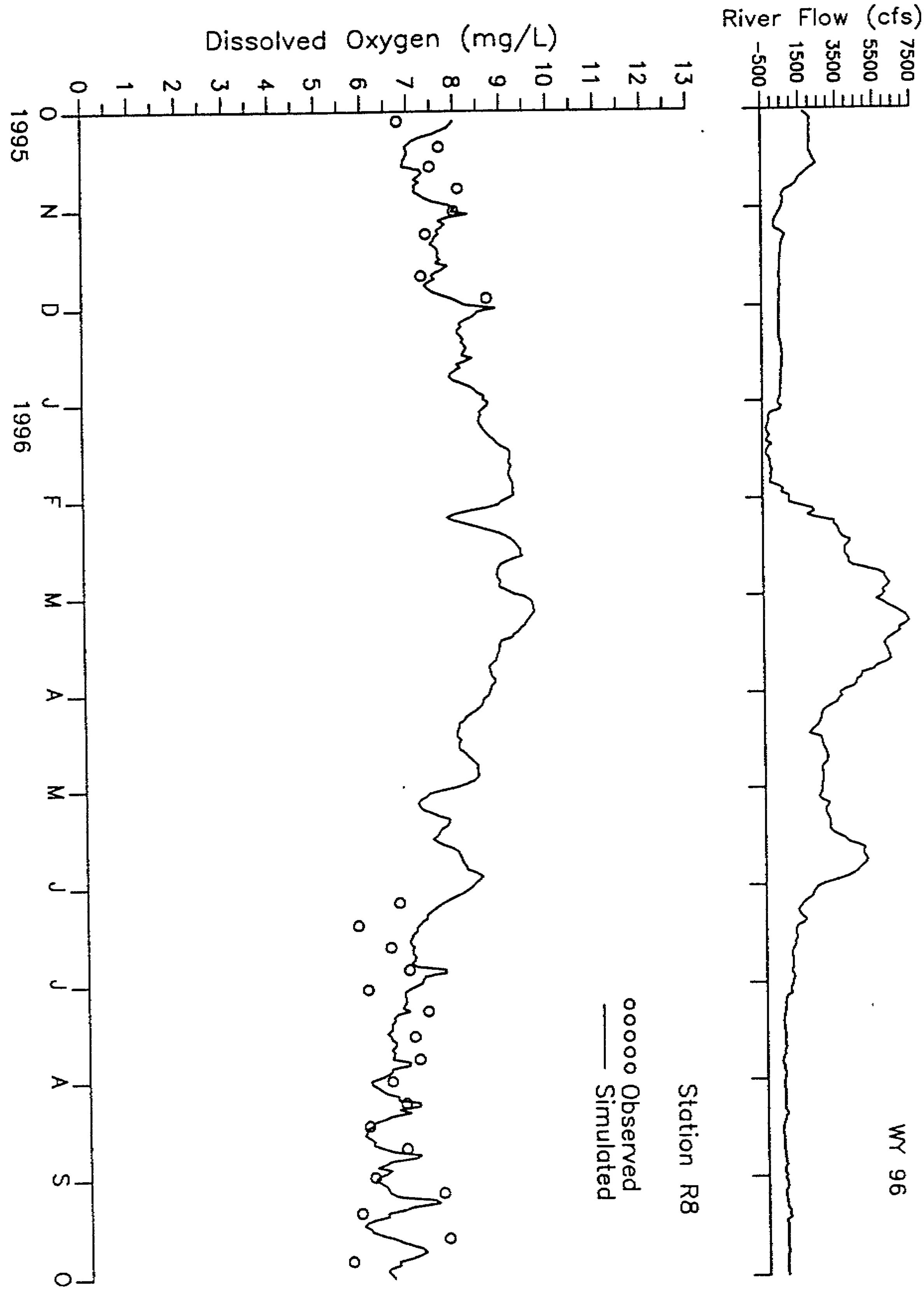


D-041563

D-041563


River Flow (cfs)
7500
5500
3500
1500
-500
WY 96
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Station R7
oooooo Observed
Simulated
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D-041564



Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
River Flow (cfs)
-500
1500
3500
5500
7500
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996
Station R8
ooooo Observed
—— Simulated
WY 96

D-041565

Appendix D.

The Flow of San Joaquin River Projected by DWR

D-041566

Run 467 - SWRCB 1995 WQCP W/ temporary barriers
Average Flow DWRDSM Channel 8

Year	T01	T02	T03	T04	T05	T06	T07	T08	T09	T10	T11	T12	T13	T14	T15	T16	T17	T18
1922	1404.	1404.	1281.	1281.	377.	377.	468.	468.	2364.	1805.	1930.	1930.	4062.	2606.	2606.	141.	-7.	1384.
1923	2737.	2737.	1554.	1554.	983.	983.	1314.	1314.	1331.	496.	1402.	1402.	3258.	434.	434.	30.	-50.	1358.
1924	2234.	2234.	1129.	1129.	-33.	-33.	-15.	-15.	28.	188.	463.	463.	1111.	119.	119.	187.	225.	1003.
1925	1118.	1118.	1116.	1116.	37.	37.	275.	275.	468.	382.	944.	944.	2589.	251.	251.	-52.	71.	1203.
1926	1290.	1290.	1119.	1119.	119.	119.	-32.	-32.	535.	58.	712.	712.	1964.	129.	129.	-158.	111.	1069.
1927	1251.	1251.	1439.	1439.	238.	238.	72.	72.	1794.	1006.	1601.	1601.	3179.	321.	321.	-23.	-75.	1970.
1928	2986.	2986.	1366.	1366.	308.	308.	415.	415.	565.	1093.	1364.	1364.	2207.	146.	146.	-101.	-140.	1120.
1929	1115.	1115.	1104.	1104.	-57.	-57.	18.	18.	-8.	174.	370.	370.	1386.	95.	95.	-87.	104.	1005.
1930	1221.	1221.	1076.	1076.	-87.	-87.	-69.	-69.	21.	215.	298.	298.	1419.	44.	44.	-186.	-42.	1007.
1931	1459.	1459.	1041.	1041.	95.	95.	94.	94.	2.	67.	258.	258.	1128.	103.	103.	15.	238.	1007.
1932	1126.	1126.	1110.	1110.	658.	658.	818.	818.	3211.	1455.	1655.	1655.	2643.	401.	401.	29.	113.	1291.
1933	2498.	2498.	1132.	1132.	182.	182.	139.	139.	171.	203.	619.	619.	1644.	100.	100.	-28.	204.	1052.
1934	1130.	1130.	1091.	1091.	-4.	-4.	21.	21.	367.	31.	497.	497.	1139.	52.	52.	-40.	92.	1037.
1935	1122.	1122.	1118.	1118.	214.	214.	584.	584.	970.	869.	2547.	2547.	2133.	1241.	1241.	55.	124.	1353.
1936	2264.	2264.	1155.	1155.	-7.	-7.	291.	291.	4817.	1963.	2217.	2217.	4233.	623.	623.	6.	-45.	1358.
1937	2192.	2192.	1172.	1172.	111.	111.	532.	532.	5711.	4100.	2835.	2835.	2949.	646.	646.	137.	85.	1417.
1938	2254.	2254.	1328.	1328.	1608.	1608.	2434.	2434.	9540.	13534.	6959.	6959.	9561.	6016.	6016.	1071.	76.	1878.
1939	3280.	3280.	1695.	1695.	370.	370.	534.	534.	1051.	636.	651.	651.	1831.	123.	123.	-79.	-59.	1167.
1940	1205.	1205.	1150.	1150.	198.	198.	1118.	1118.	3013.	3860.	2234.	2234.	4505.	325.	325.	18.	0.	1432.
1941	1829.	1829.	1312.	1312.	1128.	1128.	1319.	1319.	6146.	4457.	3696.	3696.	3518.	2991.	2991.	215.	151.	1355.
1942	3313.	3313.	1725.	1725.	1757.	1757.	3369.	3369.	3830.	2045.	2419.	2419.	2008.	1939.	1939.	357.	62.	1517.
1943	2548.	2548.	2201.	2201.	926.	926.	4144.	4144.	4039.	6853.	2831.	2831.	2169.	720.	720.	91.	31.	1437.
1944	2405.	2405.	1351.	1351.	162.	162.	287.	287.	1087.	768.	884.	884.	2459.	203.	203.	-59.	-57.	1306.
1945	1319.	1319.	1361.	1361.	48.	48.	40.	40.	3250.	2898.	2272.	2272.	4063.	471.	471.	54.	-13.	1452.
1946	2746.	2746.	1657.	1657.	1870.	1870.	2251.	2251.	2163.	1365.	1580.	1580.	3579.	311.	311.	6.	5.	1441.
1947	1672.	1672.	1734.	1734.	479.	479.	240.	240.	495.	226.	292.	292.	1532.	96.	96.	-127.	-139.	1130.
1948	1137.	1137.	1083.	1083.	71.	71.	7.	7.	-9.	215.	974.	974.	2754.	255.	255.	-51.	-75.	1261.
1949	1168.	1168.	1113.	1113.	-62.	-62.	-79.	-79.	3.	468.	634.	634.	2076.	143.	143.	-89.	-66.	1224.
1950	1172.	1172.	1117.	1117.	77.	77.	-28.	-28.	400.	378.	672.	672.	2075.	101.	101.	-96.	-98.	1208.
1951	1181.	1181.	4068.	4068.	5277.	5277.	4666.	4666.	3641.	2140.	964.	964.	2747.	162.	162.	-19.	-44.	1351.
1952	1387.	1387.	1261.	1261.	400.	400.	2741.	2741.	2965.	4592.	3996.	3996.	5889.	4153.	4153.	588.	-1.	1579.
1953	3077.	3077.	1600.	1600.	758.	758.	1646.	1646.	1974.	1014.	591.	591.	2145.	122.	122.	-39.	-79.	1233.
1954	1194.	1194.	1117.	1117.	-49.	-49.	63.	63.	196.	408.	1103.	1103.	2358.	174.	174.	-79.	-81.	1237.
1955	1176.	1176.	1109.	1109.	-52.	-52.	-16.	-16.	26.	156.	366.	366.	1883.	130.	130.	-111.	-128.	1167.
1956	1160.	1160.	1117.	1117.	4614.	4614.	8553.	8553.	6040.	2251.	1533.	1533.	2162.	2704.	2704.	235.	-25.	1412.
1957	2174.	2174.	1456.	1456.	196.	196.	184.	184.	858.	757.	512.	512.	2319.	198.	198.	-38.	-91.	1207.
1958	1252.	1252.	1143.	1143.	-39.	-39.	12.	12.	1293.	4301.	5676.	5676.	4973.	4849.	4849.	270.	39.	1532.
1959	2789.	2789.	1563.	1563.	166.	166.	439.	439.	1458.	1023.	340.	340.	1462.	84.	84.	-106.	-142.	1115.
1960	1120.	1120.	1085.	1085.	90.	90.	21.	21.	116.	150.	423.	423.	1513.	94.	94.	-106.	37.	1092.
1961	1098.	1098.	1076.	1076.	-69.	-69.	-76.	-76.	35.	65.	150.	150.	1137.	53.	53.	-117.	-113.	1047.
1962	1115.	1115.	1074.	1074.	-86.	-86.	-99.	-99.	2045.	1413.	1258.	1258.	2302.	128.	128.	-105.	-127.	1176.
1963	1160.	1160.	1092.	1092.	-67.	-67.	47.	47.	2110.	550.	1789.	1789.	4042.	631.	631.	91.	-33.	1364.
1964	2183.	2183.	1592.	1592.	81.	81.	126.	126.	198.	301.	296.	296.	1568.	100.	100.	-155.	-158.	1047.
1965	1159.	1159.	1227.	1227.	1431.	1431.	4420.	4420.	2788.	1565.	2433.	2433.	4191.	762.	762.	83.	-16.	1272.
1966	3125.	3125.	2508.	2508.	1570.	1570.	1590.	1590.	1963.	1040.	394.	394.	1741.	121.	121.	-92.	-116.	1156.
1967	1238.	1238.	1148.	1148.	440.	440.	635.	635.	1220.	2480.	5143.	5143.	6121.	6003.	6003.	3467.	-26.	2028.
1968	3330.	3330.	1524.	1524.	365.	365.	428.	428.	1285.	642.	411.	411.	1620.	99.	99.	-90.	-108.	1122.
1969	1228.	1228.	1129.	1129.	56.	56.	5620.	5620.	13368.	8228.	8166.	8166.	10393.	7110.	7110.	1328.	34.	1843.
1970	3087.	3087.	1858.	1858.	1017.	1017.	6559.	6559.	3478.	2659.	1193.	1193.	2935.	221.	221.	-34.	-38.	1380.
1971	1354.	1354.	1290.	1290.	252.	252.	287.	287.	1045.	1168.	599.	599.	2244.	104.	104.	-47.	-104.	1220.
1972	1195.	1195.	1096.	1096.	-21.	-21.	-55.	-55.	247.	170.	196.	196.	1320.	62.	62.	-97.	-141.	1029.

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1973	1150.	1150.	1115.	1115.	-45.	-45.	498.	498.	2896.	3295.	2284.	2284.	1884.	536.	536.	6.	-62.	1366.
1974	2418.	2418.	1792.	1792.	551.	551.	3246.	3246.	2504.	3036.	2715.	2715.	1867.	547.	547.	51.	-31.	1385.
1975	2803.	2803.	1539.	1539.	337.	337.	464.	464.	2306.	3188.	2298.	2298.	4518.	2209.	2209.	88.	-1.	1350.
1976	2819.	2819.	1350.	1350.	85.	85.	70.	70.	482.	114.	231.	231.	1241.	83.	83.	-99.	-38.	1071.
1977	2053.	2053.	1594.	1594.	246.	246.	316.	316.	174.	230.	54.	54.	1174.	247.	247.	209.	249.	1036.
1978	1175.	1175.	1134.	1134.	14.	14.	734.	734.	2504.	4093.	5685.	5685.	4027.	2550.	2550.	696.	79.	1917.
1979	2889.	2889.	1438.	1438.	88.	88.	1276.	1276.	3444.	3139.	1780.	1780.	3938.	257.	257.	-17.	-68.	1332.
1980	2056.	2056.	1274.	1274.	89.	89.	5886.	5886.	9904.	5522.	2363.	2363.	2357.	2184.	2184.	1165.	45.	1870.
1981	1807.	1807.	1543.	1543.	271.	271.	749.	749.	617.	693.	565.	565.	1693.	102.	102.	-108.	-138.	1144.
1982	1271.	1271.	1207.	1207.	151.	151.	3382.	3382.	7652.	5843.	10786.	10786.	5769.	3625.	3625.	829.	-1.	2713.
1983	4741.	4741.	3092.	3092.	7371.	7371.	9922.	9922.	15012.	17041.	8101.	8101.	7400.	14837.	14837.	5105.	-104.	2444.
1984	4521.	4521.	5106.	5106.	8441.	8441.	5805.	5805.	3743.	2091.	997.	997.	2715.	217.	217.	6.	55.	1452.
1985	1349.	1349.	1327.	1327.	44.	44.	99.	99.	832.	398.	393.	393.	1672.	118.	118.	-117.	-139.	1132.
1986	1222.	1222.	1200.	1200.	-18.	-18.	156.	156.	10727.	10540.	3603.	3603.	2923.	2744.	2744.	35.	126.	1431.
1987	2433.	2433.	1289.	1289.	44.	44.	51.	51.	318.	294.	377.	377.	1322.	67.	67.	-113.	-154.	1097.
1988	1108.	1108.	1085.	1085.	-91.	-91.	-97.	-97.	-24.	169.	425.	425.	1228.	59.	59.	-95.	-107.	1045.
1989	1109.	1109.	1052.	1052.	132.	132.	188.	188.	73.	-2.	186.	186.	1361.	52.	52.	-135.	66.	1043.
1990	1098.	1098.	1043.	1043.	-100.	-100.	-39.	-39.	47.	116.	220.	220.	1227.	48.	48.	-151.	99.	1029.
1991	1094.	1094.	1059.	1059.	132.	132.	304.	304.	104.	325.	365.	365.	1542.	117.	117.	88.	256.	1003.
1992	1130.	1130.	1143.	1143.	195.	195.	237.	237.	324.	211.	329.	329.	1354.	94.	94.	44.	218.	1130.
1993	1193.	1193.	1156.	1156.	-24.	-24.	2075.	2075.	1044.	657.	884.	884.	4465.	1728.	1728.	114.	33.	1481.
1994	2940.	2940.	1372.	1372.	-36.	-36.	102.	102.	276.	88.	241.	241.	1538.	123.	123.	-61.	-43.	1109.

Tides

T01	Oct	1 - 15
T02	Oct	16 - 31
T03	Nov	1 - 10
T04	Nov	11 - 30
T05	Dec	1 - 15
T06	Dec	16 - 31
T07	Jan	1 - 20
T08	Jan	21 - 31
T09	Feb	1 - 28
T10	Mar	1 - 31
T11	Apr	1 - 15
T12	Apr	16 - 30
T13	May	1 - 31
T14	Jun	1 - 4
T15	Jun	5 - 30
T16	Jul	1 - 31
T17	Aug	1 - 31
T18	Sep	1 - 30

Run 469A - SWRCB 1995 WQCP w/ temporary barriers
Average Flow DWRDSM Channel 8

Year	T01	T02	T03	T04	T05	T06	T07	T08	T09	T10	T11	T12	T13	T14	T15	T16	T17	T18
1922	1487.	1487.	1284.	1274.	385.	377.	476.	466.	2369.	1807.	2155.	2155.	2030.	2518.	2518.	235.	228.	1385.
1923	2736.	2736.	1564.	1553.	1057.	1057.	1314.	1314.	1395.	944.	1823.	1823.	1756.	330.	326.	66.	138.	1339.
1924	2214.	2214.	1104.	1096.	-5.	-9.	-55.	-59.	112.	364.	459.	459.	1740.	322.	322.	308.	318.	949.
1925	1420.	1420.	1051.	1045.	-40.	-43.	40.	38.	460.	459.	1250.	1250.	3743.	297.	293.	131.	269.	1218.
1926	1402.	1402.	1072.	1064.	26.	23.	-145.	-148.	352.	402.	1109.	1109.	3399.	220.	217.	-147.	215.	1063.
1927	1437.	1437.	1417.	1403.	106.	101.	52.	52.	1753.	1013.	1810.	1810.	1708.	893.	882.	104.	241.	1483.
1928	2976.	2976.	1379.	1365.	344.	336.	414.	414.	564.	652.	1204.	1204.	3674.	241.	238.	-69.	-9.	1126.
1929	1409.	1409.	1053.	1043.	-73.	-77.	-144.	-146.	74.	212.	482.	482.	1757.	251.	250.	201.	260.	934.
1930	1388.	1388.	964.	959.	-142.	-144.	-134.	-137.	160.	289.	612.	612.	1822.	45.	44.	-187.	-49.	1002.
1931	1133.	1133.	922.	914.	86.	85.	-78.	-81.	170.	233.	450.	450.	1886.	176.	175.	275.	376.	962.
1932	1008.	1008.	1012.	1007.	666.	650.	832.	818.	2992.	1548.	1518.	1518.	3739.	321.	316.	199.	310.	1276.
1933	2292.	2292.	1112.	1105.	176.	175.	78.	74.	369.	433.	757.	757.	2564.	413.	411.	250.	395.	1024.
1934	1406.	1406.	988.	982.	-87.	-90.	-140.	-143.	273.	283.	428.	428.	1865.	118.	117.	102.	202.	1012.
1935	1384.	1384.	1065.	1058.	100.	98.	583.	583.	950.	877.	2226.	2226.	2123.	1157.	1147.	211.	327.	1342.
1936	2254.	2254.	1171.	1163.	134.	130.	291.	291.	4813.	1910.	2233.	2233.	1761.	312.	307.	137.	196.	1348.
1937	1938.	1938.	1181.	1172.	160.	154.	475.	466.	4833.	3639.	2862.	2862.	2940.	556.	549.	264.	314.	1428.
1938	2242.	2242.	1342.	1327.	1602.	1602.	2480.	2480.	8870.	12531.	6954.	6954.	9410.	5189.	5189.	1043.	211.	1877.
1939	3196.	3196.	1709.	1699.	411.	403.	535.	526.	1092.	668.	798.	798.	2556.	134.	131.	-40.	34.	1149.
1940	1497.	1497.	1139.	1133.	218.	216.	1118.	1104.	2971.	3833.	1951.	1951.	1759.	930.	920.	69.	391.	1408.
1941	1705.	1705.	1286.	1275.	1062.	1062.	1264.	1264.	5533.	4265.	3696.	3696.	3471.	2940.	2939.	365.	271.	1364.
1942	3313.	3313.	1656.	1646.	1416.	1416.	3067.	3067.	3822.	2045.	2430.	2430.	2038.	1859.	1859.	424.	240.	1514.
1943	2408.	2408.	2208.	2202.	1002.	1002.	4144.	4144.	4040.	6861.	2833.	2833.	2135.	910.	900.	242.	312.	1425.
1944	2400.	2400.	1360.	1348.	155.	149.	308.	302.	851.	768.	1069.	1069.	2862.	228.	225.	-6.	72.	1305.
1945	1497.	1497.	1374.	1363.	52.	48.	121:	116.	3270.	2848.	2026.	2026.	3756.	383.	378.	71.	181.	1436.
1946	2642.	2642.	1631.	1620.	1828.	1828.	1855.	1855.	2040.	1365.	1847.	1847.	3750.	343.	339.	39.	103.	1425.
1947	1661.	1661.	1730.	1722.	488.	479.	263.	257.	580.	393.	1138.	1138.	2532.	107.	105.	-104.	18.	1148.
1948	1441.	1441.	1025.	1017.	96.	95.	-152.	-155.	155.	196.	1249.	1249.	3696.	332.	326.	70.	216.	1238.
1949	1475.	1475.	1074.	1063.	-113.	-116.	-141.	-144.	64.	420.	1284.	1284.	2833.	198.	195.	-49.	104.	1227.
1950	1484.	1484.	1084.	1076.	27.	24.	-34.	-38.	392.	371.	1249.	1249.	3671.	132.	130.	-63.	25.	1204.
1951	1490.	1490.	3249.	3249.	3512.	3512.	3743.	3743.	3357.	2133.	1855.	1855.	1747.	321.	317.	35.	71.	1342.
1952	1483.	1483.	1261.	1249.	394.	394.	2409.	2409.	2208.	4217.	4003.	4003.	5857.	3368.	3368.	515.	124.	1591.
1953	3007.	3007.	1628.	1619.	765.	765.	1654.	1654.	1974.	1039.	1278.	1278.	3683.	294.	294.	0.	165.	1218.
1954	1467.	1467.	1131.	1117.	50.	47.	29.	29.	355.	409.	1200.	1200.	3670.	253.	250.	-38.	45.	1235.
1955	1471.	1471.	1072.	1058.	-96.	-96.	27.	23.	411.	438.	807.	807.	2576.	173.	170.	-93.	185.	1143.
1956	1486.	1486.	1093.	1083.	4411.	4411.	8183.	8183.	5033.	2101.	2166.	2166.	2067.	2638.	2642.	144.	159.	1411.
1957	3196.	3196.	1222.	1210.	88.	83.	130.	126.	438.	756.	1251.	1251.	3714.	369.	364.	-20.	58.	1216.
1958	1478.	1478.	1144.	1131.	-55.	-59.	161.	161.	1302.	3942.	5676.	5676.	4930.	3696.	3696.	234.	125.	1532.
1959	3258.	3258.	1350.	1339.	241.	235.	440.	440.	1450.	1064.	784.	784.	2543.	84.	83.	-81.	-38.	1105.
1960	1400.	1400.	1008.	999.	22.	20.	-130.	-133.	109.	261.	587.	587.	1739.	109.	107.	-14.	242.	1096.
1961	1351.	1351.	1013.	1002.	-132.	-135.	-149.	-151.	-123.	29.	428.	428.	1767.	28.	27.	-93.	22.	1054.
1962	1030.	1030.	991.	983.	-160.	-162.	-38.	-40.	2004.	1440.	1377.	1377.	3672.	200.	197.	-80.	125.	1163.
1963	1480.	1480.	1055.	1041.	-127.	-127.	38.	33.	1430.	884.	1822.	1822.	1712.	880.	868.	190.	178.	1324.
1964	1696.	1696.	1580.	1580.	113.	107.	224.	224.	415.	433.	791.	791.	2536.	176.	173.	-145.	-47.	1055.
1965	1474.	1474.	1240.	1230.	1044.	1044.	3388.	3388.	2819.	1481.	2149.	2149.	2045.	890.	879.	122.	244.	1261.
1966	3008.	3008.	2447.	2447.	1536.	1530.	1605.	1605.	1737.	1040.	1292.	1292.	2838.	184.	182.	-59.	6.	1161.
1967	1483.	1483.	1162.	1150.	437.	437.	636.	636.	1220.	2442.	5136.	5136.	6096.	5169.	5169.	3163.	123.	2028.
1968	3287.	3287.	1315.	1304.	228.	222.	323.	323.	1320.	663.	1142.	1142.	2556.	121.	119.	-56.	21.	1111.
1969	1486.	1486.	1116.	1105.	55.	50.	5605.	5605.	12407.	7657.	8166.	8166.	10345.	7090.	7089.	1256.	178.	1843.
1970	2983.	2983.	1876.	1869.	1017.	1017.	6559.	6559.	3514.	2661.	1839.	1839.	1763.	355.	350.	12.	154.	1372.
1971	1482.	1482.	1303.	1289.	251.	251.	216.	216.	530.	1145.	1245.	1245.	3703.	302.	297.	-26.	25.	1205.
1972	1469.	1469.	1059.	1047.	-14.	-18.	38.	35.	374.	372.	1149.	1149.	2530.	93.	91.	-152.	-49.	1027.

1973	1453.	1453.	1054.	1040.	-94.	-94.	376.	376.	2783.	3243.	1964.	1964.	1752.	389.	384.	39.	166.	1342.
1974	2306.	2306.	1736.	1736.	483.	483.	2504.	2504.	1805.	2558.	2731.	2731.	2029.	864.	853.	72.	87.	1397.
1975	2476.	2476.	1297.	1285.	237.	231.	299.	293.	2080.	3188.	2320.	2320.	2025.	2135.	2131.	103.	141.	1350.
1976	2819.	2819.	1363.	1350.	165.	160.	103.	99.	281.	145.	450.	450.	1741.	37.	36.	-73.	102.	1043.
1977	2054.	2054.	1588.	1582.	263.	260.	134.	133.	274.	254.	449.	449.	1771.	305.	304.	335.	296.	853.
1978	961.	961.	992.	987.	-30.	-33.	785.	785.	2564.	4104.	5679.	5679.	3993.	2490.	2489.	747.	323.	1938.
1979	2898.	2898.	1450.	1438.	164.	159.	1234.	1234.	3436.	3132.	1840.	1840.	1764.	311.	307.	43.	243.	1299.
1980	2042.	2042.	1274.	1261.	87.	82.	5083.	5083.	9912.	5526.	2388.	2388.	2328.	2124.	2124.	1118.	245.	1871.
1981	1667.	1667.	1555.	1546.	313.	307.	741.	741.	666.	737.	1133.	1133.	2548.	117.	115.	-99.	-12.	1144.
1982	1496.	1496.	1210.	1210.	137.	137.	3378.	3378.	6339.	5843.	10784.	10784.	5739.	3578.	3578.	754.	136.	2723.
1983	4641.	4641.	3092.	3092.	7390.	7390.	9937.	9937.	15017.	17040.	8101.	8101.	7391.	14821.	14821.	5104.	25.	2302.
1984	4521.	4521.	5115.	5115.	8449.	8449.	5808.	5808.	3744.	2089.	1832.	1832.	1761.	318.	314.	45.	288.	1454.
1985	1479.	1479.	1329.	1329.	55.	49.	98.	94.	406.	400.	766.	766.	2543.	164.	162.	-99.	-25.	1120.
1986	1492.	1492.	1217.	1209.	-15.	-19.	135.	130.	8841.	10469.	3612.	3612.	2899.	2716.	2715.	268.	228.	1420.
1987	2423.	2423.	1287.	1279.	15.	11.	92.	88.	326.	302.	442.	442.	1741.	42.	40.	-89.	56.	1090.
1988	1349.	1349.	1001.	995.	-164.	-167.	-172.	-172.	56.	201.	467.	467.	1760.	104.	103.	189.	353.	996.
1989	985.	985.	902.	895.	72.	70.	-60.	-63.	251.	-9.	521.	521.	1748.	60.	59.	-119.	186.	1035.
1990	994.	994.	931.	922.	-139.	-142.	-102.	-105.	-6.	118.	428.	428.	1888.	3.	3.	-81.	304.	996.
1991	961.	961.	926.	920.	95.	94.	175.	175.	298.	303.	594.	594.	1864.	236.	236.	205.	226.	936.
1992	1027.	1027.	1101.	1095.	133.	132.	-77.	-80.	421.	295.	544.	544.	1854.	169.	168.	288.	258.	884.
1993	1187.	1187.	1141.	1135.	-24.	-27.	2069.	2069.	982.	920.	2155.	2155.	2050.	1626.	1626.	246.	319.	1485.
1994	2932.	2932.	1382.	1368.	-28.	-32.	67.	64.	267.	157.	457.	457.	1893.	133.	130.	-22.	-18.	1085.

Tides

T01	Oct 1 - 15
T02	Oct 16 - 31
T03	Nov 1 - 10
T04	Nov 11 - 30
T05	Dec 1 - 15
T06	Dec 16 - 31
T07	Jan 1 - 20
T08	Jan 21 - 31
T09	Feb 1 - 28
T10	Mar 1 - 31
T11	Apr 1 - 15
T12	Apr 16 - 30
T13	May 1 - 31
T14	Jun 1 - 4
T15	Jun 5 - 30
T16	Jul 1 - 31
T17	Aug 1 - 31
T18	Sep 1 - 30

Run 469B - SWRCB 1995 WQCP w/ permanent flow control structures
Average Flow DWRDSM Channel 8 (cfs)

Year	T01	T02	T03	T04	T05	T06	T07	T08	T09	T10	T11	T12	T13	T14	T15	T16	T17	T18
1922	1967.	1967.	1688.	1688.	382.	374.	472.	463.	2357.	1798.	2223.	6126.	5812.	3181.	3181.	575.	597.	1837.
1923	3928.	3928.	2088.	2088.	1051.	1051.	1307.	1307.	1388.	939.	1896.	5295.	5014.	699.	695.	416.	512.	1752.
1924	3055.	3055.	1442.	1442.	-3.	-6.	-53.	-56.	114.	370.	548.	1887.	1740.	628.	631.	609.	644.	1214.
1925	1841.	1841.	1352.	1352.	-35.	-38.	47.	46.	457.	457.	1330.	3939.	3743.	640.	637.	451.	602.	1585.
1926	1846.	1846.	1398.	1399.	32.	29.	-140.	-143.	349.	401.	1191.	3622.	3399.	530.	528.	142.	528.	1386.
1927	1886.	1886.	1885.	1885.	106.	101.	52.	52.	1744.	1007.	1888.	5287.	5018.	1307.	1302.	440.	580.	1969.
1928	4324.	4324.	1835.	1835.	342.	334.	414.	414.	561.	648.	1281.	3884.	3674.	554.	552.	249.	340.	1468.
1929	1856.	1856.	1384.	1384.	-70.	-73.	-140.	-142.	79.	216.	570.	1921.	1757.	564.	567.	493.	574.	1196.
1930	1796.	1796.	1229.	1229.	-137.	-139.	-130.	-133.	166.	291.	702.	2351.	1822.	318.	320.	95.	266.	1287.
1931	1479.	1479.	1193.	1193.	93.	91.	-72.	-75.	177.	238.	538.	1884.	1886.	456.	459.	573.	707.	1230.
1932	1298.	1298.	1286.	1286.	661.	645.	826.	812.	2976.	1542.	1582.	4423.	3749.	686.	683.	506.	651.	1651.
1933	3161.	3161.	1439.	1439.	183.	181.	80.	76.	371.	435.	839.	2697.	2564.	744.	745.	544.	731.	1314.
1934	1833.	1833.	1255.	1255.	-82.	-85.	-136.	-139.	277.	290.	516.	1889.	1865.	397.	401.	383.	520.	1306.
1935	1797.	1797.	1387.	1387.	107.	104.	582.	582.	945.	871.	2302.	6311.	5913.	1581.	1579.	555.	672.	1771.
1936	3126.	3126.	1532.	1532.	138.	135.	288.	288.	4785.	1900.	2300.	6317.	5033.	687.	684.	480.	559.	1771.
1937	2624.	2624.	1546.	1546.	159.	154.	472.	462.	4806.	3619.	2936.	7870.	7995.	924.	919.	603.	670.	1868.
1938	3107.	3107.	1785.	1785.	1592.	1592.	2468.	2468.	8811.	12440.	6970.	6970.	9344.	6518.	6518.	1462.	599.	2554.
1939	3201.	3201.	2293.	2293.	409.	402.	533.	525.	1087.	665.	881.	2785.	2556.	446.	445.	284.	386.	1482.
1940	1964.	1964.	1464.	1464.	225.	223.	1111.	1097.	2956.	3812.	2027.	5635.	5028.	1332.	1327.	415.	750.	1861.
1941	2286.	2286.	1697.	1697.	1055.	1055.	1256.	1256.	5501.	4241.	3790.	3790.	3456.	3698.	3697.	699.	648.	1819.
1942	4875.	4875.	2218.	2219.	1408.	1408.	3052.	3052.	3801.	2035.	2508.	6837.	5825.	2380.	2380.	812.	629.	2021.
1943	6830.	6830.	3070.	3070.	997.	997.	4121.	4121.	4017.	6818.	2911.	7854.	6049.	1319.	1314.	594.	667.	1886.
1944	3376.	3376.	1799.	1799.	154.	148.	310.	304.	847.	763.	1147.	3352.	2862.	573.	571.	328.	437.	1703.
1945	1966.	1966.	1819.	1819.	52.	48.	123.	118.	3253.	2833.	2091.	5702.	3756.	762.	758.	427.	557.	1885.
1946	3773.	3773.	2186.	2186.	1818.	1818.	1846.	1846.	2030.	1357.	1909.	5243.	3750.	709.	706.	387.	493.	1869.
1947	2217.	2217.	2325.	2325.	484.	475.	262.	255.	577.	392.	1209.	3552.	2532.	412.	412.	203.	361.	1486.
1948	1892.	1892.	1333.	1333.	103.	102.	-147.	-150.	162.	199.	1329.	3927.	3696.	715.	712.	398.	564.	1635.
1949	1965.	1965.	1413.	1413.	-109.	-112.	-137.	-139.	68.	416.	1352.	3885.	2833.	519.	518.	273.	466.	1603.
1950	1958.	1958.	1416.	1416.	33.	31.	-32.	-36.	389.	369.	1322.	3894.	3680.	451.	451.	256.	392.	1578.
1951	1978.	1978.	4775.	4775.	3493.	3493.	3723.	3723.	3339.	2122.	1921.	5282.	5040.	681.	677.	373.	452.	1770.
1952	1970.	1970.	1668.	1668.	391.	391.	2397.	2397.	2197.	4194.	4011.	4011.	5833.	4231.	4231.	960.	510.	2137.
1953	8280.	8280.	2168.	2168.	761.	761.	1646.	1646.	1965.	1033.	1351.	3906.	3683.	673.	673.	327.	523.	1619.
1954	1957.	1957.	1498.	1498.	55.	52.	35.	35.	354.	407.	1288.	3892.	3671.	582.	579.	289.	417.	1619.
1955	1957.	1957.	1419.	1419.	-92.	-92.	30.	26.	410.	437.	896.	2749.	2576.	490.	489.	217.	507.	1488.
1956	1958.	1958.	1432.	1432.	4386.	4386.	8131.	8131.	5004.	2090.	2236.	6135.	5902.	3323.	3331.	518.	537.	1884.
1957	4694.	4694.	1613.	1613.	89.	84.	134.	130.	436.	751.	1327.	3909.	3714.	755.	751.	312.	419.	1591.
1958	1980.	1980.	1513.	1513.	-53.	-56.	165.	165.	1296.	3921.	5688.	5688.	4908.	4642.	4642.	599.	522.	2056.
1959	4781.	4781.	1780.	1780.	242.	237.	439.	439.	1443.	1059.	869.	2723.	2543.	380.	381.	232.	309.	1445.
1960	1841.	1841.	1312.	1312.	29.	27.	-125.	-128.	108.	262.	668.	2333.	1739.	404.	404.	291.	570.	1420.
1961	1778.	1778.	1333.	1334.	-128.	-131.	-144.	-147.	-119.	34.	509.	1899.	1767.	306.	308.	217.	357.	1358.
1962	1343.	1343.	1284.	1284.	-155.	-158.	-31.	-33.	1994.	1432.	1445.	4119.	3672.	519.	518.	234.	457.	1534.
1963	1974.	1974.	1397.	1397.	-123.	-123.	38.	34.	1421.	879.	1910.	5311.	5032.	1291.	1286.	549.	549.	1759.
1964	2285.	2285.	2122.	2122.	112.	108.	226.	226.	414.	433.	877.	2717.	2536.	504.	503.	150.	298.	1388.
1965	1942.	1942.	1635.	1635.	1036.	1036.	3369.	3369.	2805.	1473.	2226.	6127.	5801.	1302.	1297.	473.	605.	1668.
1966	4376.	4376.	3462.	3462.	1528.	1521.	1597.	1597.	1728.	1034.	1361.	3894.	2838.	490.	489.	264.	367.	1519.
1967	1957.	1957.	1535.	1535.	435.	435.	632.	632.	1214.	2430.	5145.	5145.	6072.	6492.	6492.	3985.	501.	2787.
1968	4810.	4810.	1733.	1733.	229.	224.	325.	325.	1313.	660.	1215.	3581.	2556.	421.	420.	264.	401.	1453.
1969	1968.	1968.	1470.	1470.	55.	50.	5572.	5572.	12319.	7607.	8112.	8112.	10272.	8940.	8940.	1700.	560.	2509.
1970	8274.	8274.	2534.	2534.	1011.	1011.	6518.	6518.	3495.	2647.	1903.	5258.	5014.	719.	715.	353.	528.	1804.
1971	1964.	1964.	1737.	1737.	250.	250.	216.	216.	527.	1138.	1321.	3905.	3703.	671.	668.	304.	392.	1603.
1972	1960.	1960.	1396.	1396.	-12.	-15.	44.	41.	373.	370.	1221.	3561.	2530.	383.	383.	141.	294.	1334.

D-041571

D-041571

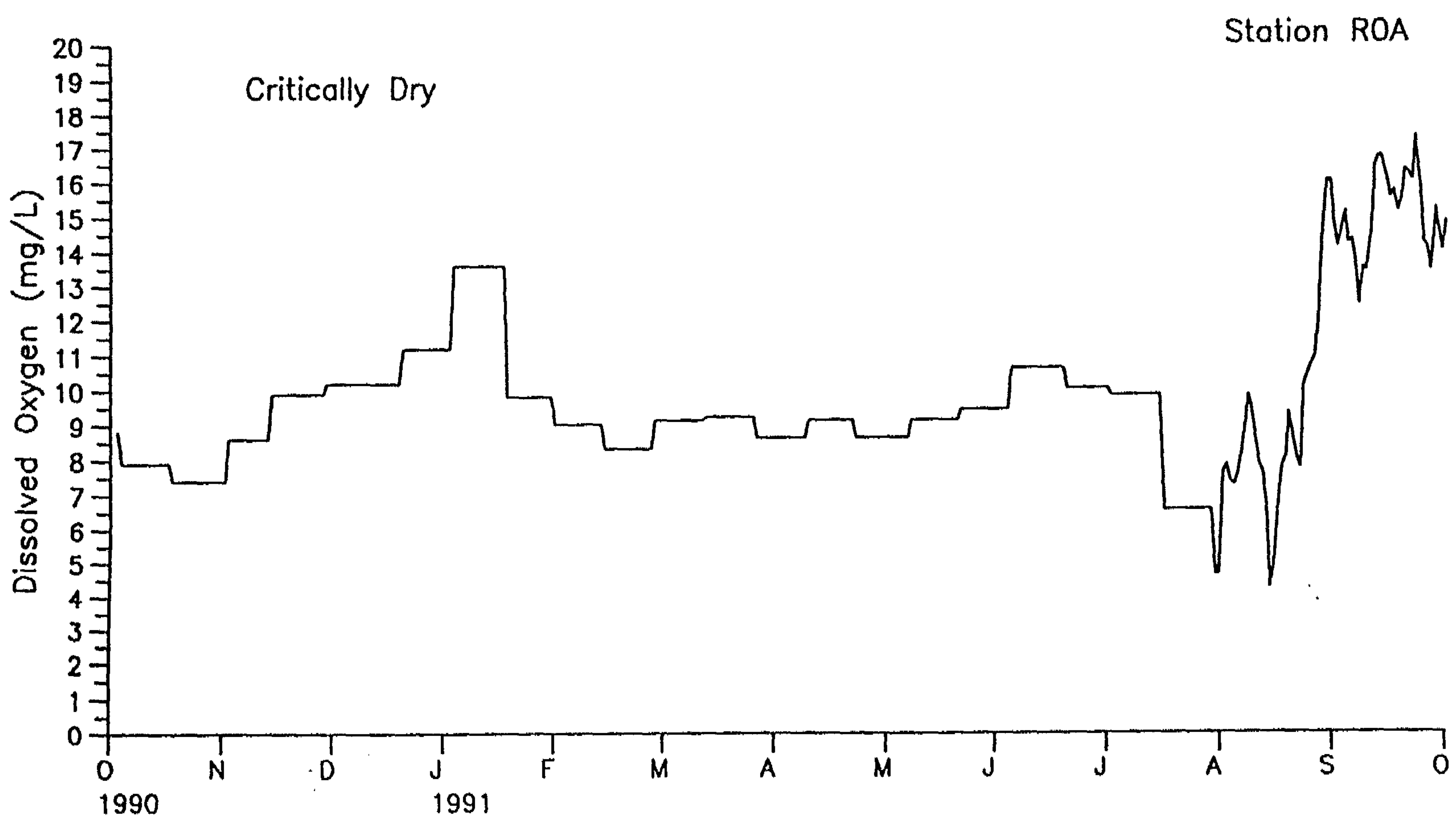
1973	1928.	1928.	1401.	1401.	-91.	-91.	375.	375.	2769.	3226.	2033.	5614.	5019.	774.	770.	386.	533.	1771.
1974	3230.	3230.	2379.	2379.	479.	479.	2492.	2492.	1796.	2544.	2812.	7605.	5809.	1282.	1277.	434.	471.	1870.
1975	3505.	3505.	1716.	1716.	238.	232.	300.	293.	2069.	3171.	2392.	6554.	5801.	2714.	2717.	462.	543.	1801.
1976	4068.	4068.	1809.	1809.	166.	161.	107.	103.	281.	147.	537.	1900.	1741.	324.	326.	224.	424.	1341.
1977	2778.	2778.	2085.	2085.	269.	266.	141.	139.	279.	258.	535.	1889.	1771.	605.	609.	643.	621.	1093.
1978	1218.	1218.	1267.	1267.	-26.	-30.	780.	780.	2551.	4082.	5689.	5689.	3977.	3144.	3145.	1150.	667.	2641.
1979	4194.	4194.	1921.	1922.	166.	162.	1228.	1228.	3418.	3116.	1911.	5279.	5017.	675.	672.	378.	577.	1703.
1980	2801.	2801.	1685.	1685.	87.	82.	5053.	5053.	9845.	5493.	2457.	6648.	6483.	2693.	2692.	1533.	586.	2536.
1981	5048.	5048.	2064.	2064.	313.	306.	737.	737.	663.	733.	1207.	3584.	2548.	420.	420.	209.	334.	1488.
1982	1973.	1973.	1621.	1621.	136.	136.	3360.	3360.	6300.	5808.	10709.	10709.	5715.	4500.	4500.	1187.	518.	3904.
1983	4645.	4645.	3075.	3075.	7343.	7343.	9871.	9871.	14906.	16911.	8048.	8048.	7373.	14707.	14707.	6424.	394.	6434.
1984	4526.	4526.	5085.	5085.	8394.	8394.	5773.	5773.	3724.	2079.	1900.	5265.	5019.	690.	687.	394.	660.	1923.
1985	1975.	1975.	1782.	1782.	55.	50.	102.	99.	404.	398.	851.	2720.	2543.	470.	469.	209.	326.	1472.
1986	1965.	1965.	1587.	1587.	-14.	-17.	134.	129.	8784.	10397.	3694.	3694.	7939.	3417.	3417.	601.	591.	1883.
1987	3413.	3413.	1687.	1688.	17.	13.	97.	93.	329.	305.	523.	1935.	1741.	332.	333.	221.	388.	1413.
1988	1771.	1771.	1284.	1284.	-160.	-162.	-167.	-167.	63.	206.	559.	1904.	1760.	383.	386.	492.	684.	1282.
1989	1261.	1261.	1166.	1166.	79.	77.	-54.	-57.	256.	-8.	602.	2311.	1748.	334.	335.	183.	487.	1358.
1990	1311.	1311.	1216.	1216.	-134.	-137.	-96.	-99.	0.	125.	517.	1885.	1888.	277.	279.	201.	621.	1283.
1991	1244.	1244.	1189.	1189.	101.	100.	180.	179.	301.	300.	680.	2345.	1864.	528.	531.	486.	544.	1196.
1992	1315.	1315.	1410.	1410.	138.	137.	-71.	-74.	419.	295.	634.	2176.	1854.	454.	457.	589.	672.	1131.
1993	1531.	1531.	1466.	1466.	-22.	-25.	2059.	2059.	977.	915.	2225.	6140.	5846.	2116.	2116.	590.	672.	1968.
1994	4249.	4249.	1837.	1837.	-26.	-29.	73.	71.	268.	163.	548.	1905.	1893.	438.	438.	303.	331.	1402.

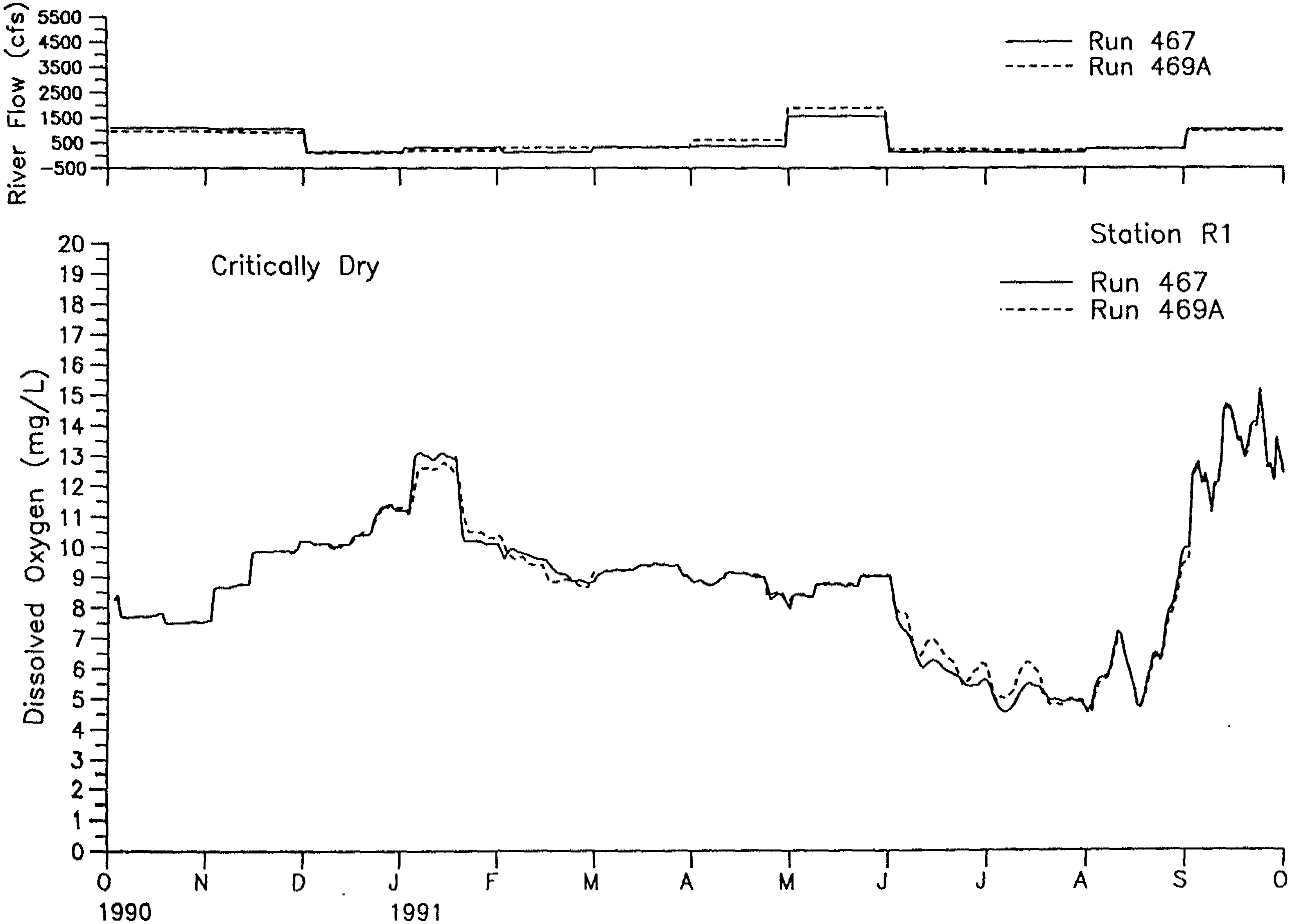
Tides

T01	Oct	1 - 15
T02	Oct	16 - 31
T03	Nov	1 - 10
T04	Nov	11 - 30
T05	Dec	1 - 15
T06	Dec	16 - 31
T07	Jan	1 - 20
T08	Jan	21 - 31
T09	Feb	1 - 28
T10	Mar	1 - 31
T11	Apr	1 - 15
T12	Apr	16 - 30
T13	May	1 - 31
T14	Jun	1 - 4
T15	Jun	5 - 30
T16	Jul	1 - 31
T17	Aug	1 - 31
T18	Sep	1 - 30

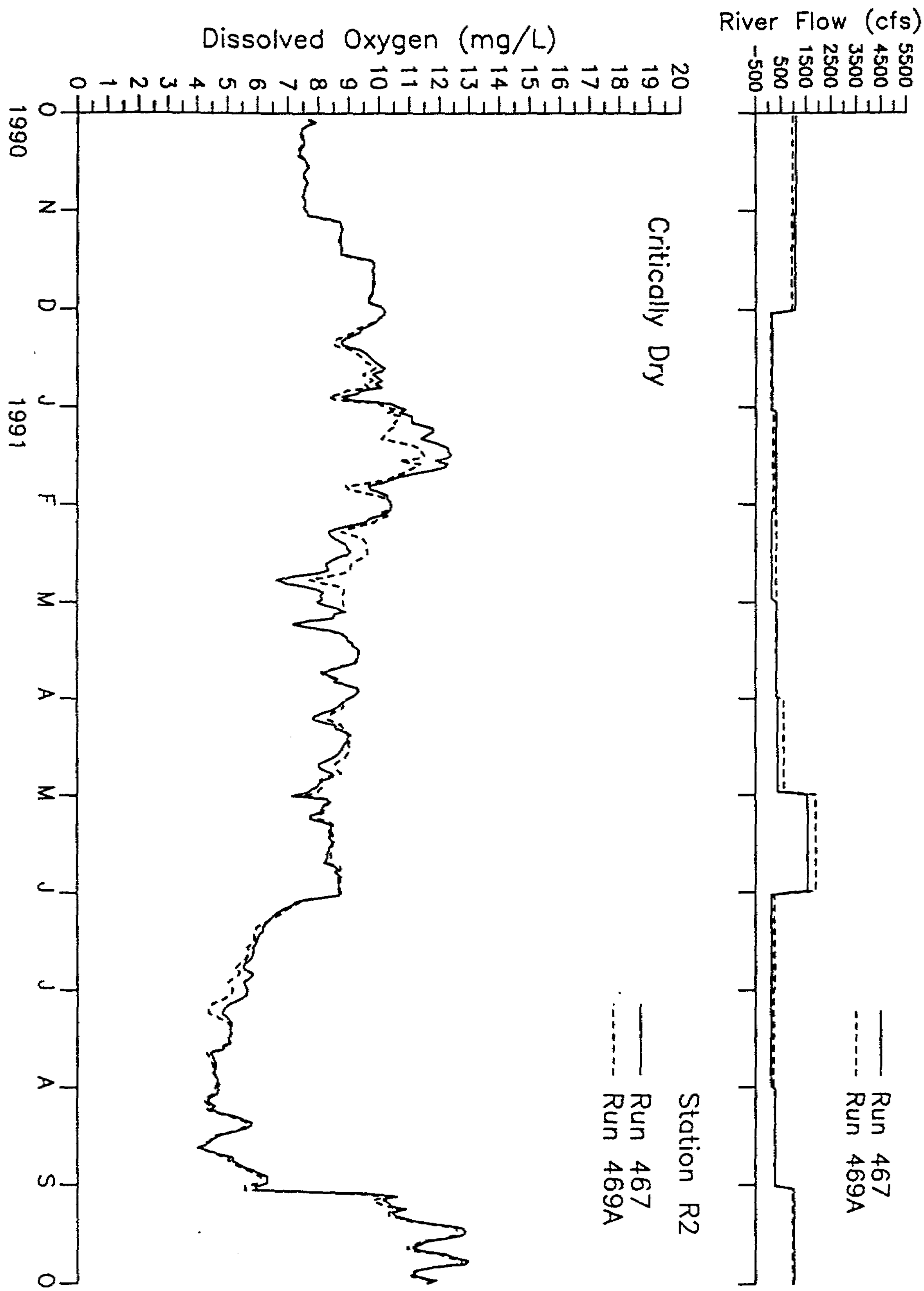
Appendix E.

Results for Critical Dry Year 1991


Station ROA
Critically Dry
Dissolved Oxygen (mg/L)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
O N D J F M A M J J A S O
1990
1991

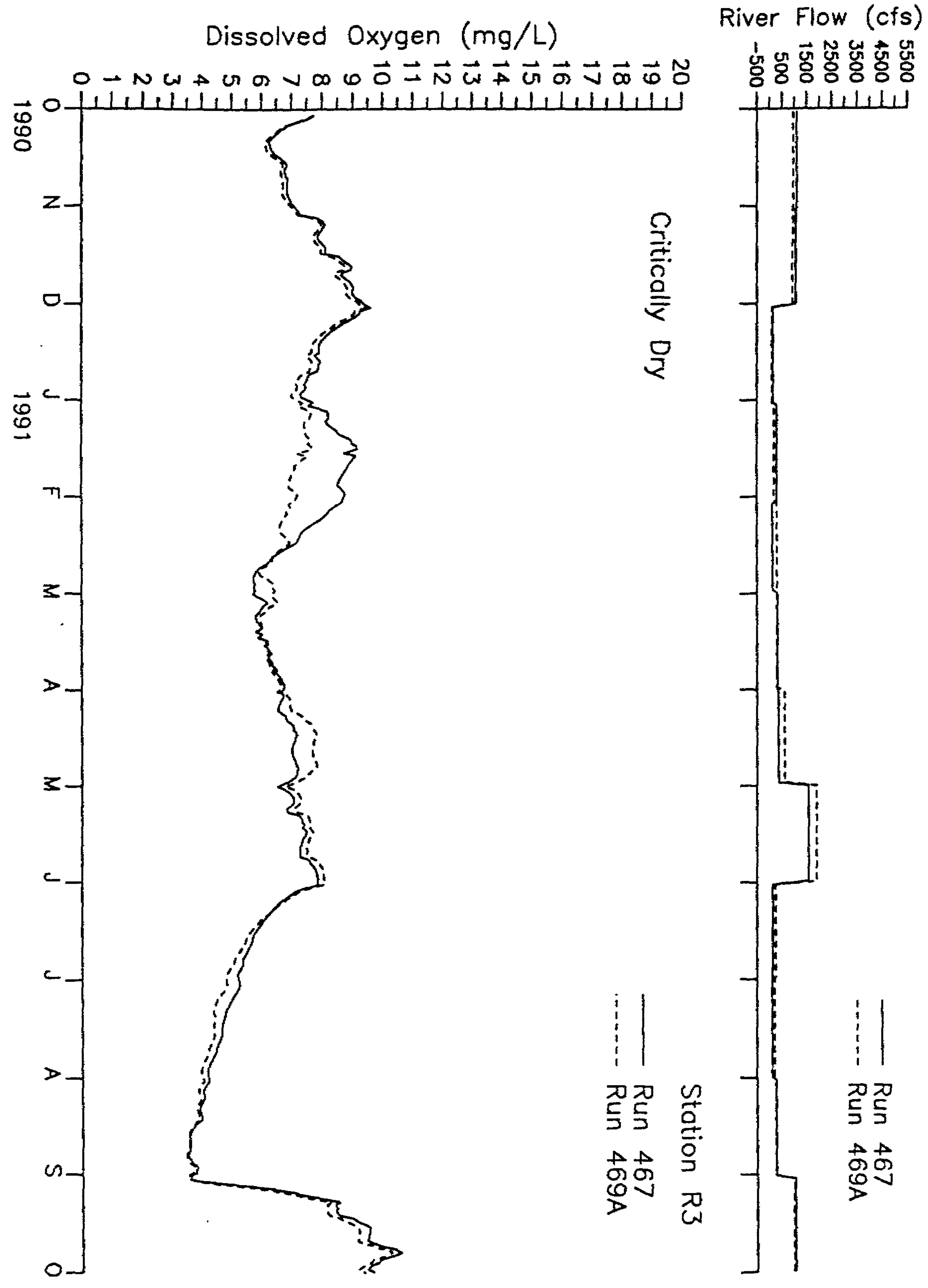

River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469A
Station R1
Critically Dry
Run 467
Run 469A
Dissolved Oxygen (mg/L)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

D-041575



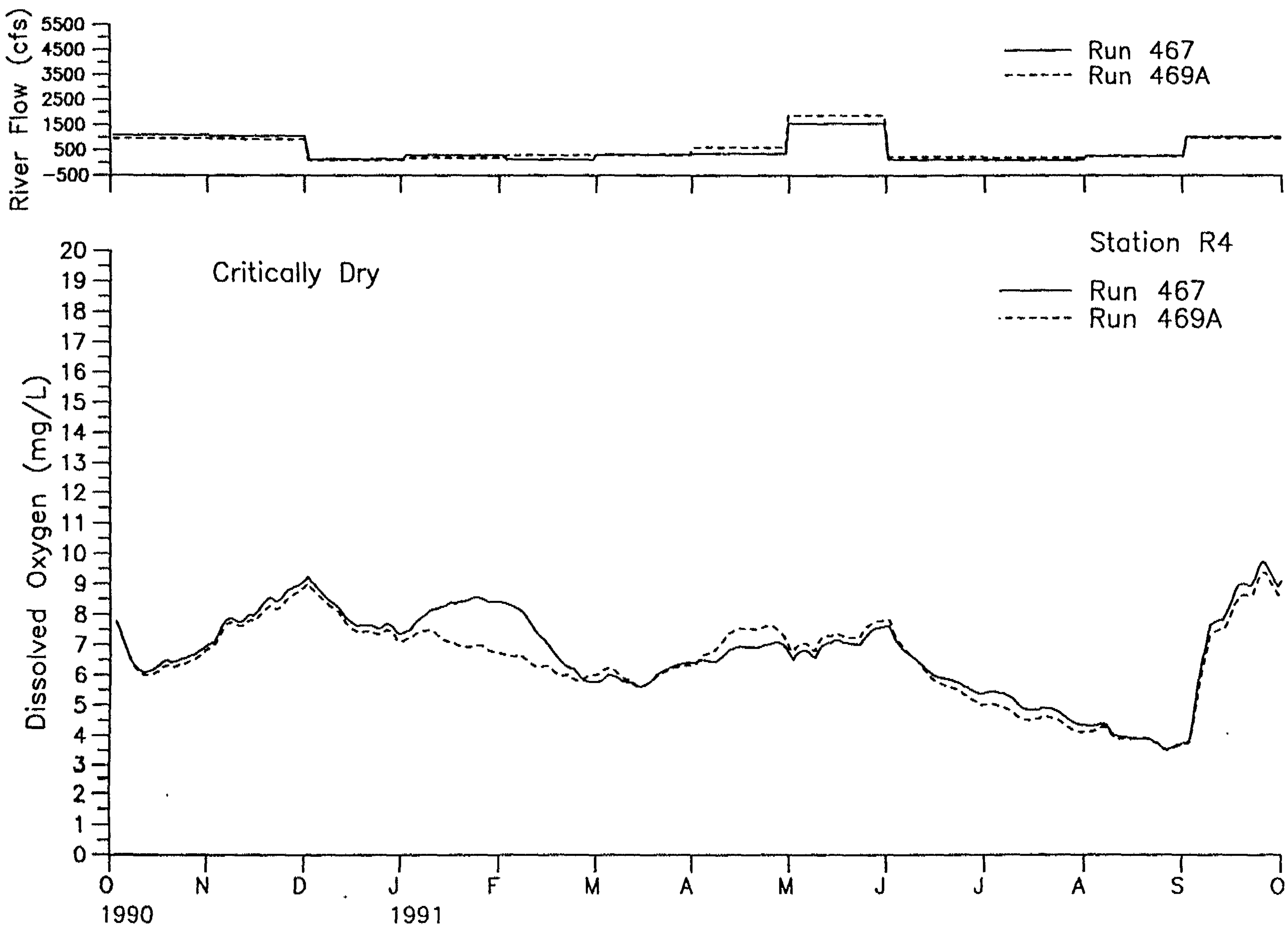
Dissolved Oxygen (mg/L)
River Flow (cfs)
Critically Dry
Station R2
Run 467
Run 469A
1990
1991
O N D J F M A M J J A S O

D-041576



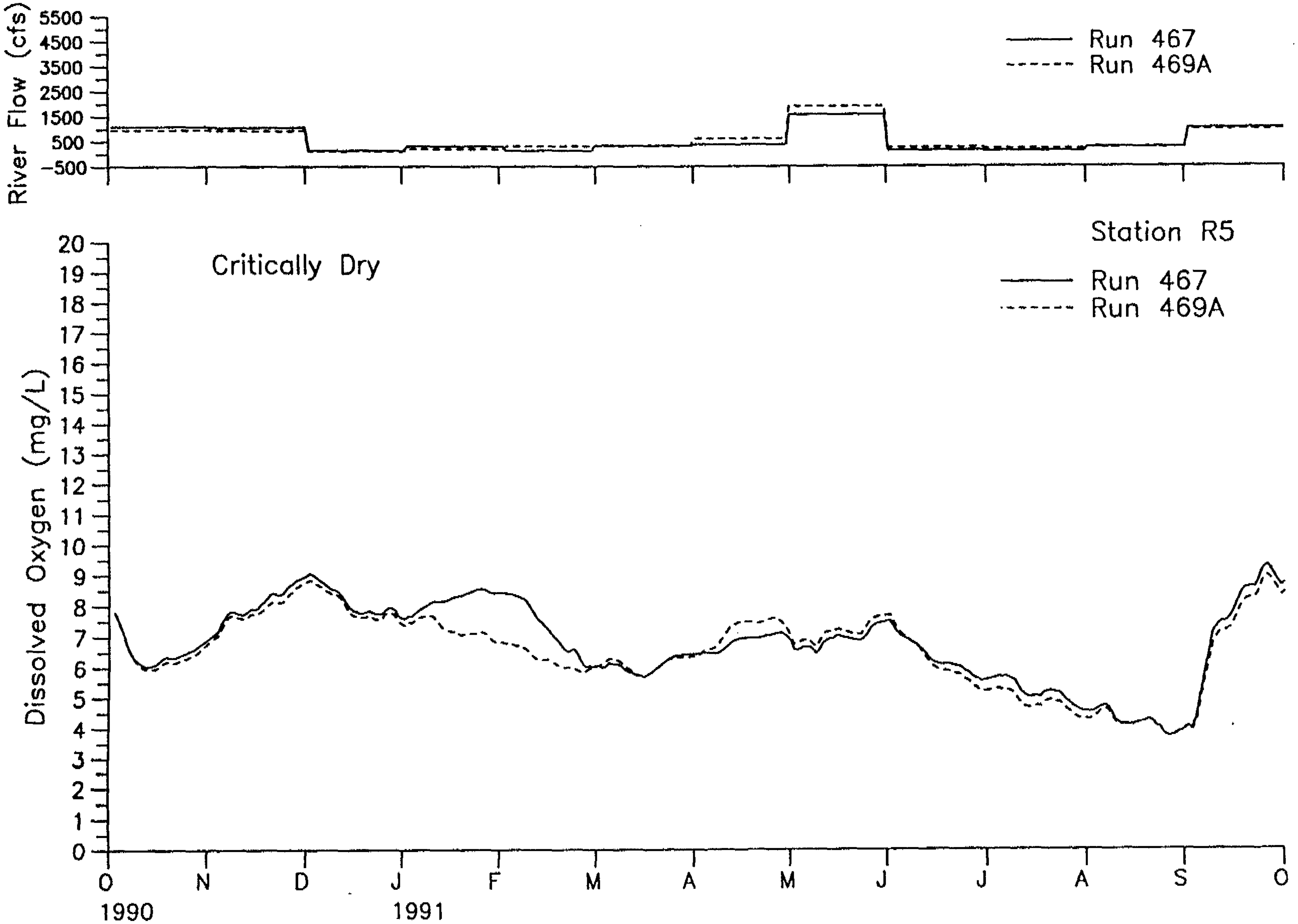
River Flow (cfs)
-500 500 1500 2500 3500 4500 5500
Run 467
Run 469A
Dissolved Oxygen (mg/L)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Critically Dry
Station R3
Run 467
Run 469A
O N D J F M A M J J A S O
1990
1991

D-041577



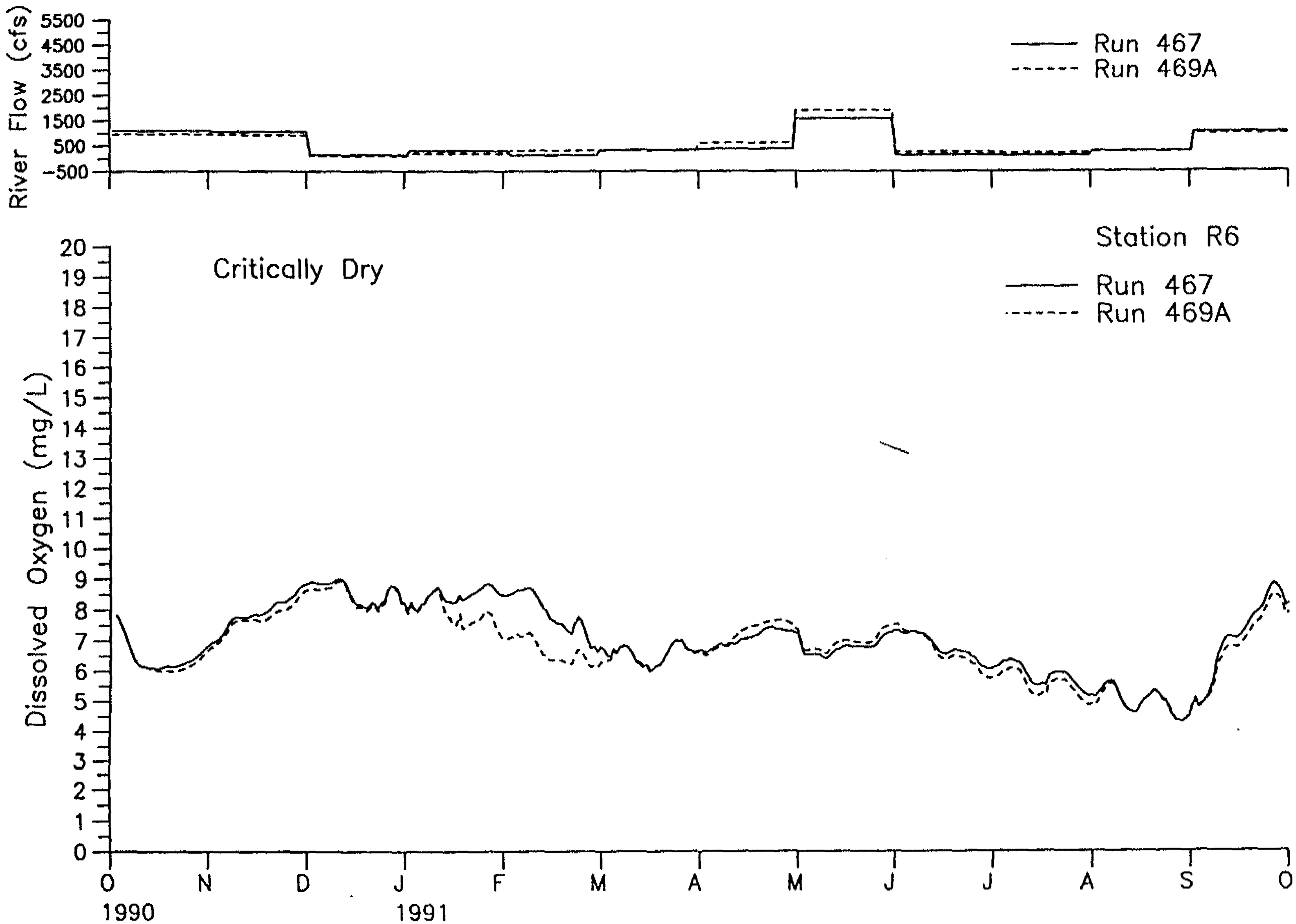
D-041578

D-041578

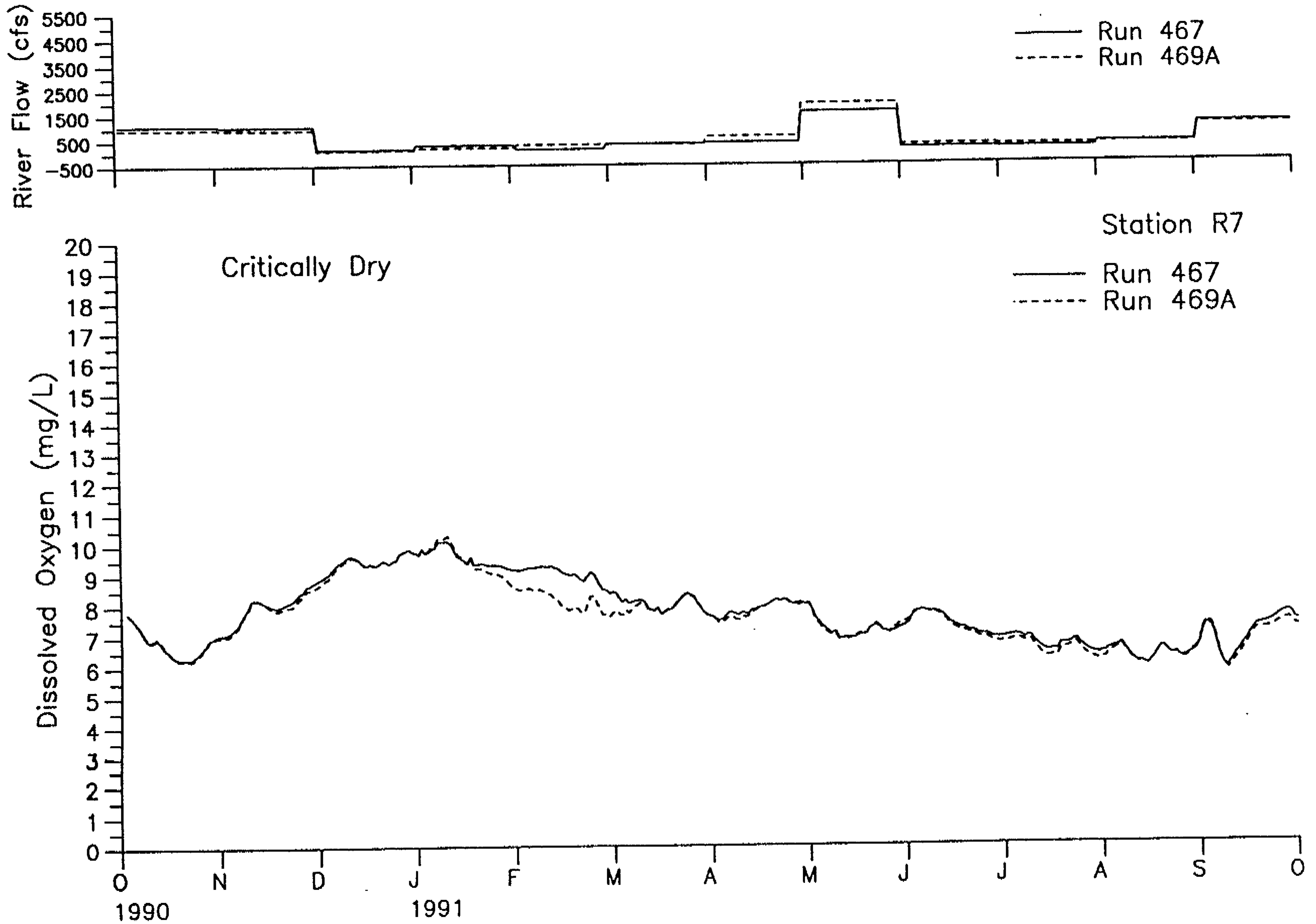


D-041579

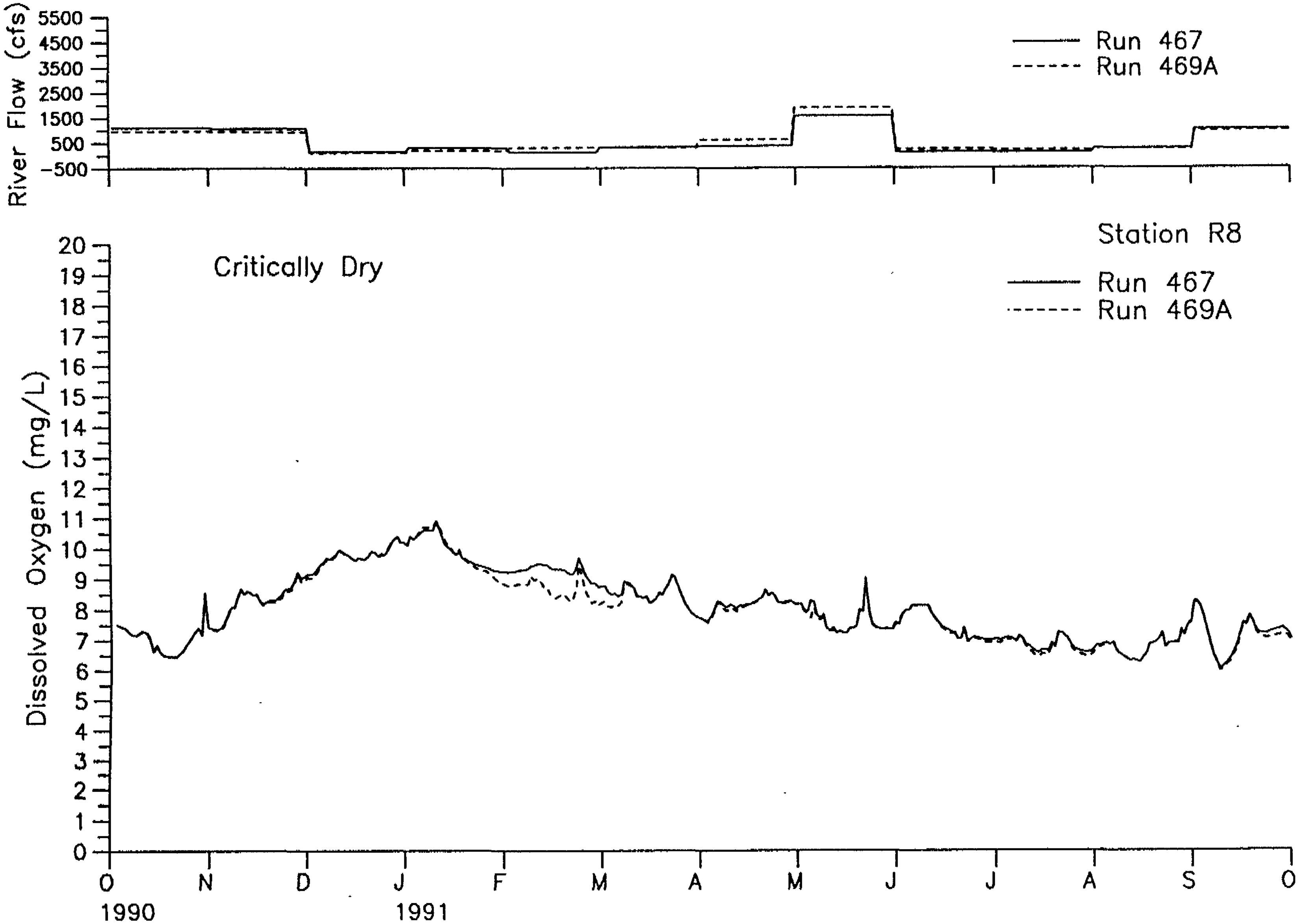
D-041579


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469A
Station R6
Critically Dry
Dissolved Oxygen (mg/L)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

D-041580

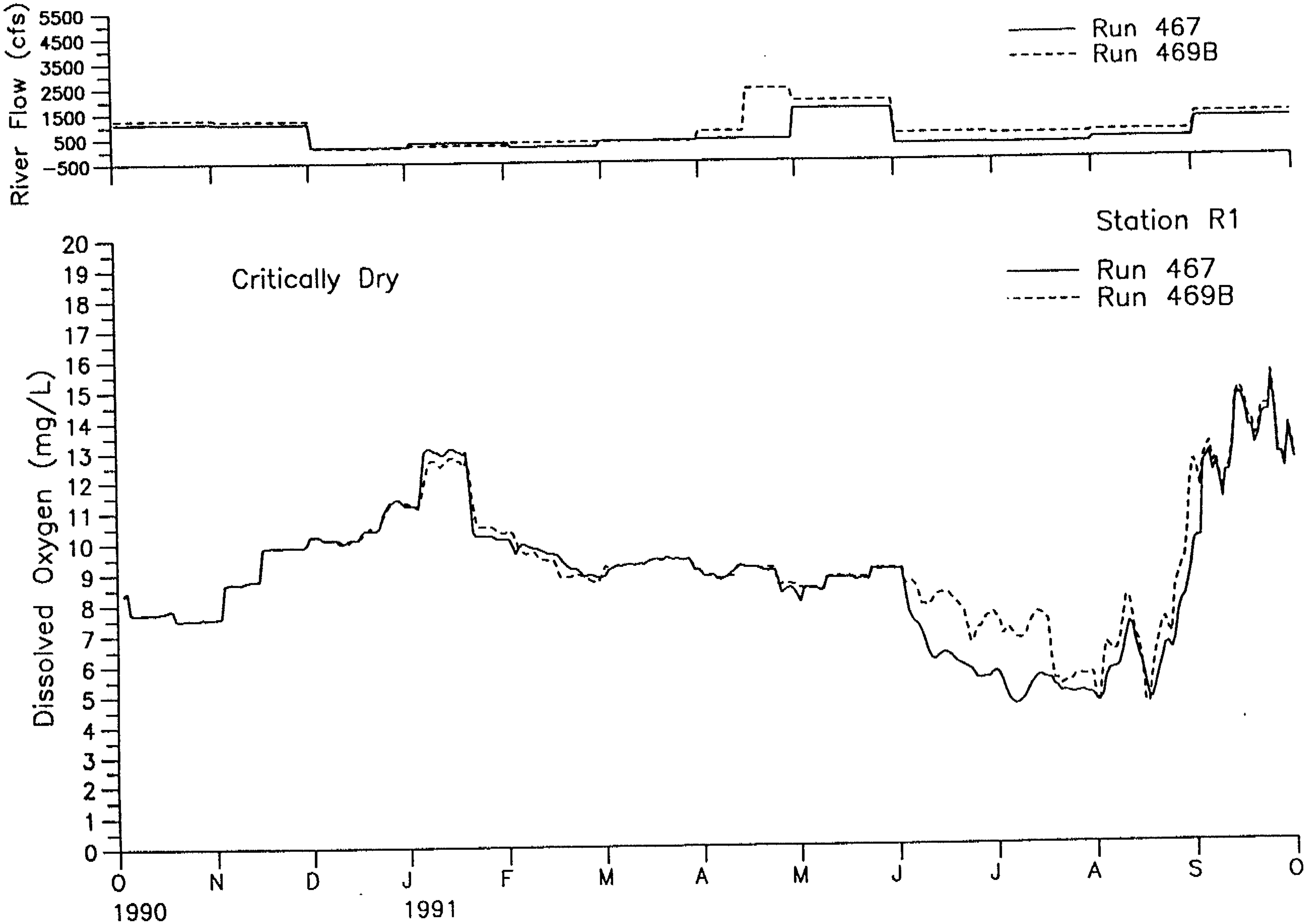

River Flow (cfs)
5500
4500
3500
2500
1500
500
−500
Run 467
Run 469A
Station R7
Critically Dry
Dissolved Oxygen (mg/L)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Run 467
Run 469A
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

D—041581

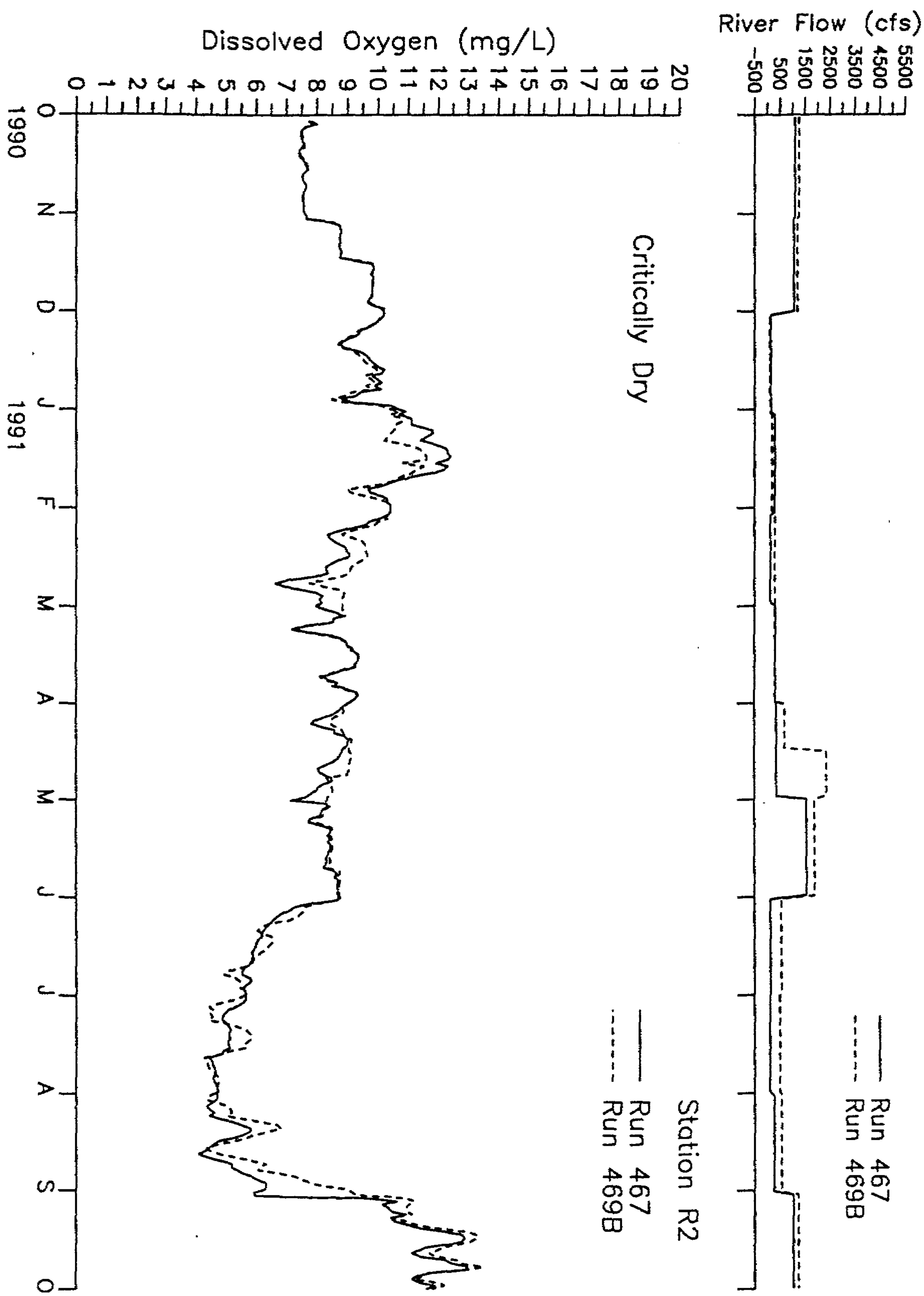


D-041582

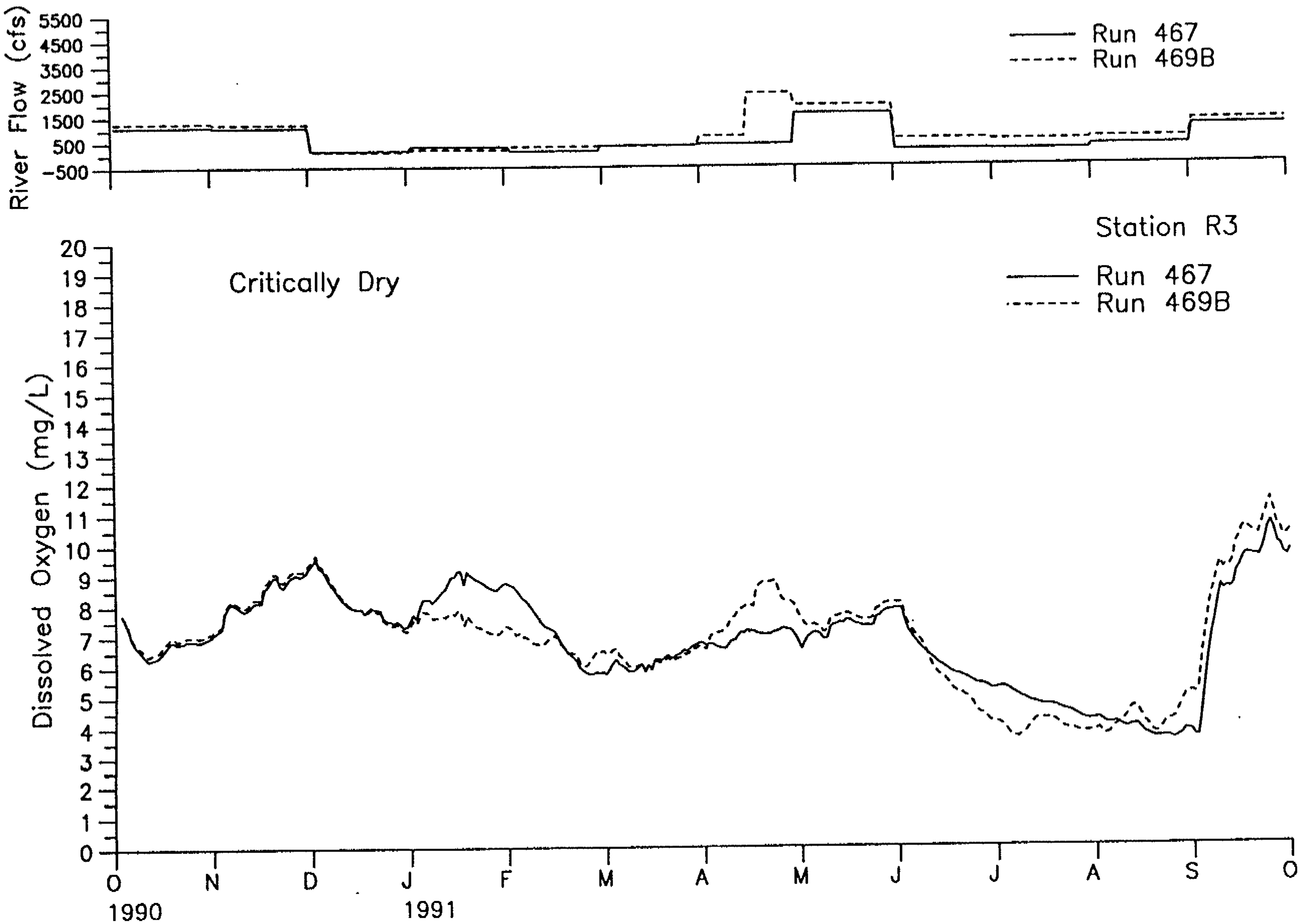
D-041582


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R1
Dissolved Oxygen (mg/L)
Critically Dry
Run 467
Run 469B
O N D J F M A M J J A S O
1990
1991

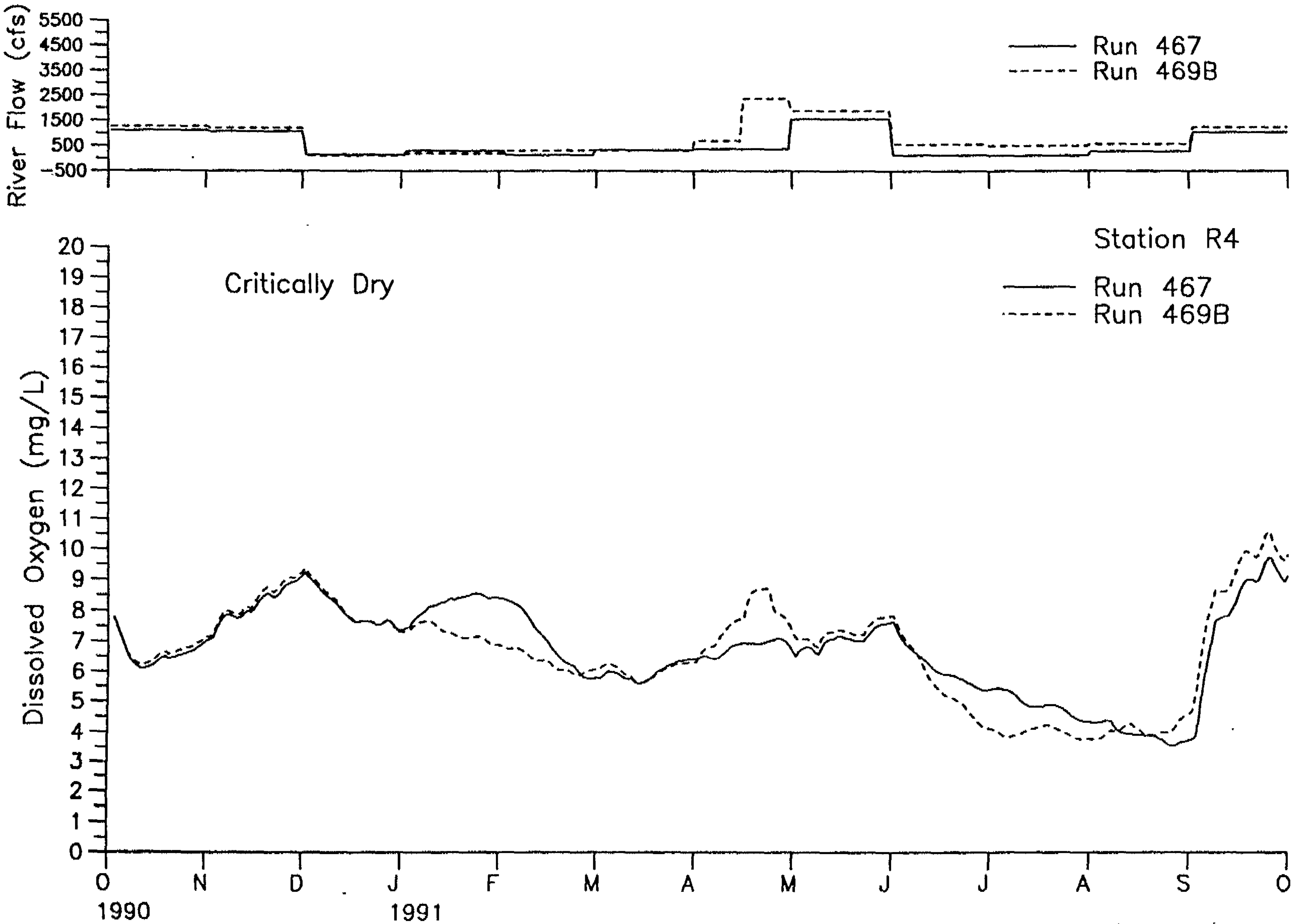
D-041583


Dissolved Oxygen (mg/L)
River Flow (cfs)
Critically Dry
Station R2
Run 467
Run 469B
1990
1991
O N D J F M A M J J A S O

D-041584

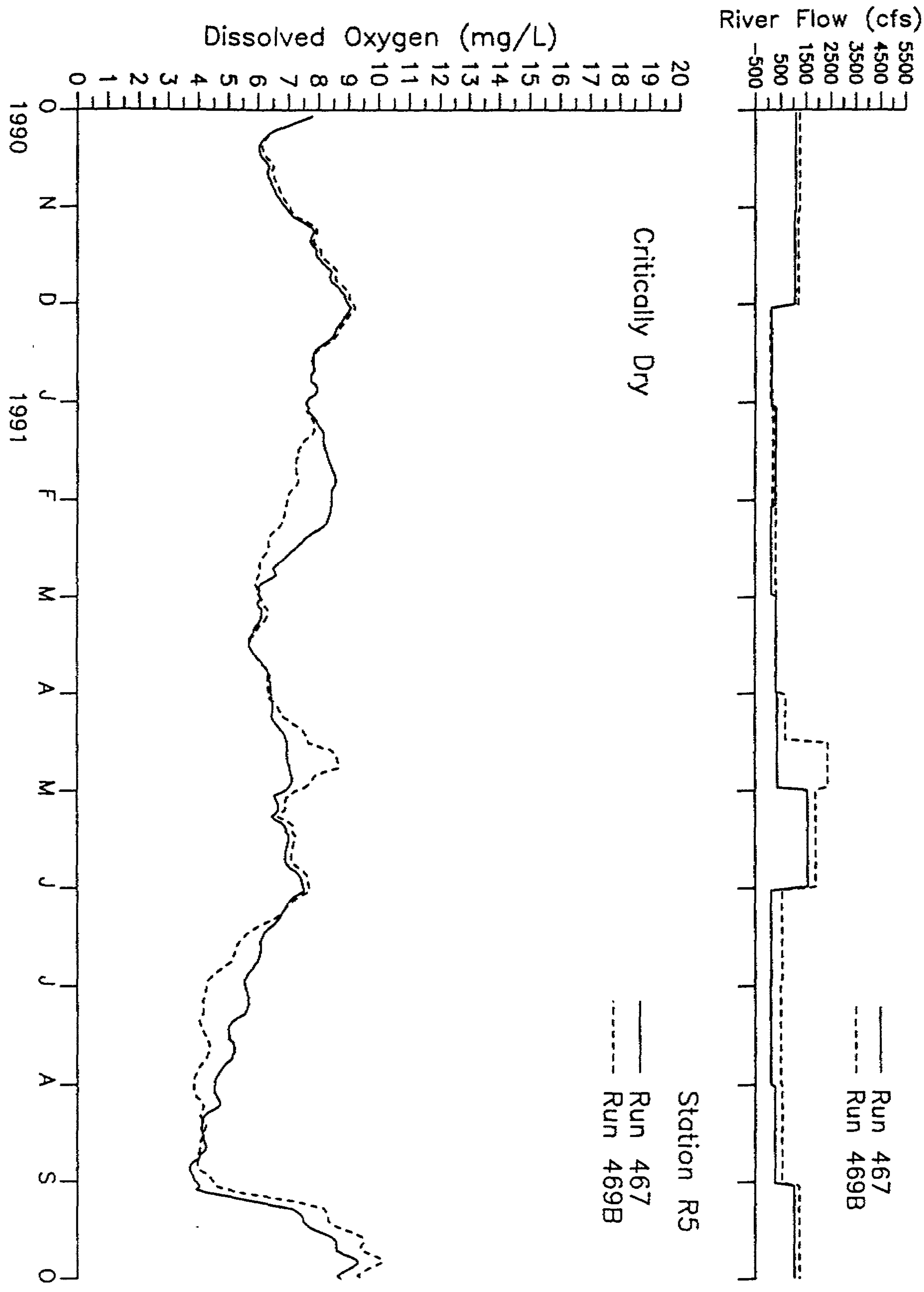

River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R3
Critically Dry
Run 467
Run 469B
Dissolved Oxygen (mg/L)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1990
1991

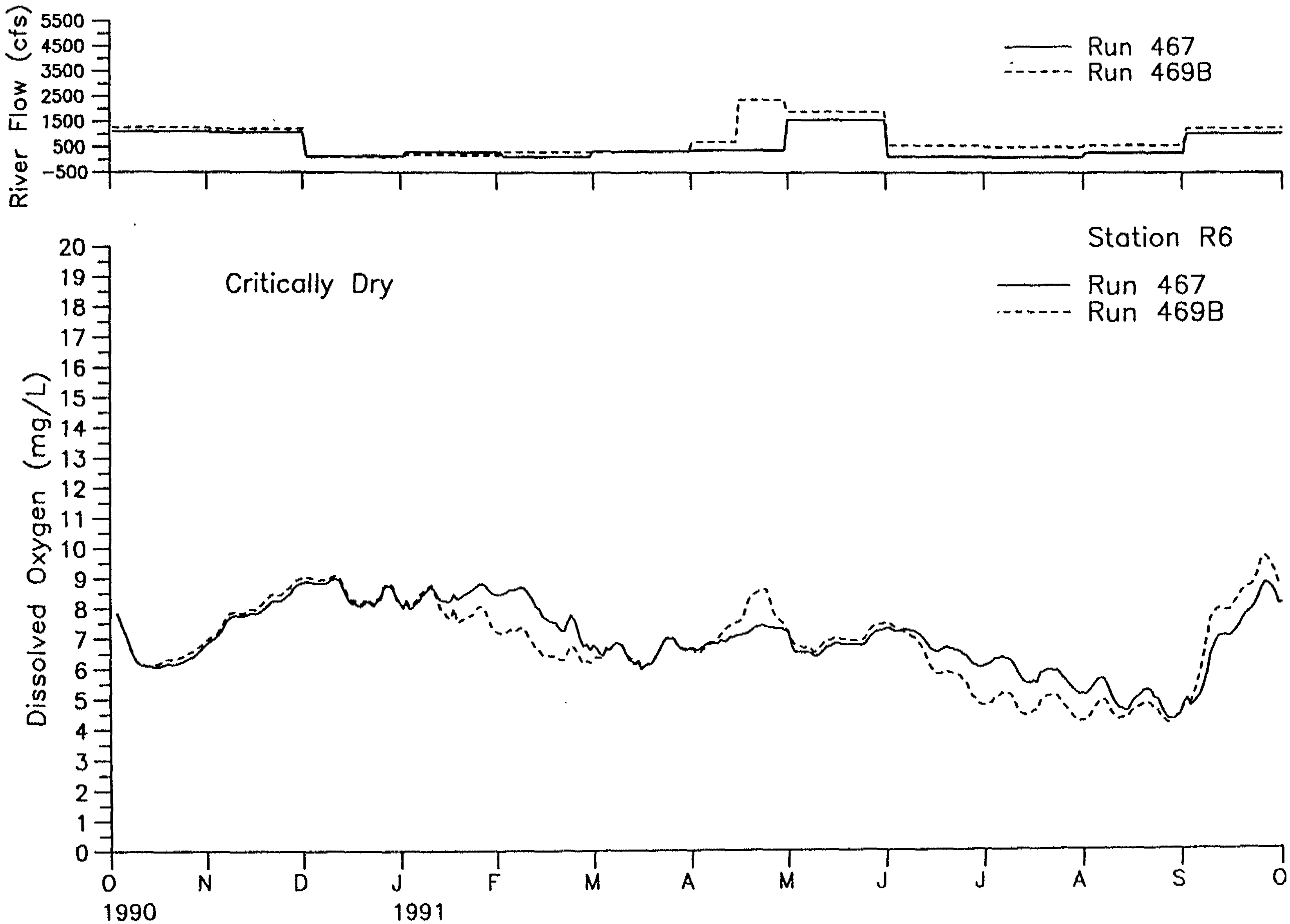
D—041585

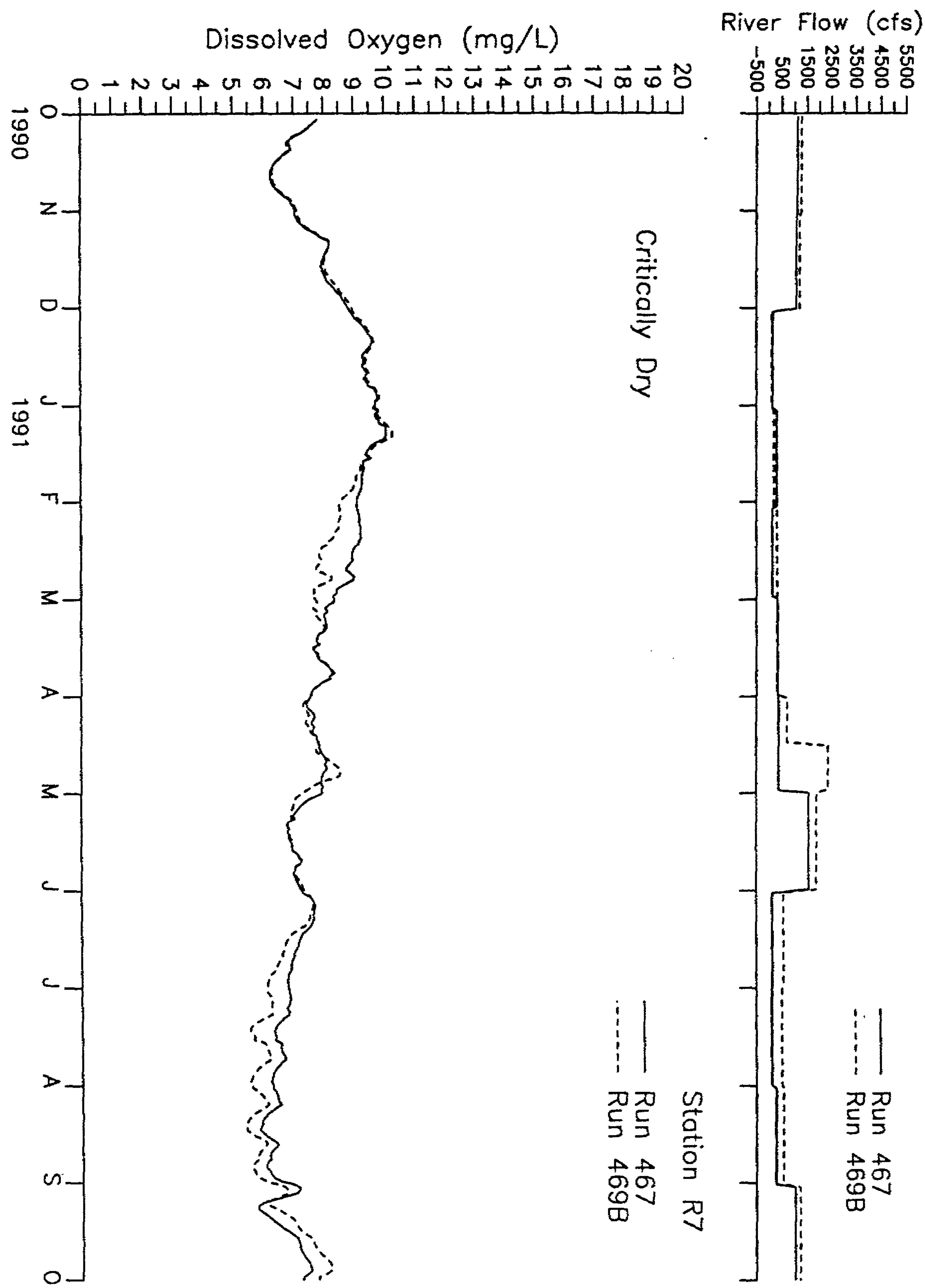


D-041586

D-041586

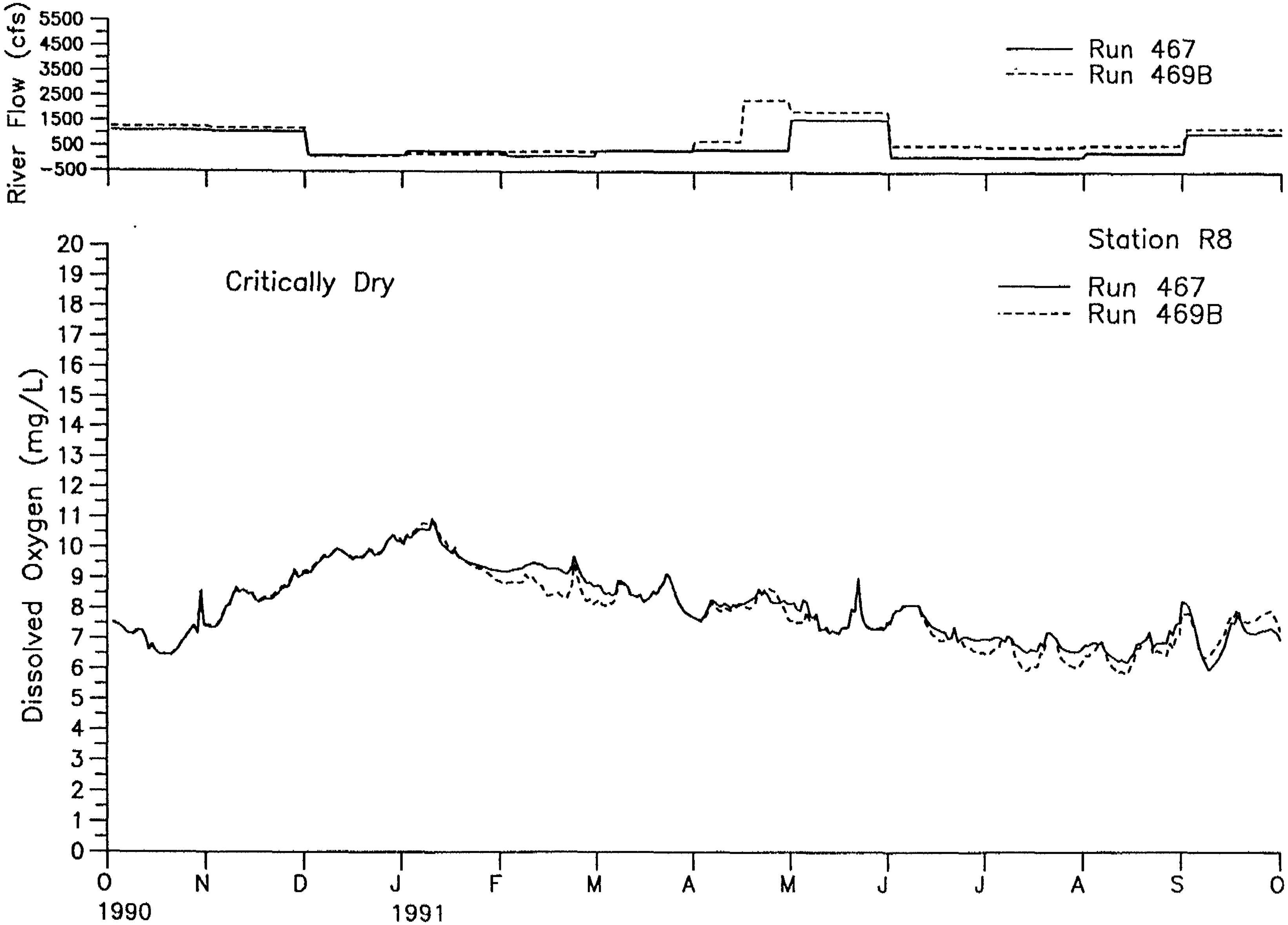

Dissolved Oxygen (mg/L)
River Flow (cfs)
Critically Dry
Station R5
Run 467
Run 469B
1990
1991
O N D J F M A M J J A S O


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R6
Critically Dry
Run 467
Run 469B
Dissolved Oxygen (mg/L)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991



D-041589

D-041589

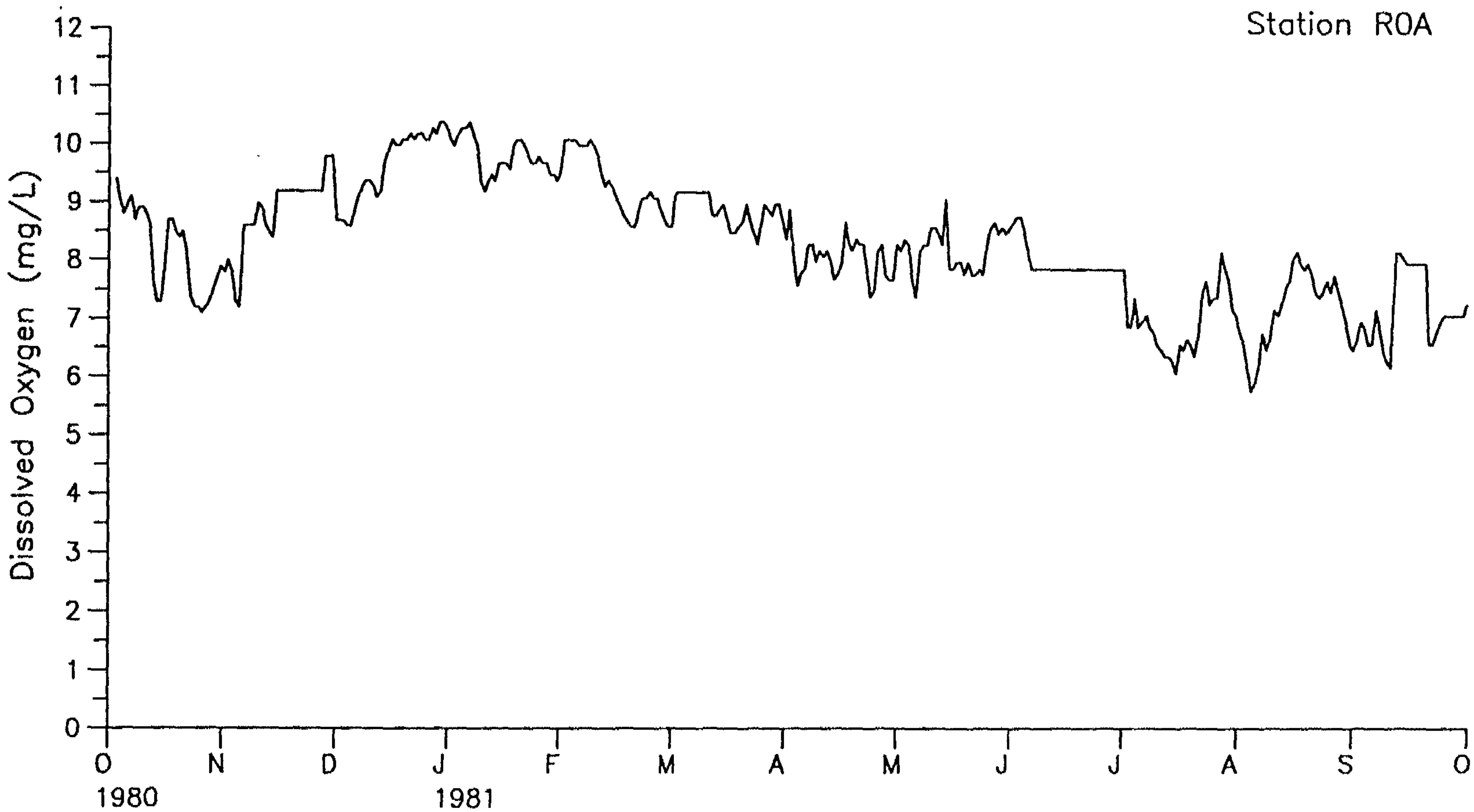


D-041590

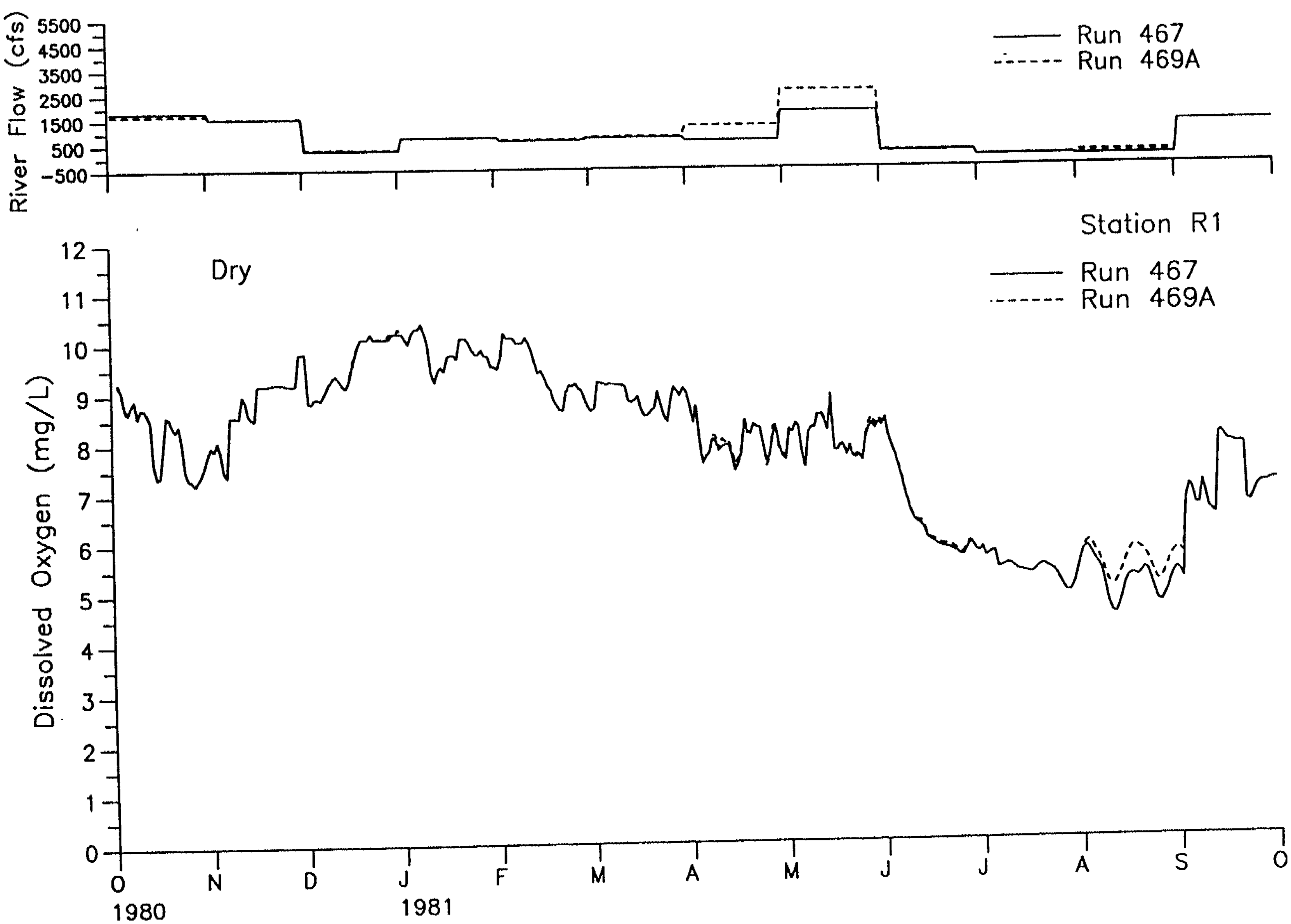
D-041590

Appendix F.

Results for Dry Year 1981

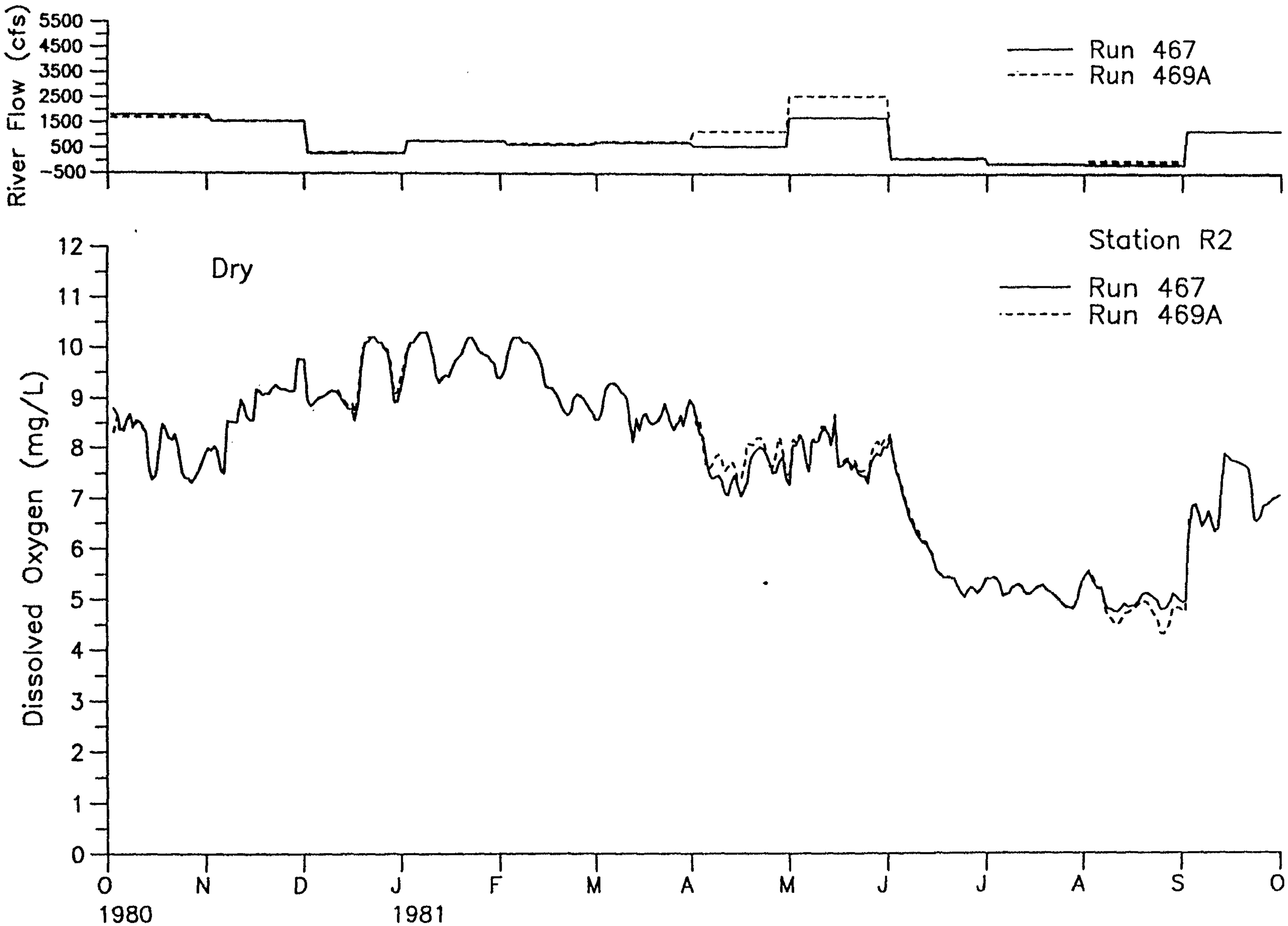

Station ROA
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
O
N
D
J
F
M
A
M
J
J
A
S
O
1980
1981

D−041592



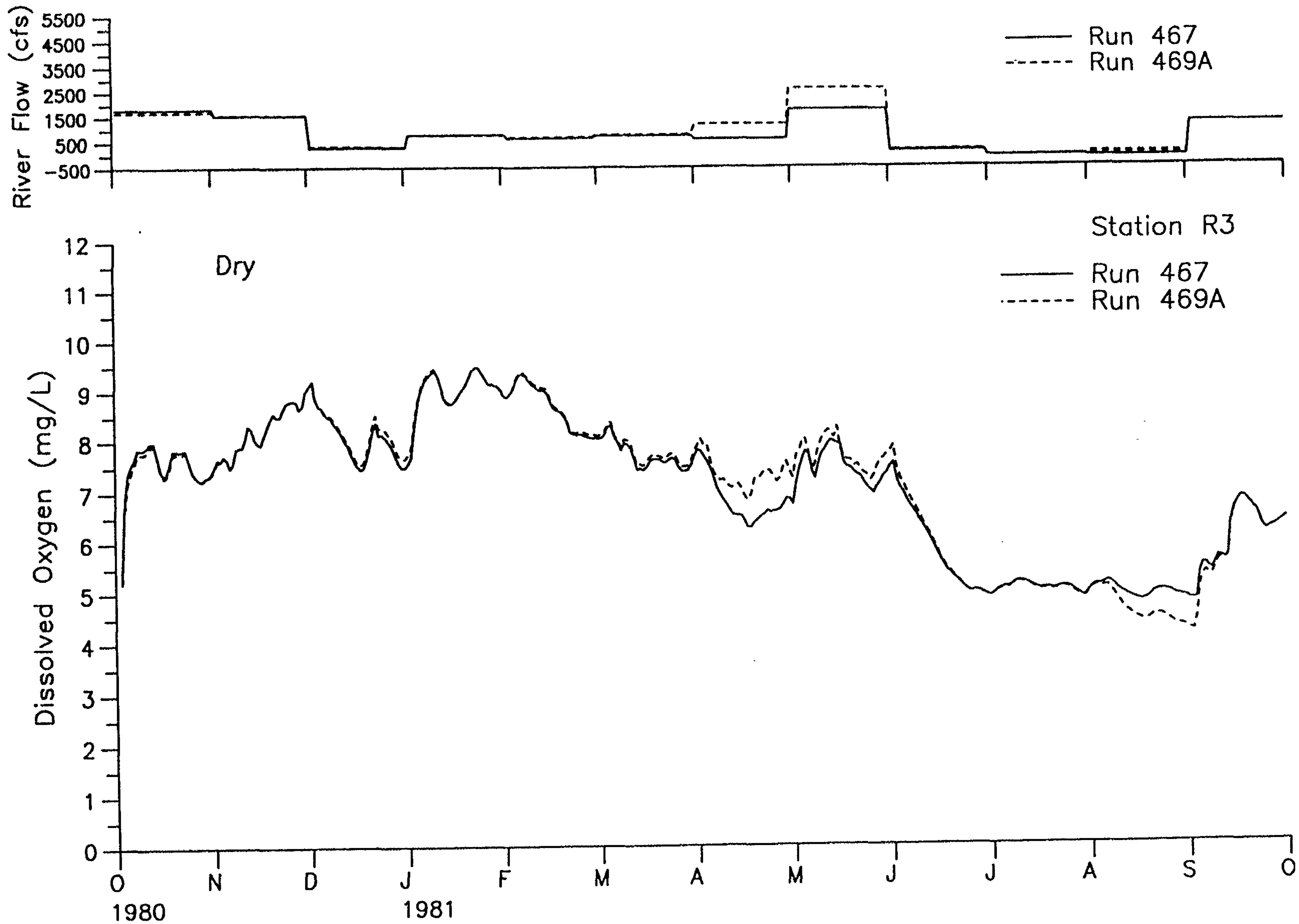
D-041593

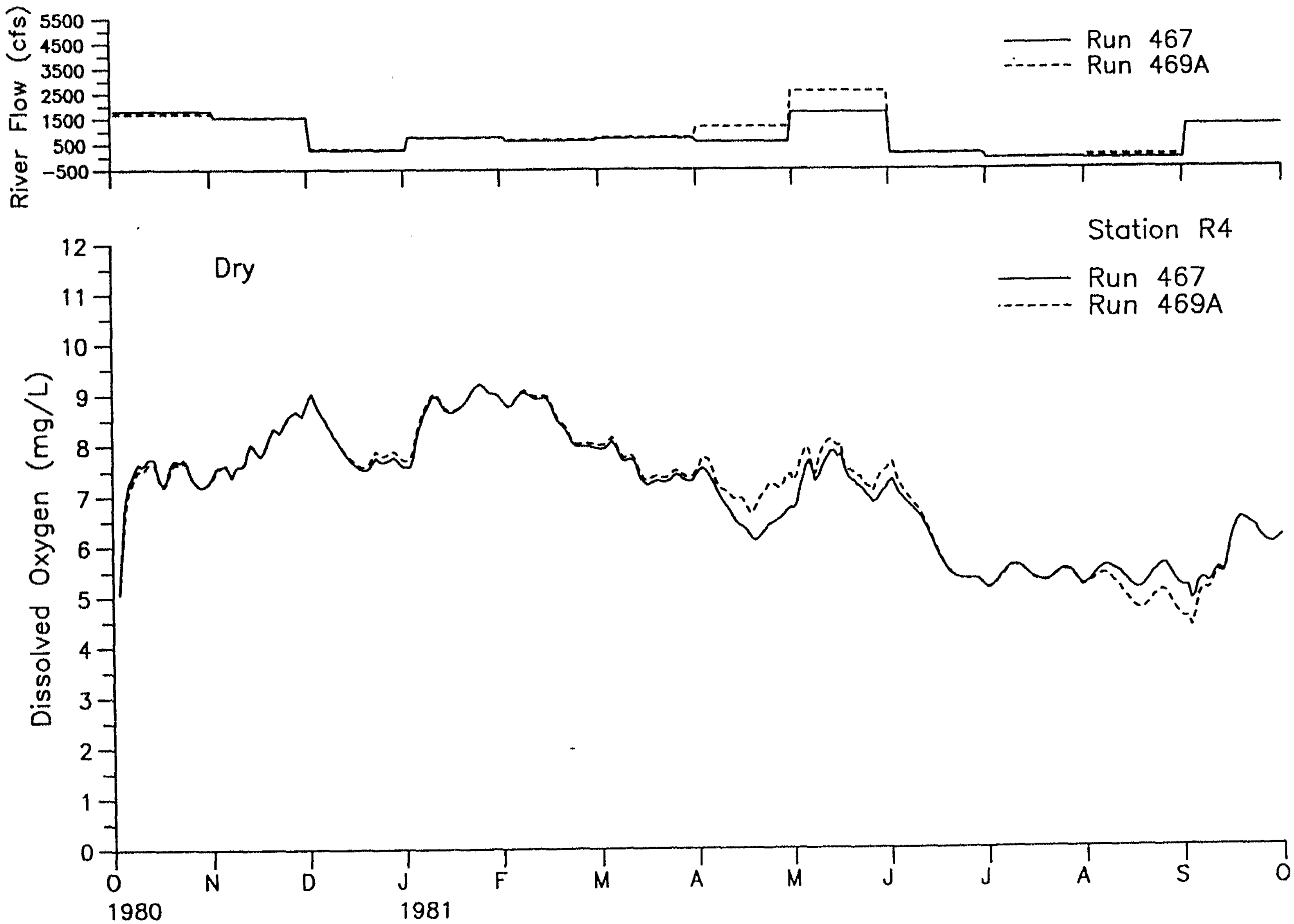
D-041593



D — 0 4 1 5 9 4

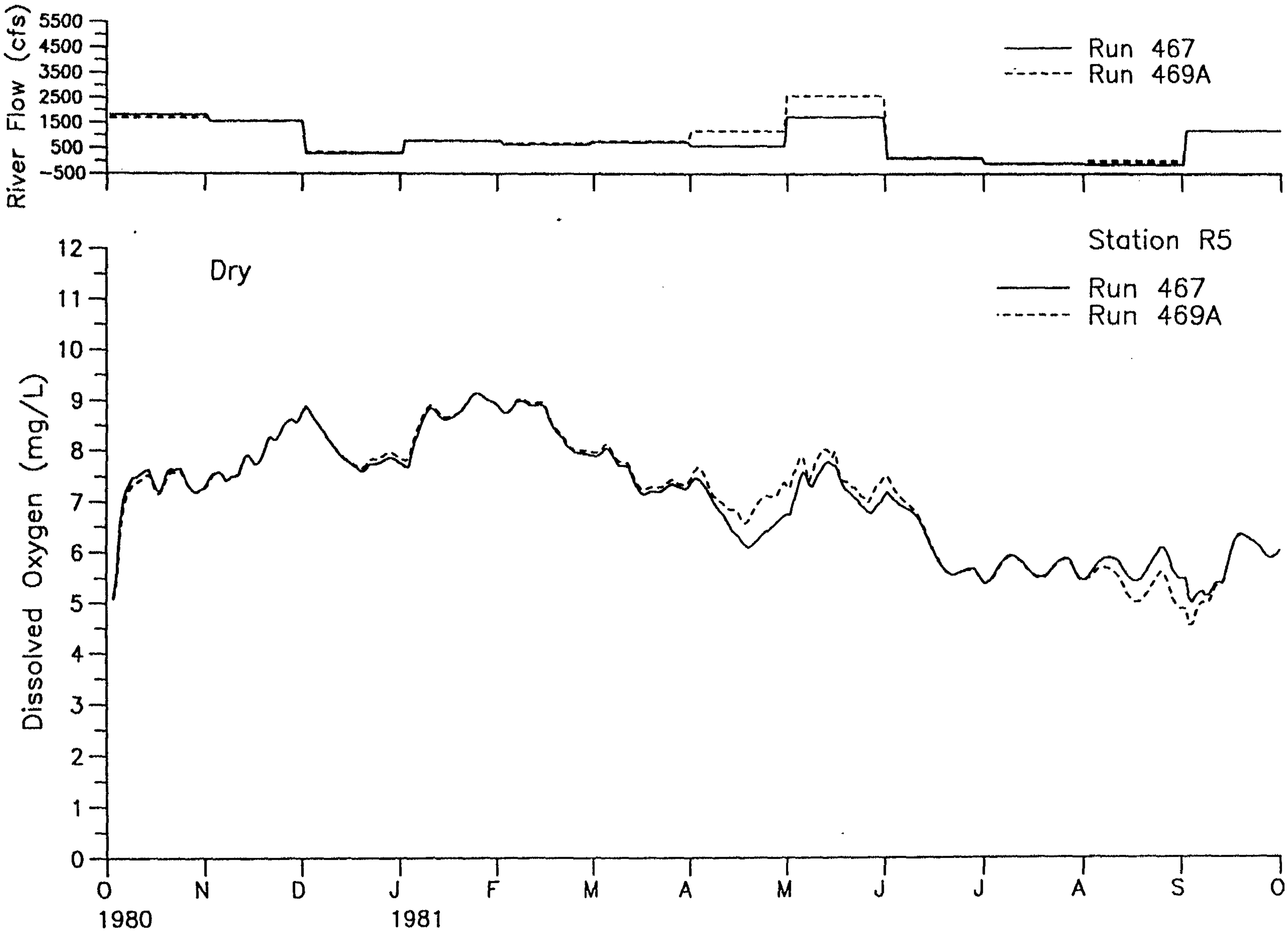
D-041594


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469A
Station R3
Dry
Run 467
Run 469A
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1980
1981



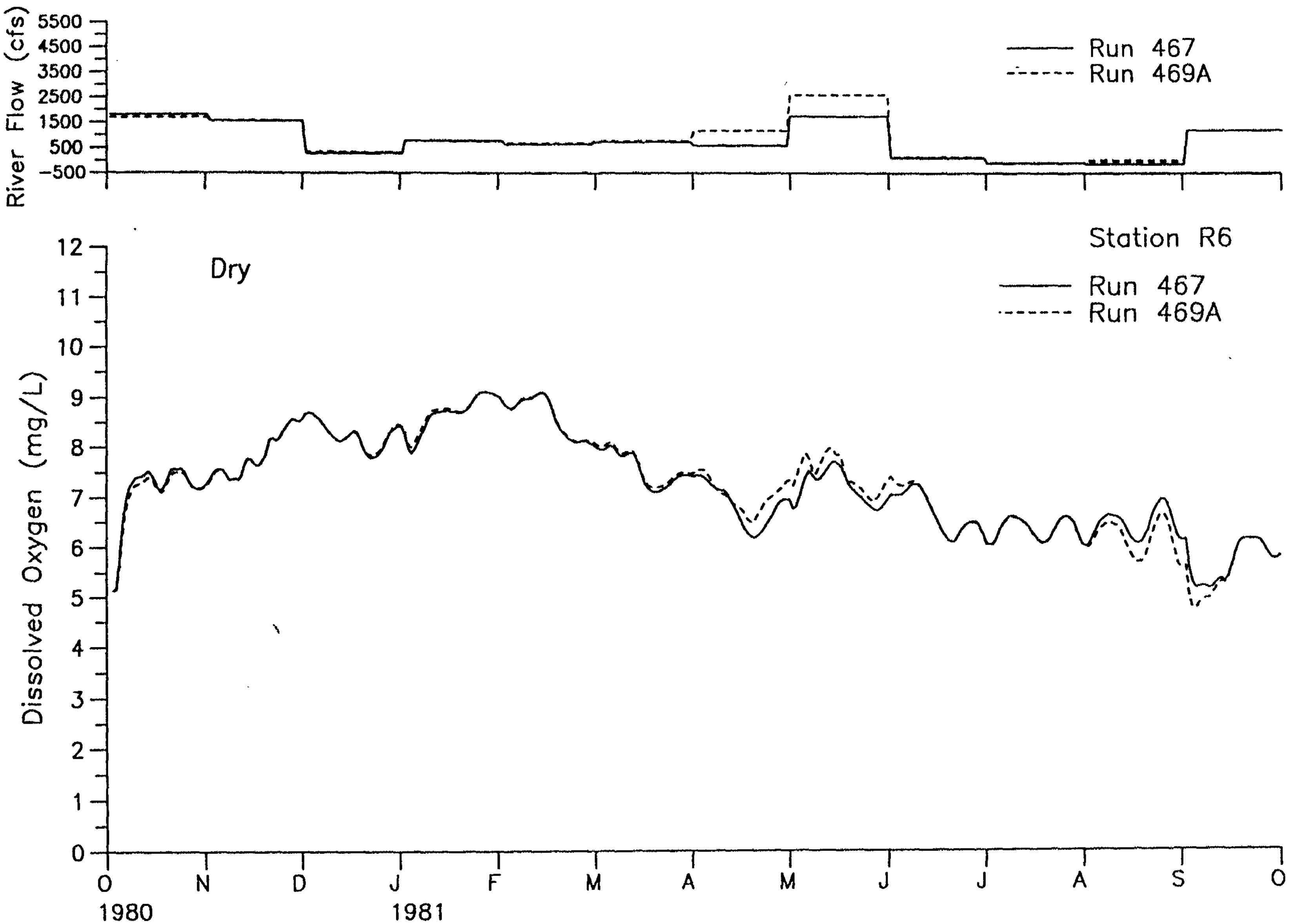
D — 0 4 1 5 9 6

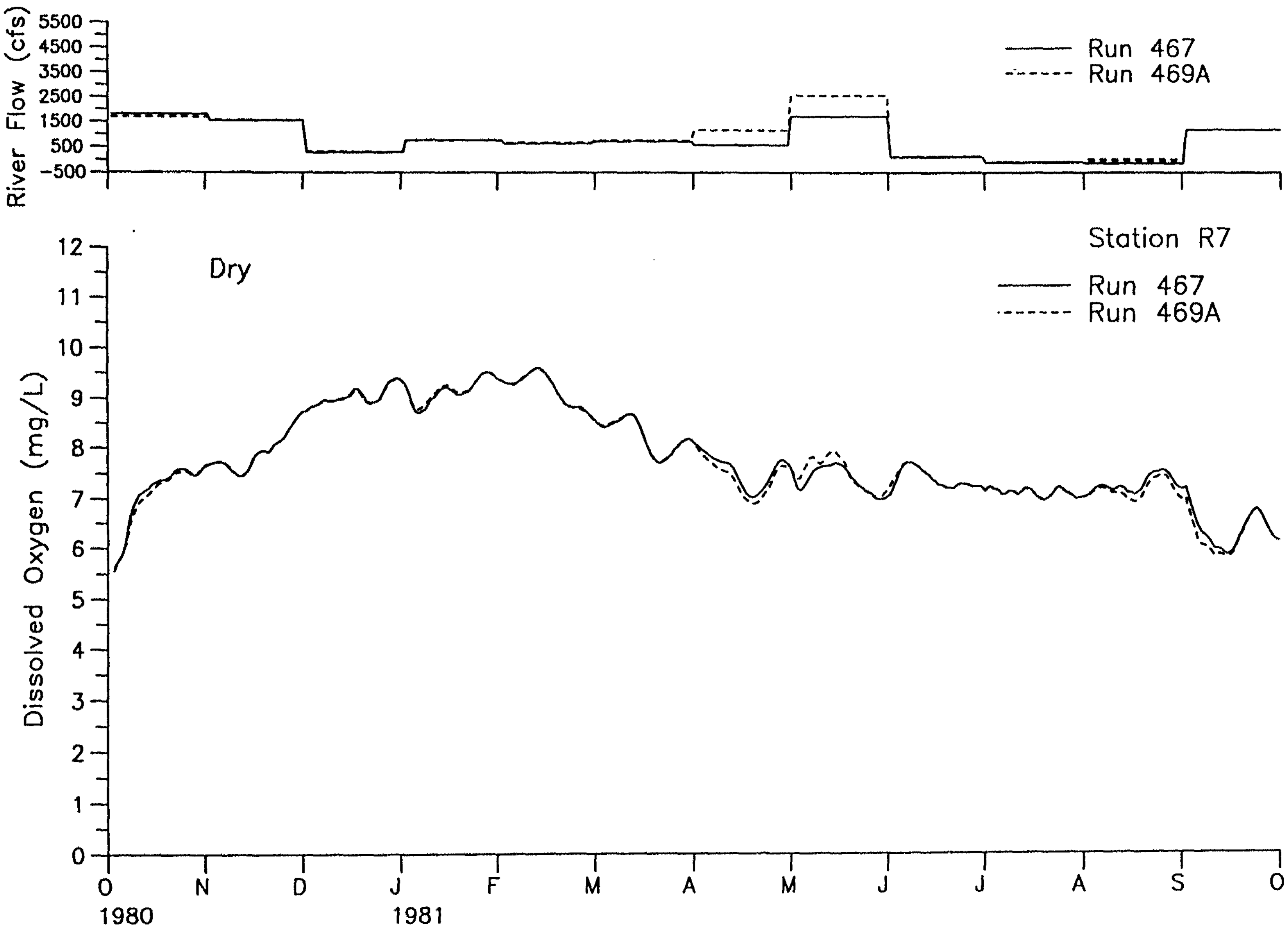
D-041596



D—041597

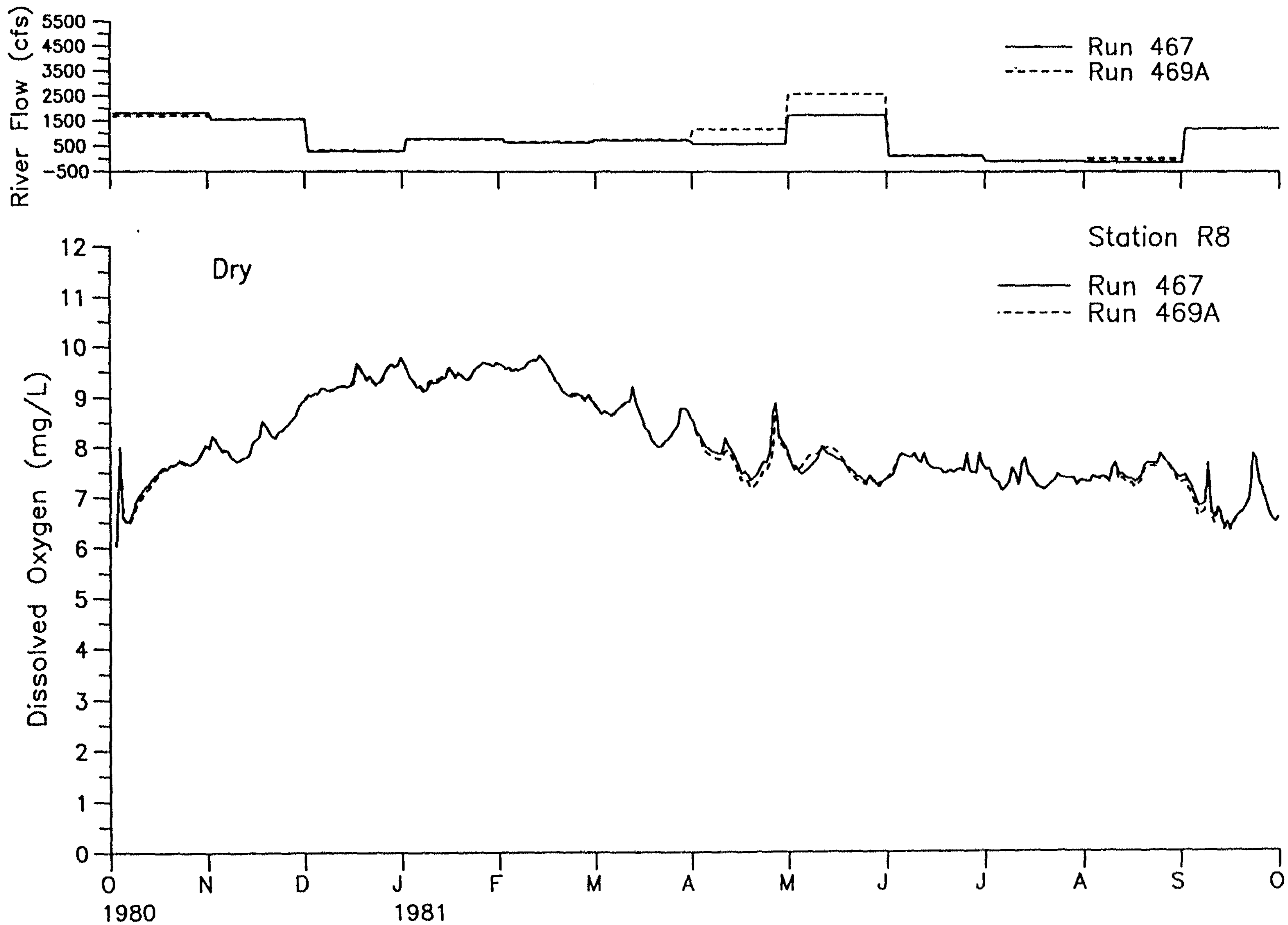
D-041597


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469A
Station R6
Dry
Run 467
Run 469A
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1980
1981



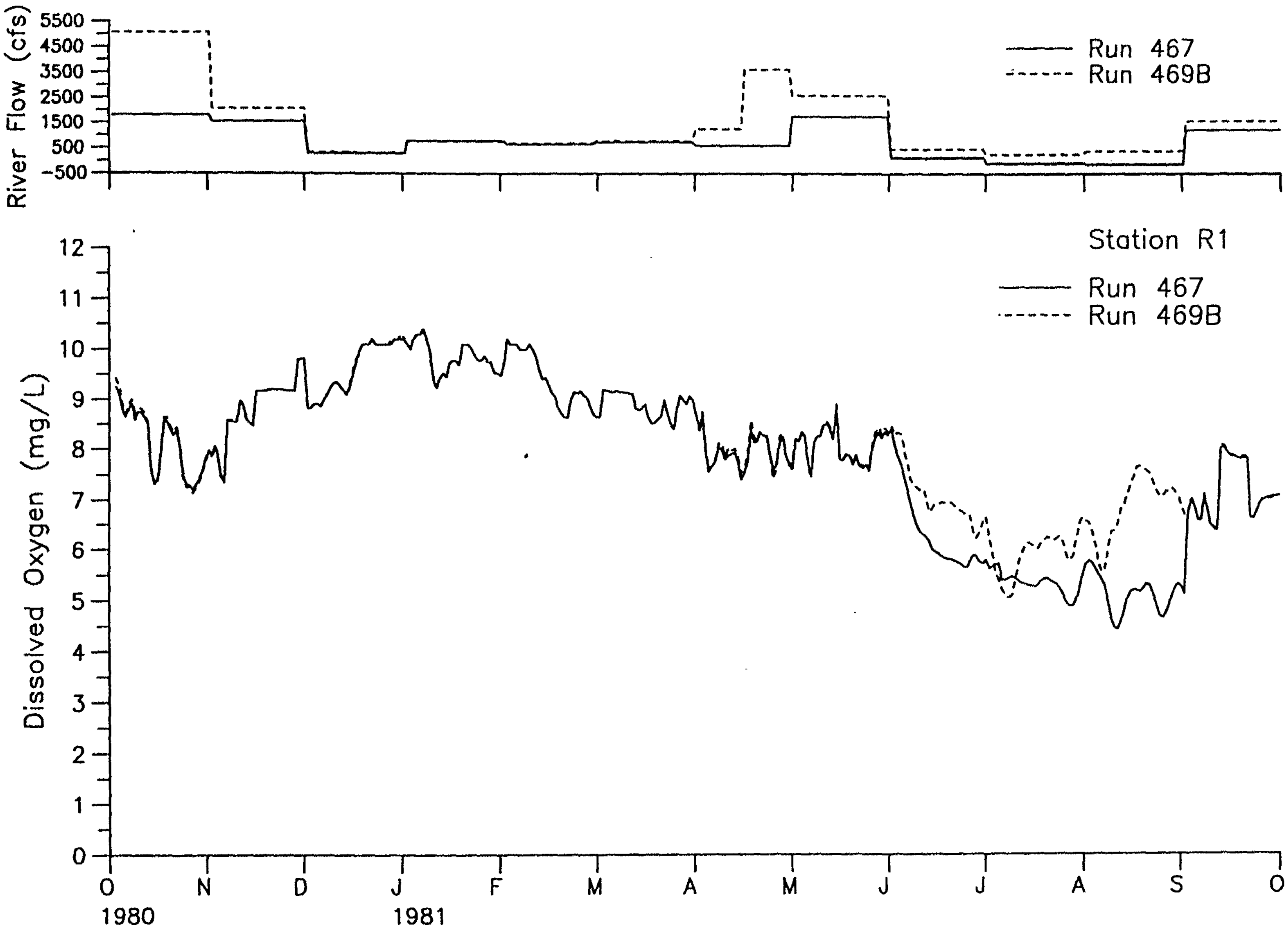
D-041599

D-041599

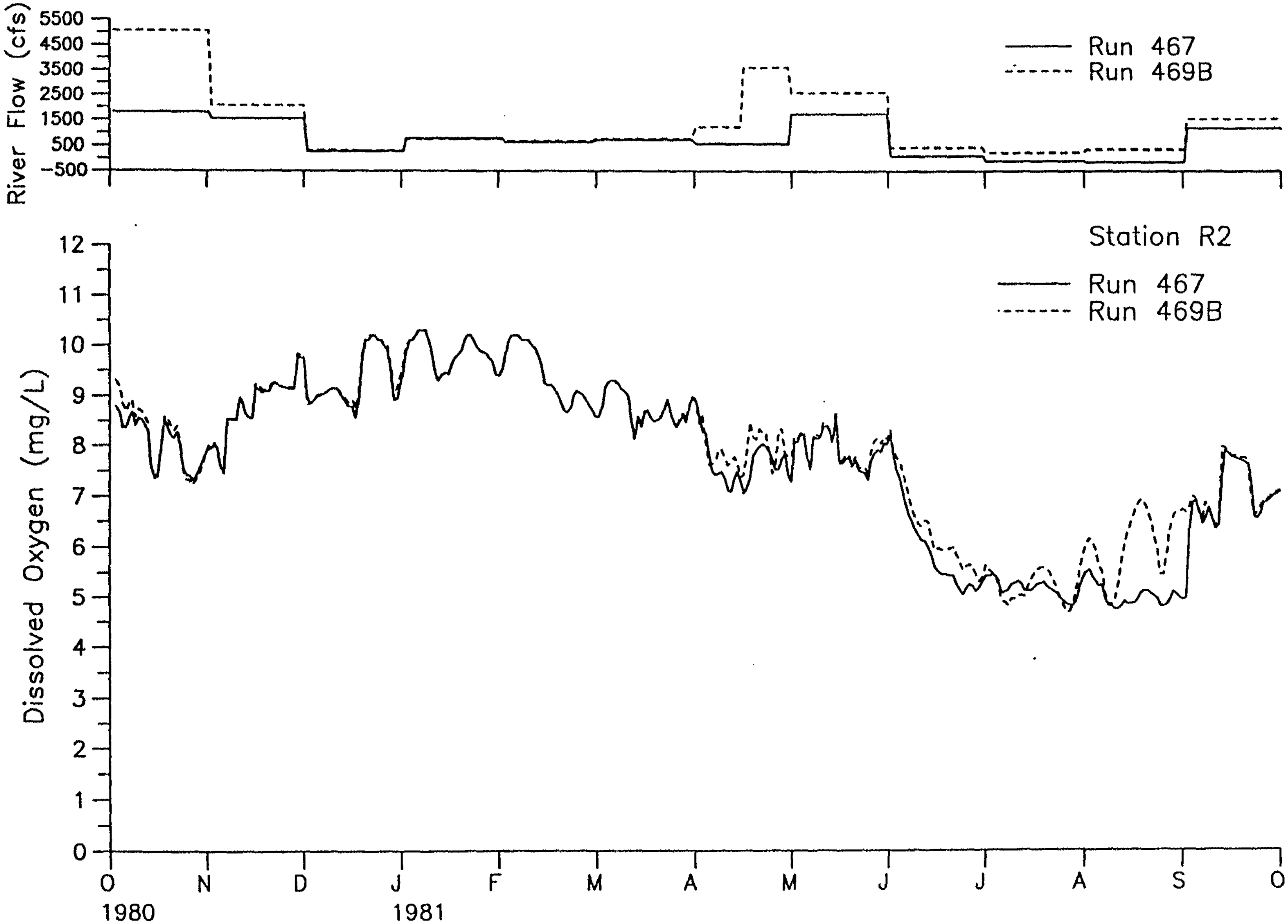

River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469A
Station R8
Dry
Run 467
Run 469A
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1980
1981

D-041600

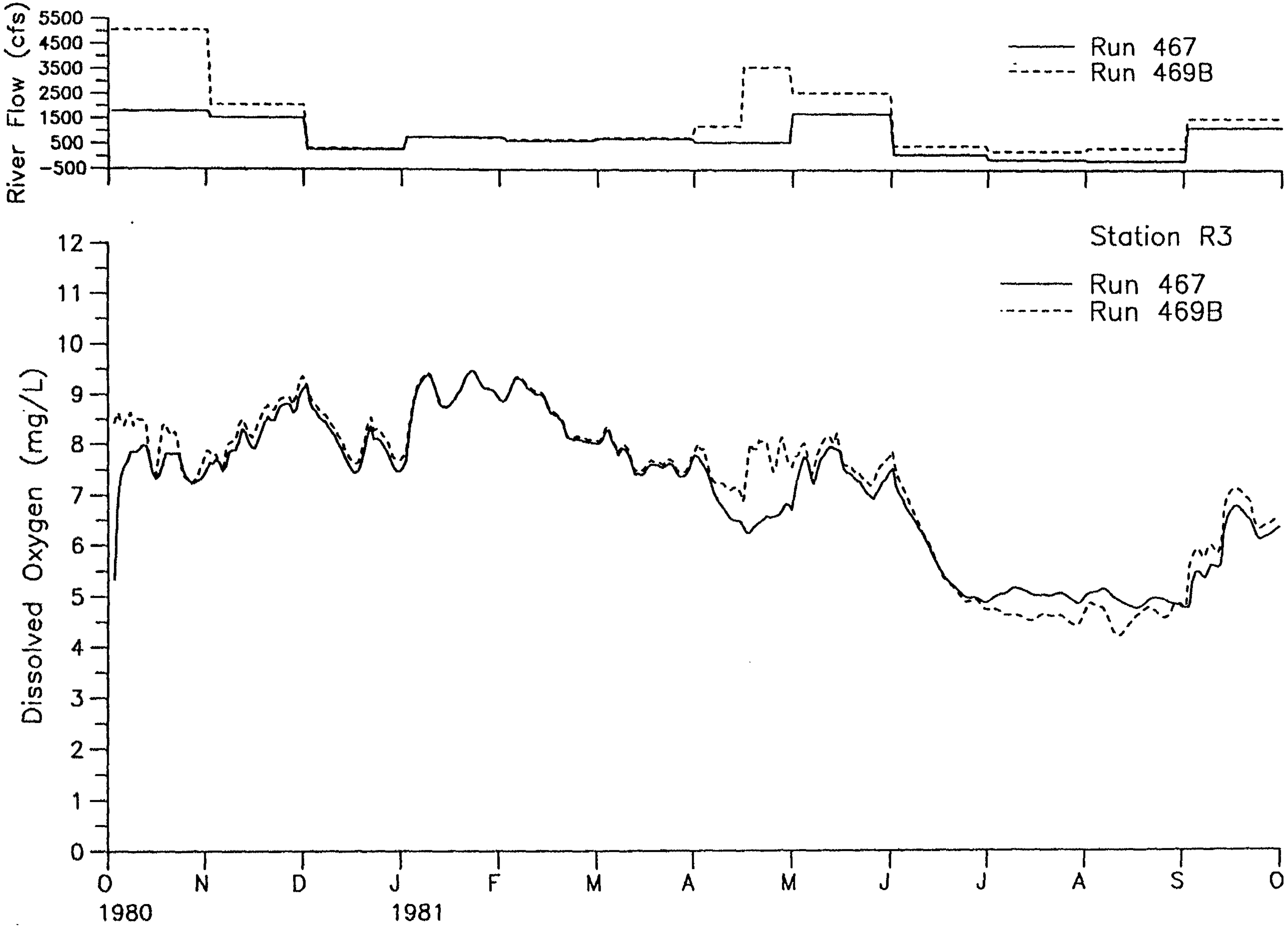
D-041601



D—041601

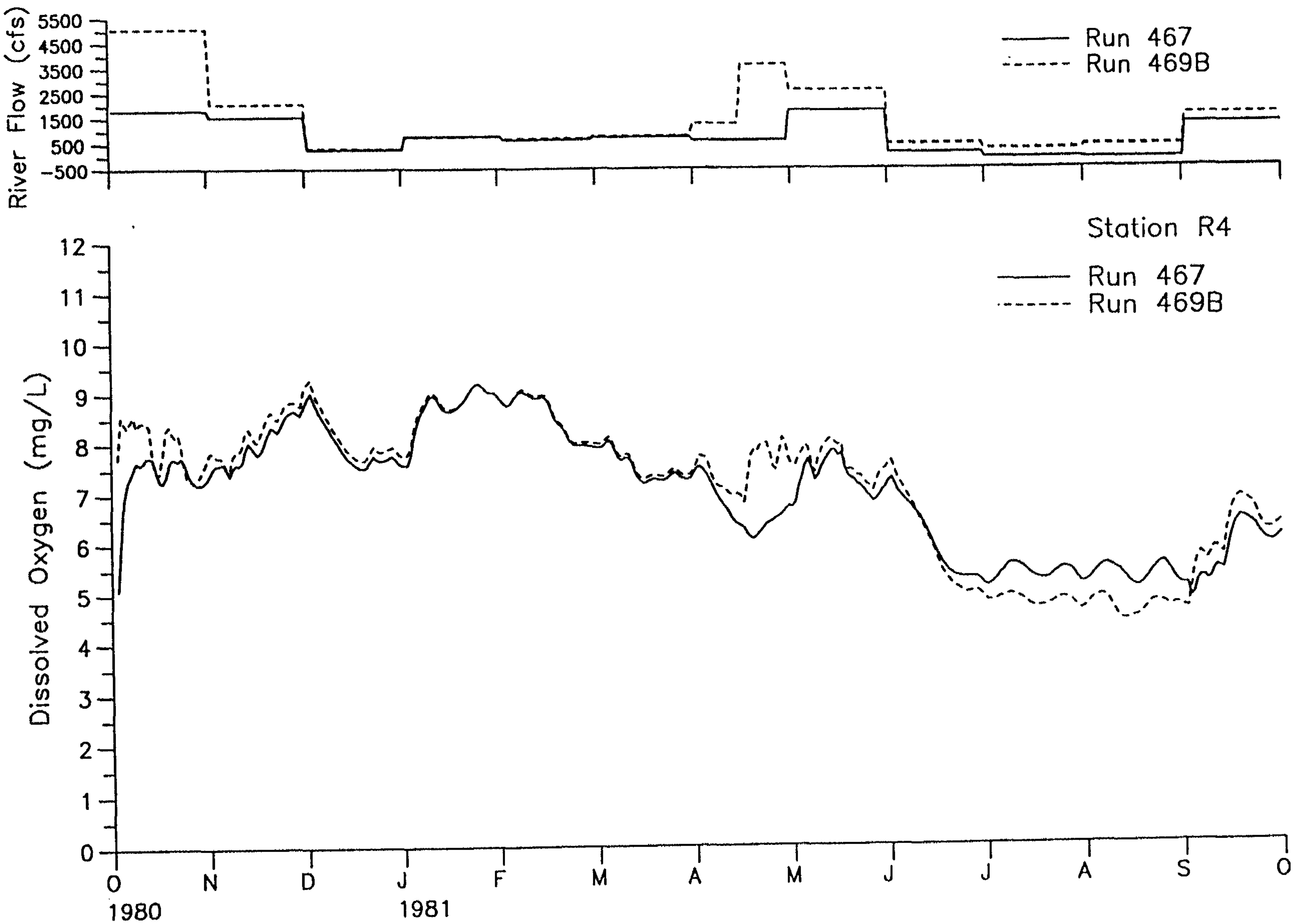

River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R2
Run 467
Run 469B
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1980
1981

D-041602



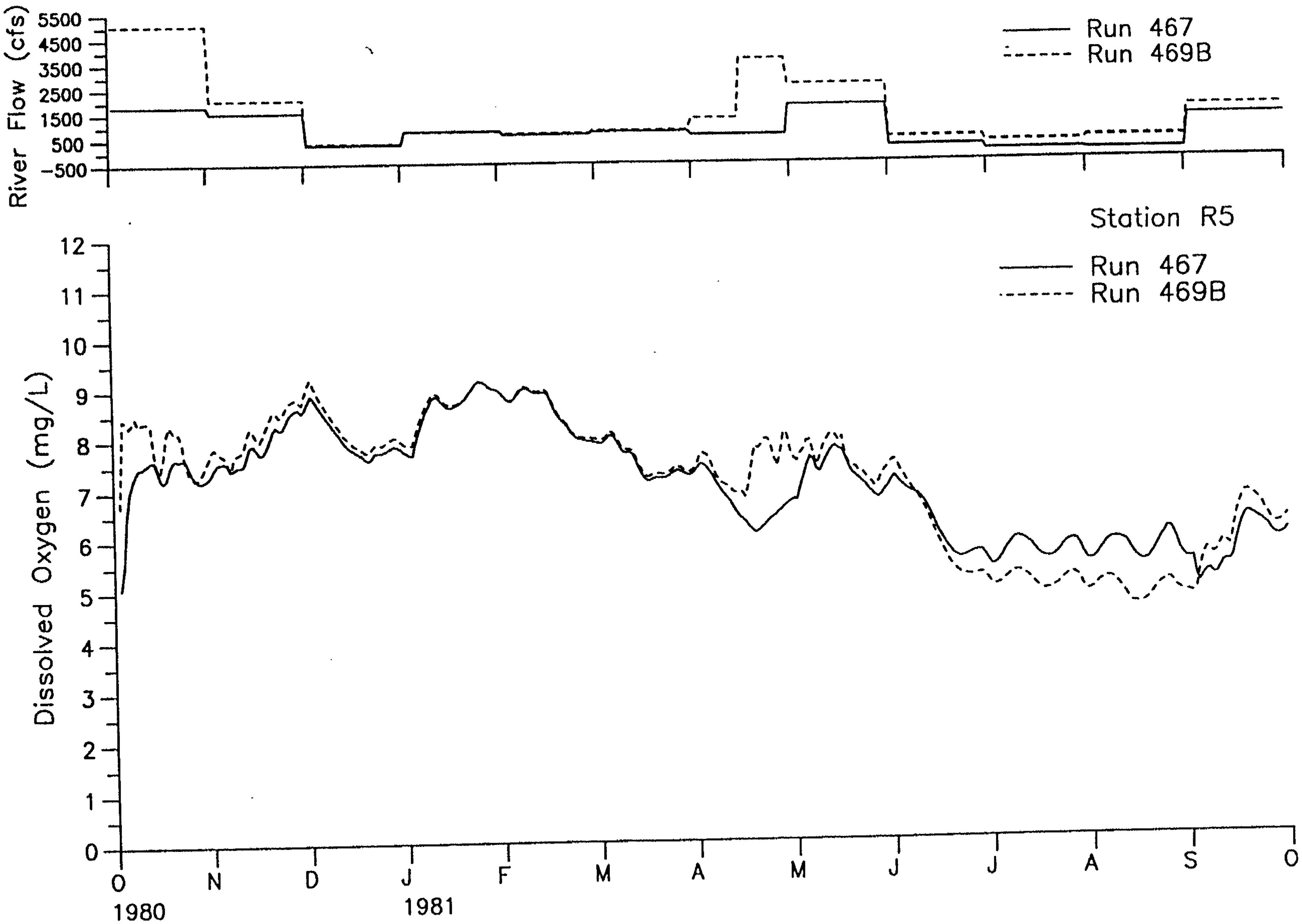
River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R3
Run 467
Run 469B
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1980
1981

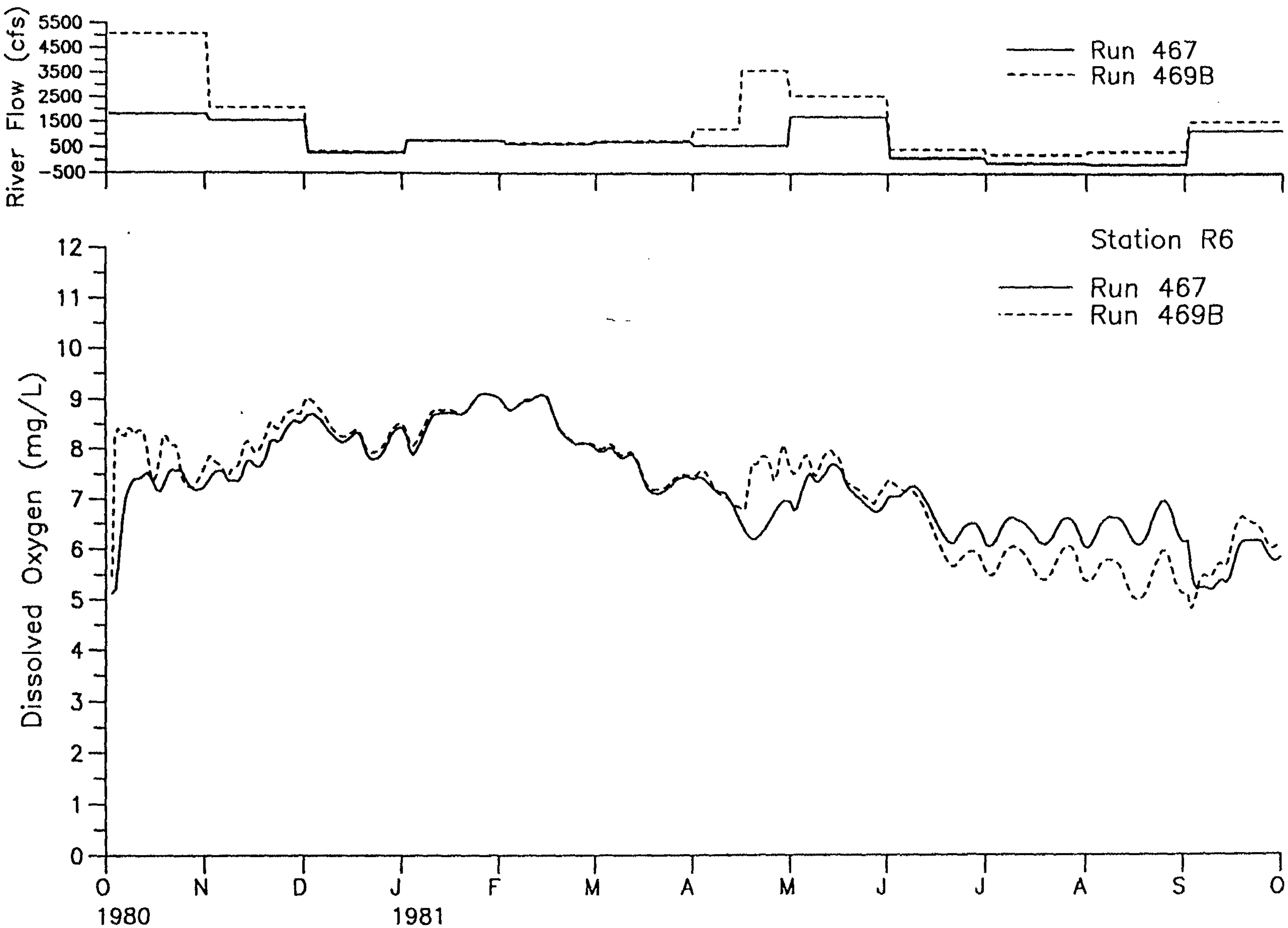
D-041603



River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R4
Run 467
Run 469B
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1980
1981

D-041604

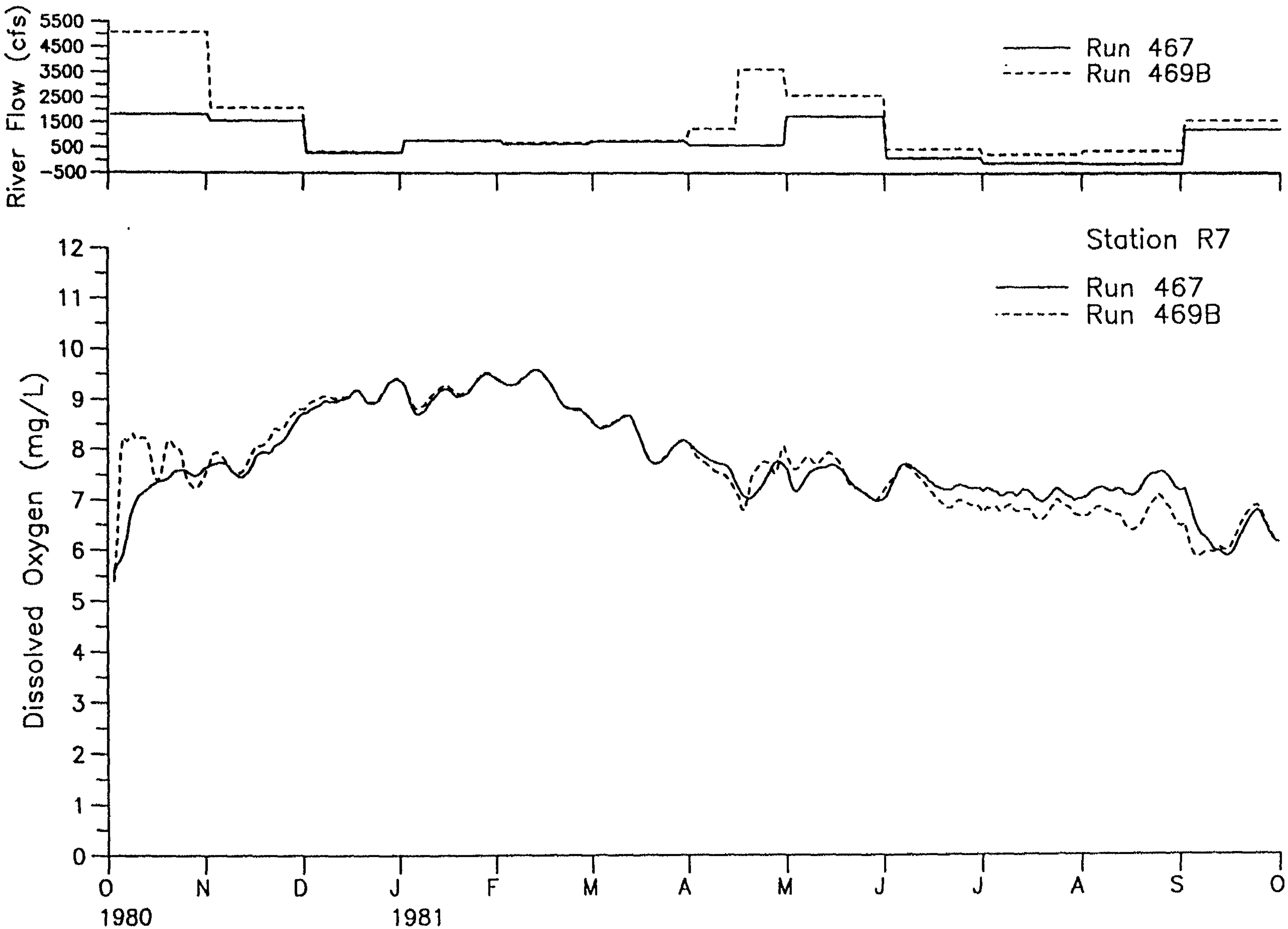

River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R5
Run 467
Run 469B
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1980
1981



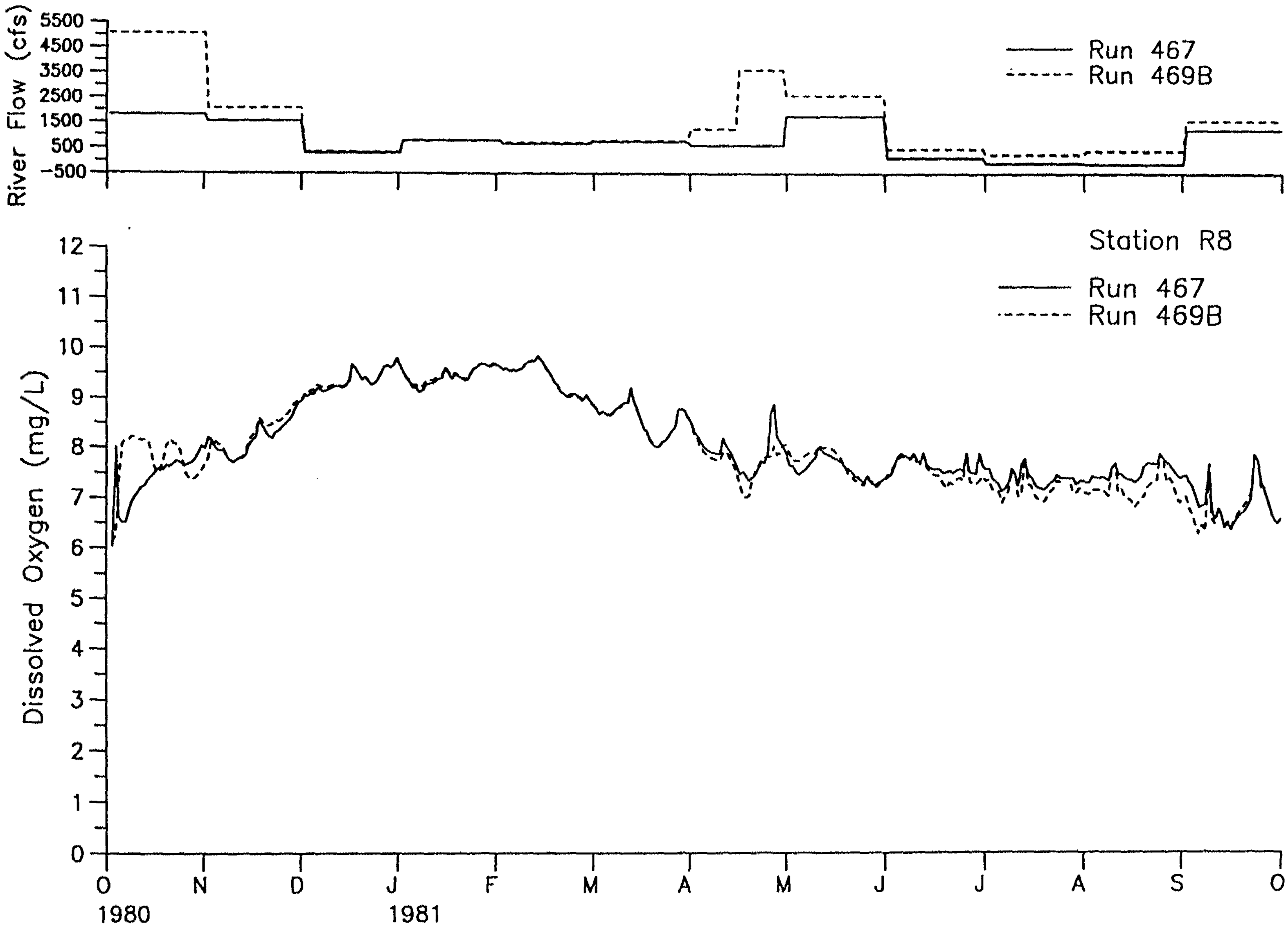
D-041606

D — 0 4 1 6 0 6

D-041607

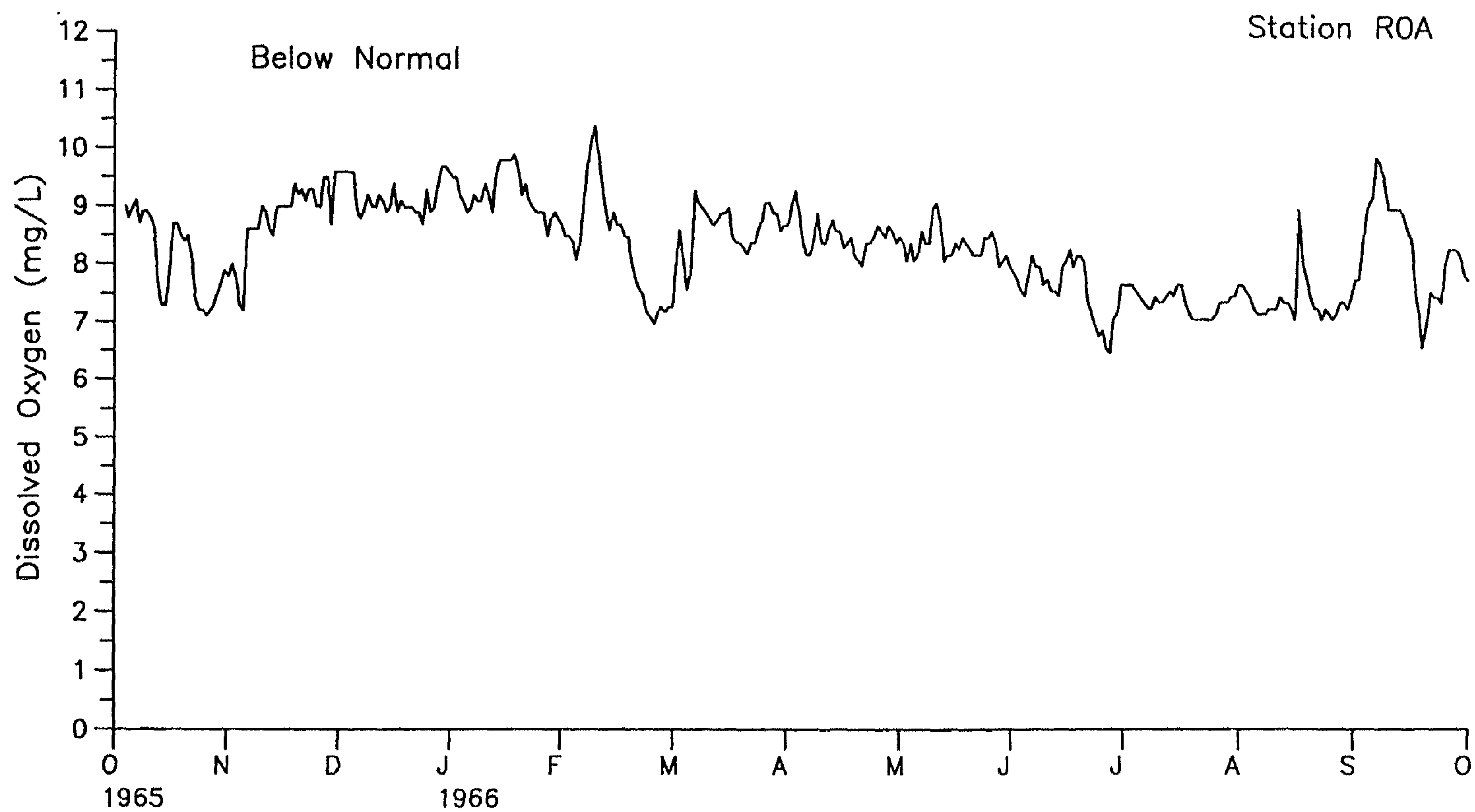


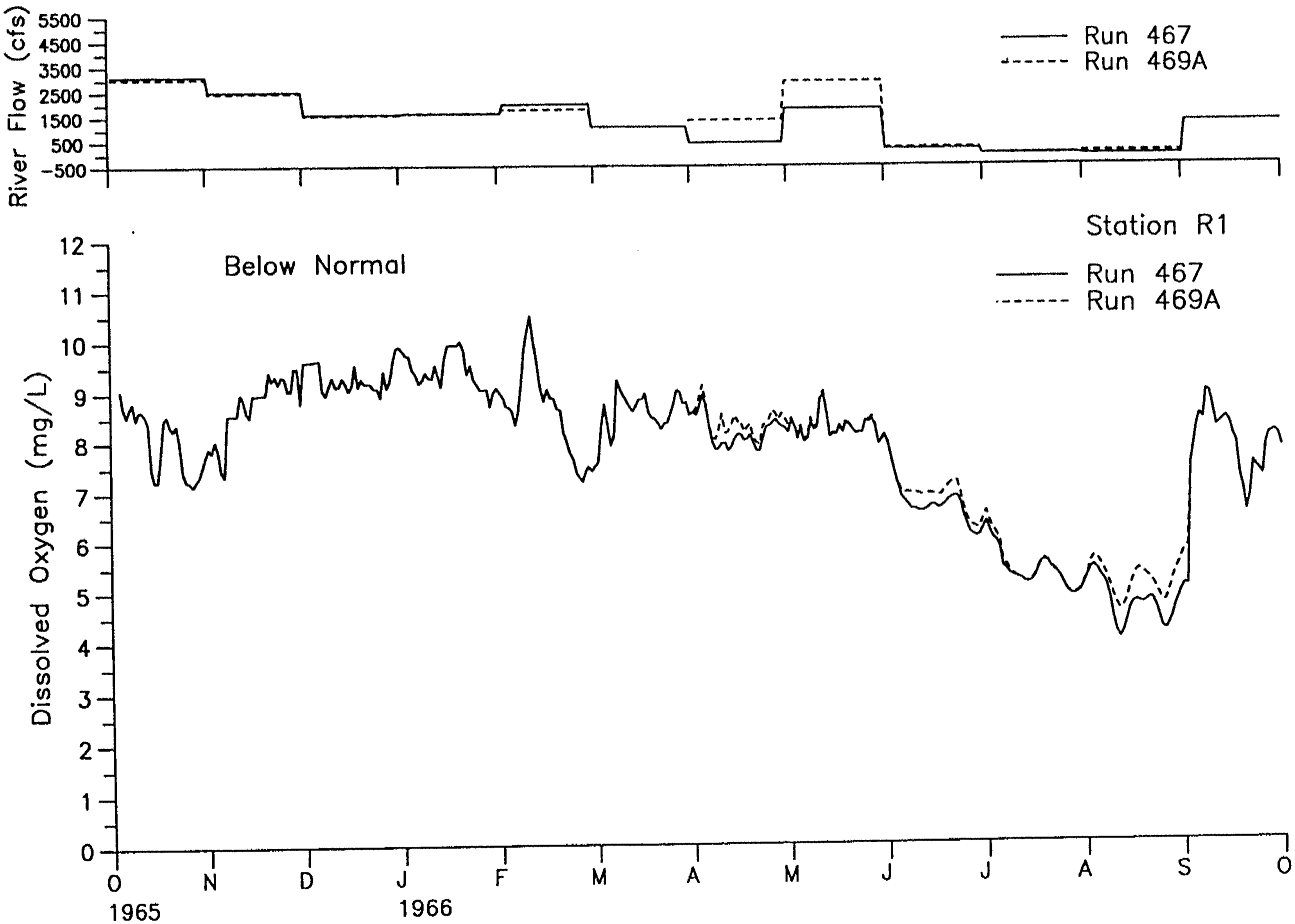
D — 0 4 1 6 0 7


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R8
Run 467
Run 469B
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1980
1981

Appendix G.

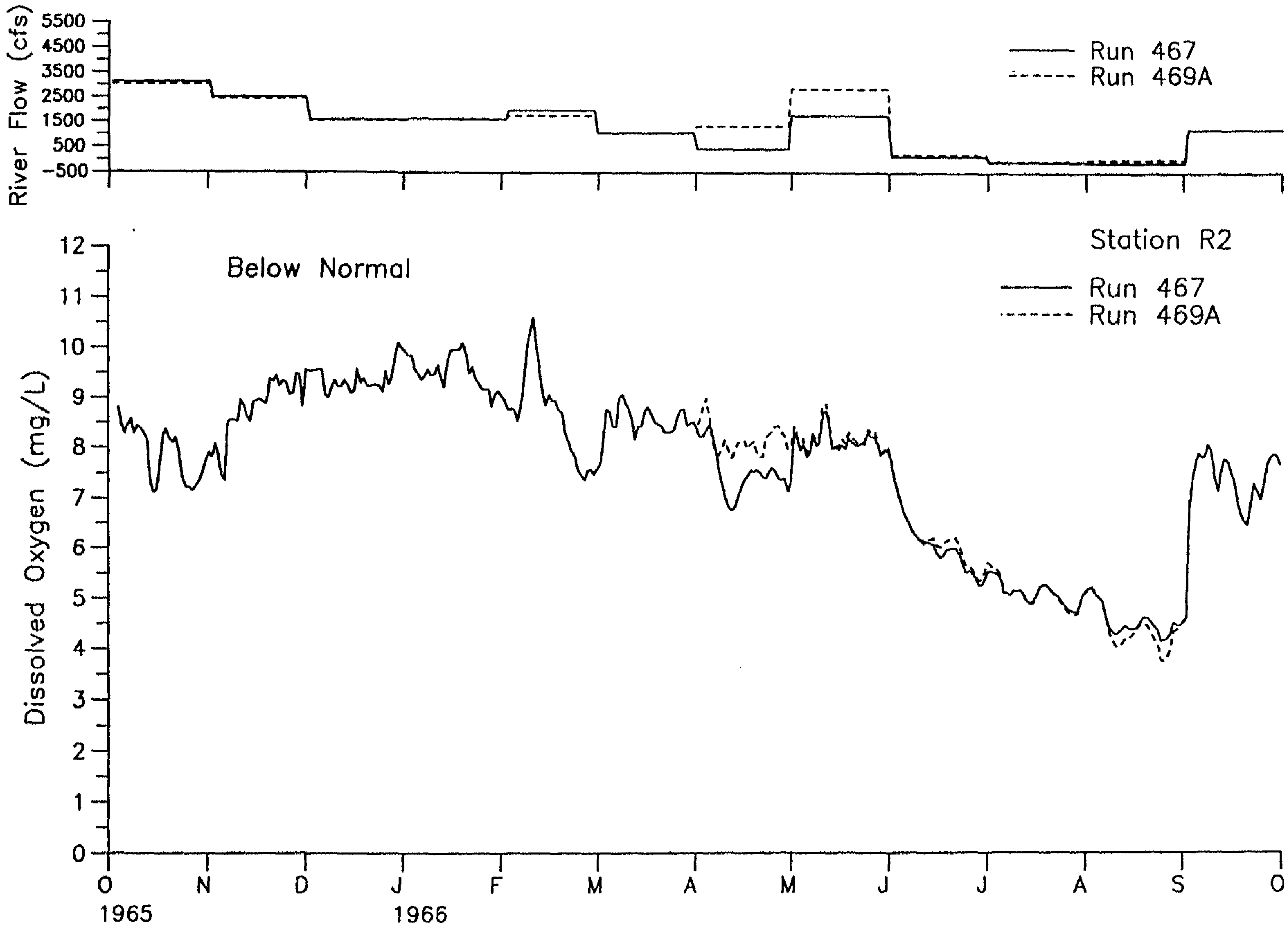
Results for Below Normal Year 1966


Station R0A
Below Normal
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
O
N
D
J
F
M
A
M
J
J
A
S
O
1965
1966

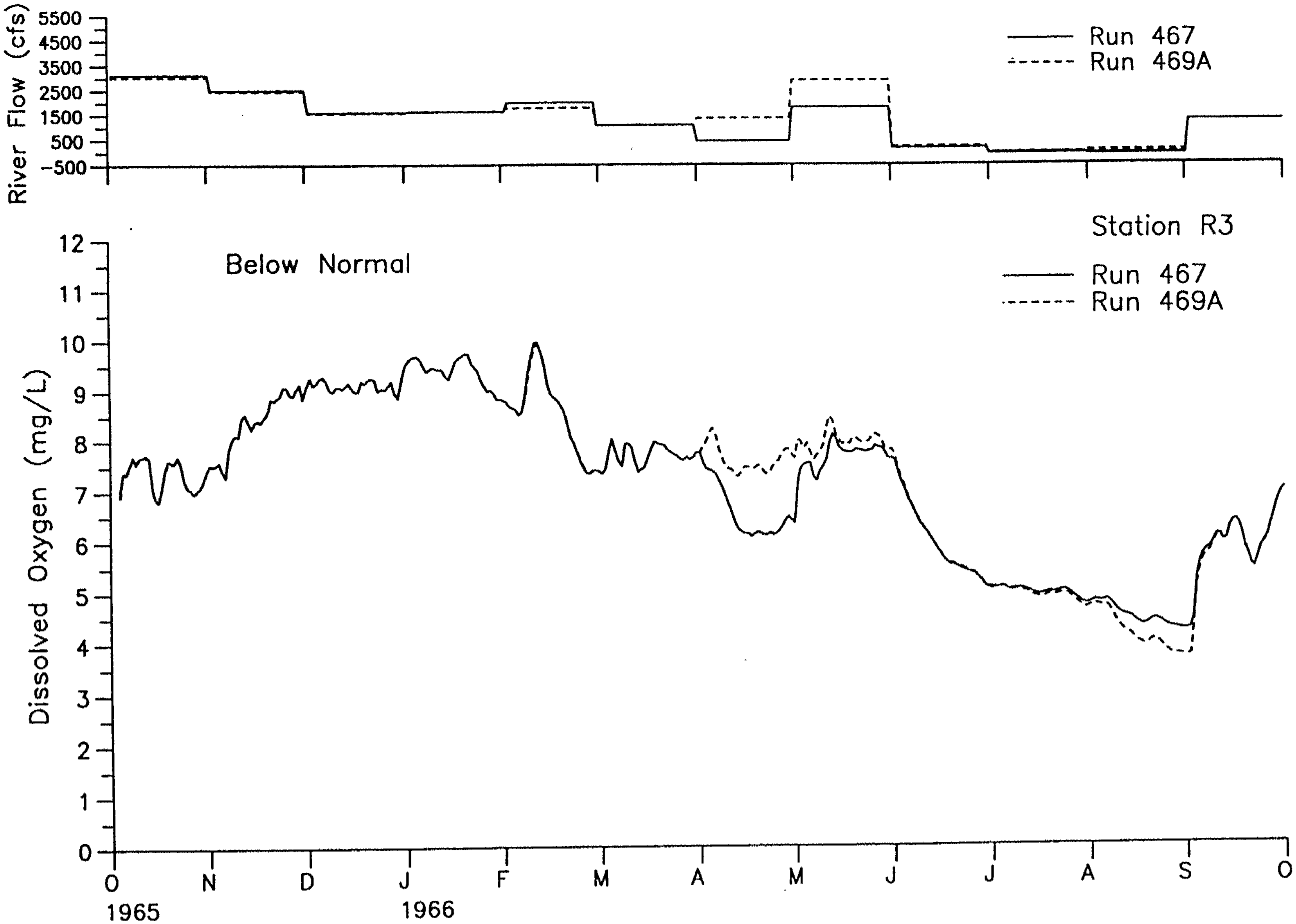


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469A
Station R1
Below Normal
Run 467
Run 469A
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1965
1966

D—041611

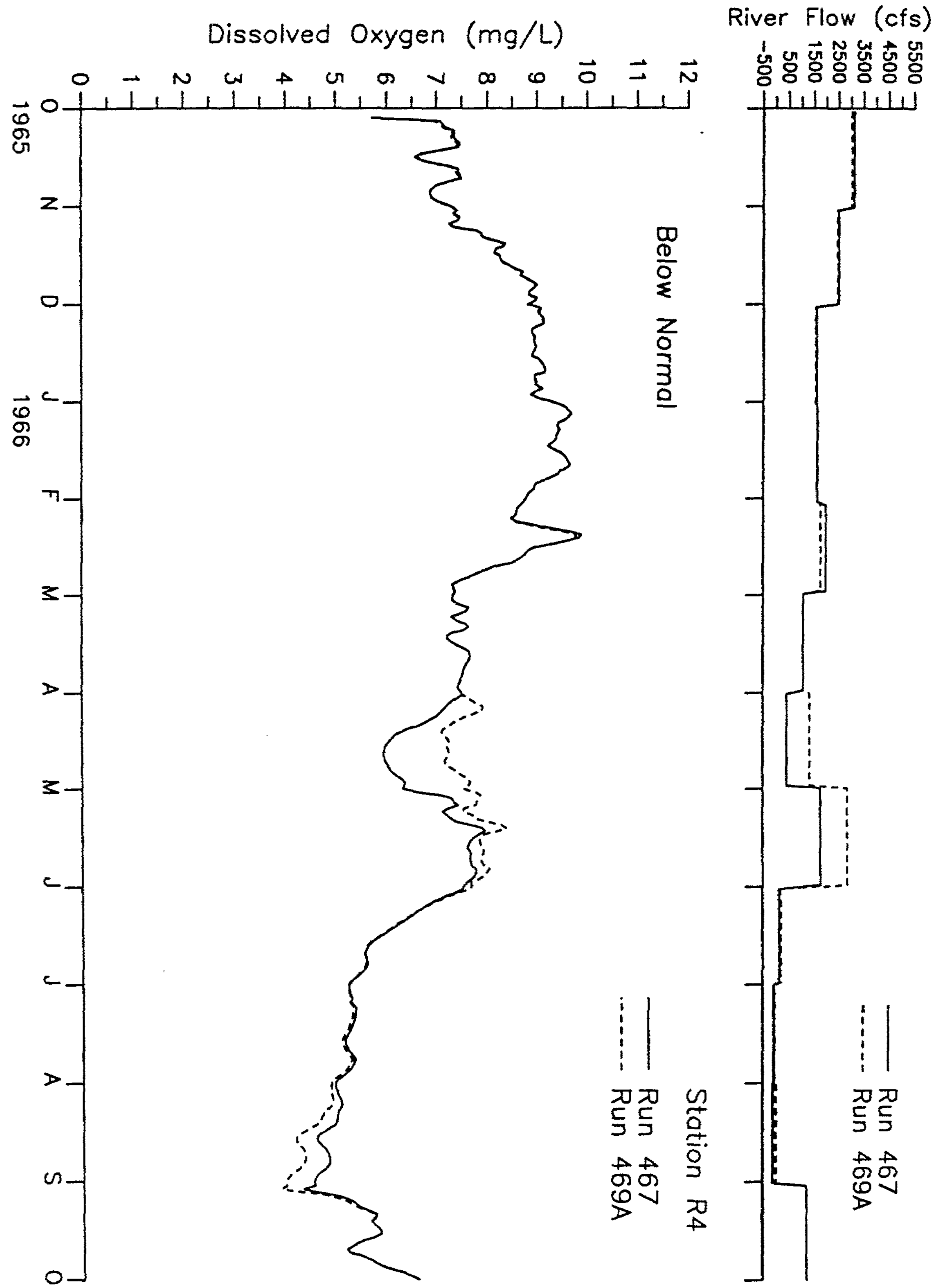

River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469A
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
Below Normal
Station R2
Run 467
Run 469A
O N D J F M A M J J A S O
1965
1966

D-041612



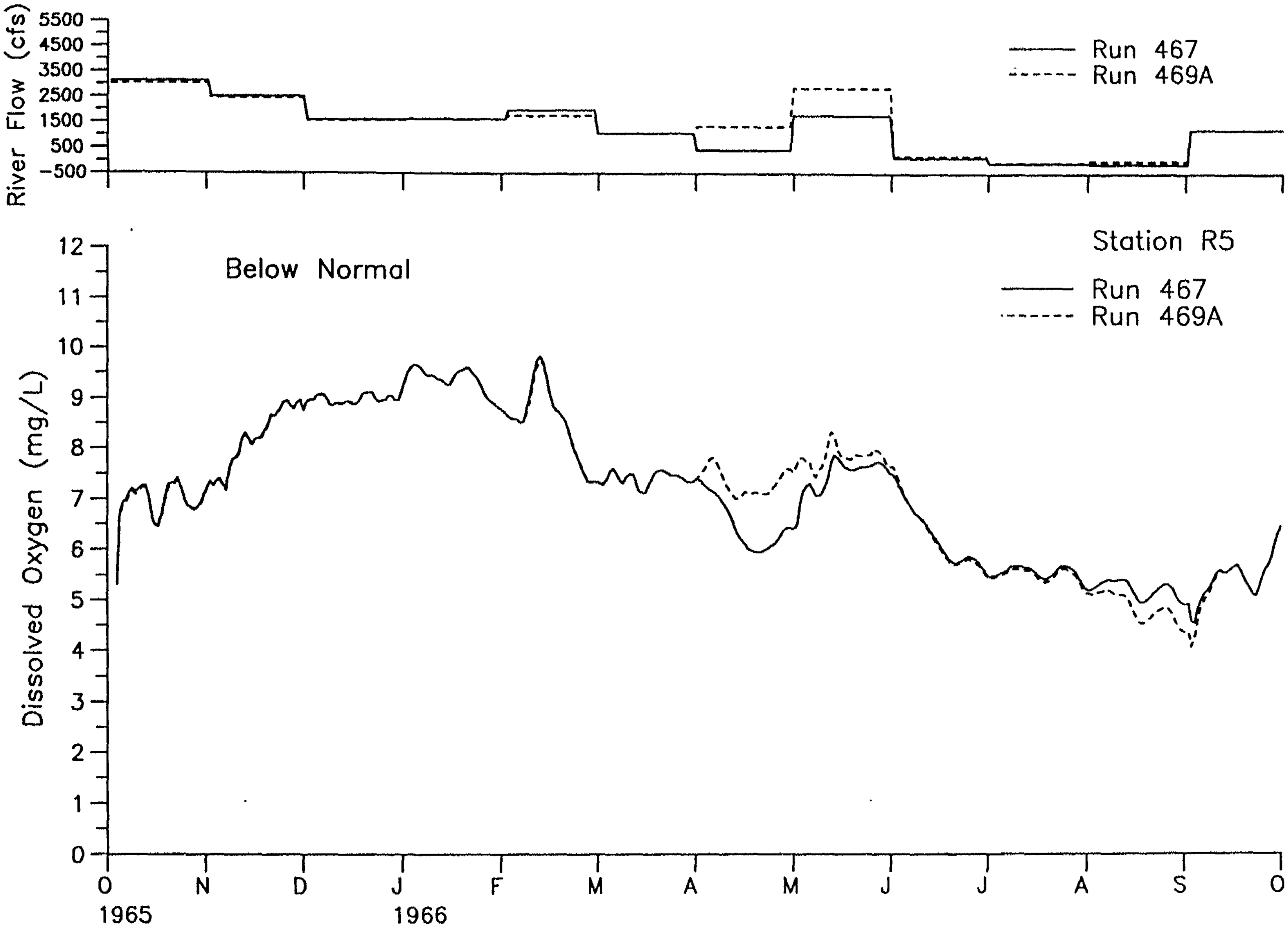
D-041613

D-041613



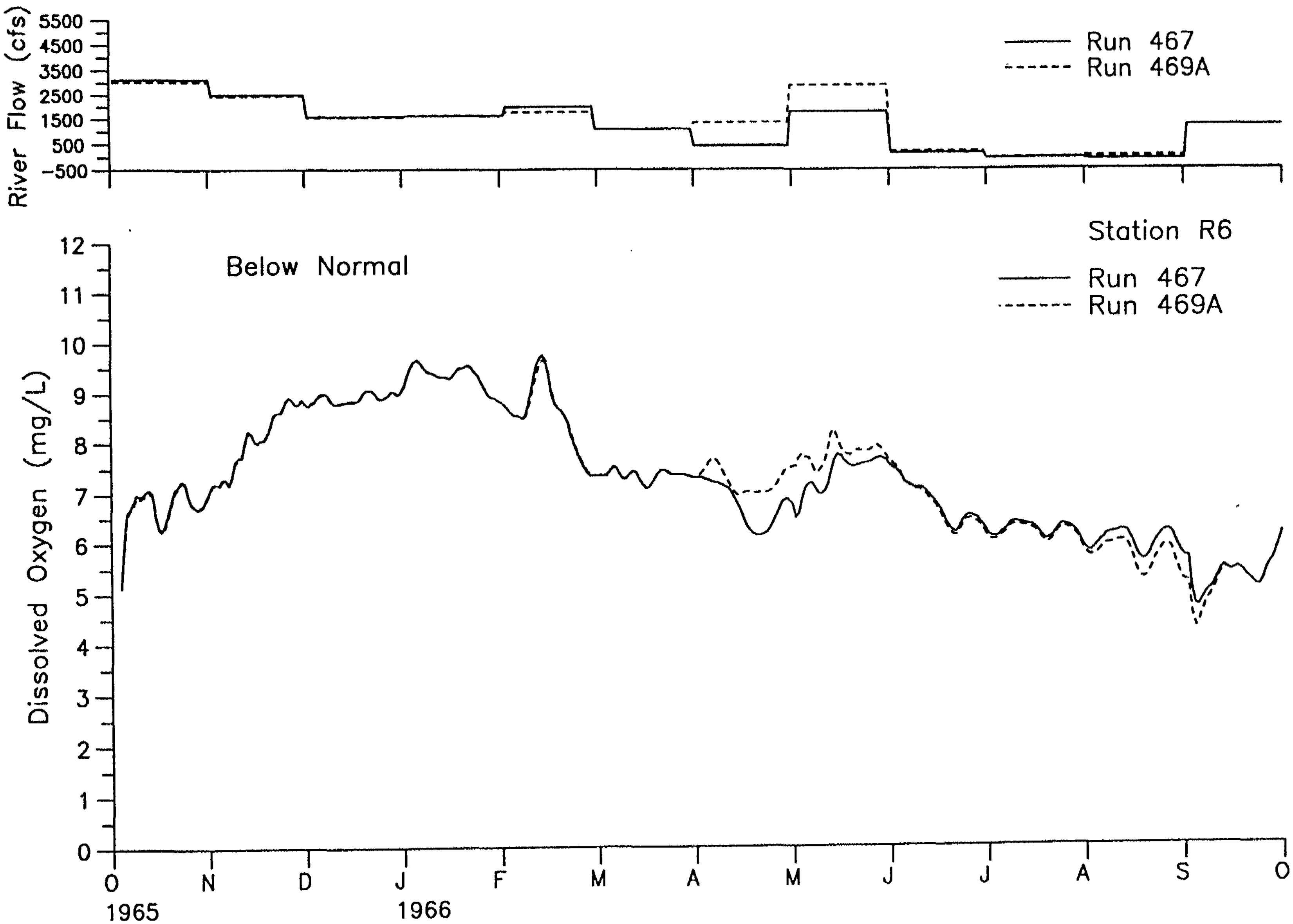
D —0 4 1 6 1 4

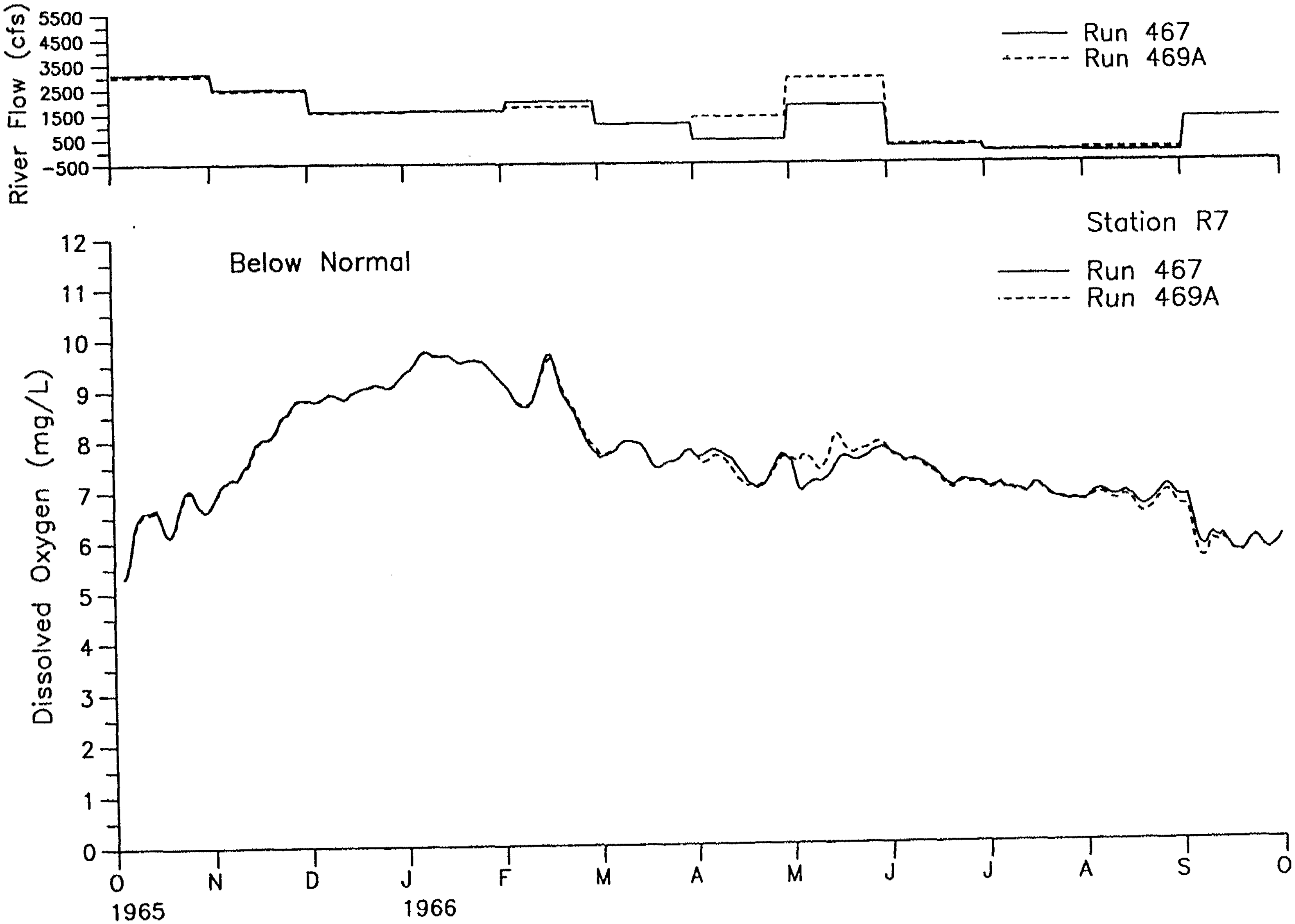
D-041614



D-041615

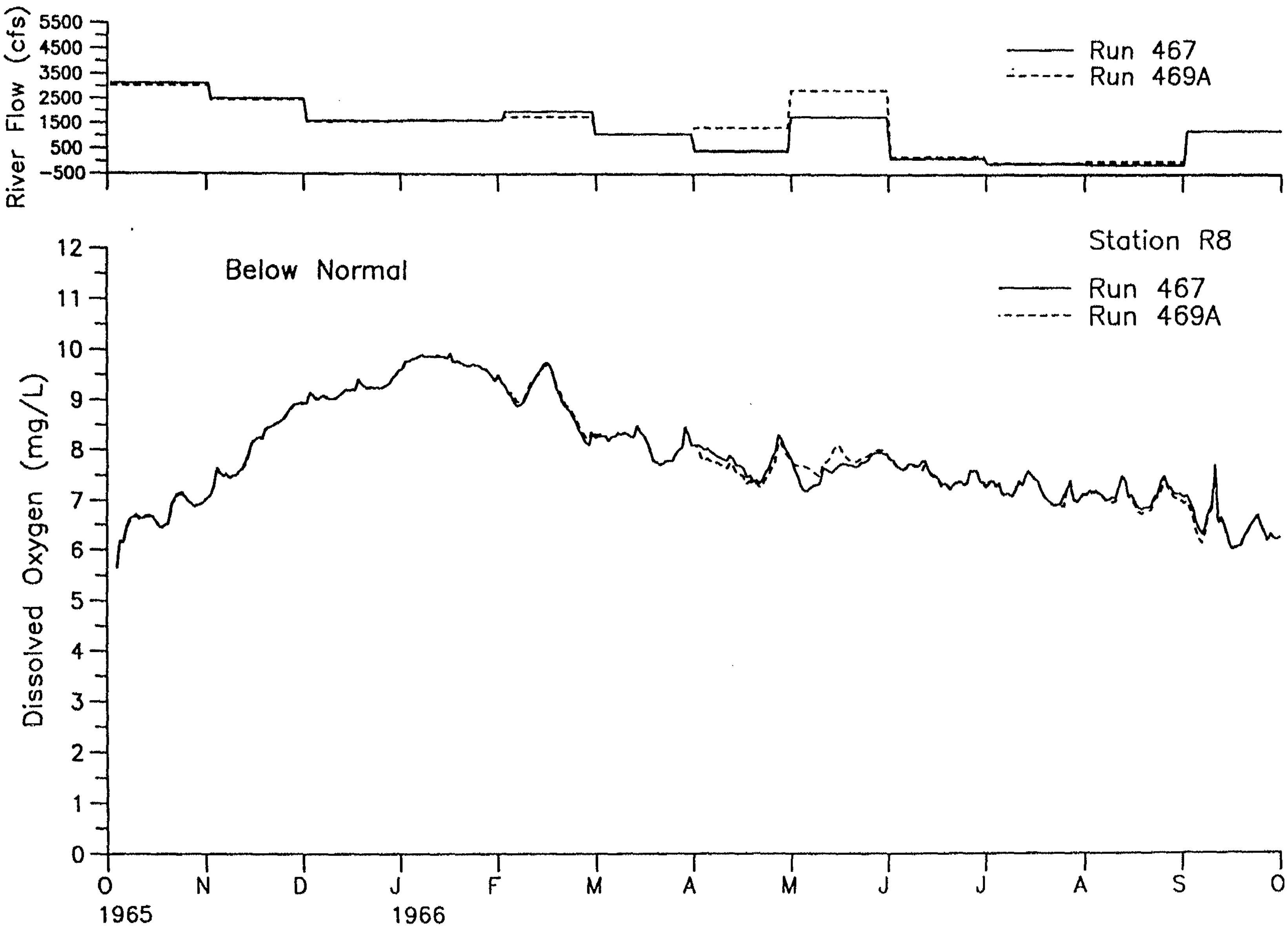
D-041615


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469A
Station R6
Below Normal
Run 467
Run 469A
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1965
1966



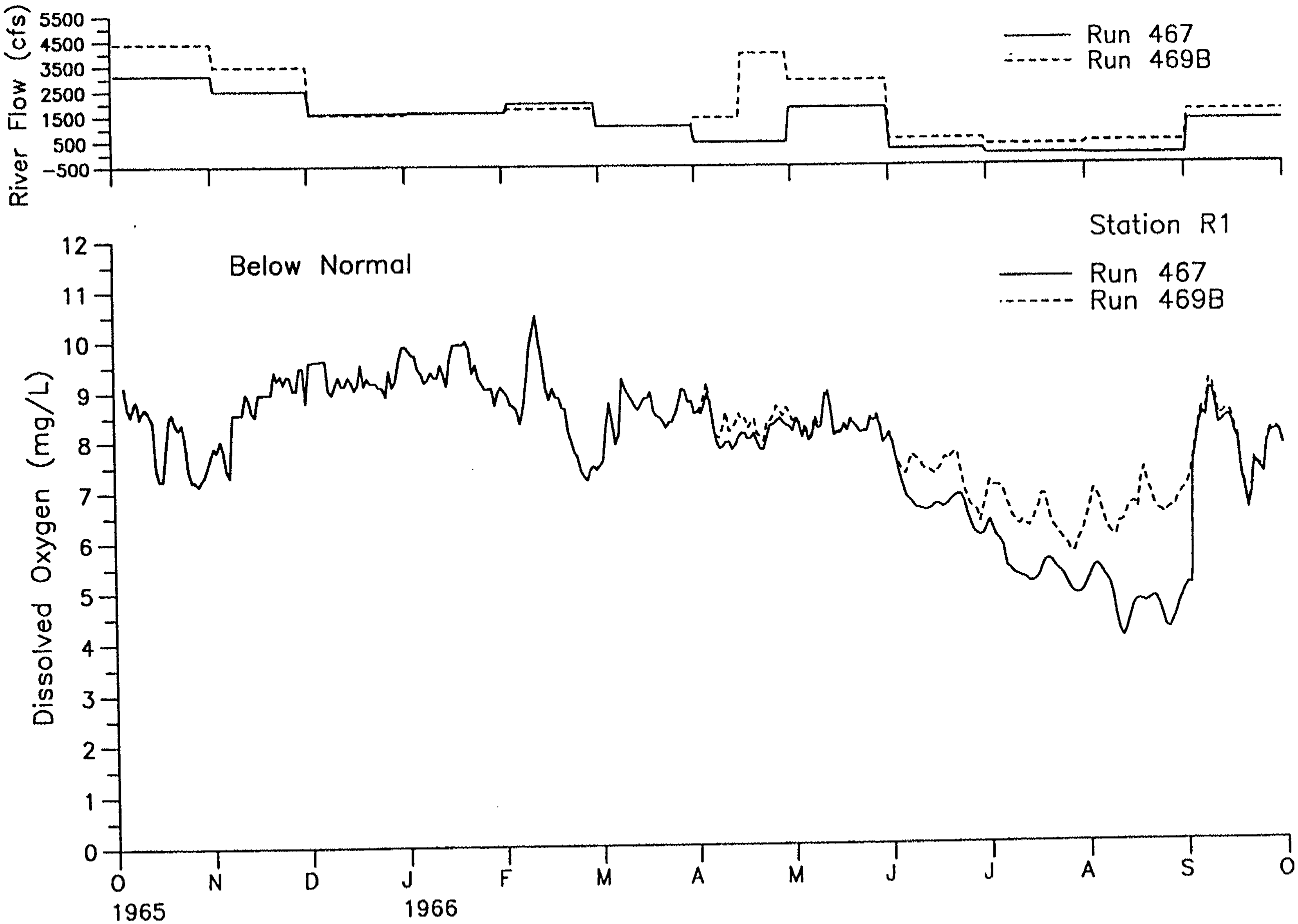
River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469A
Station R7
Below Normal
Run 467
Run 469A
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1965
1966

D-041617



D-041618

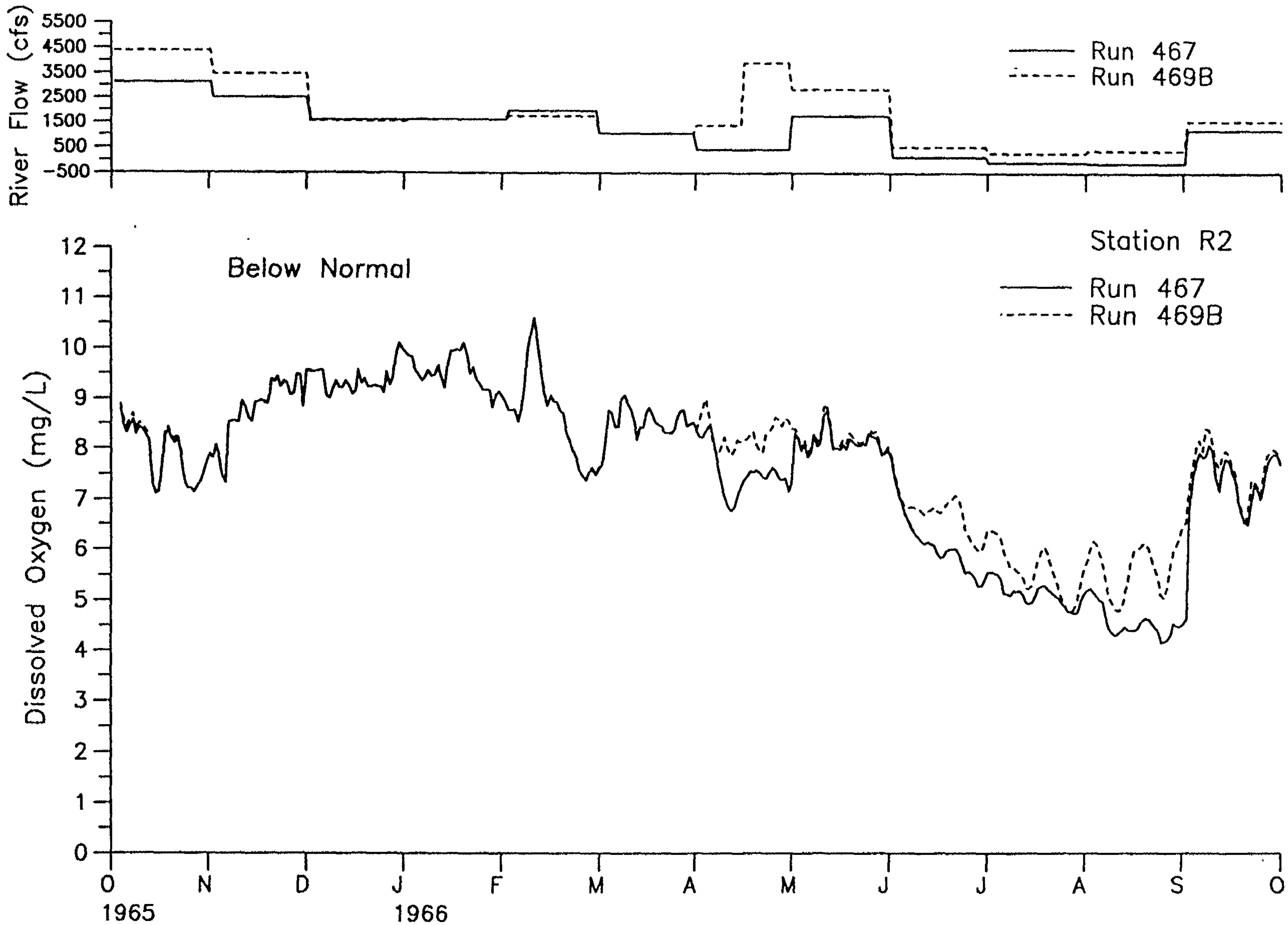
D-041618



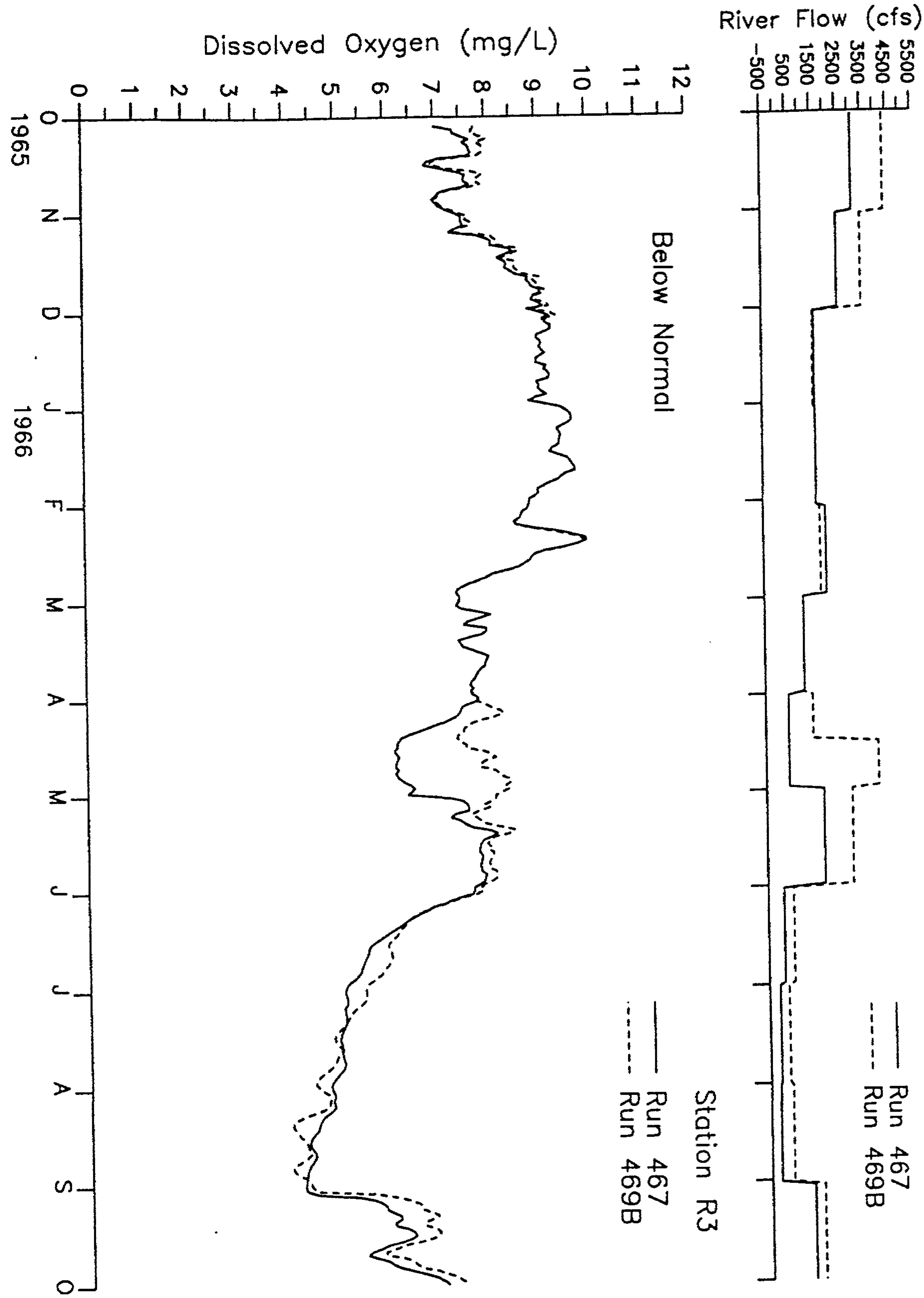
River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R1
Below Normal
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1965
1966

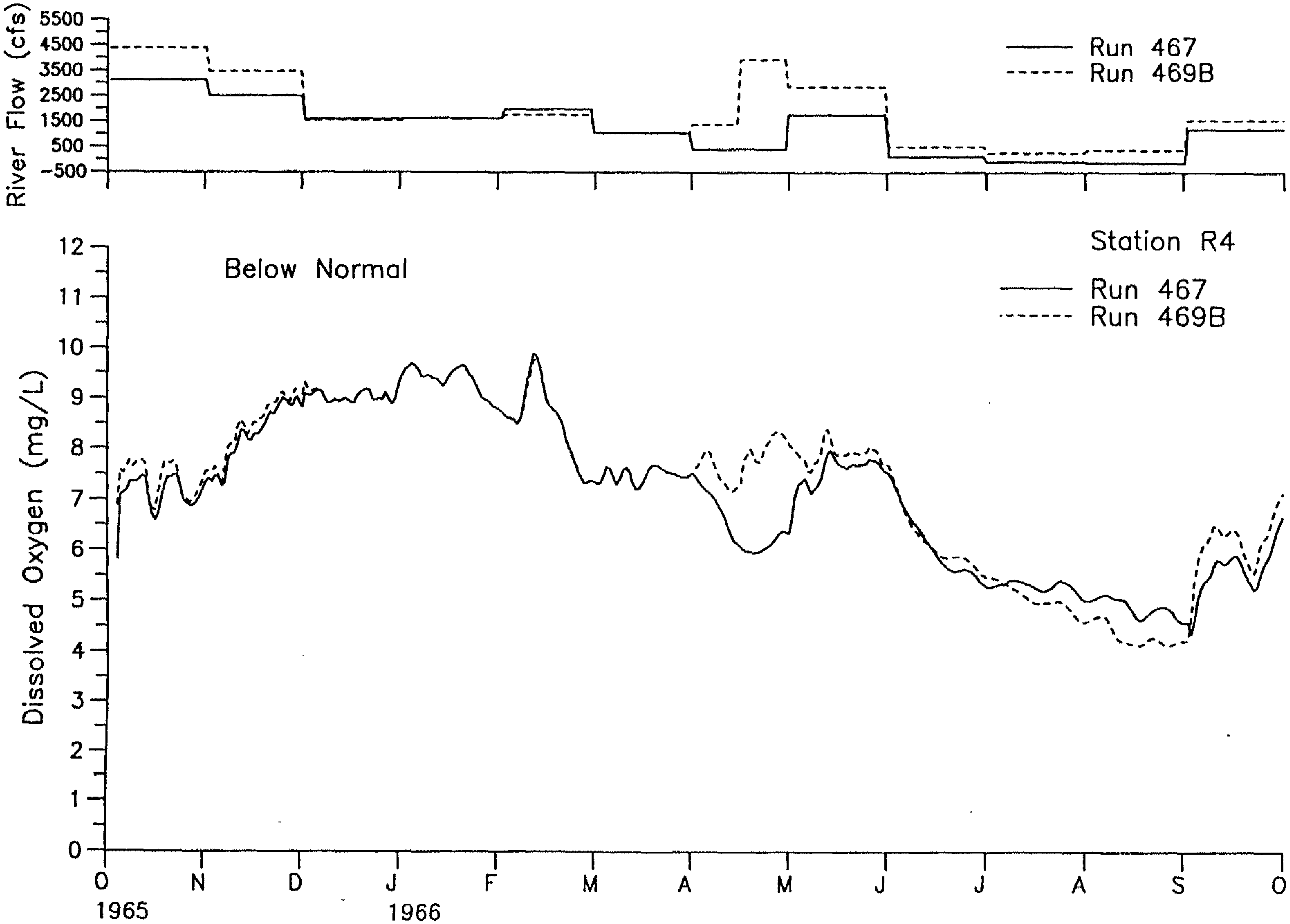
D-041619

D-041620

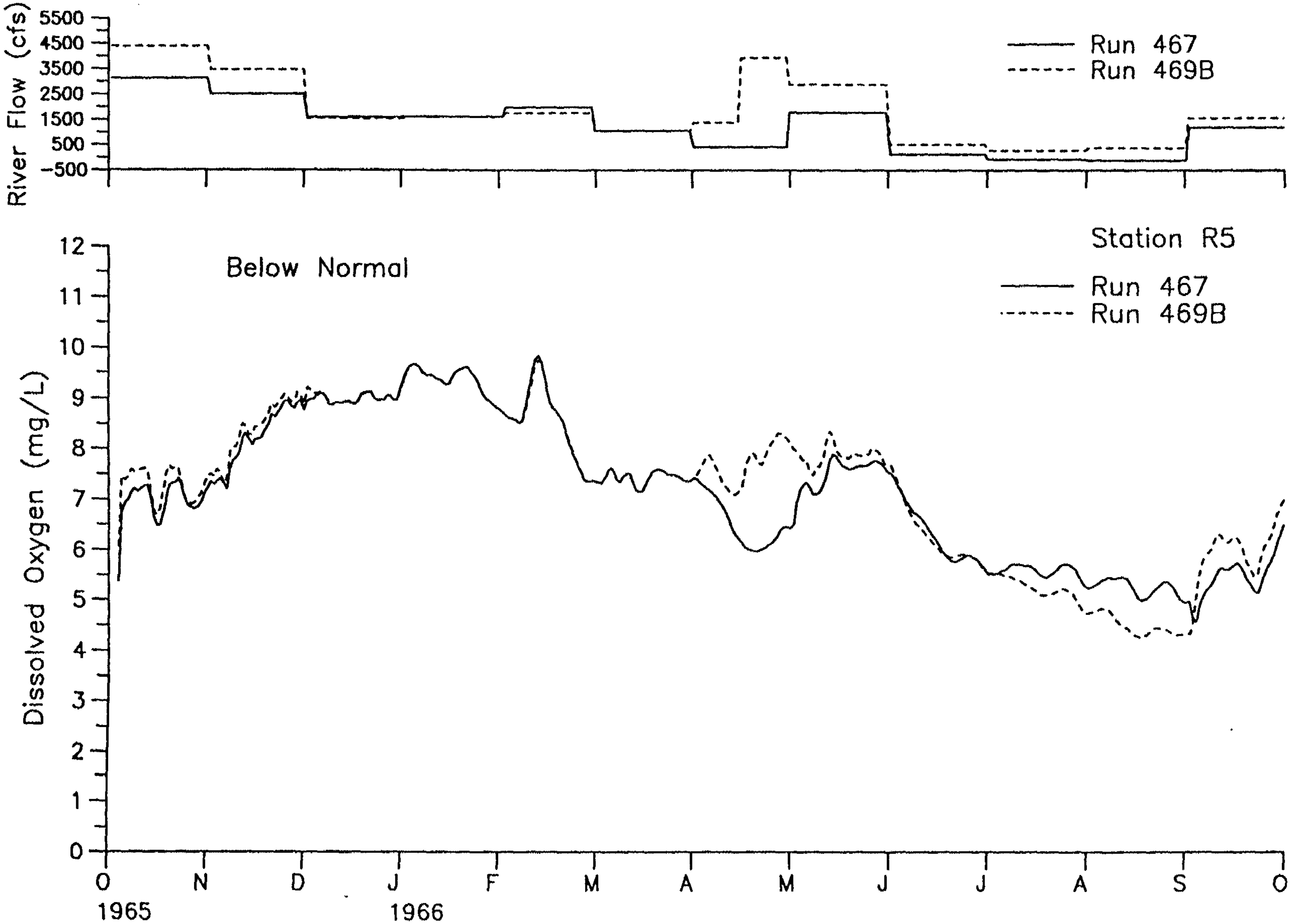


D-041620

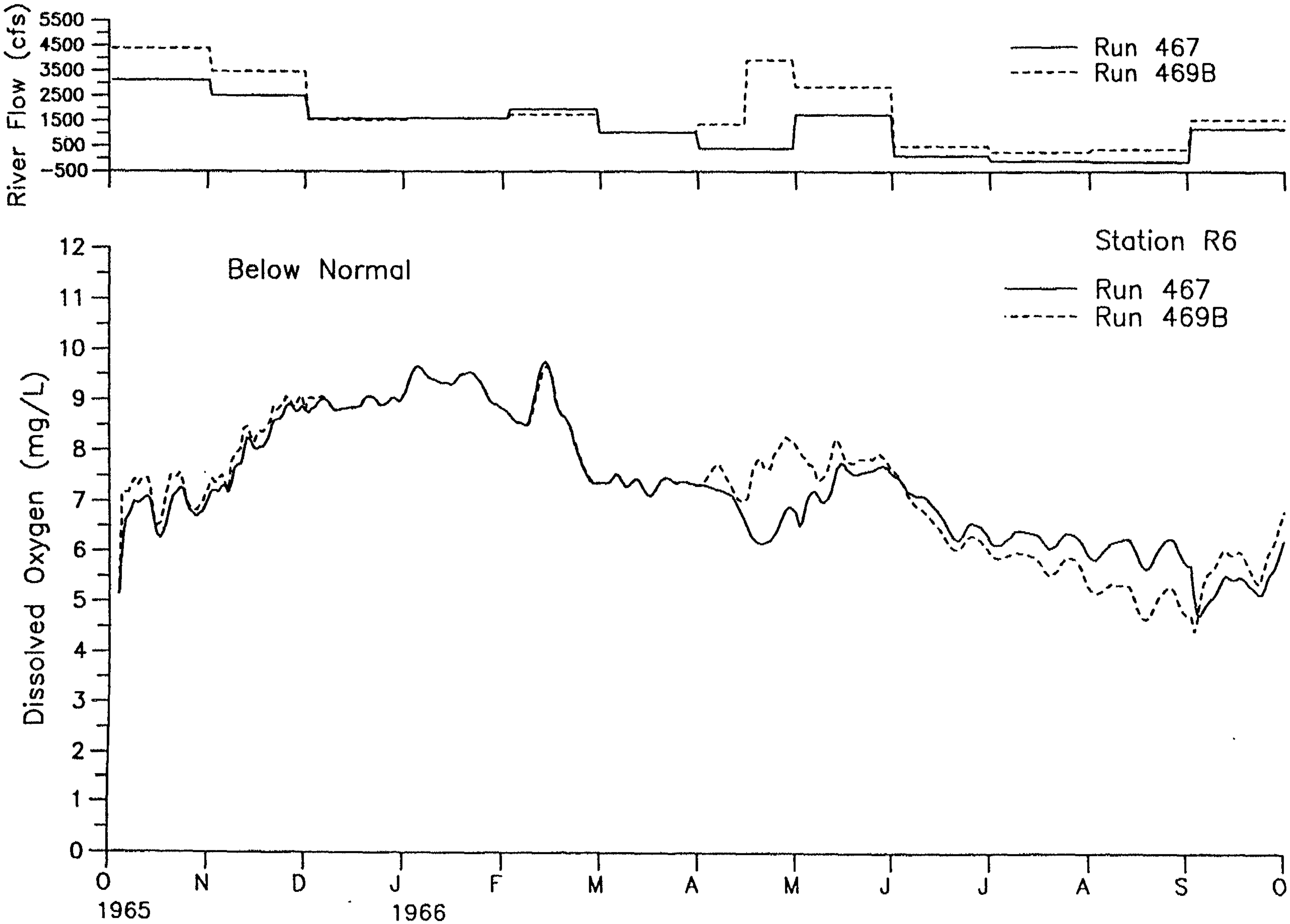

River Flow (cfs)
-500
500
1500
2500
3500
4500
5500
Run 467
Run 469B
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
Below Normal
Station R3
Run 467
Run 469B
O
N
D
J
F
M
A
M
J
J
A
S
O
1965
1966


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R4
Below Normal
Run 467
Run 469B
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1965
1966

D-041622

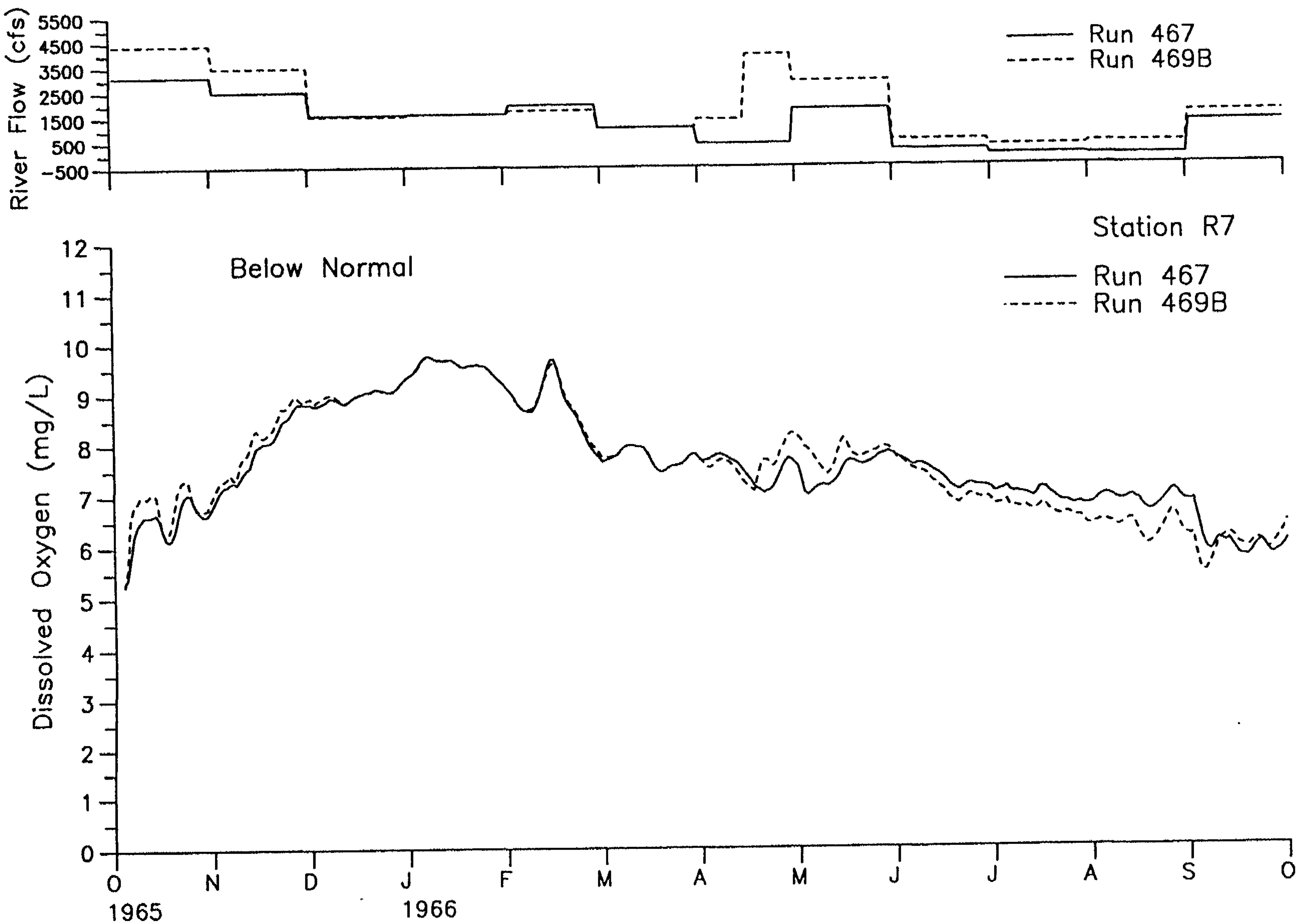

River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R5
Below Normal
Run 467
Run 469B
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1965
1966

D-041623

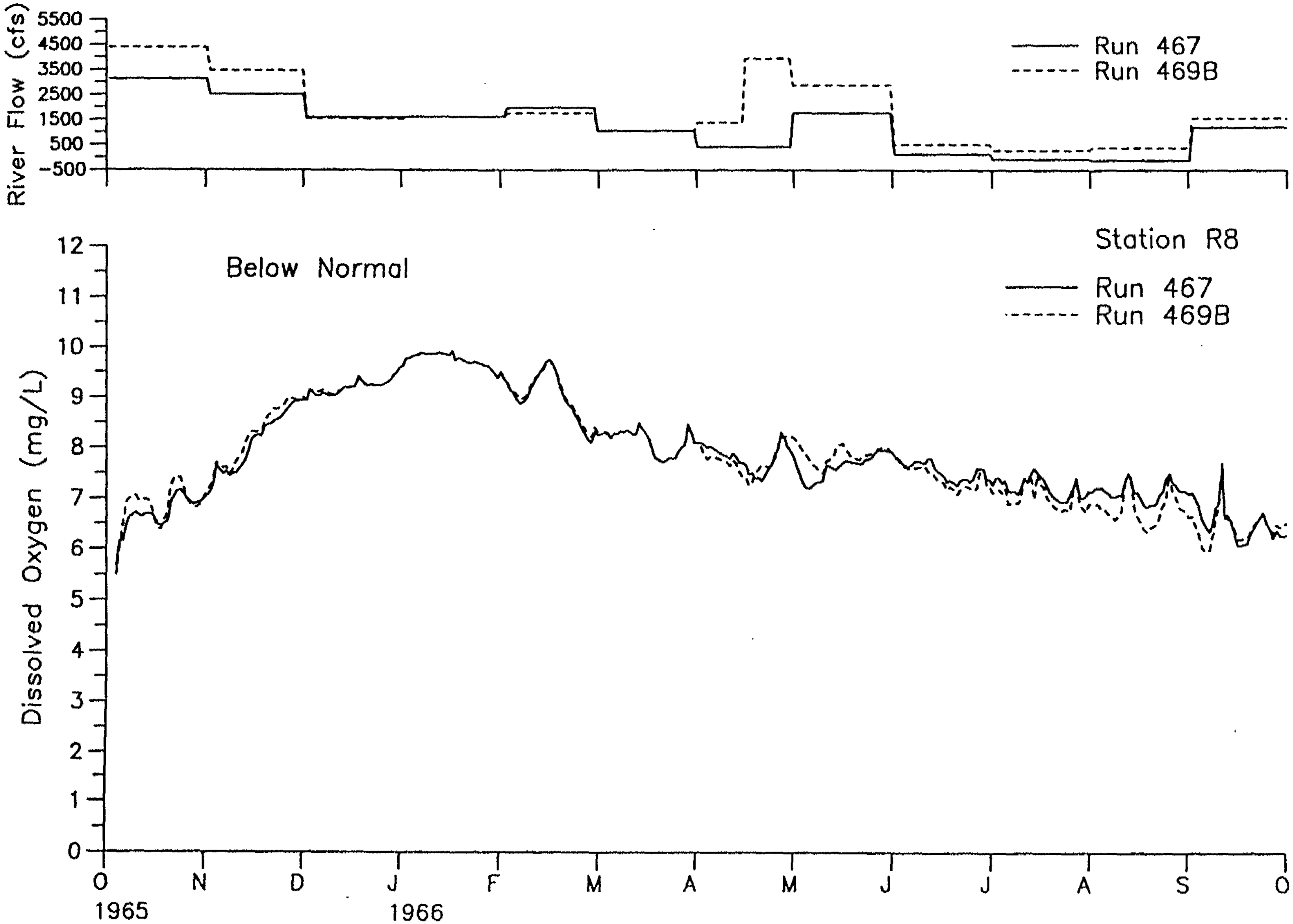


D-041624

D-041624



River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R7
Below Normal
Run 467
Run 469B
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1965
1966

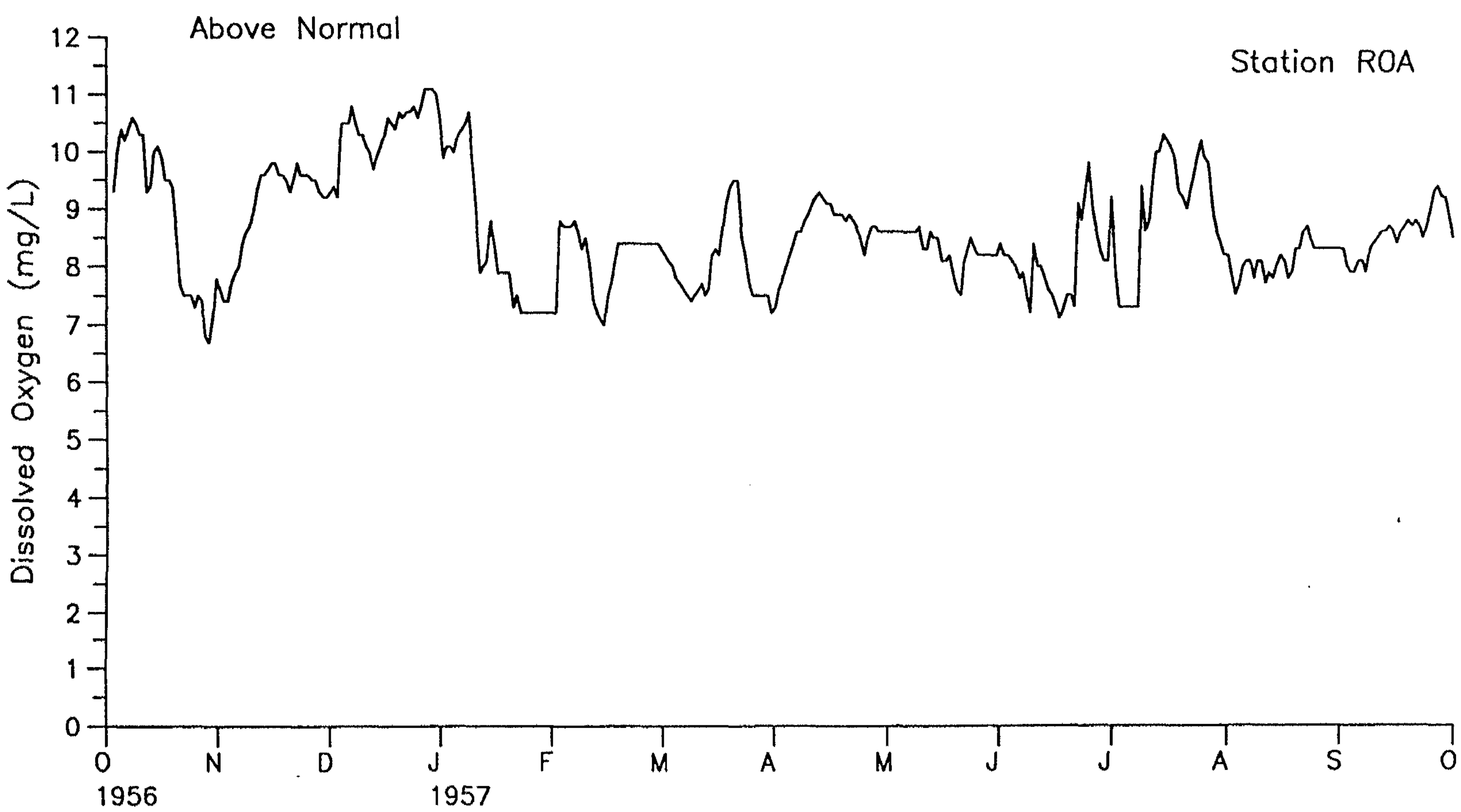


D-041626

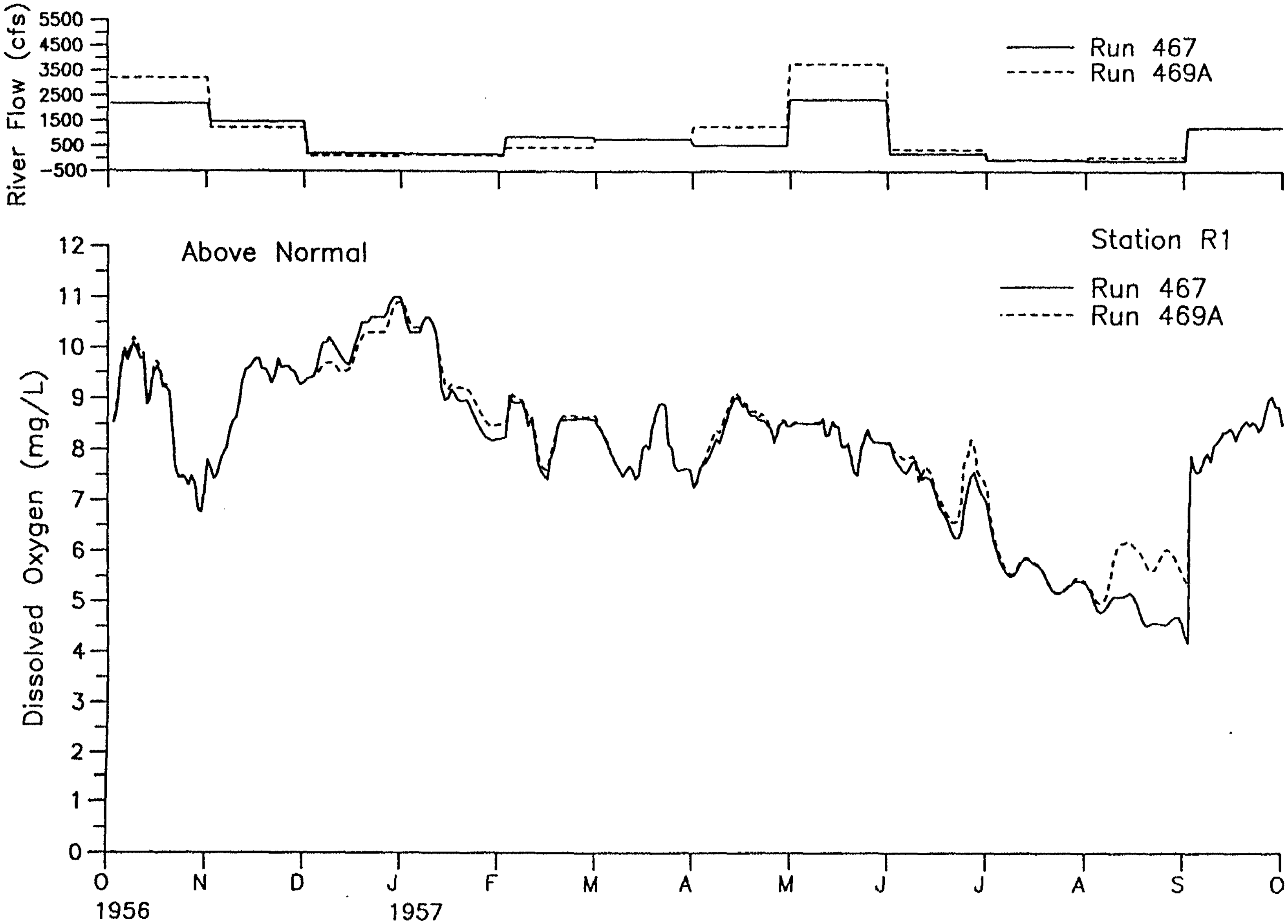
D-041626

Appendix H.

Results for Above Normal Year 1957

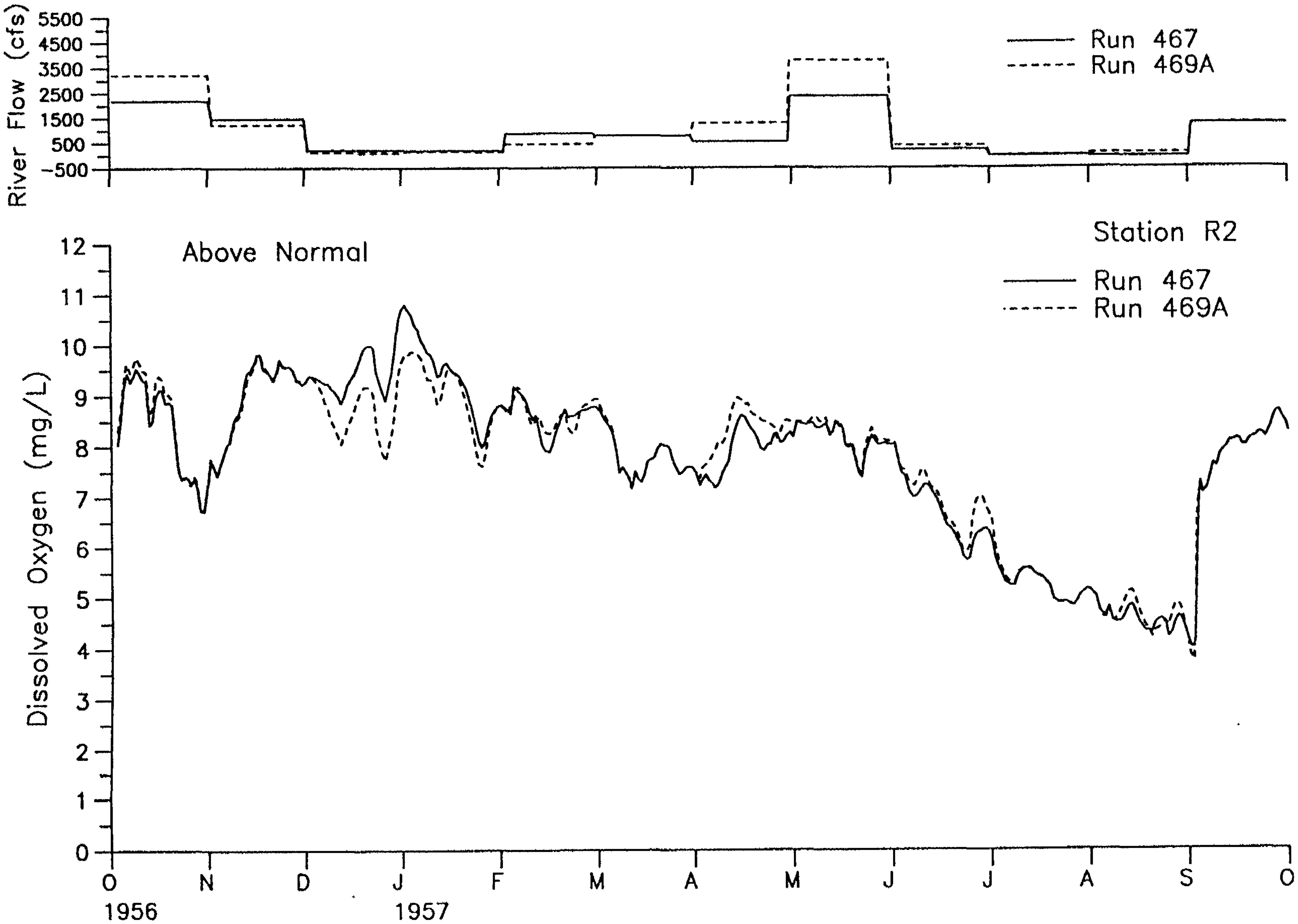

Above Normal
Station ROA
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957

D-041628



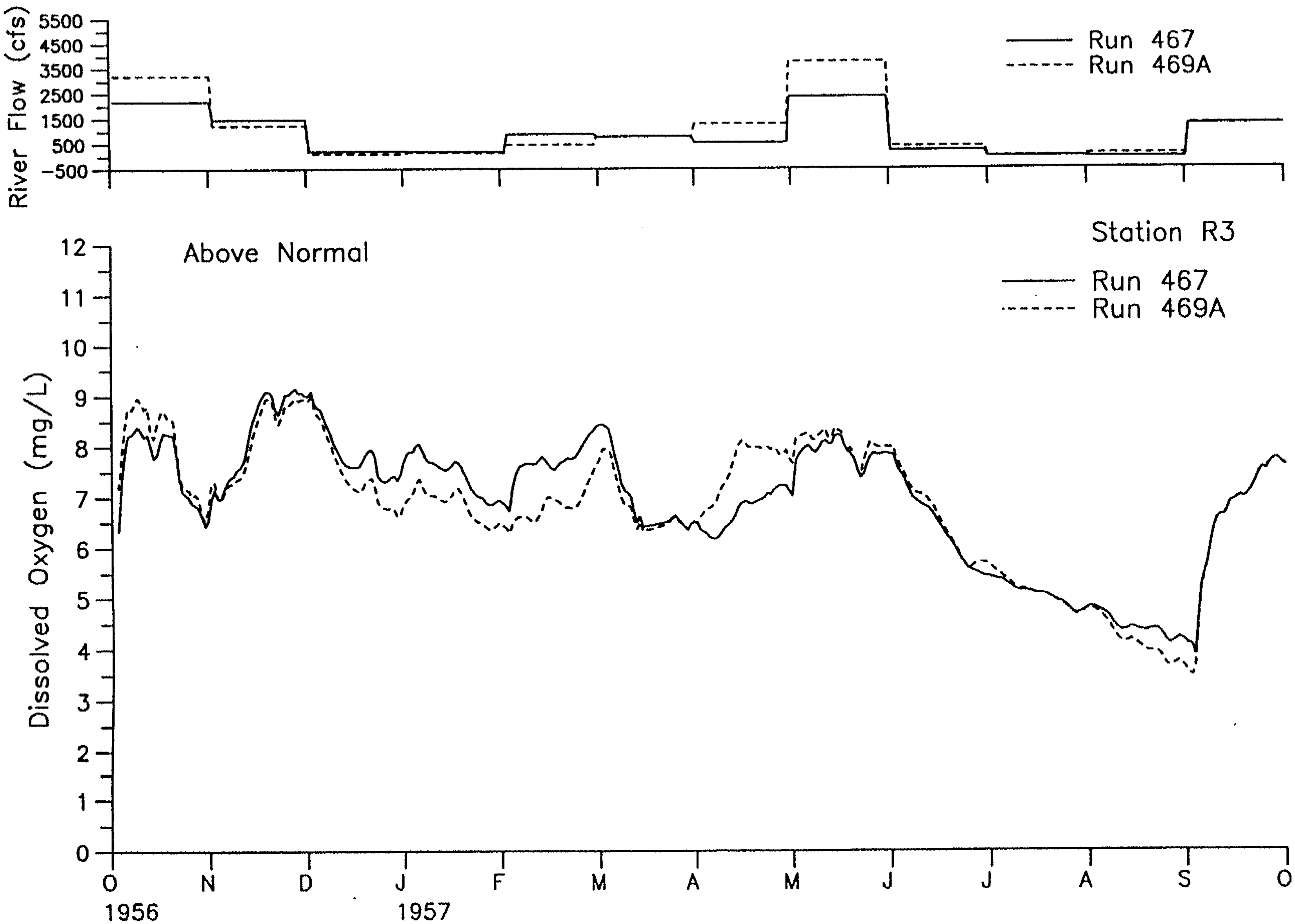
D-041629

D-041629

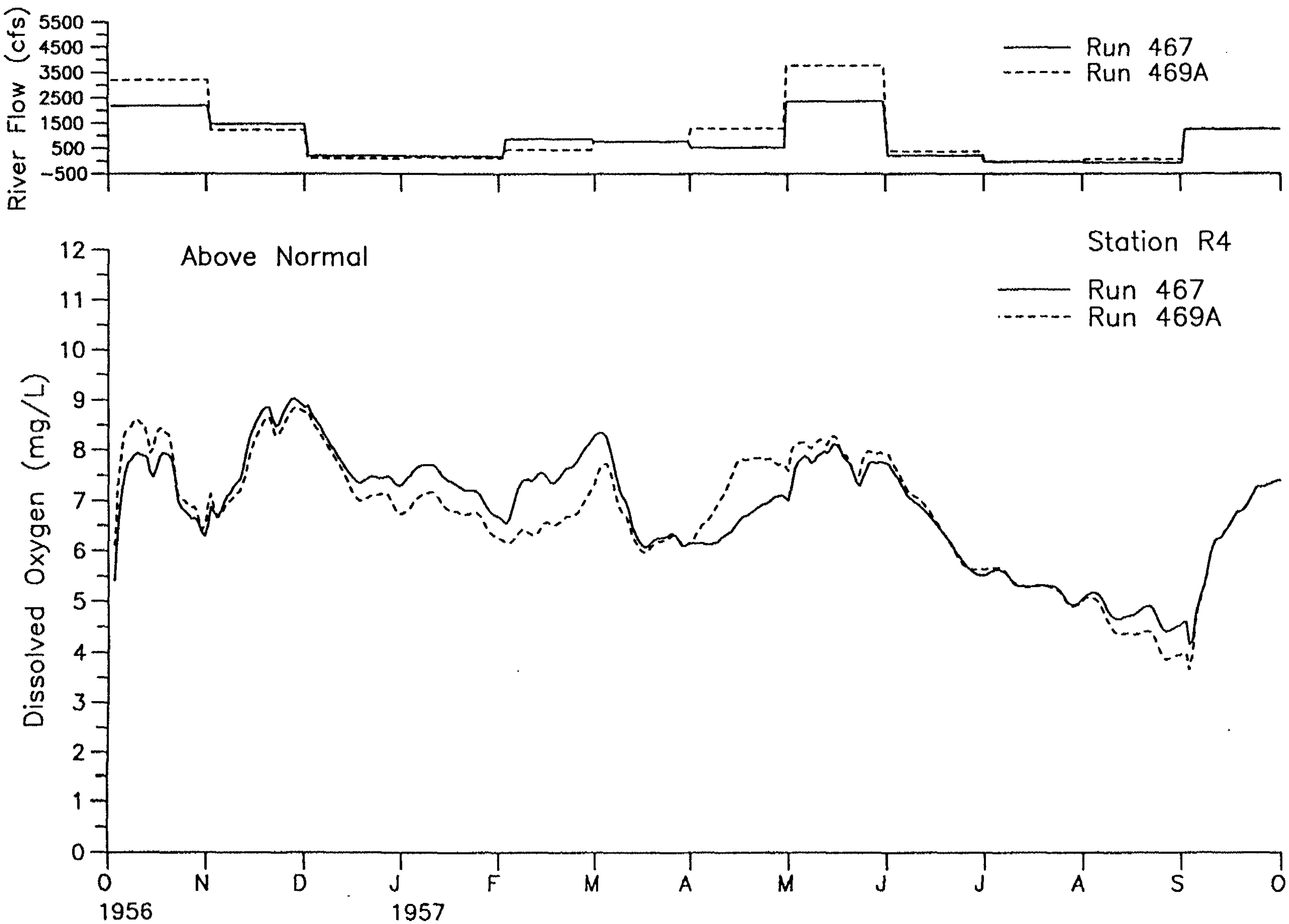


D-041630

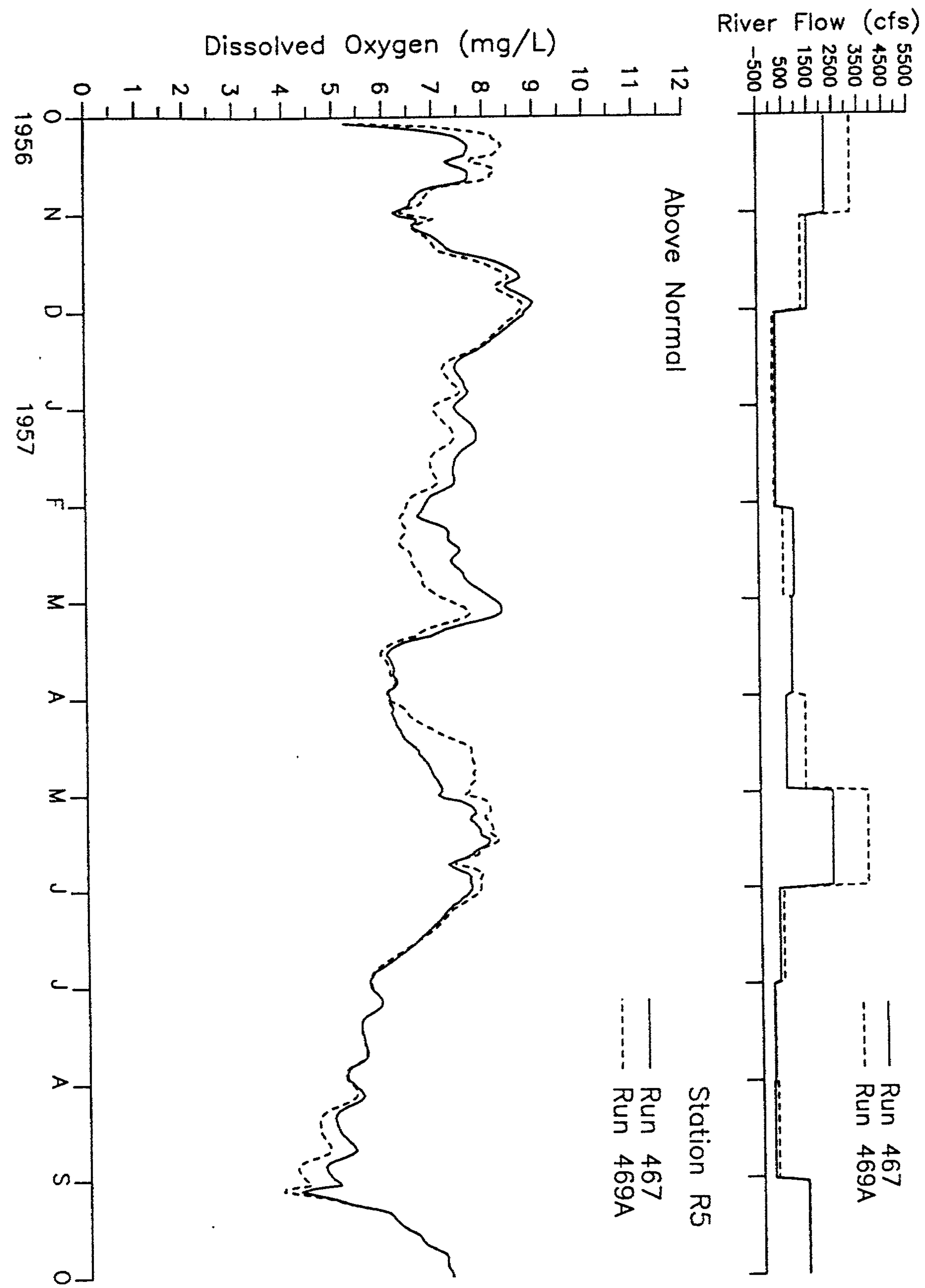
D-041630


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469A
Station R3
Above Normal
Run 467
Run 469A
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957

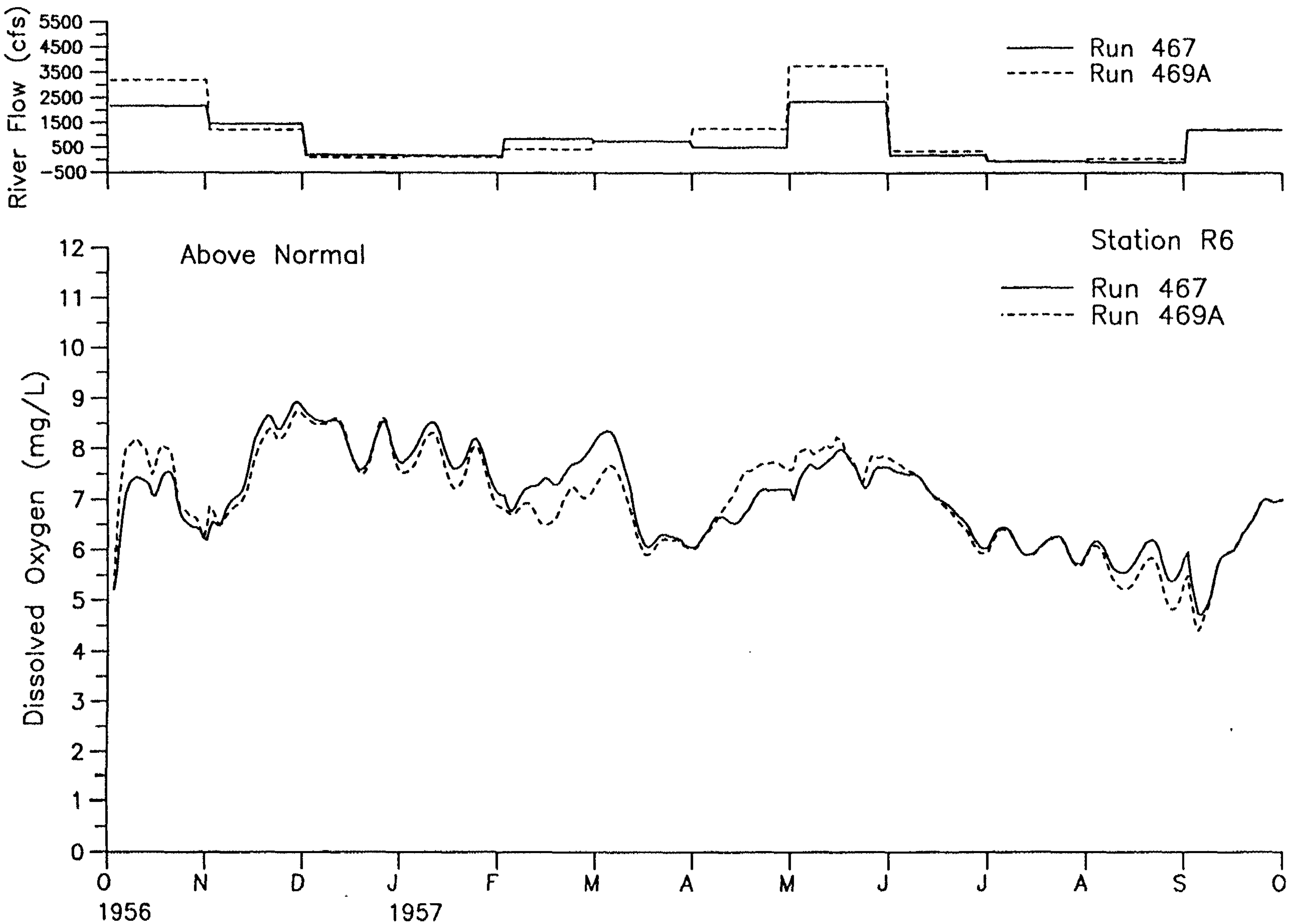
D-041631



River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469A
Station R4
Above Normal
Run 467
Run 469A
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957

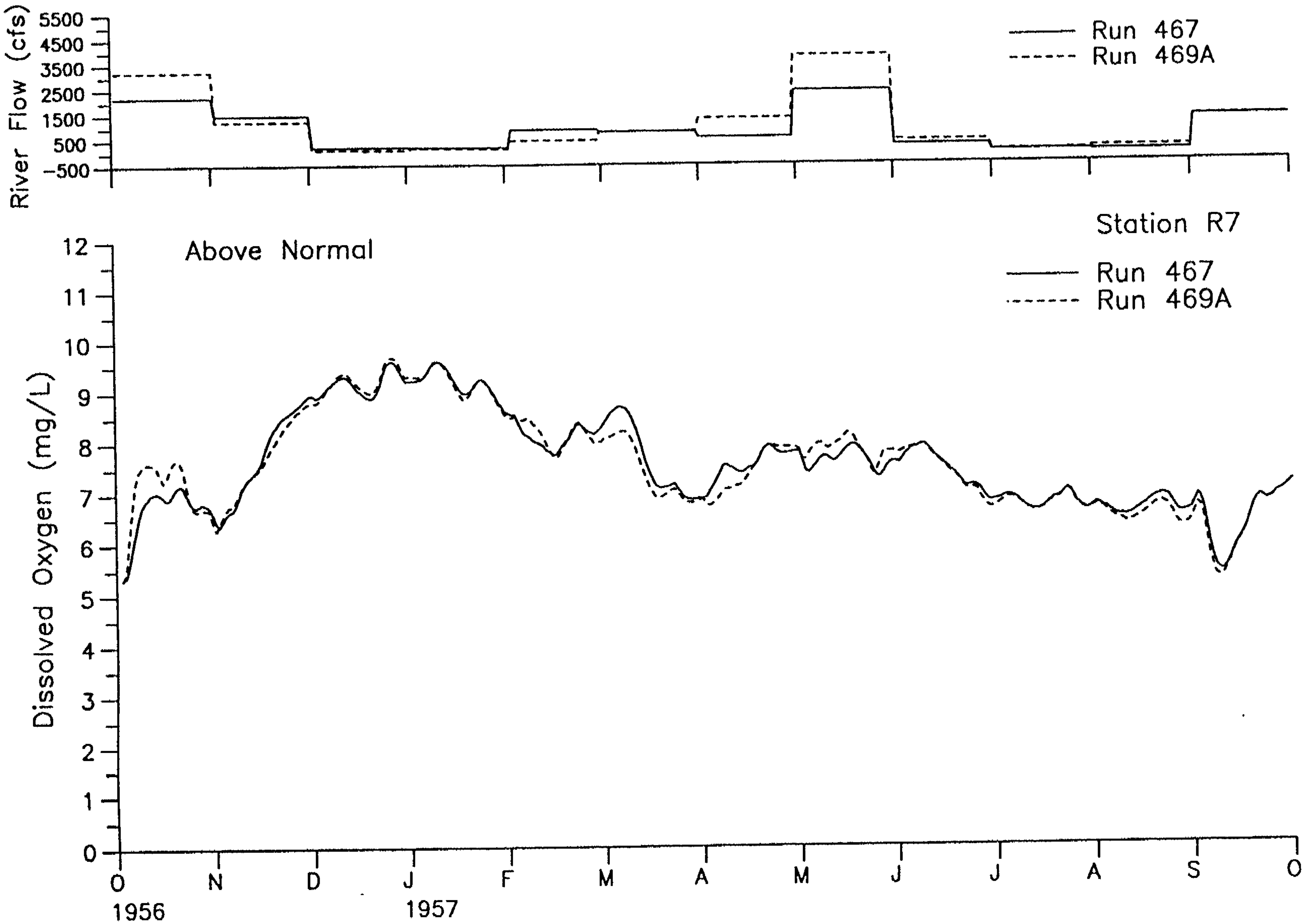


River Flow (cfs)
Dissolved Oxygen (mg/L)
Above Normal
Station R5
Run 467
Run 469A
1956
1957
O N D J F M A M J J A S O

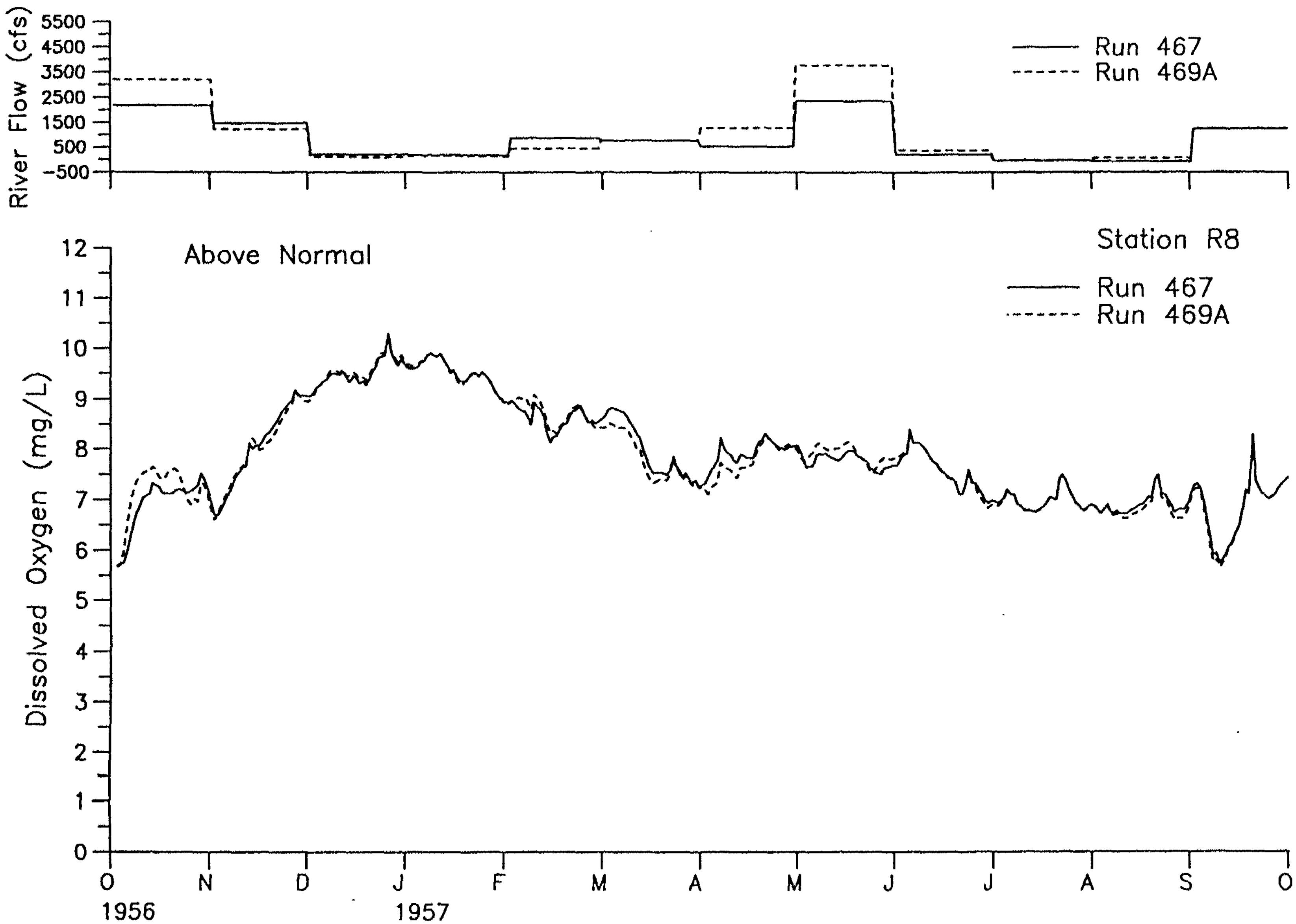


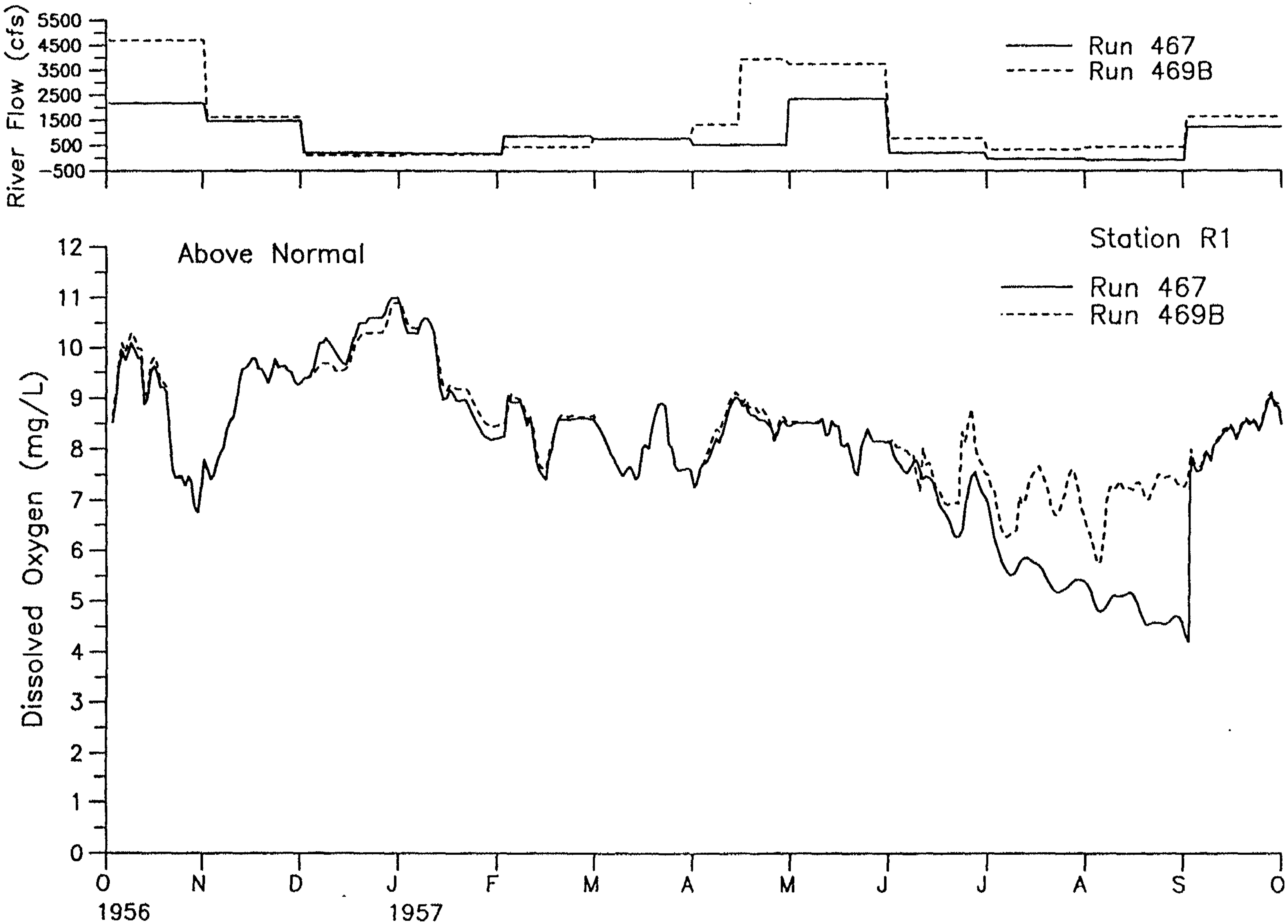
D-041634

D-041634

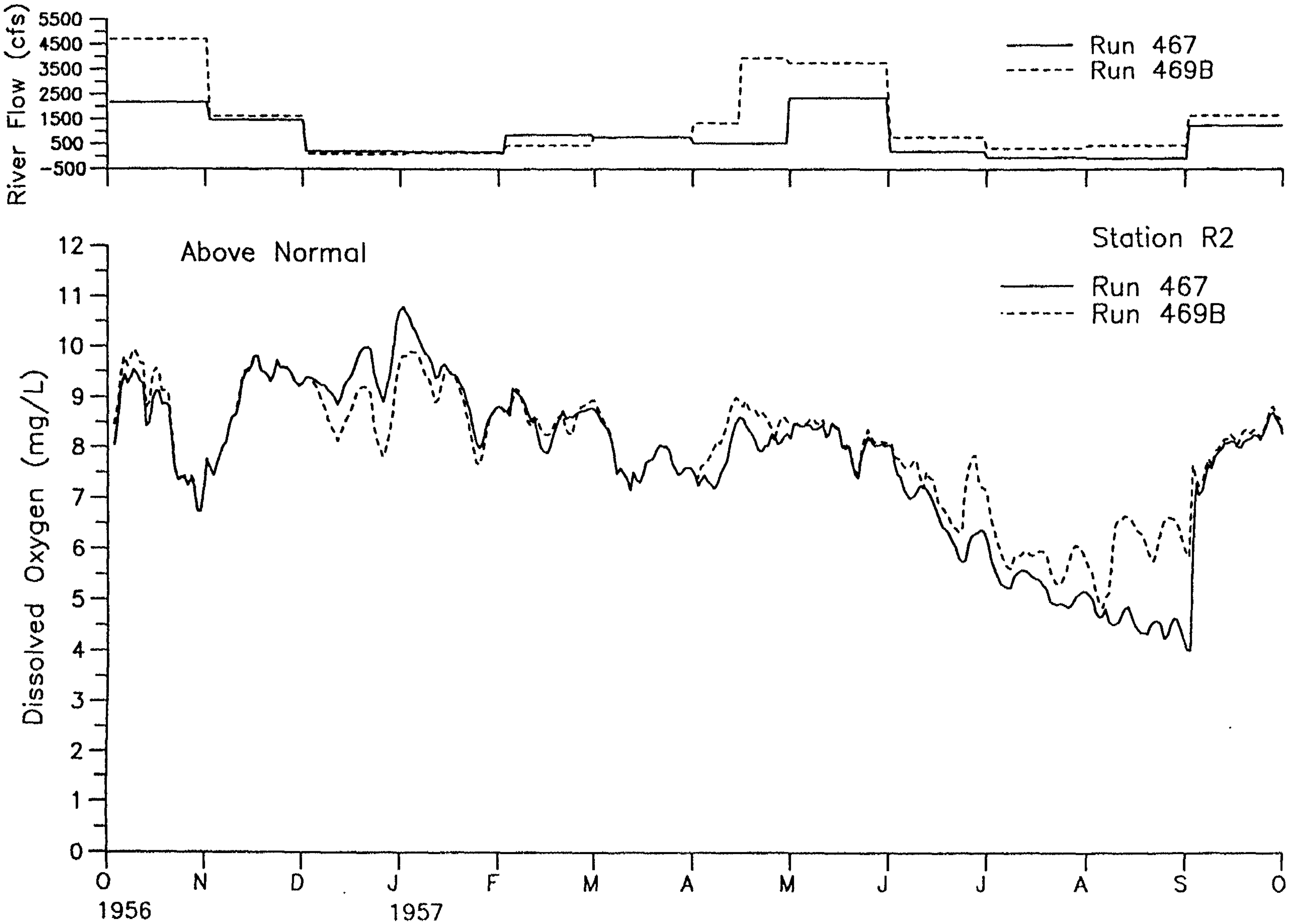


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469A
Station R7
Above Normal
Run 467
Run 469A
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469A
Station R8
Above Normal
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957

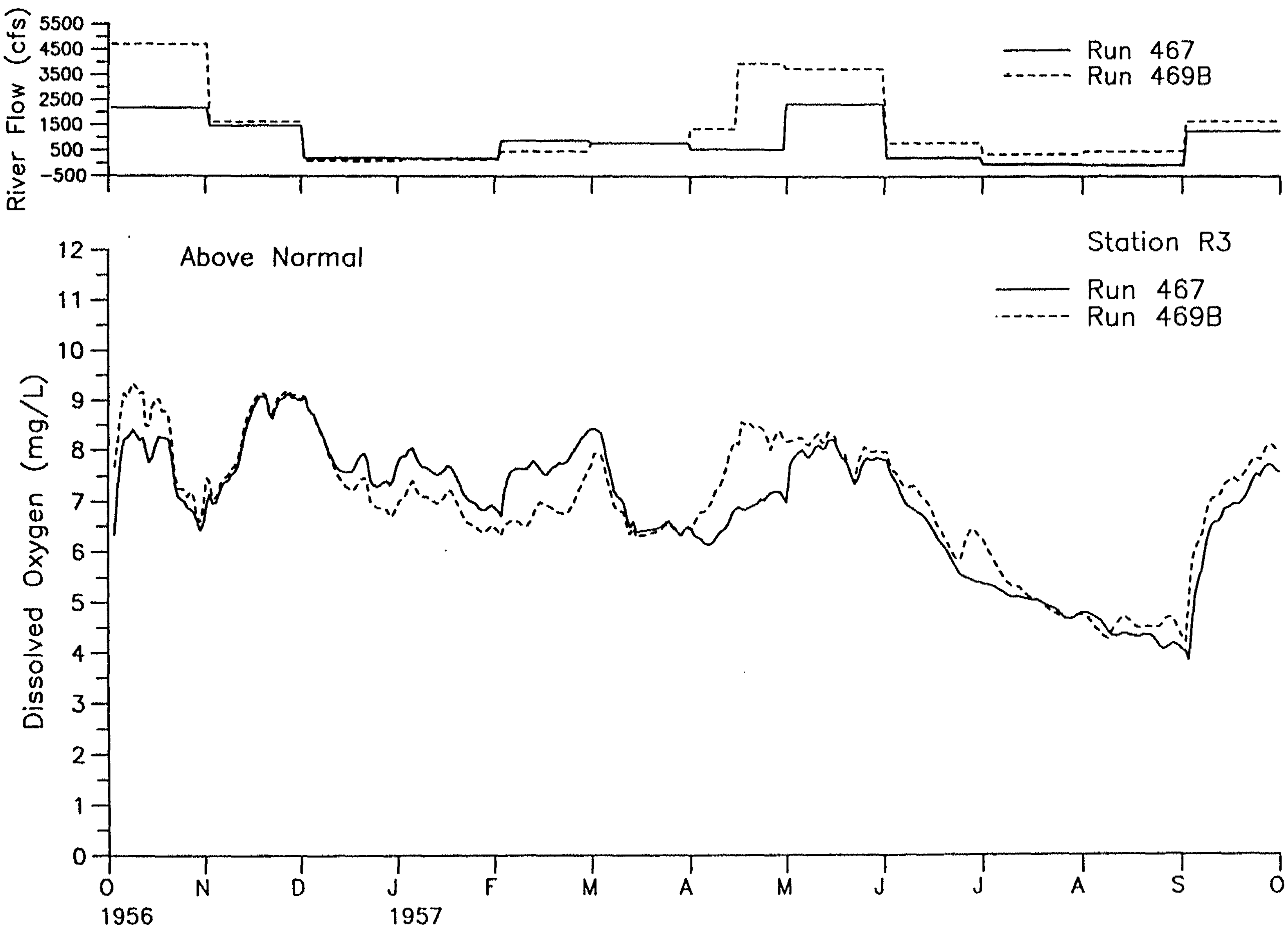

River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Dissolved Oxygen (mg/L)
Above Normal
Station R1
Run 467
Run 469B
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957

D-041637

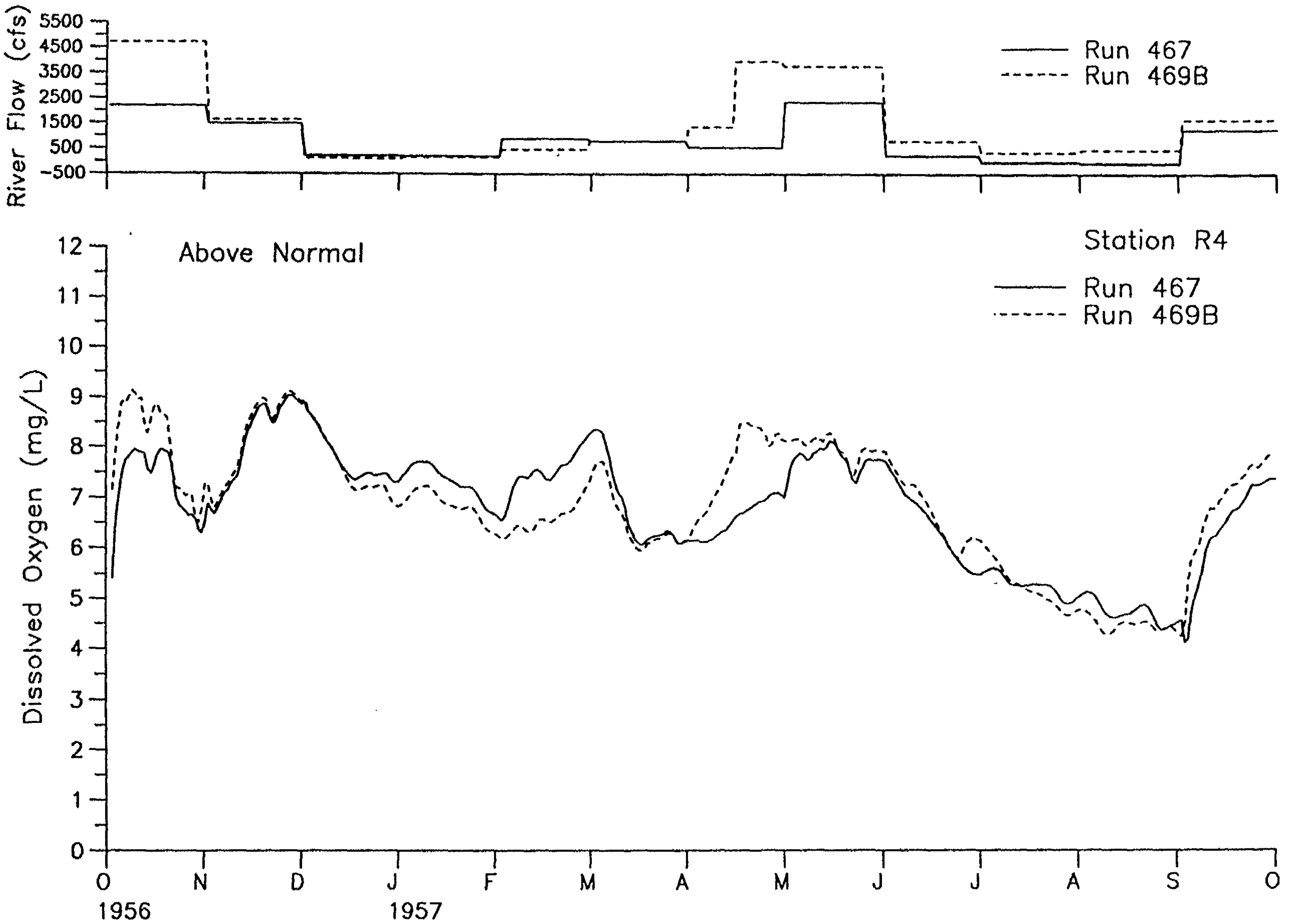


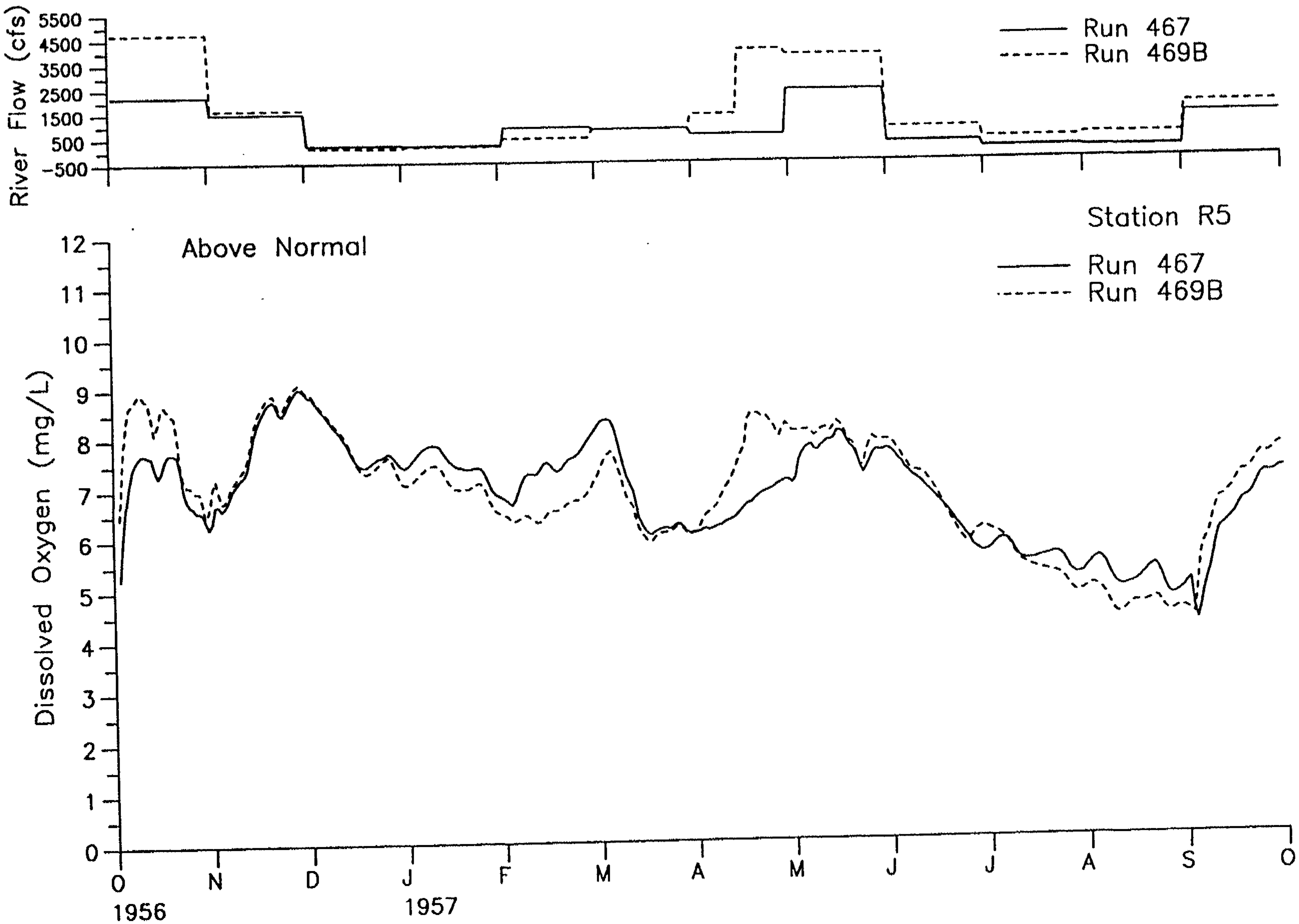
D—041638

D-041638

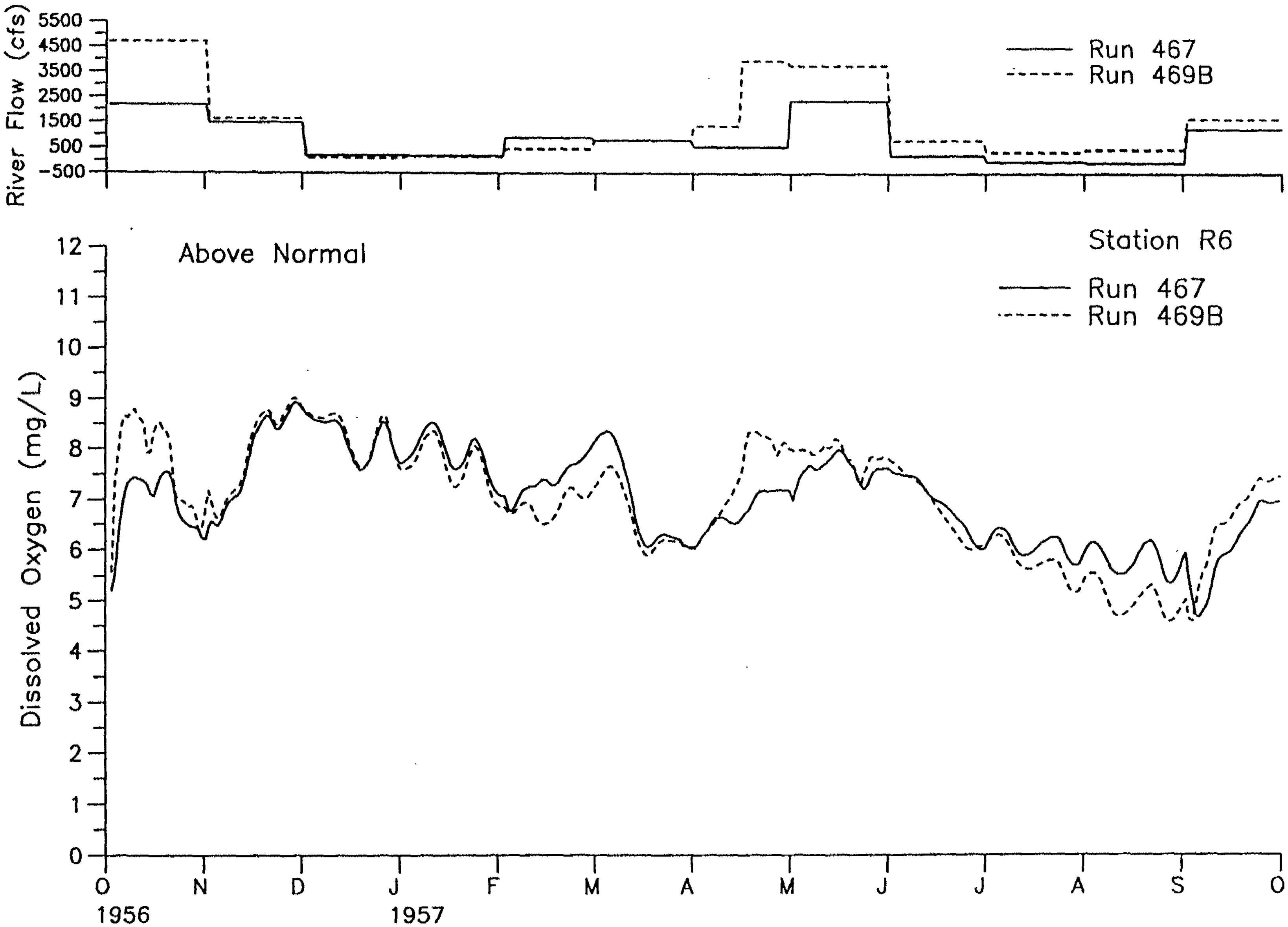


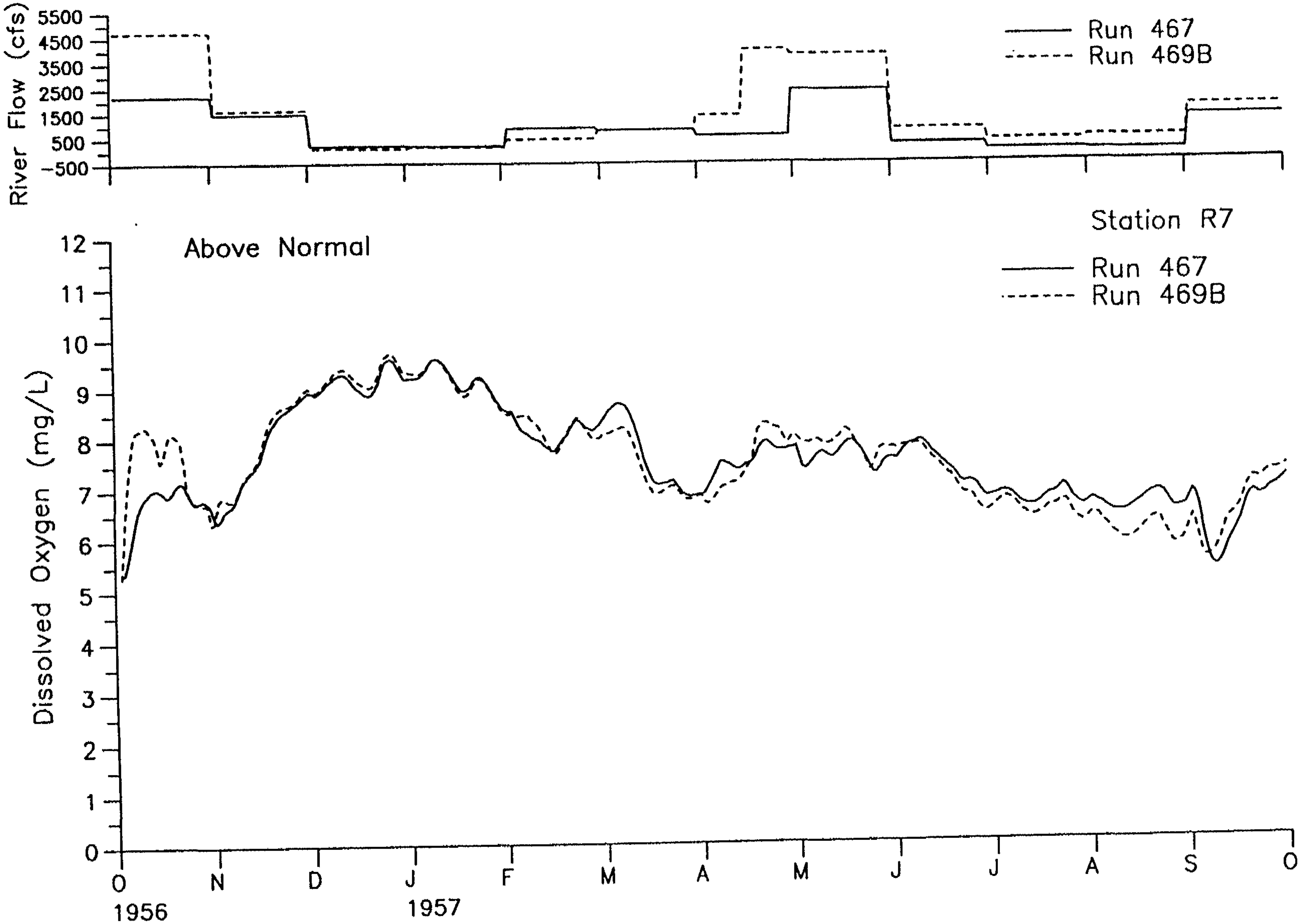
River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R3
Above Normal
Run 467
Run 469B
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957

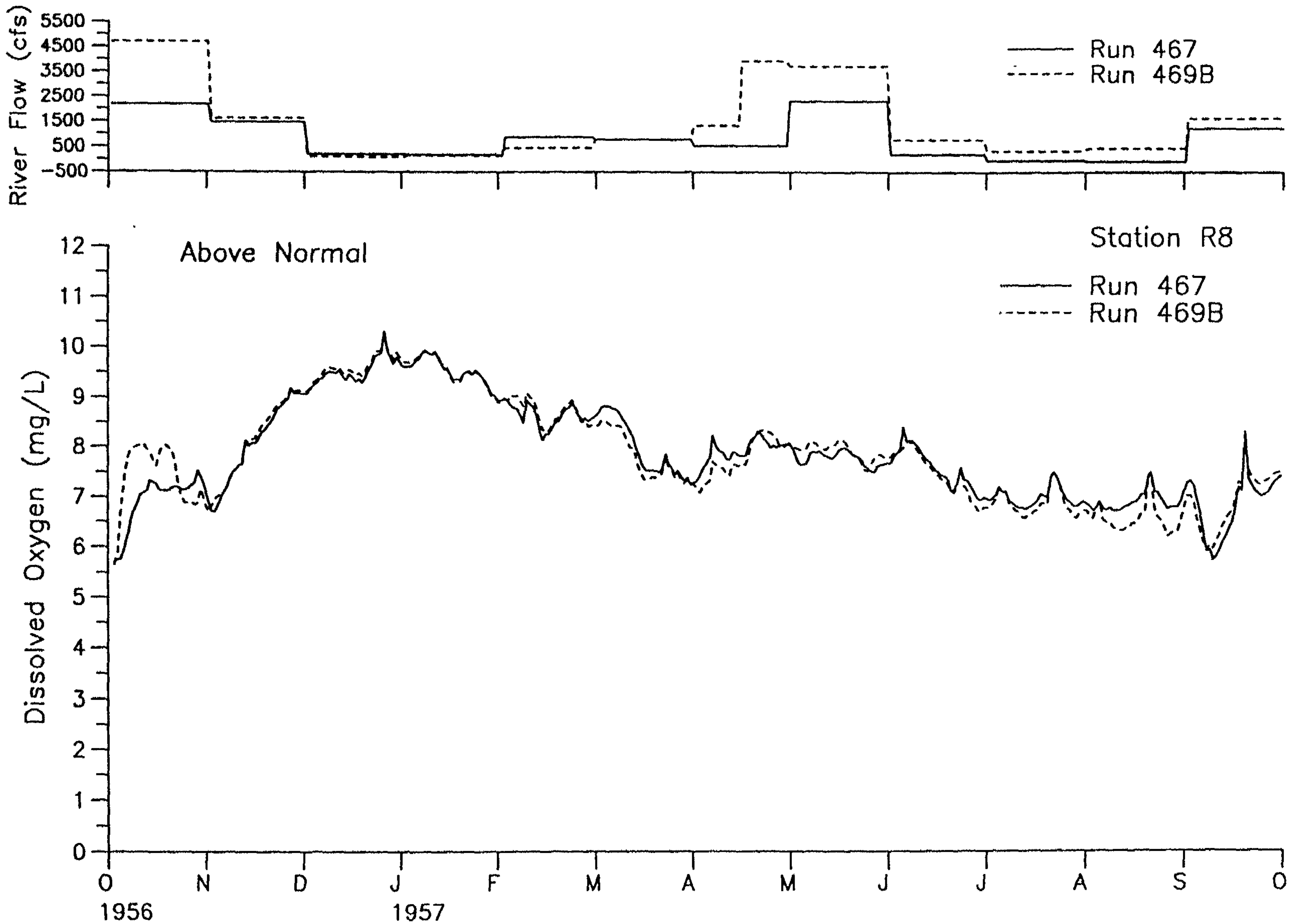

River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R4
Above Normal
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R5
Above Normal
Run 467
Run 469B
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957

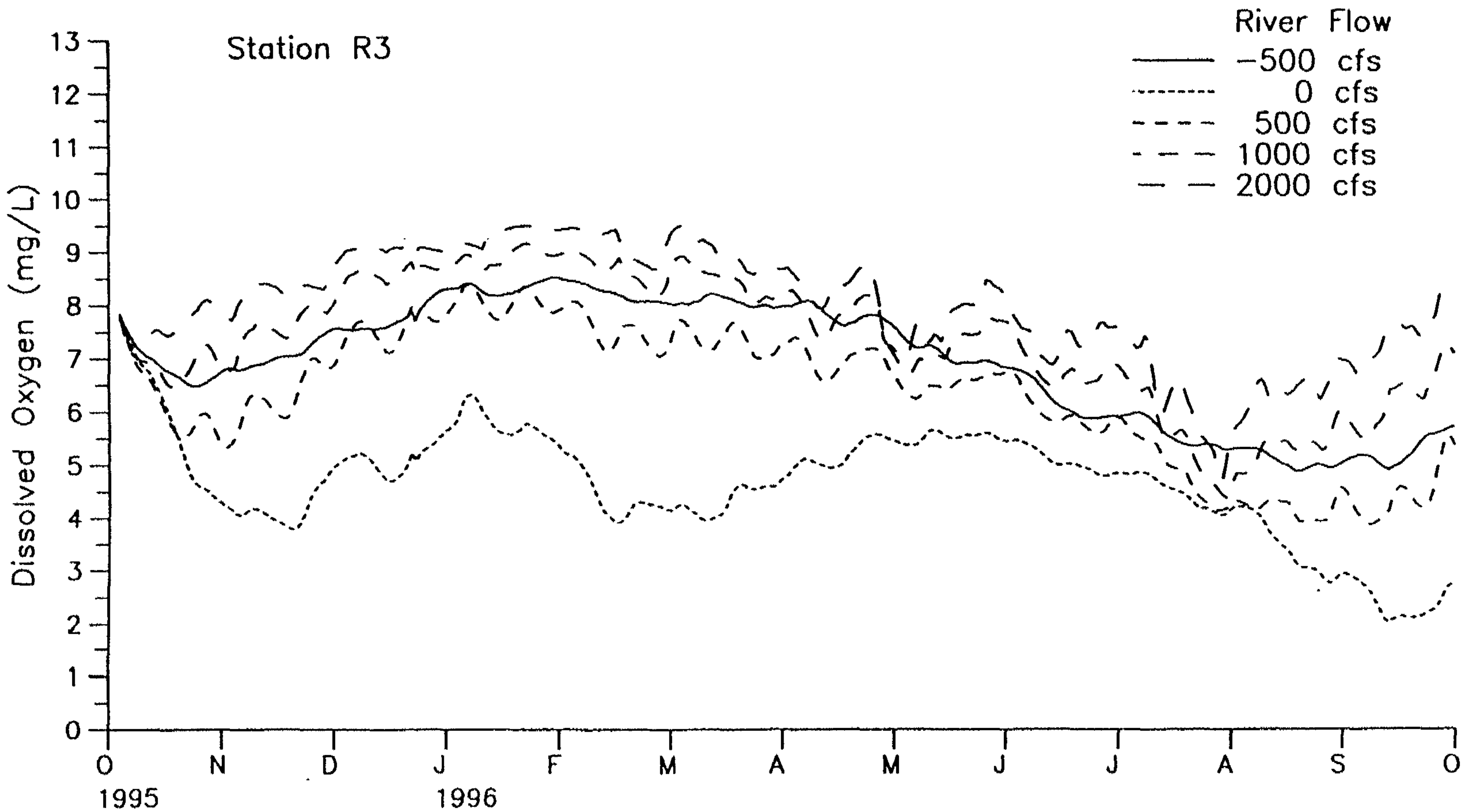
D-041641

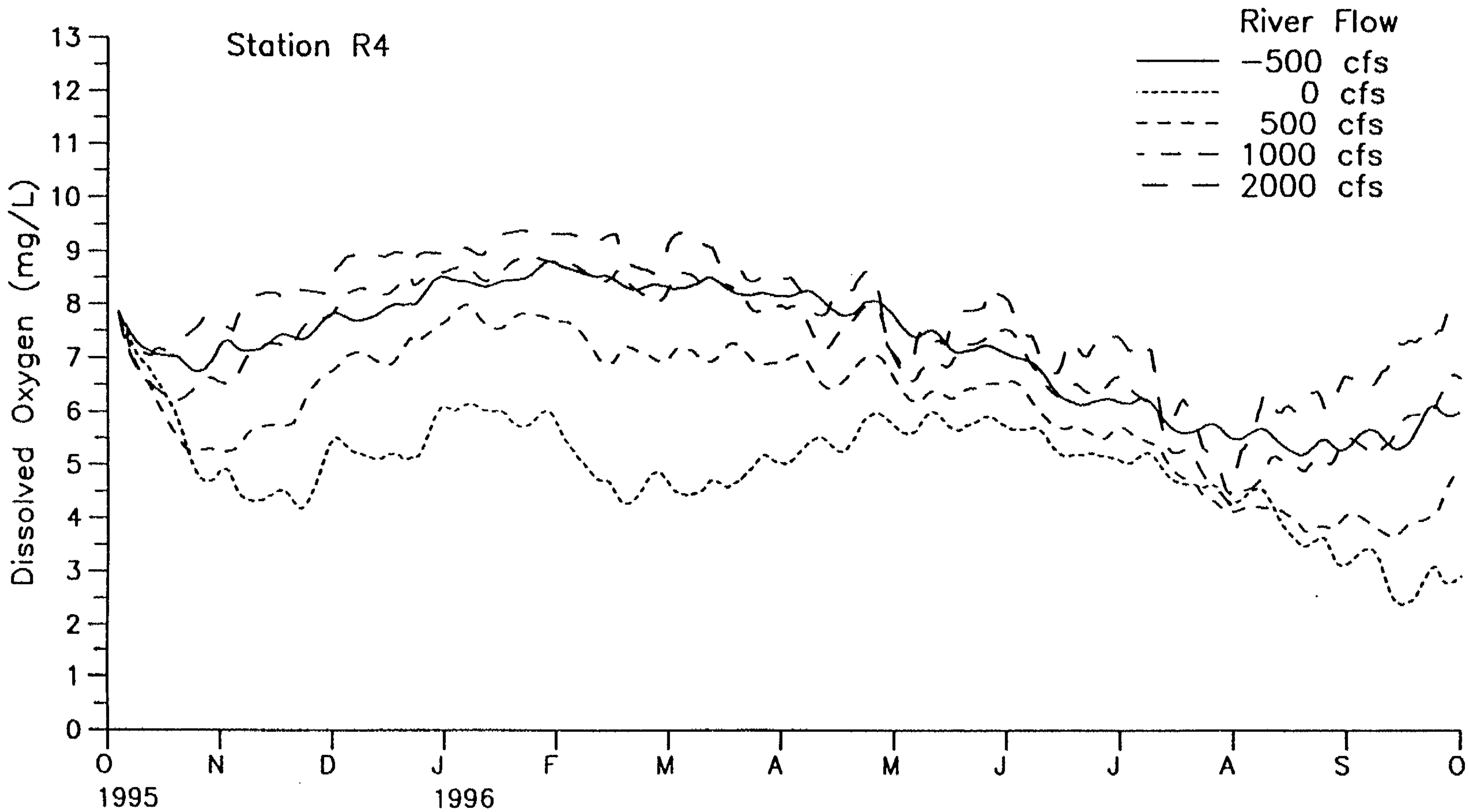

River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R6
Above Normal
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957

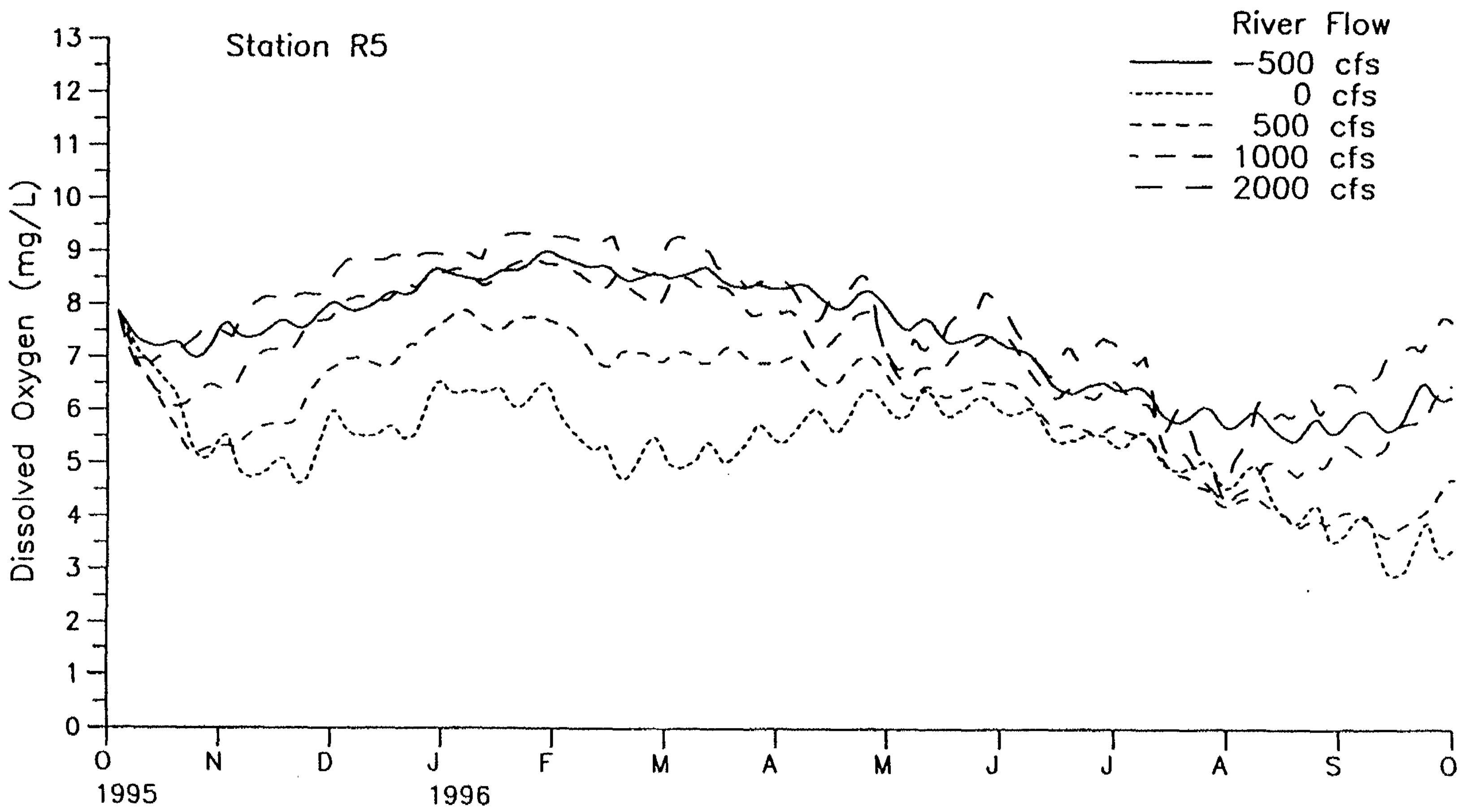

River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Station R7
Above Normal
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
Run 467
Run 469B
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957

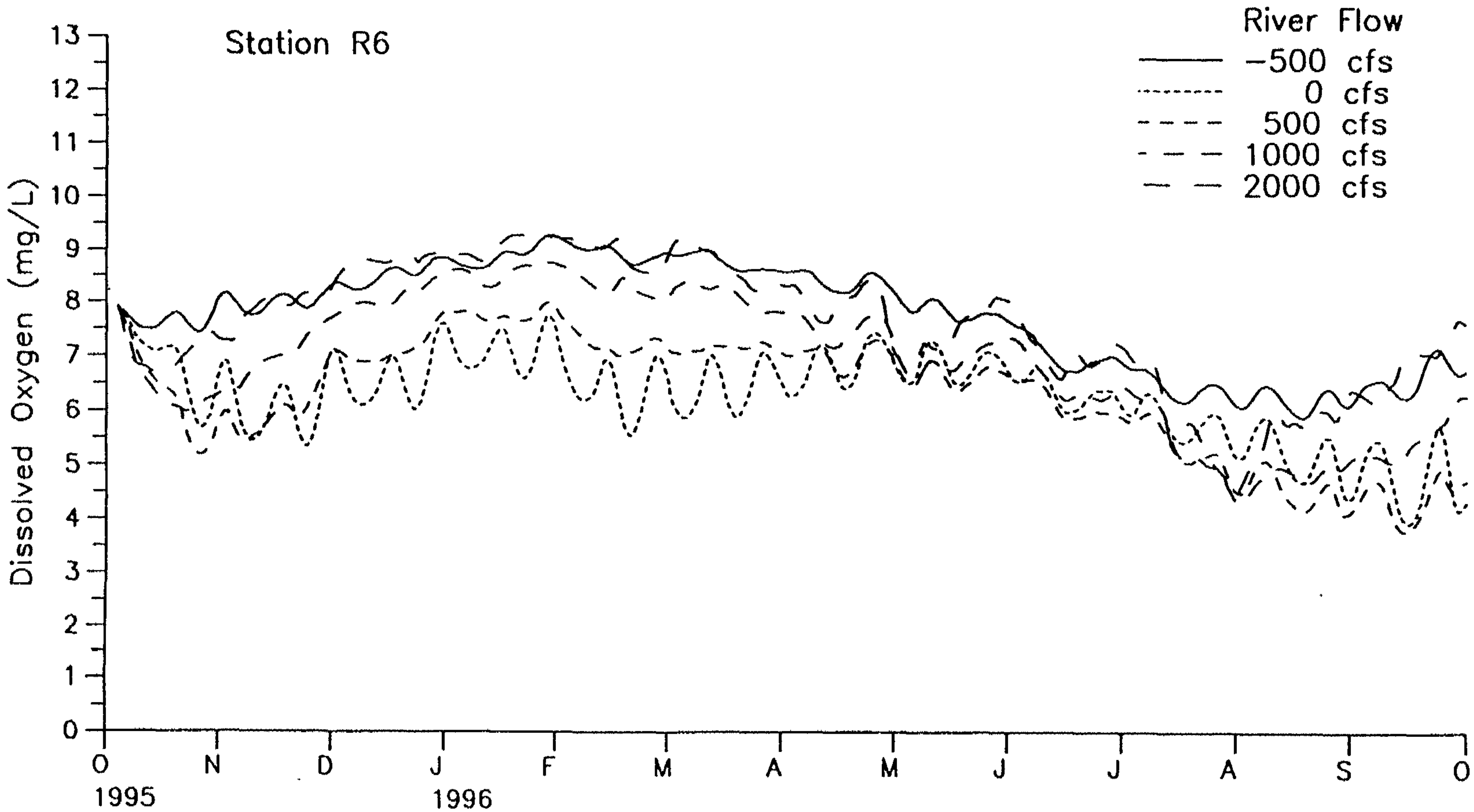

River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 467
Run 469B
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
Above Normal
Station R8
Run 467
Run 469B
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957

D-041644


Station R3
River Flow
−500 cfs
0 cfs
500 cfs
1000 cfs
2000 cfs
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

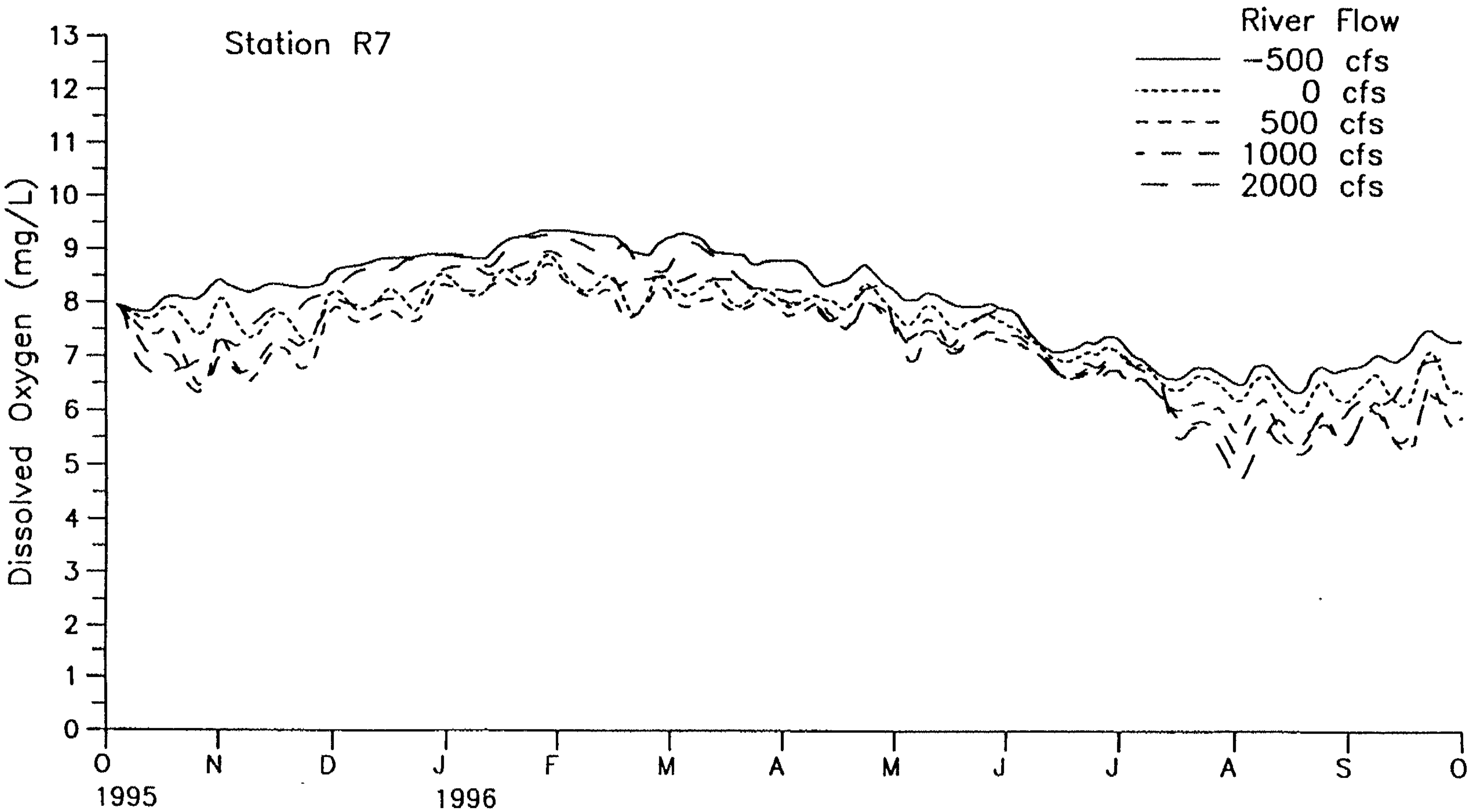

Station R4
River Flow
−500 cfs
0 cfs
500 cfs
1000 cfs
2000 cfs
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996


Station R5
River Flow
-500 cfs
0 cfs
500 cfs
1000 cfs
2000 cfs
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996



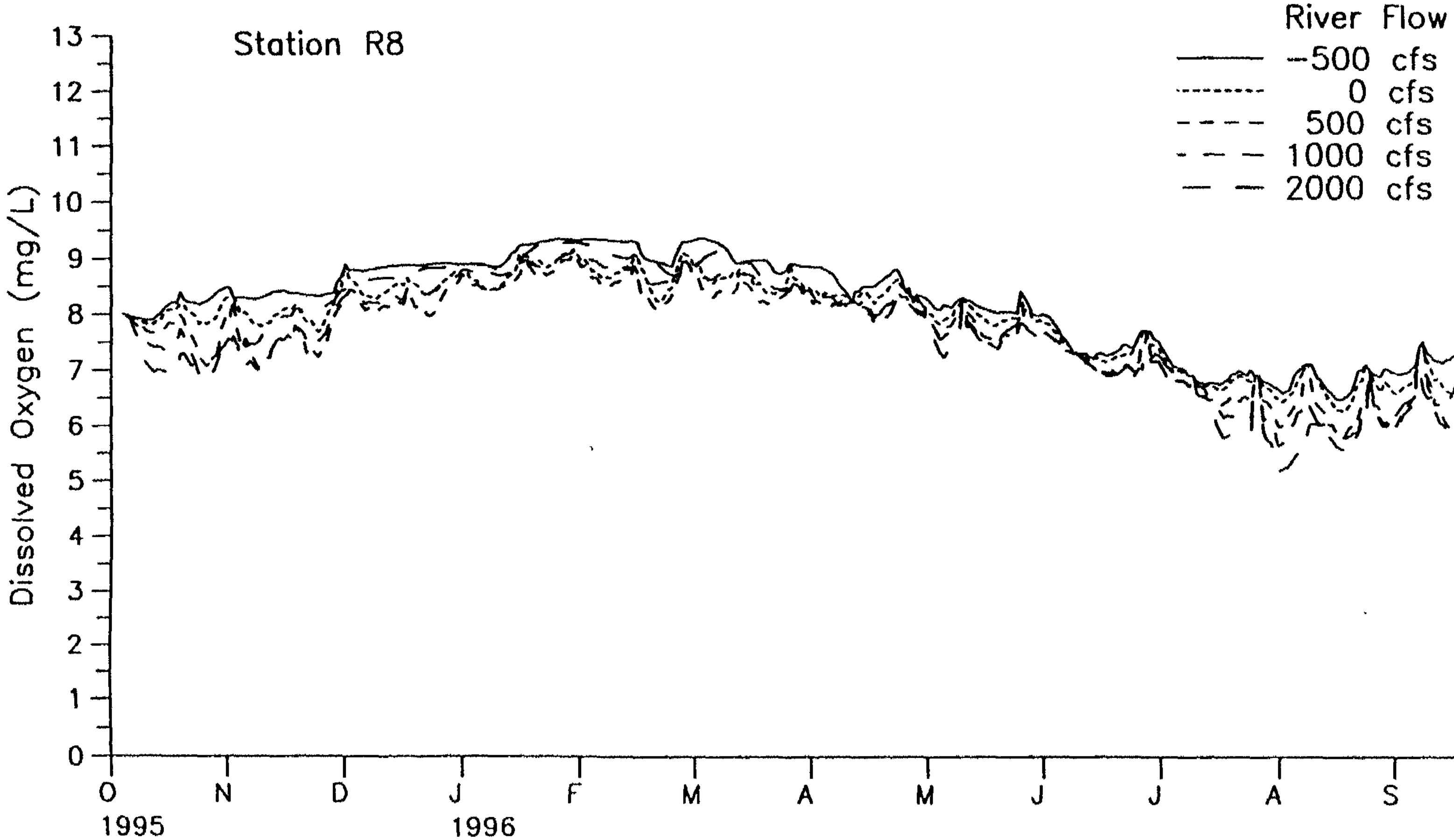
D-041648

D-041648



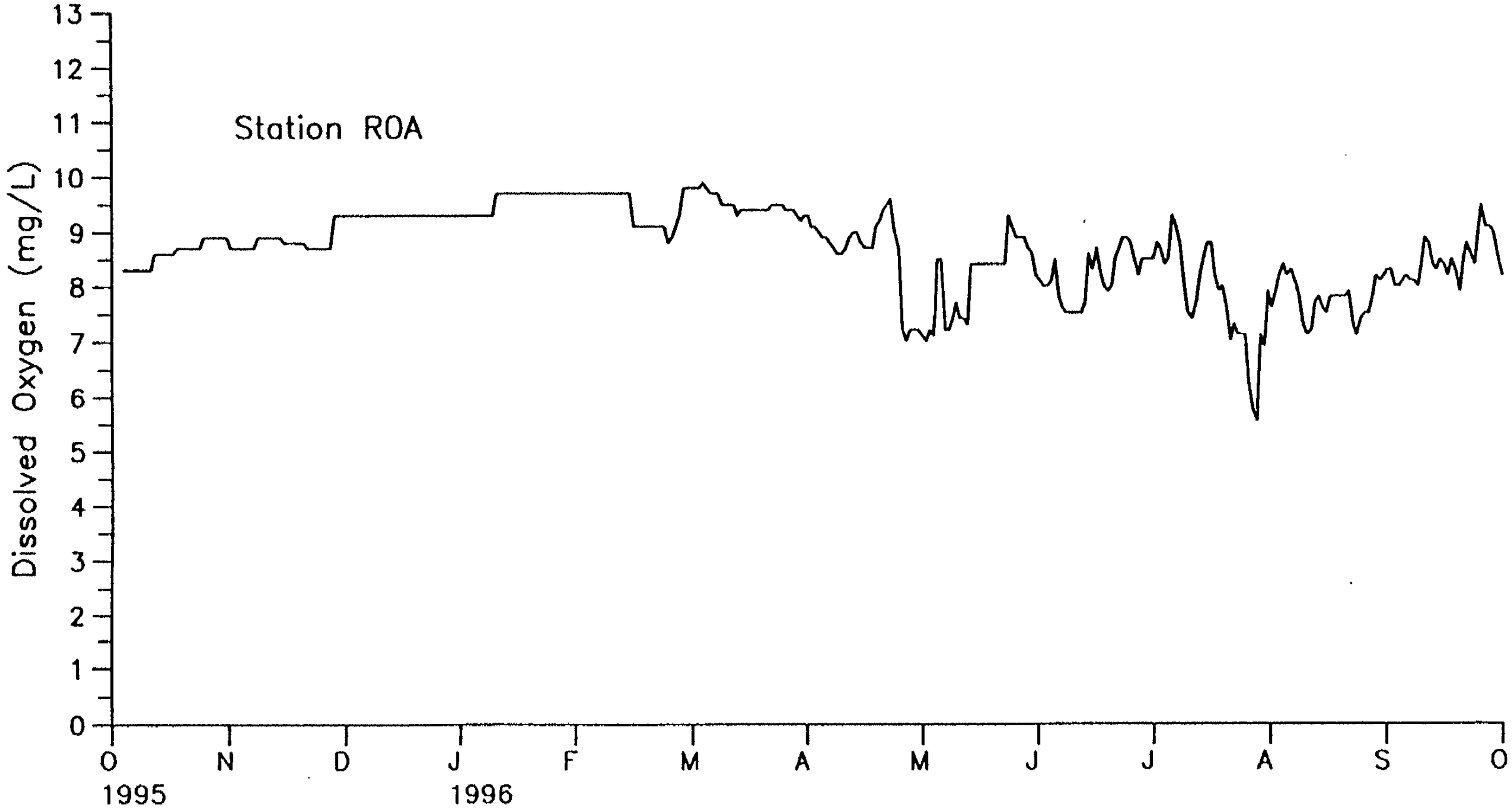
D-041649

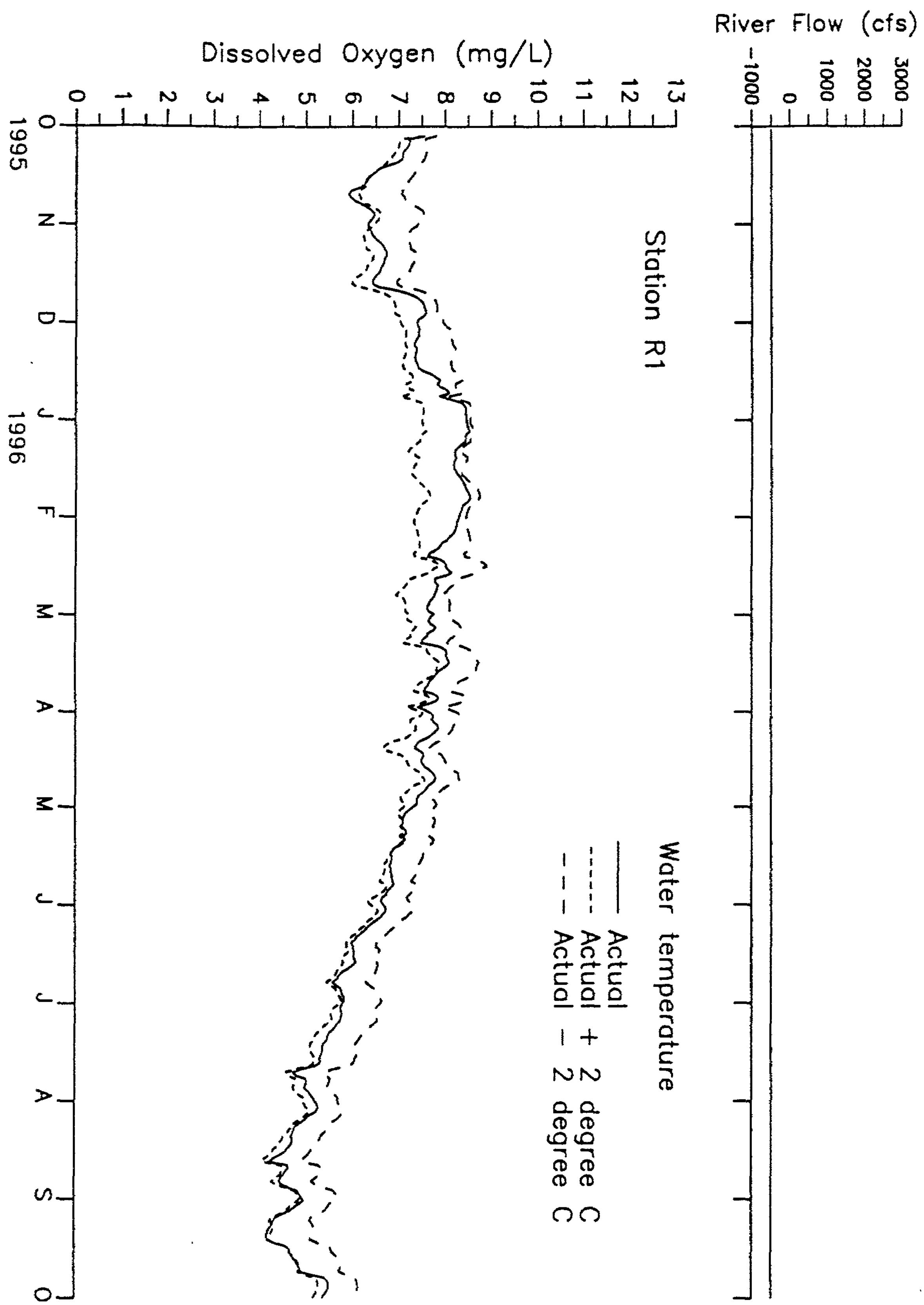
D-041649


Station R8
River Flow
-500 cfs
0 cfs
500 cfs
1000 cfs
2000 cfs
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1995
1996

Appendix K.

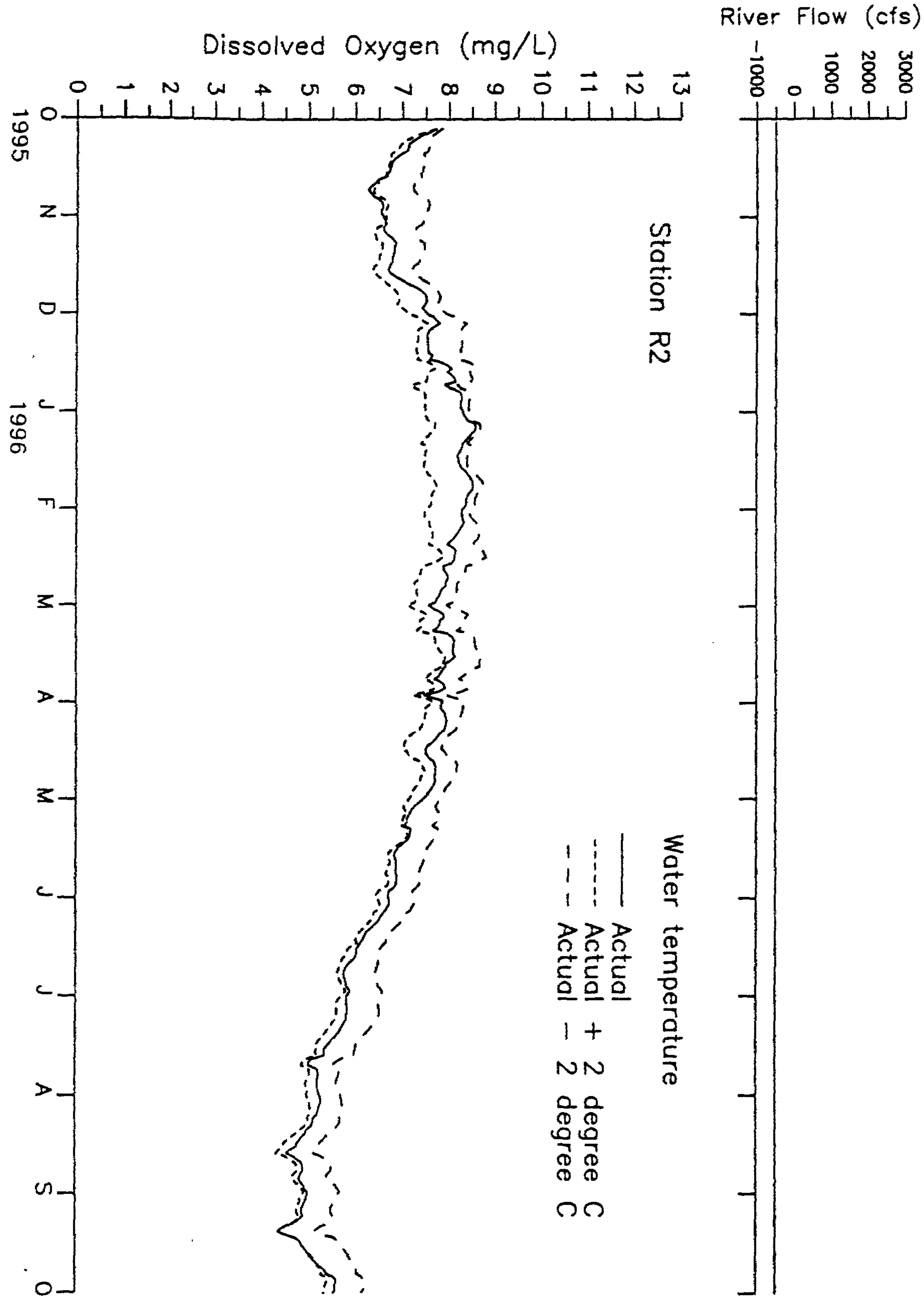
Sensitivity of DO to Temperature

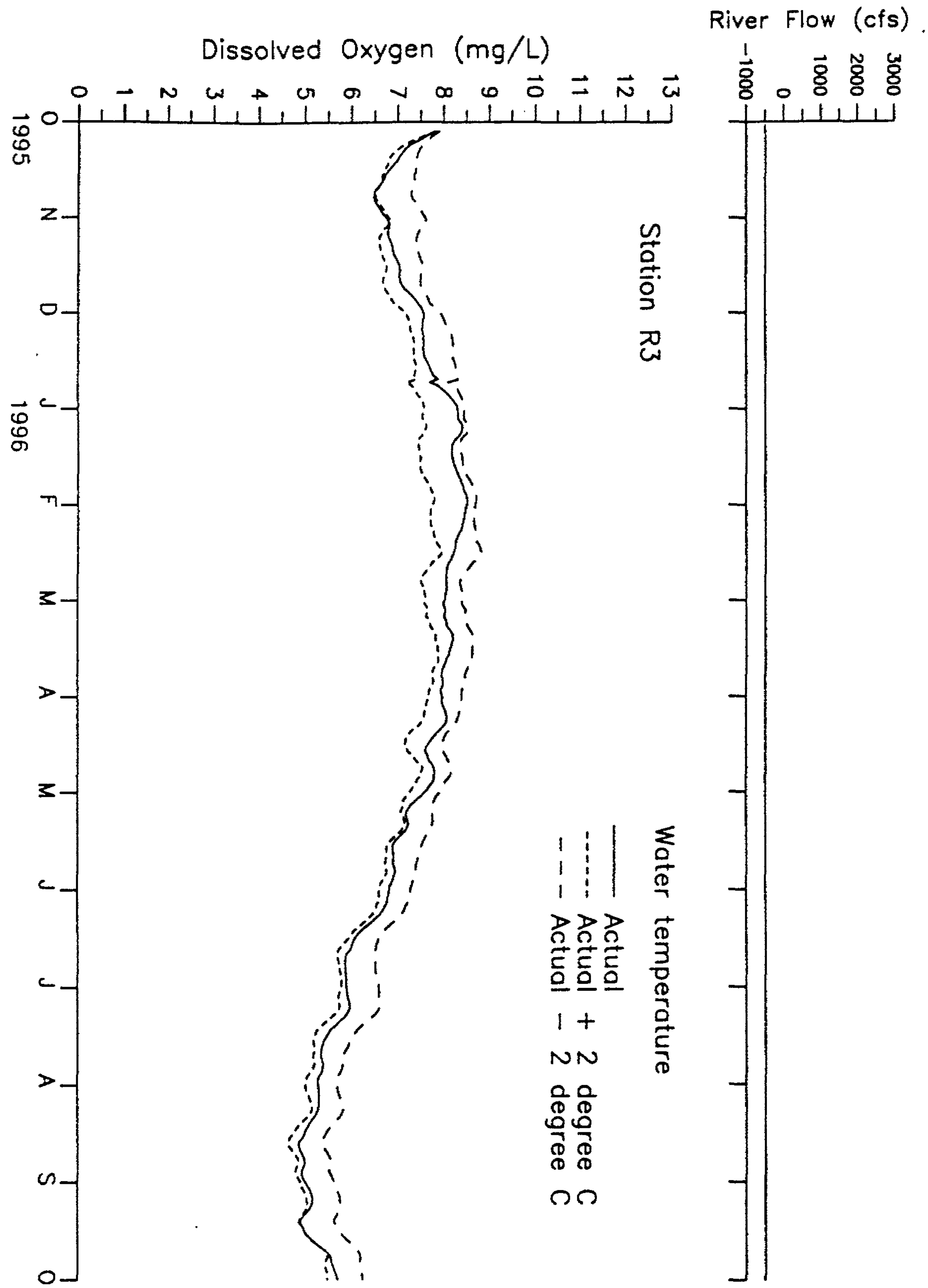

Station ROA
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996



D −0 4 1 6 5 3

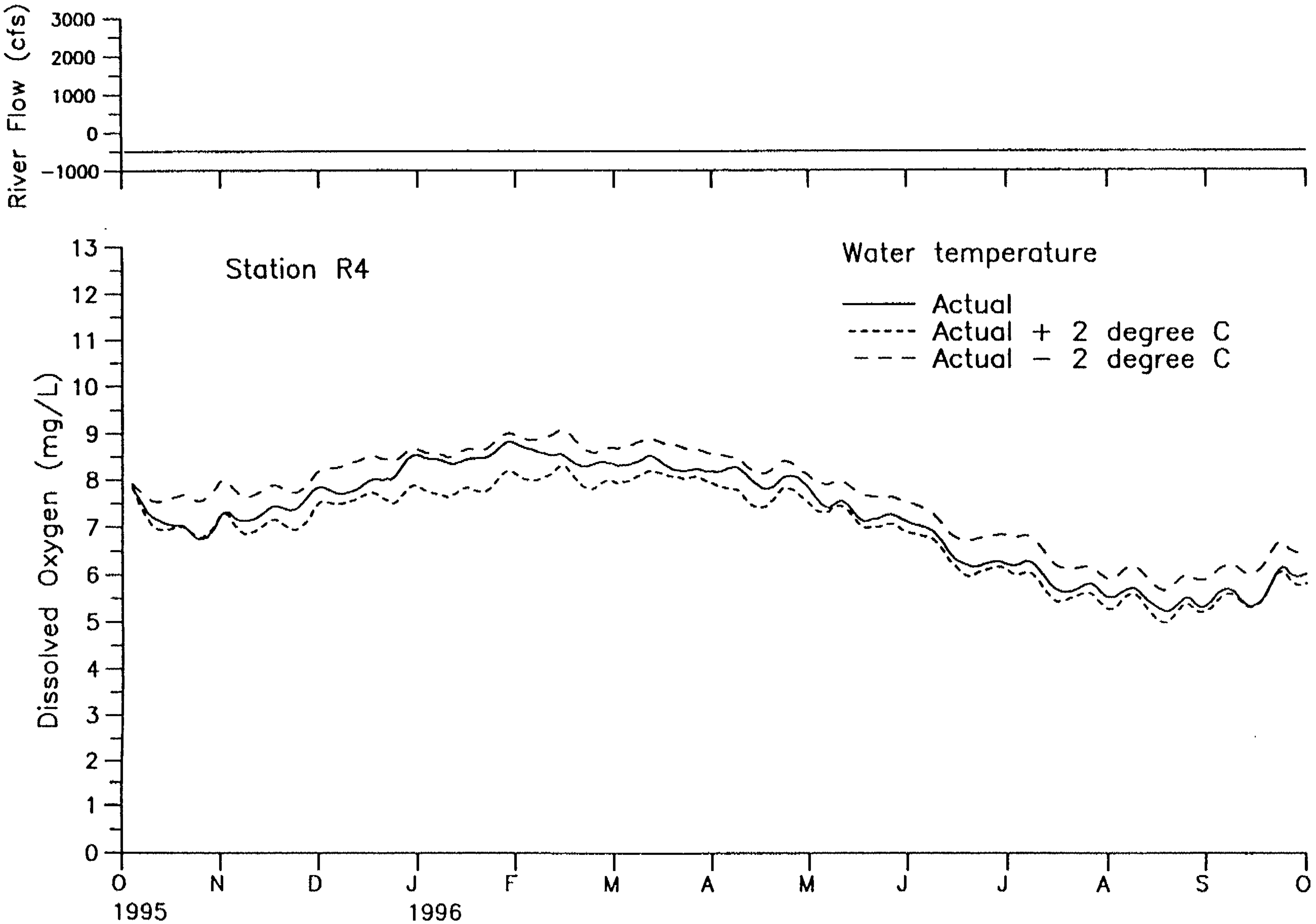
D-041653


River Flow (cfs)
-1000
0
1000
2000
3000
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Station R2
Water temperature
Actual
Actual + 2 degree C
Actual − 2 degree C
O
1995
N
D
J
1996
F
M
A
M
J
J
A
S
O



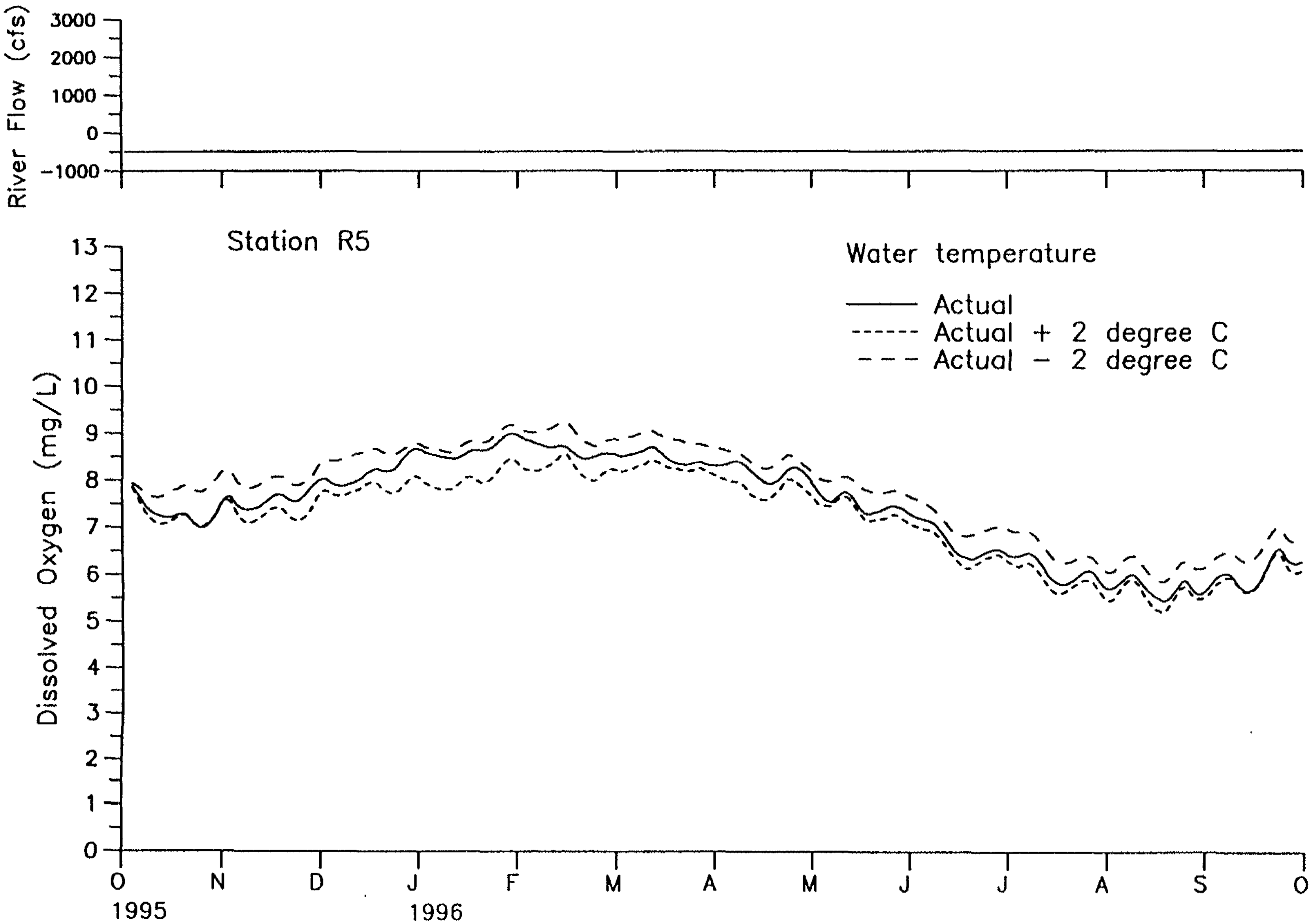
D −0 4 1 6 5 5

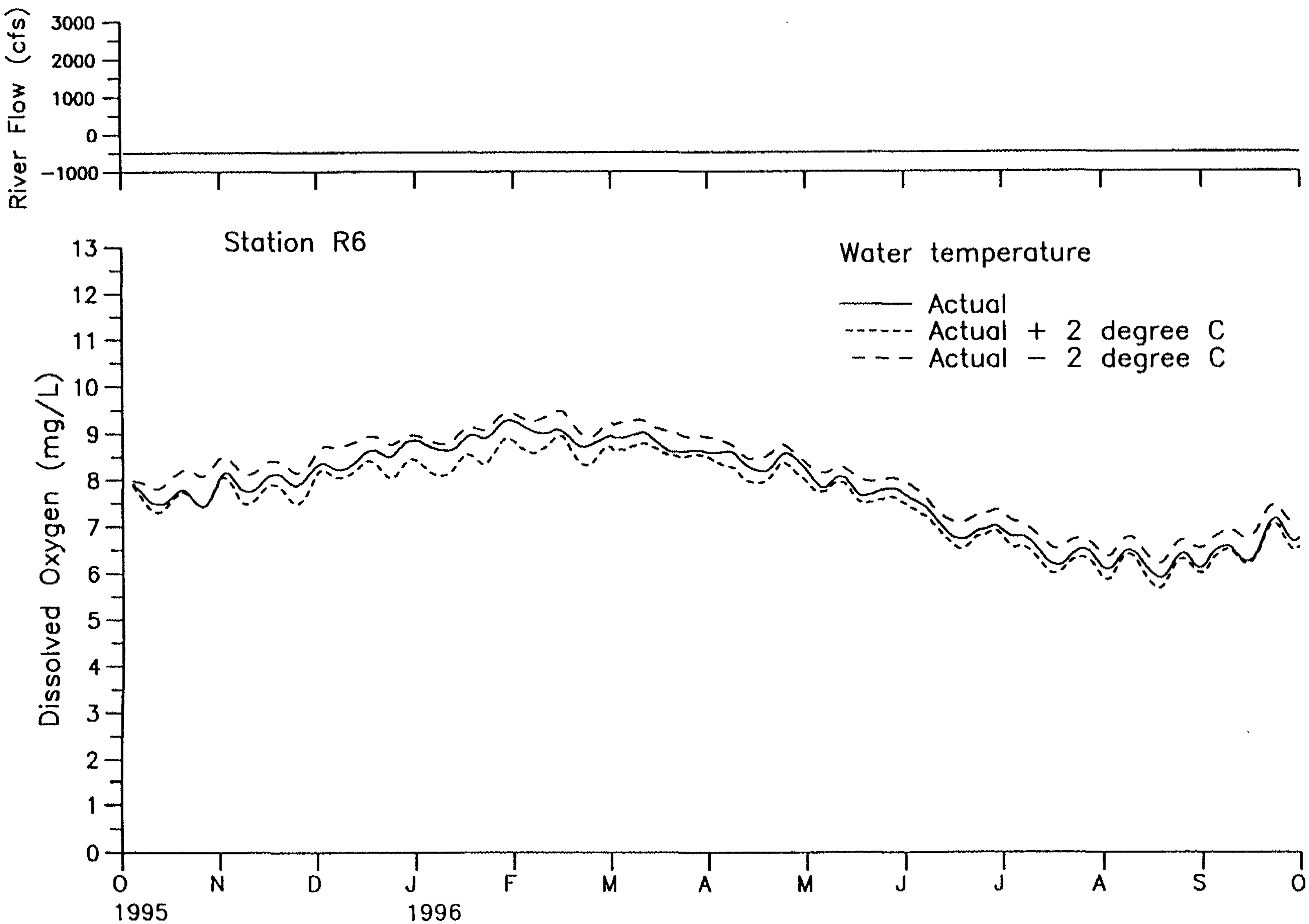
D-041655



D −0 4 1 6 5 6

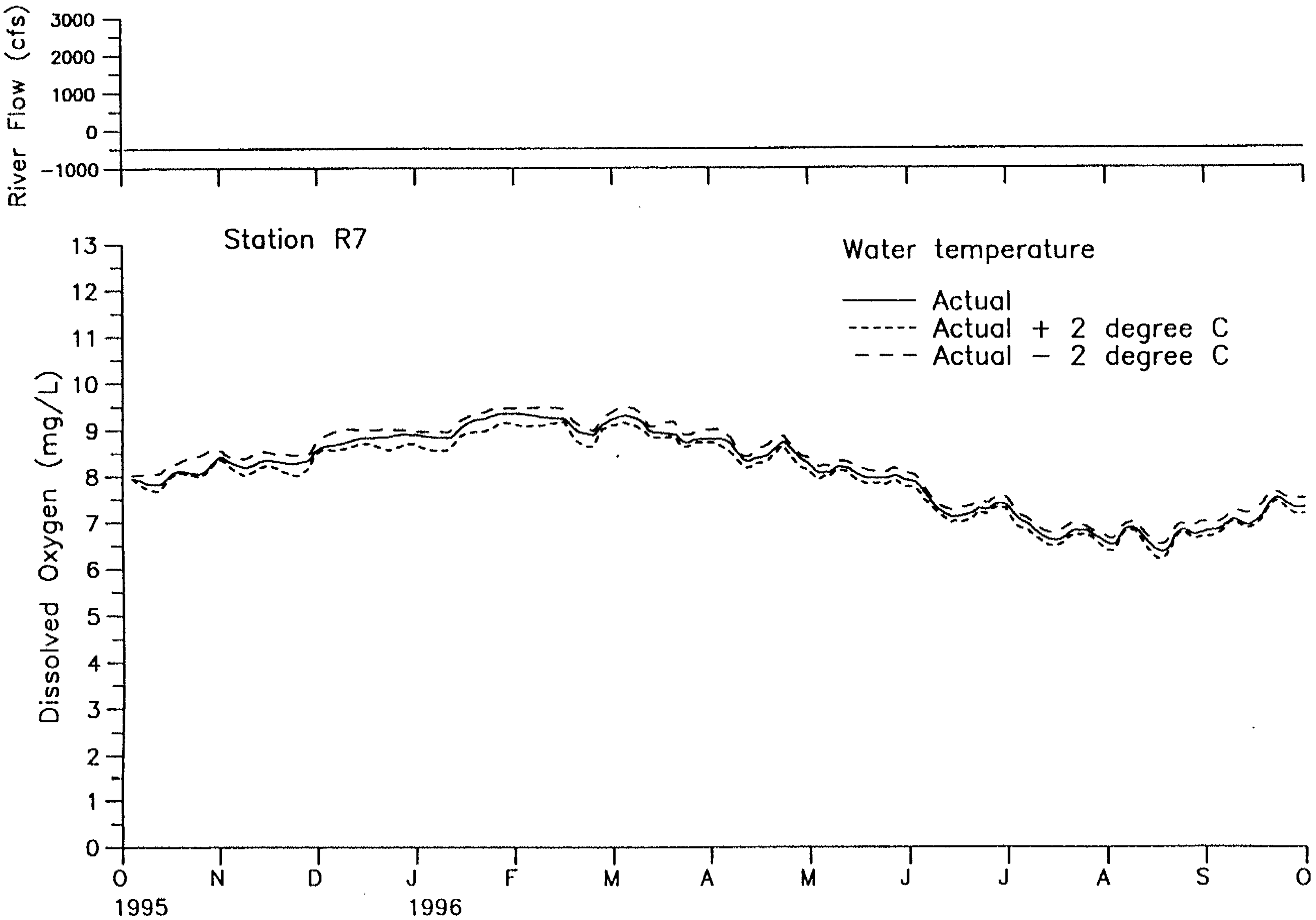
D-041656


River Flow (cfs)
3000
2000
1000
0
-1000
Station R5
Water temperature
Actual
Actual + 2 degree C
Actual - 2 degree C
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996



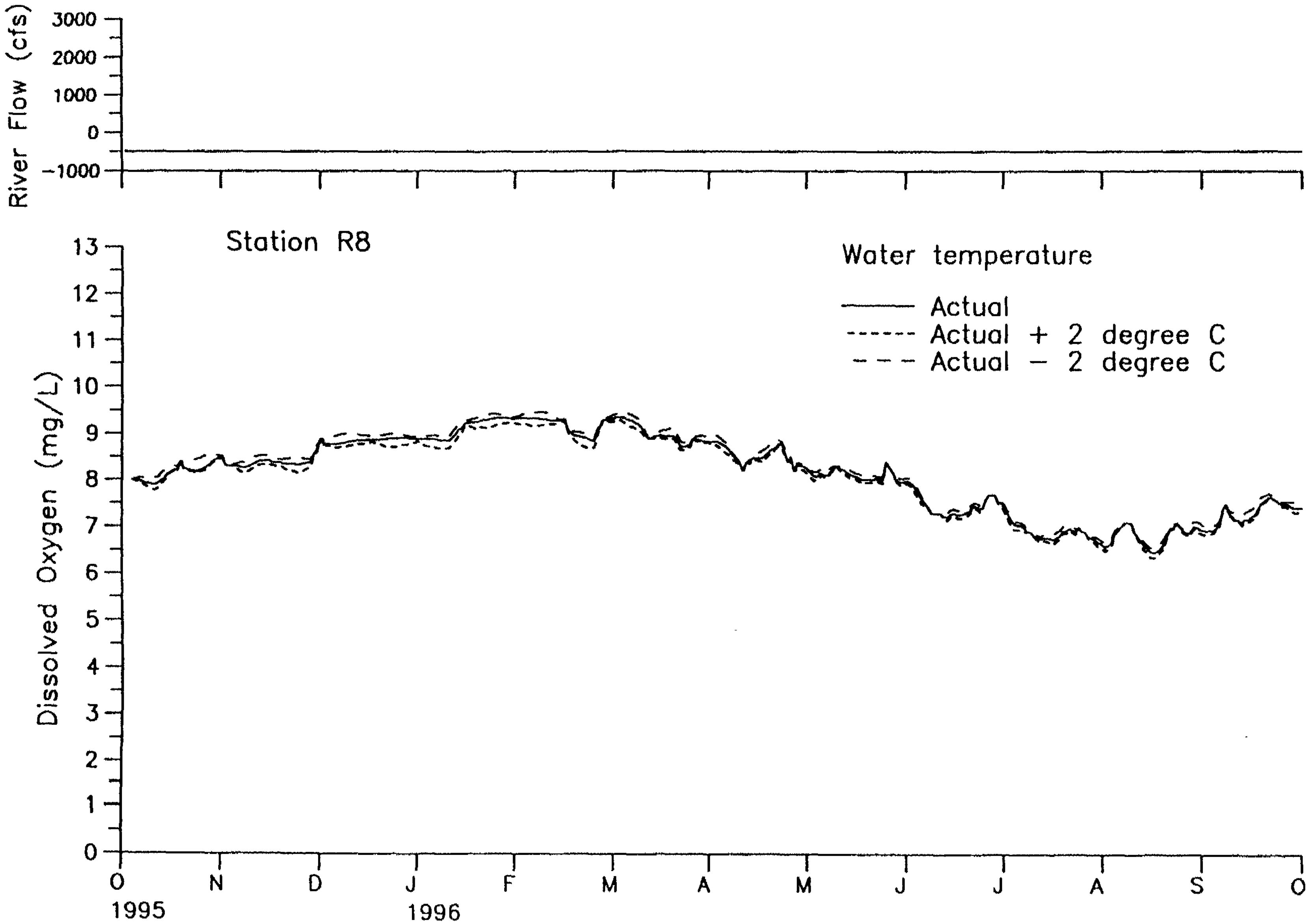
D −0 4 1 6 5 8

D-041658



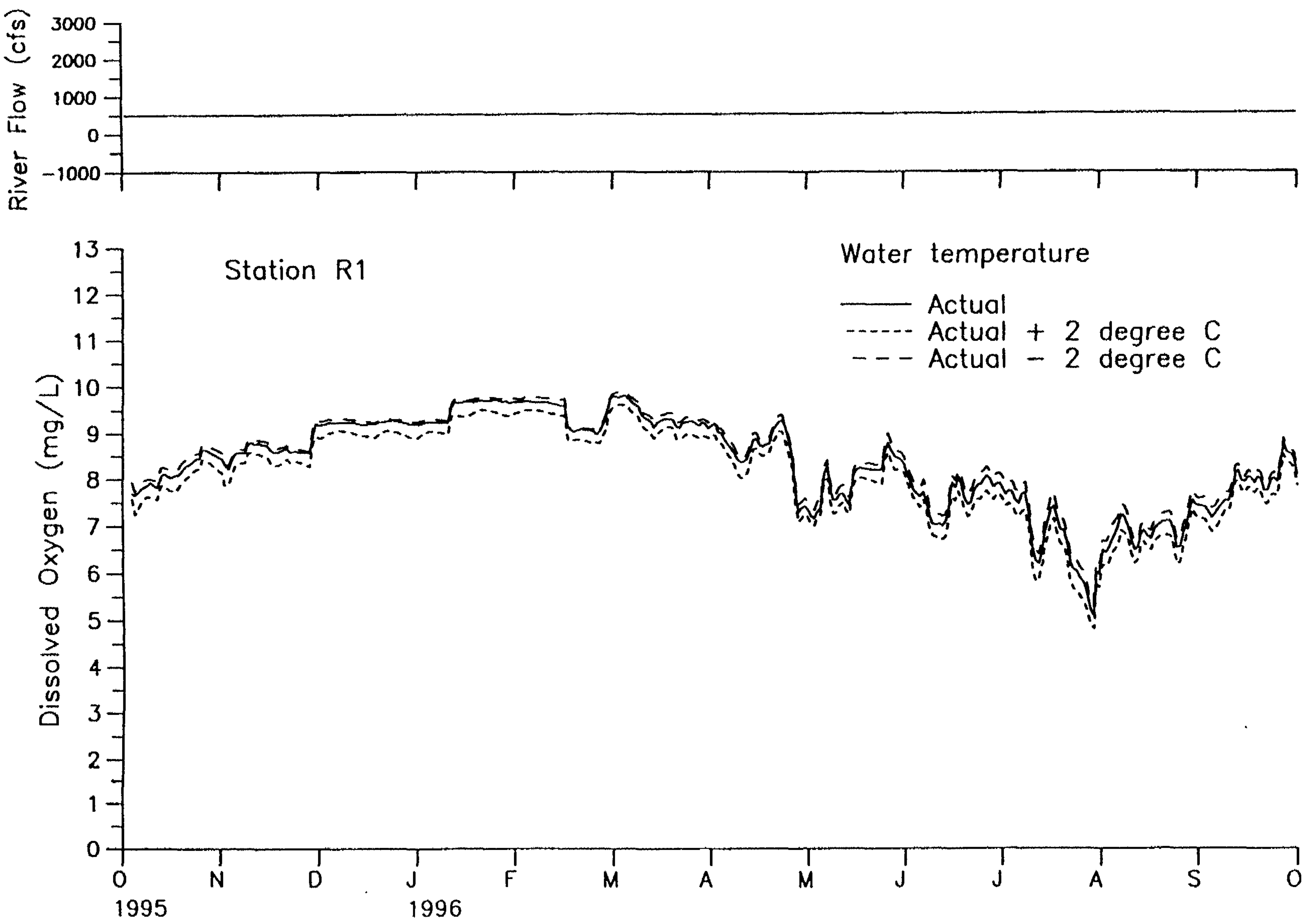
D —0 4 1 6 5 9

D-041659

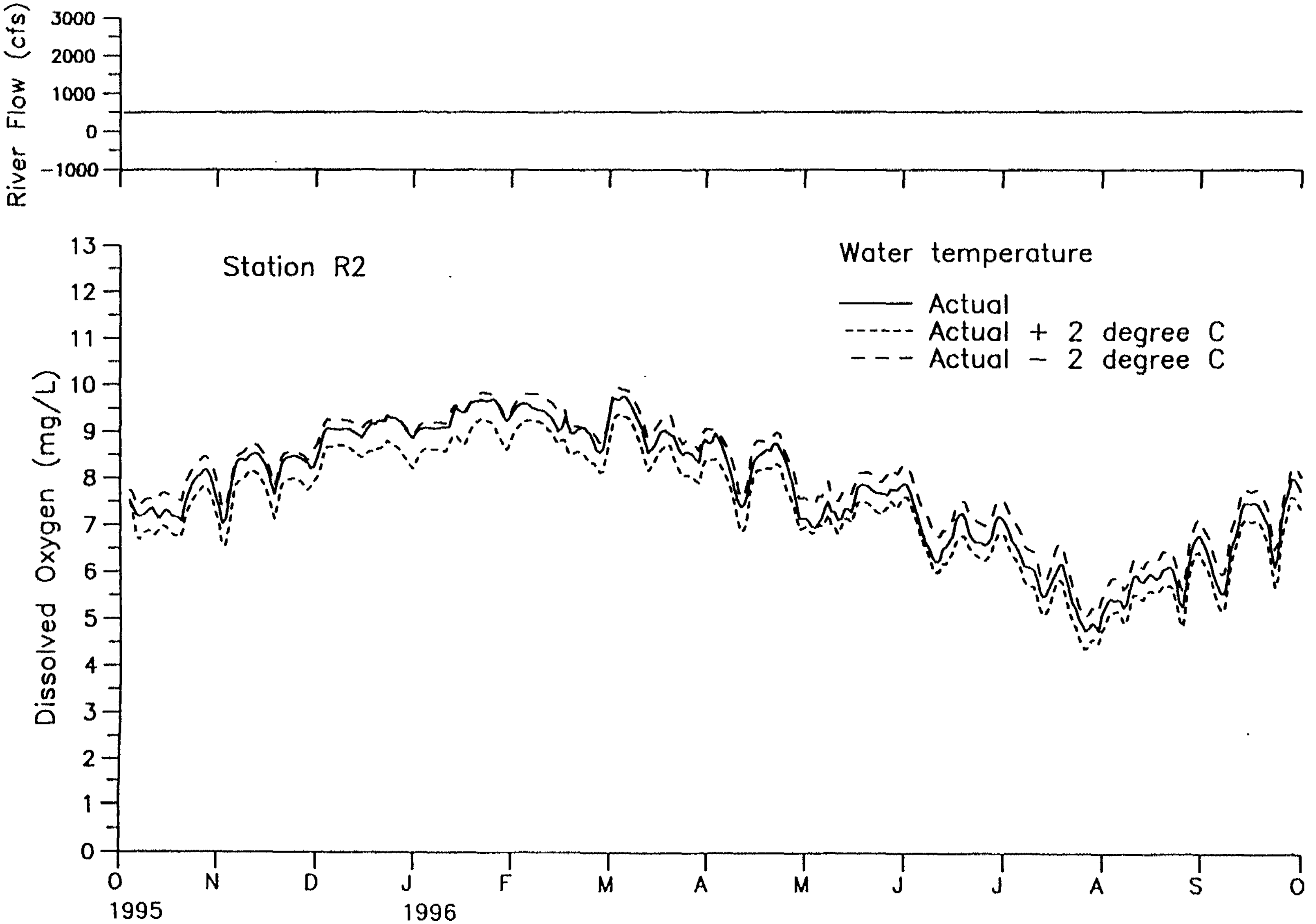


D—041660

D-041660

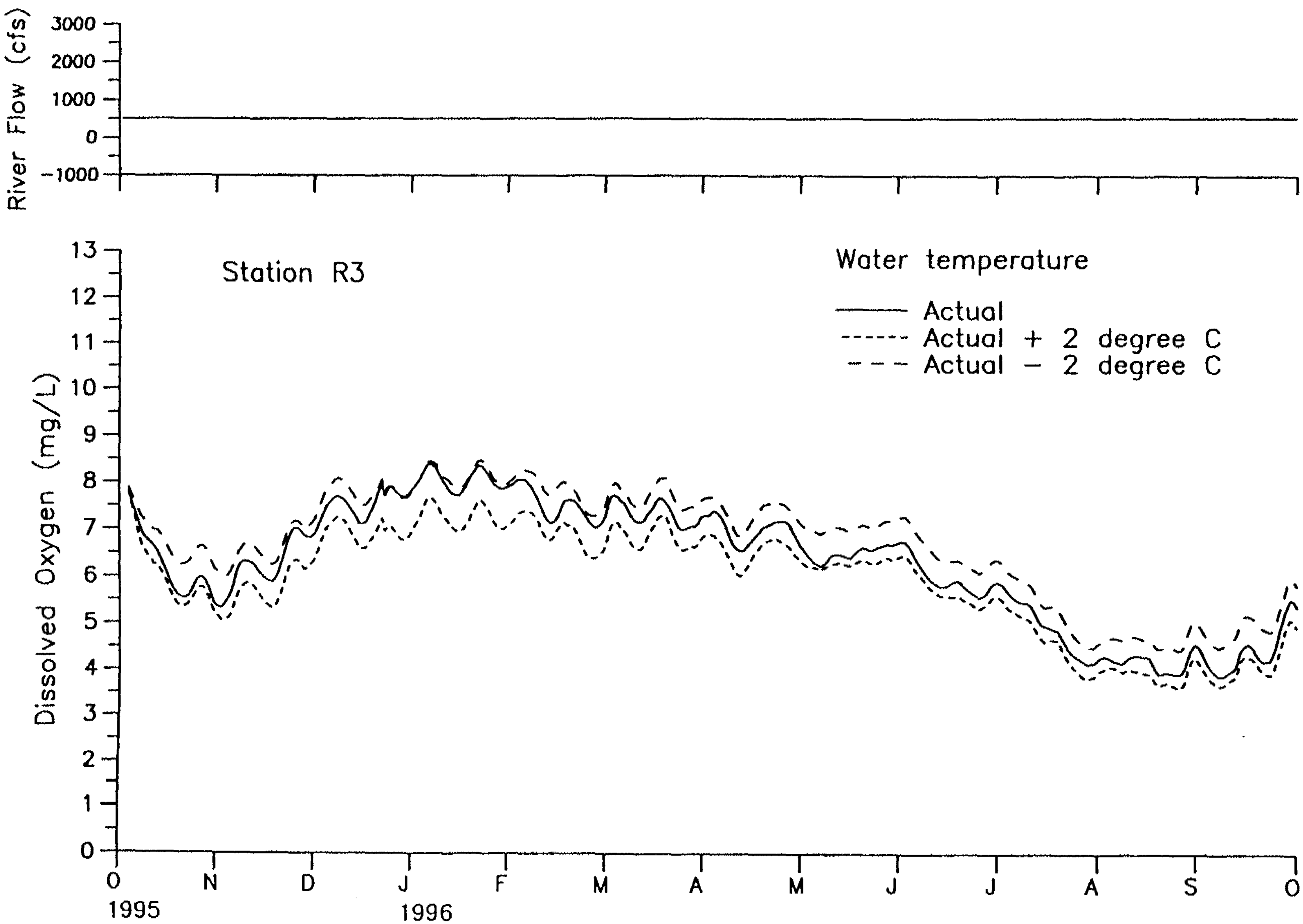


River Flow (cfs)
3000
2000
1000
0
−1000
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Station R1
Water temperature
Actual
Actual + 2 degree C
Actual − 2 degree C
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

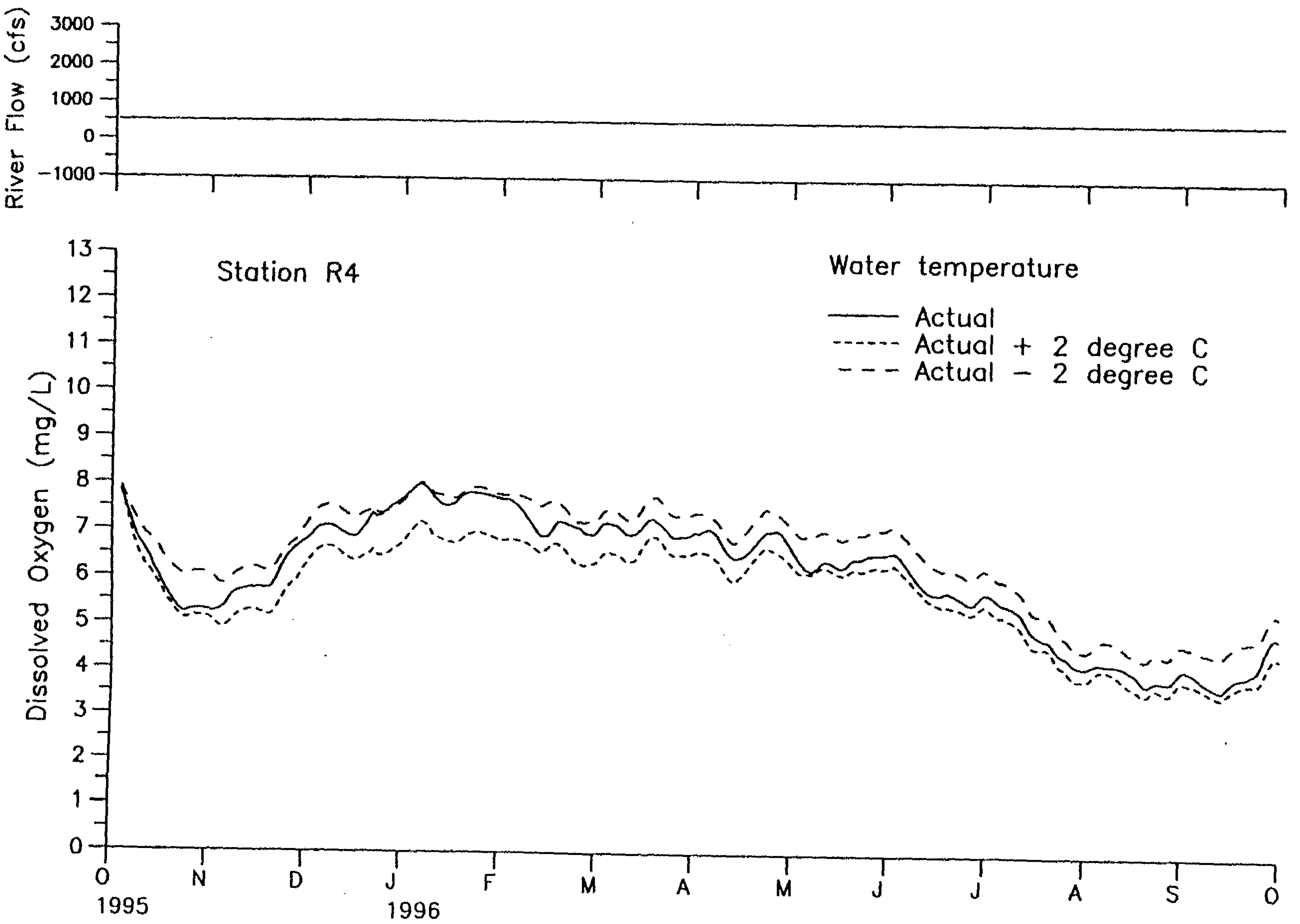


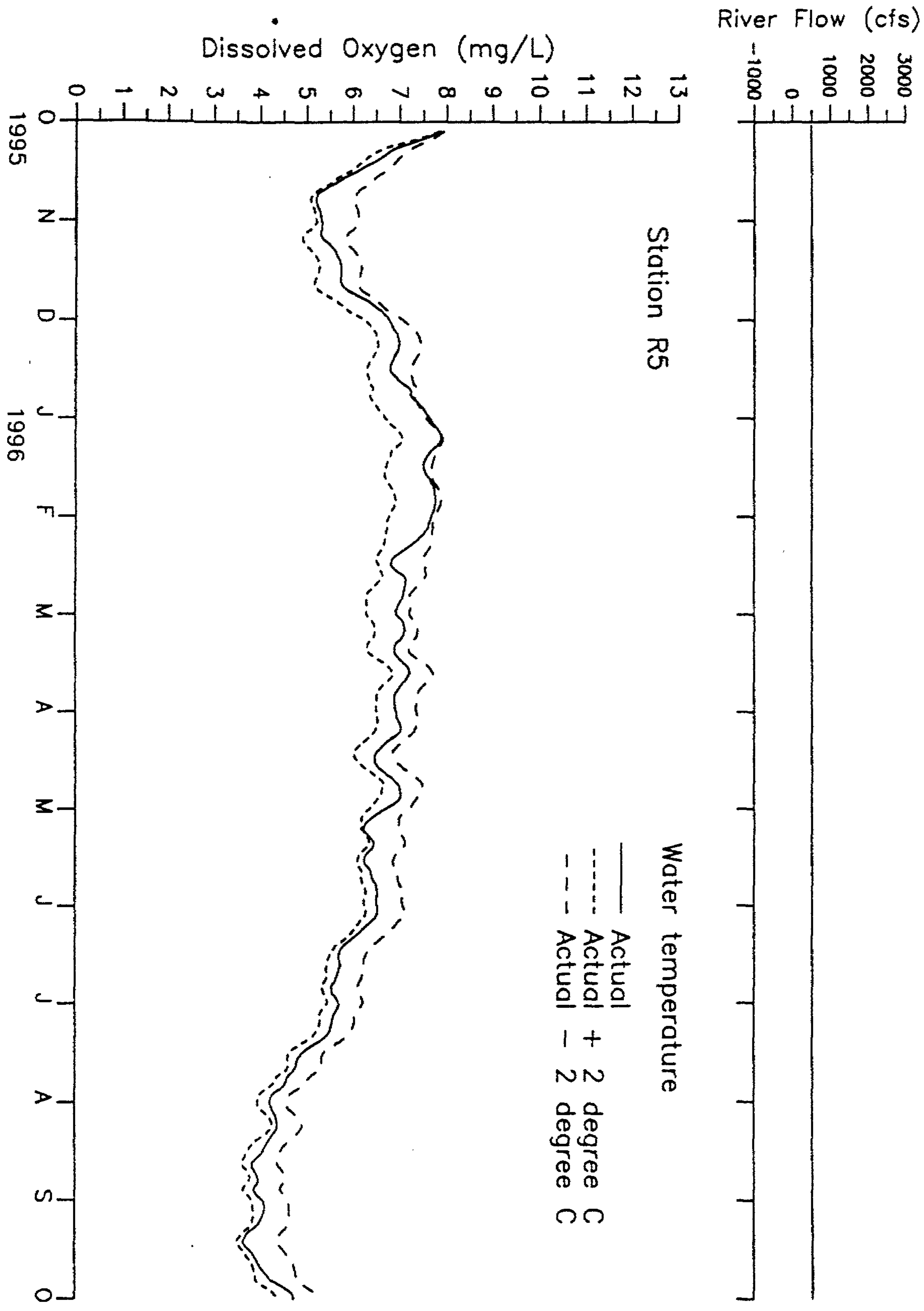
D —0 4 1 6 6 2

D-041662


River Flow (cfs)
3000
2000
1000
0
-1000
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Station R3
Water temperature
Actual
Actual + 2 degree C
Actual − 2 degree C
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

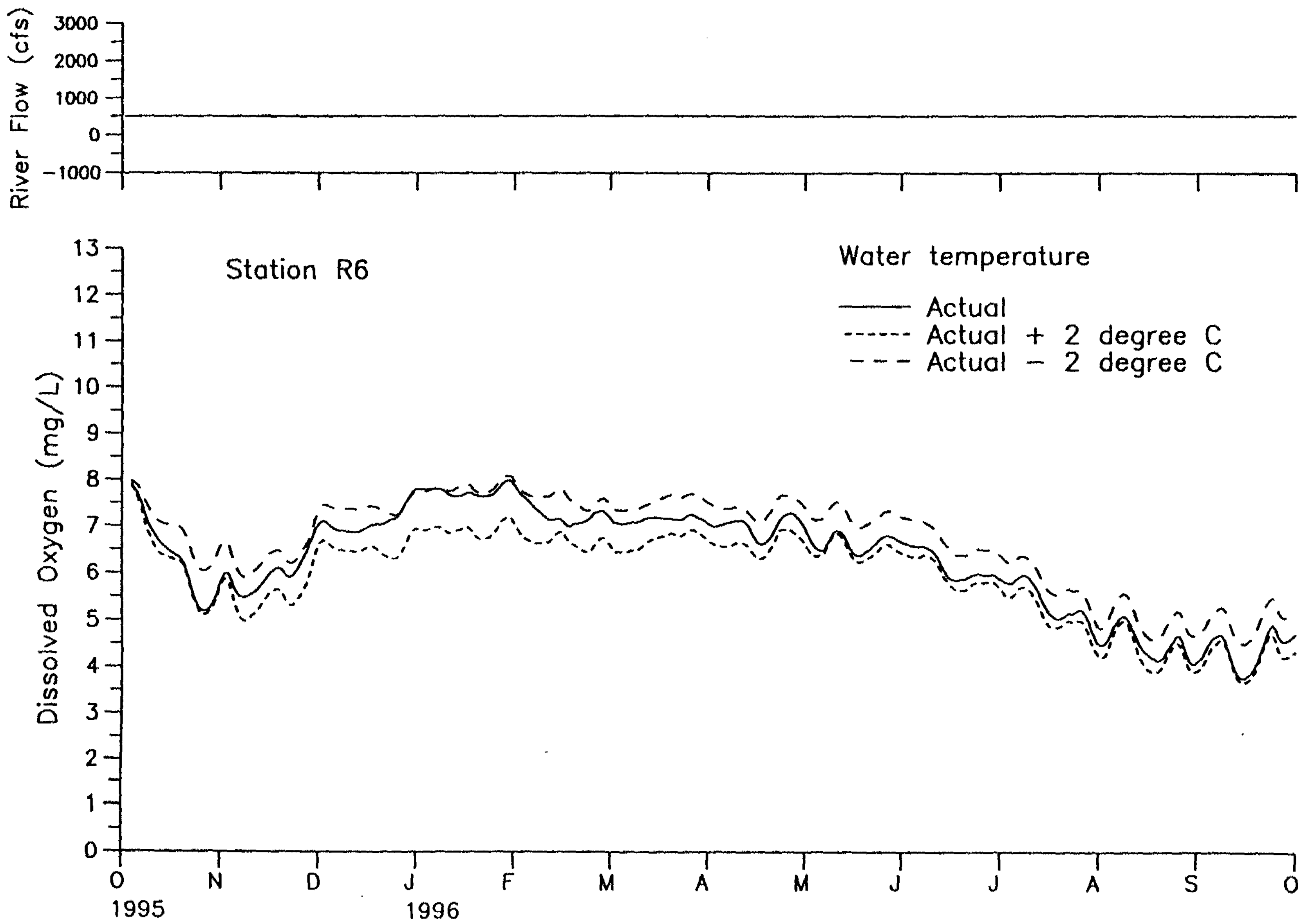
D-041663


River Flow (cfs)
3000
2000
1000
0
-1000
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Station R4
Water temperature
Actual
Actual + 2 degree C
Actual − 2 degree C
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

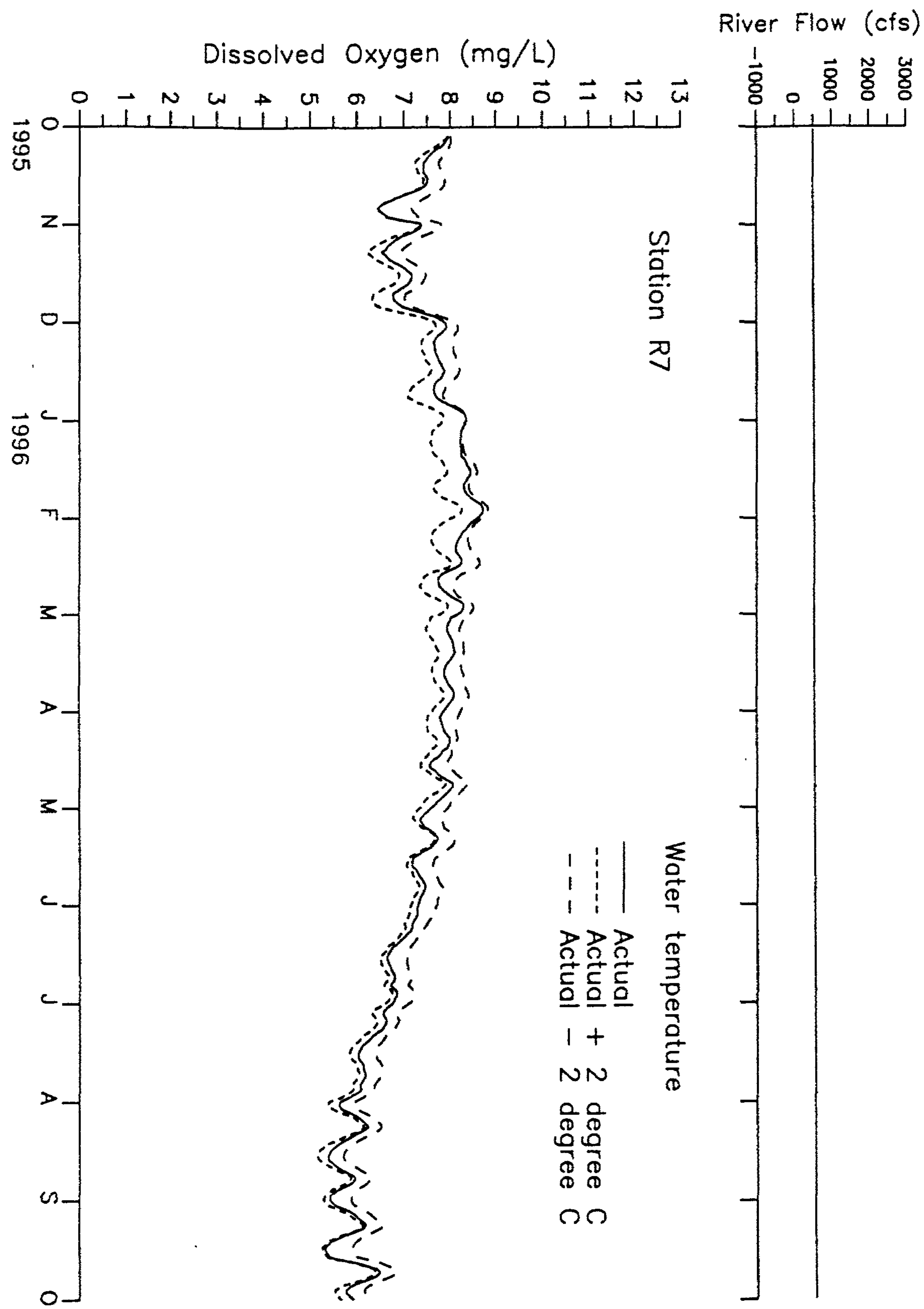


Station R5
Water temperature
Actual
Actual + 2 degree C
Actual − 2 degree C
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
River Flow (cfs)
-1000
0
1000
2000
3000
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

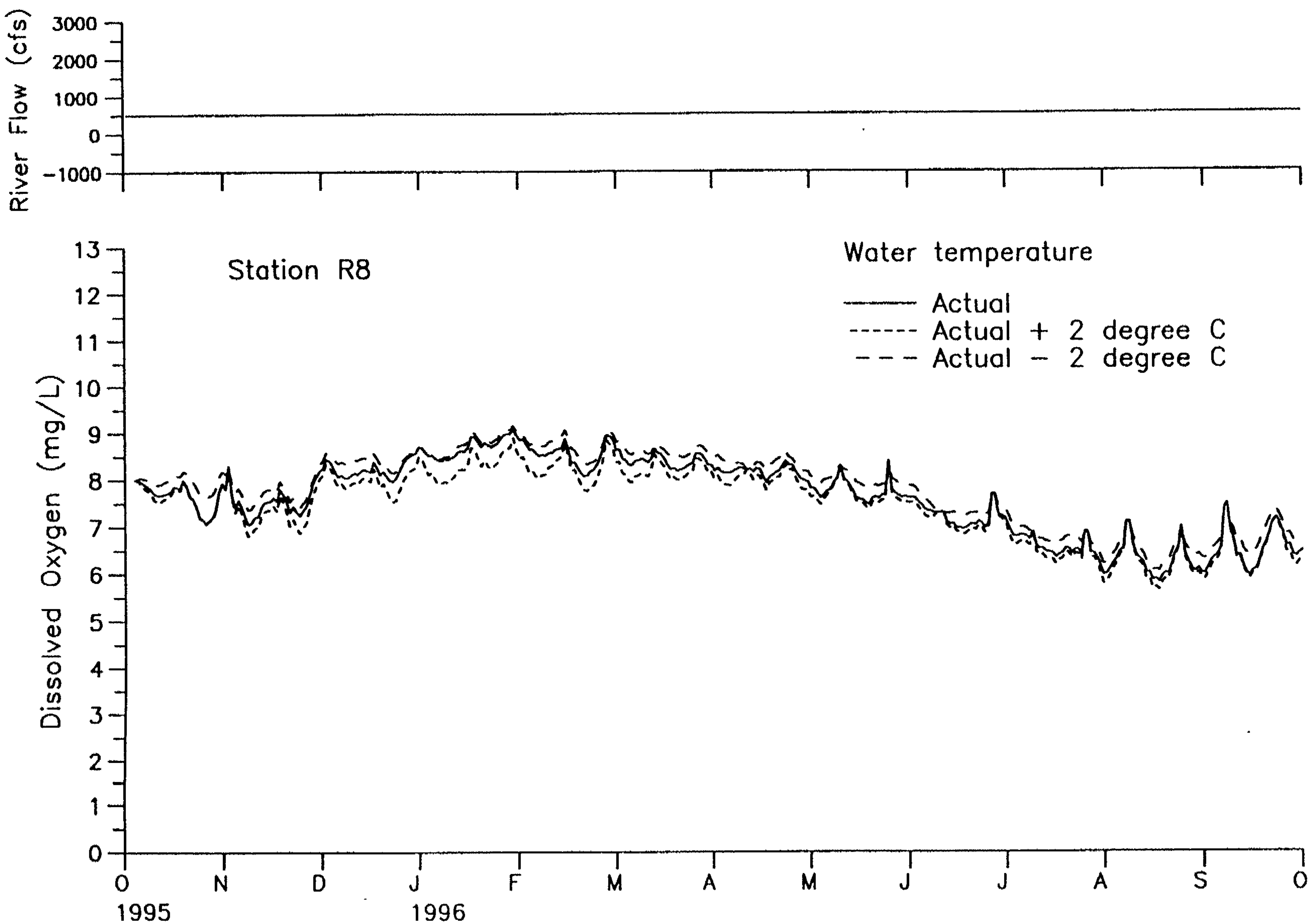
D −0 4 1 6 6 5



River Flow (cfs)
3000
2000
1000
0
−1000
Station R6
Water temperature
Actual
Actual + 2 degree C
Actual − 2 degree C
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

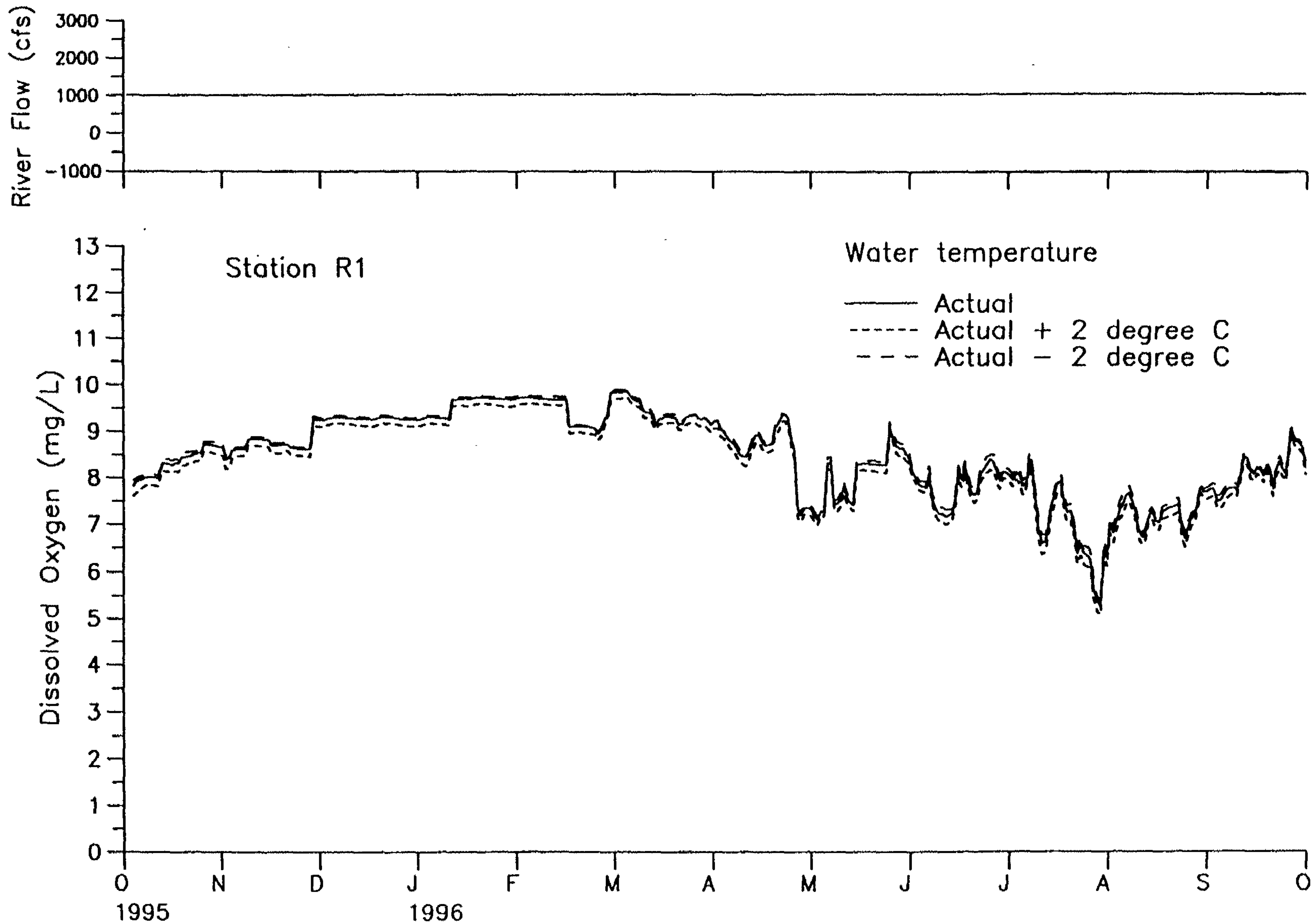


River Flow (cfs)
-1000
0
1000
2000
3000
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Station R7
Water temperature
Actual
Actual + 2 degree C
Actual - 2 degree C
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

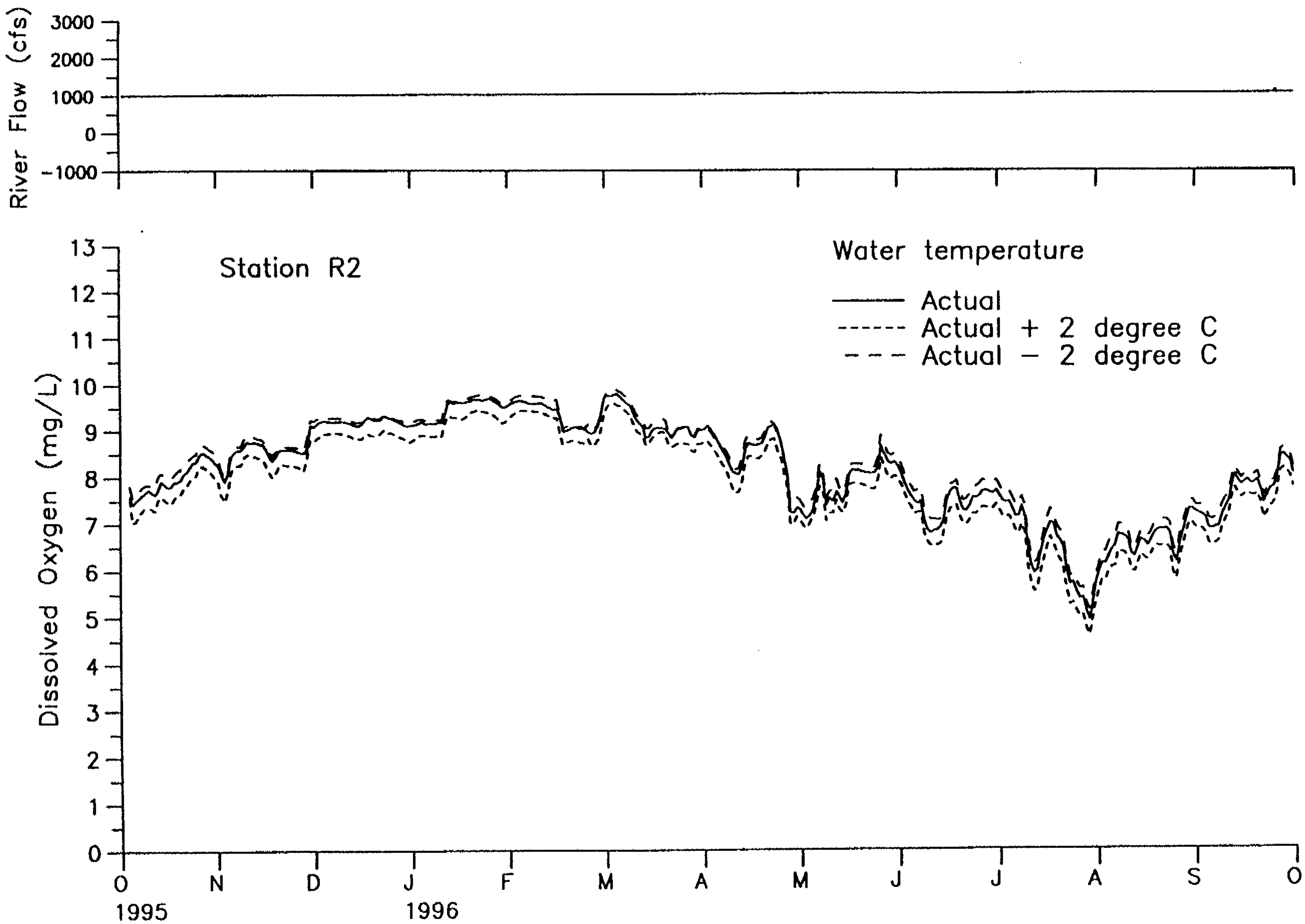


D-041668

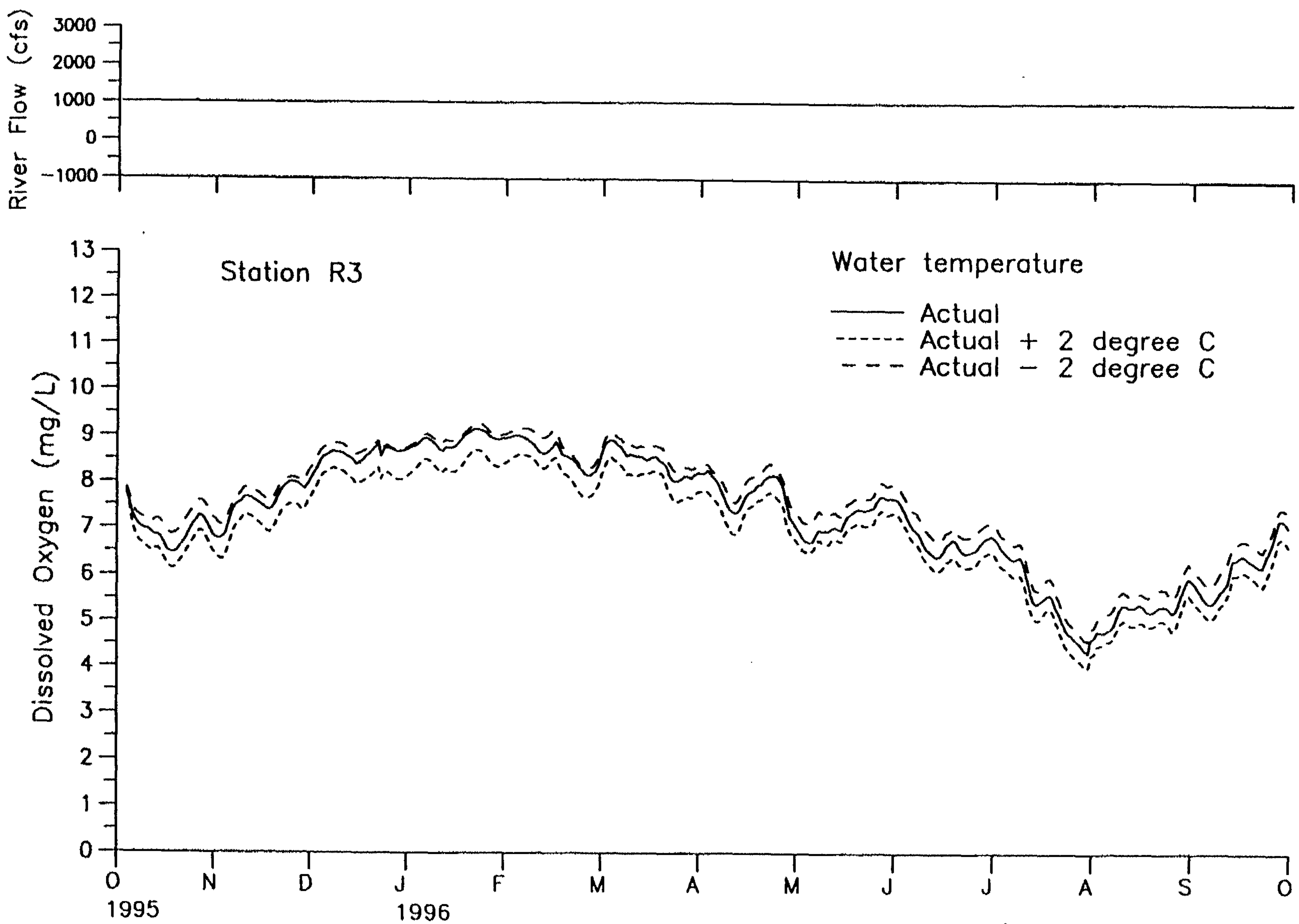
D−041668

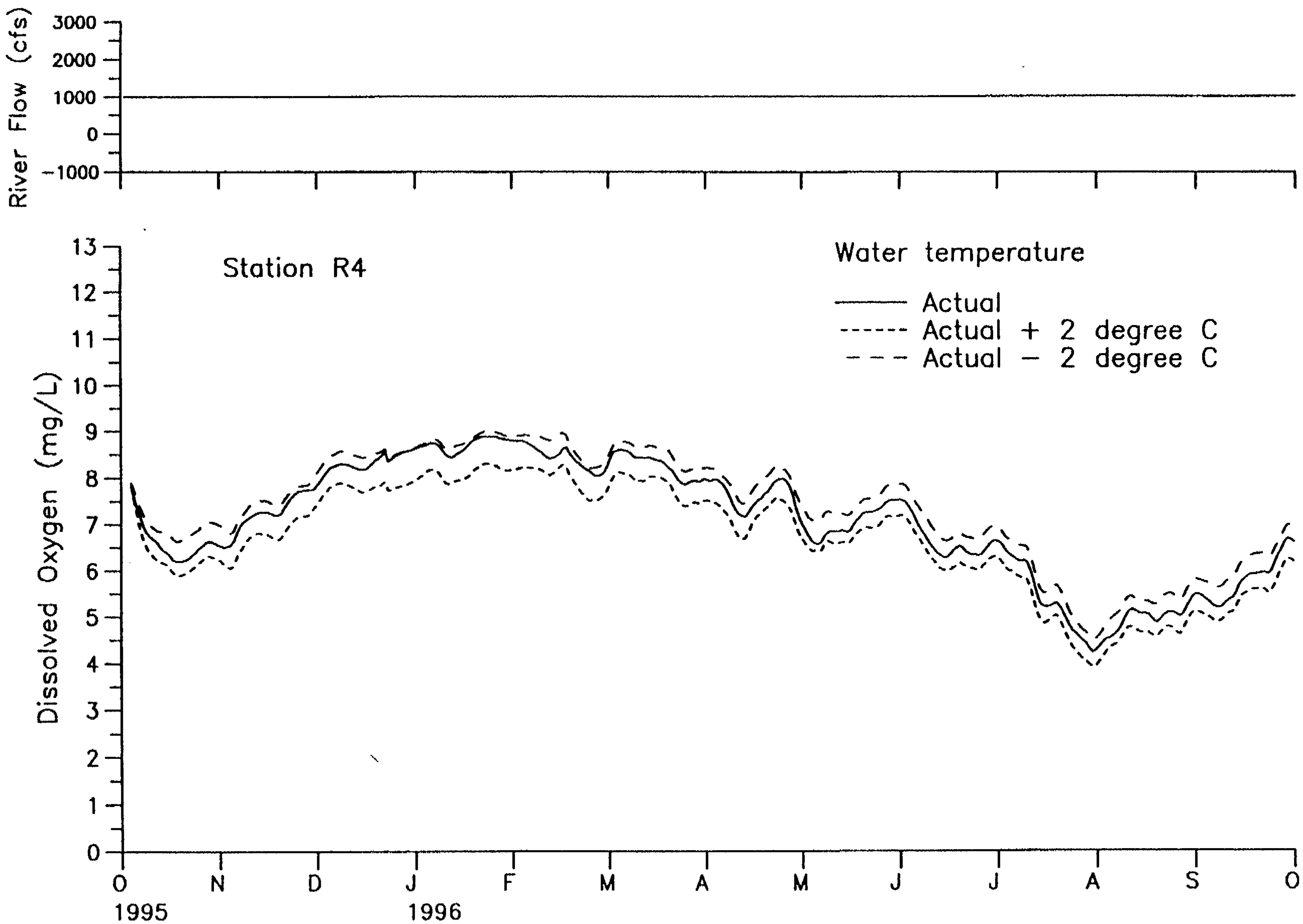

River Flow (cfs)
3000
2000
1000
0
-1000
Station R1
Water temperature
Actual
Actual + 2 degree C
Actual − 2 degree C
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1995
1996

D-041669


River Flow (cfs)
3000
2000
1000
0
-1000
Station R2
Water temperature
Actual
Actual + 2 degree C
Actual − 2 degree C
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

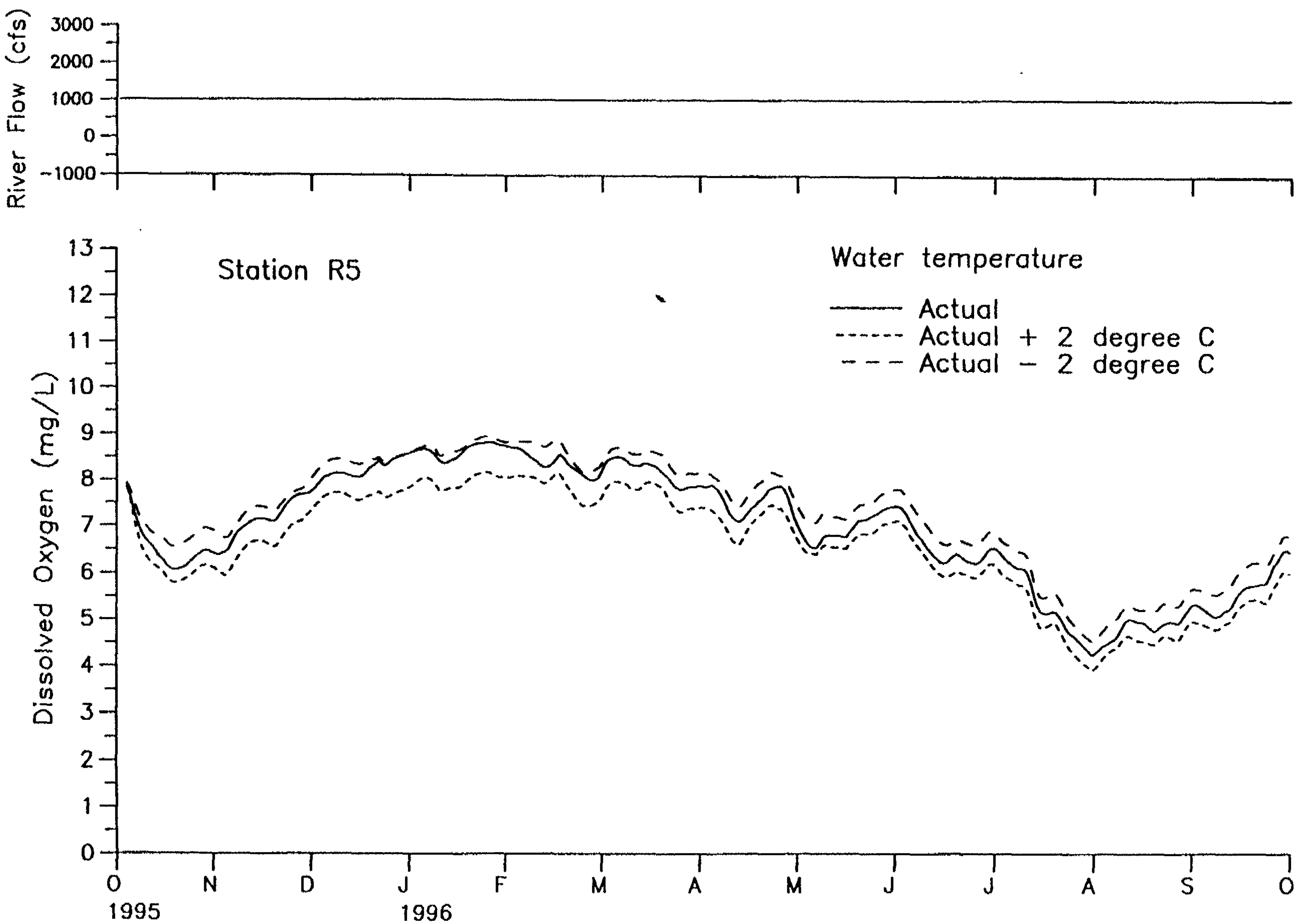
D — 0 4 1 6 7 0


River Flow (cfs)
3000
2000
1000
0
-1000
Station R3
Water temperature
Actual
Actual + 2 degree C
Actual - 2 degree C
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1995
1996



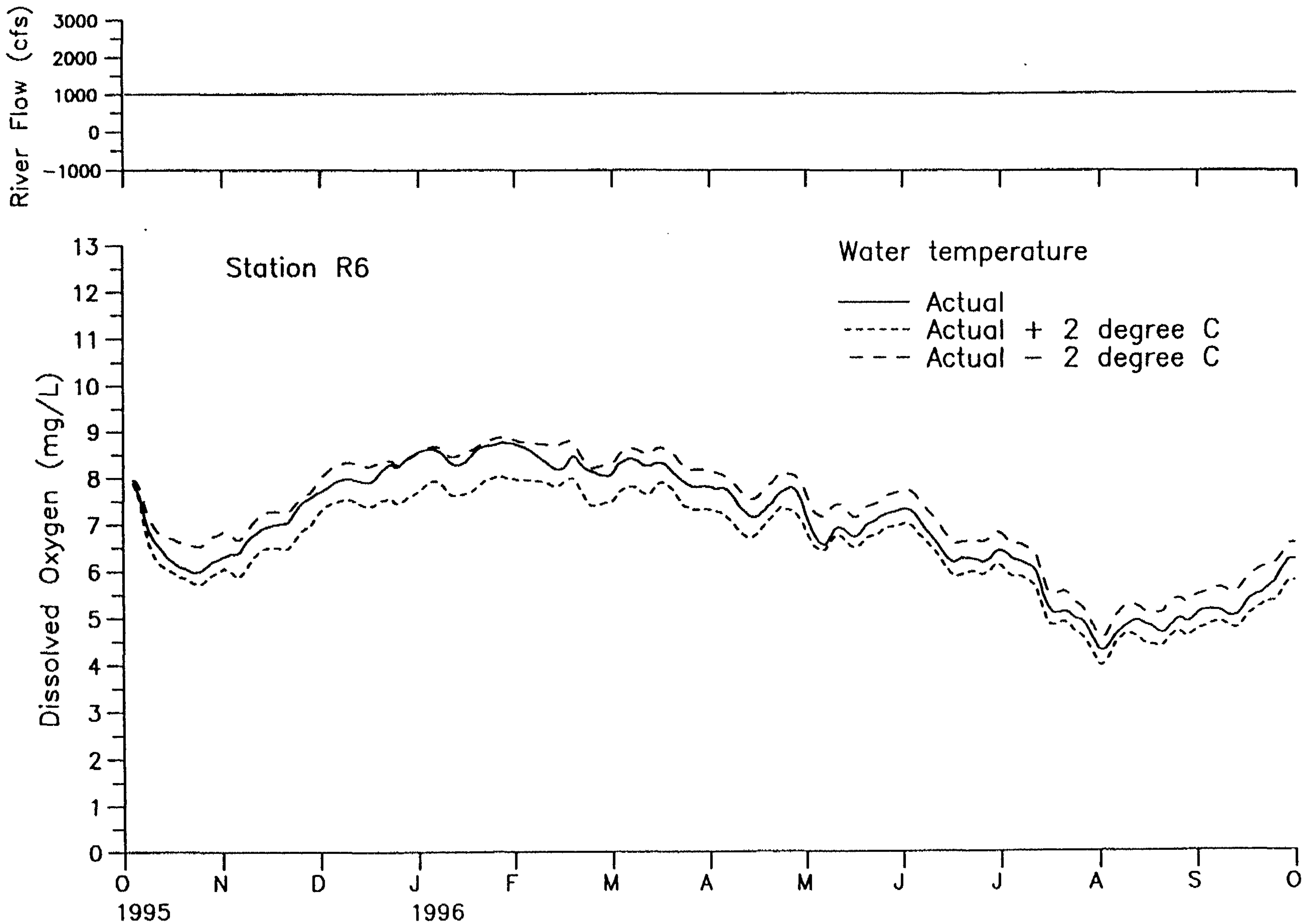
D —0 4 1 6 7 2

D-041672



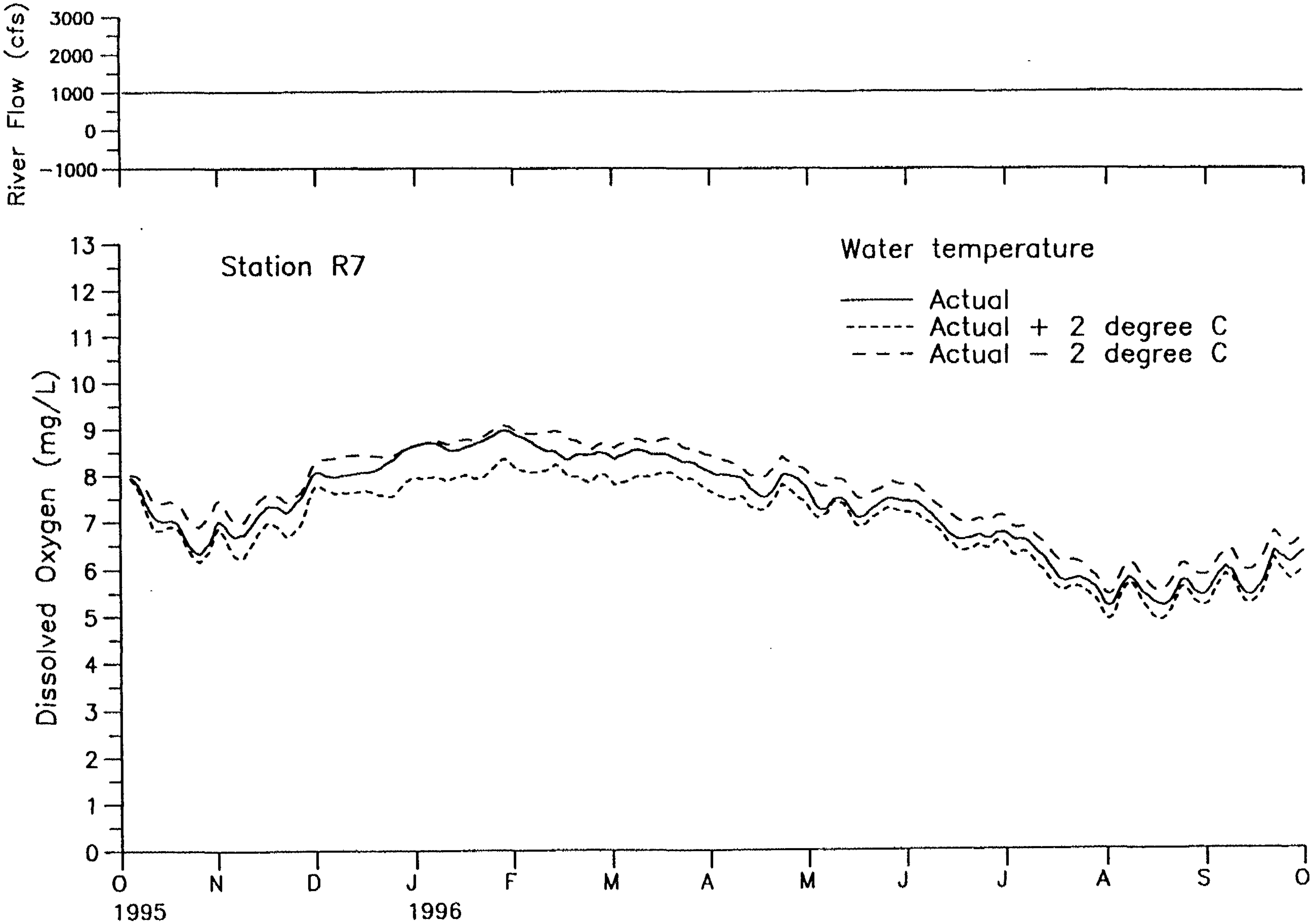
D—041673

D-041673



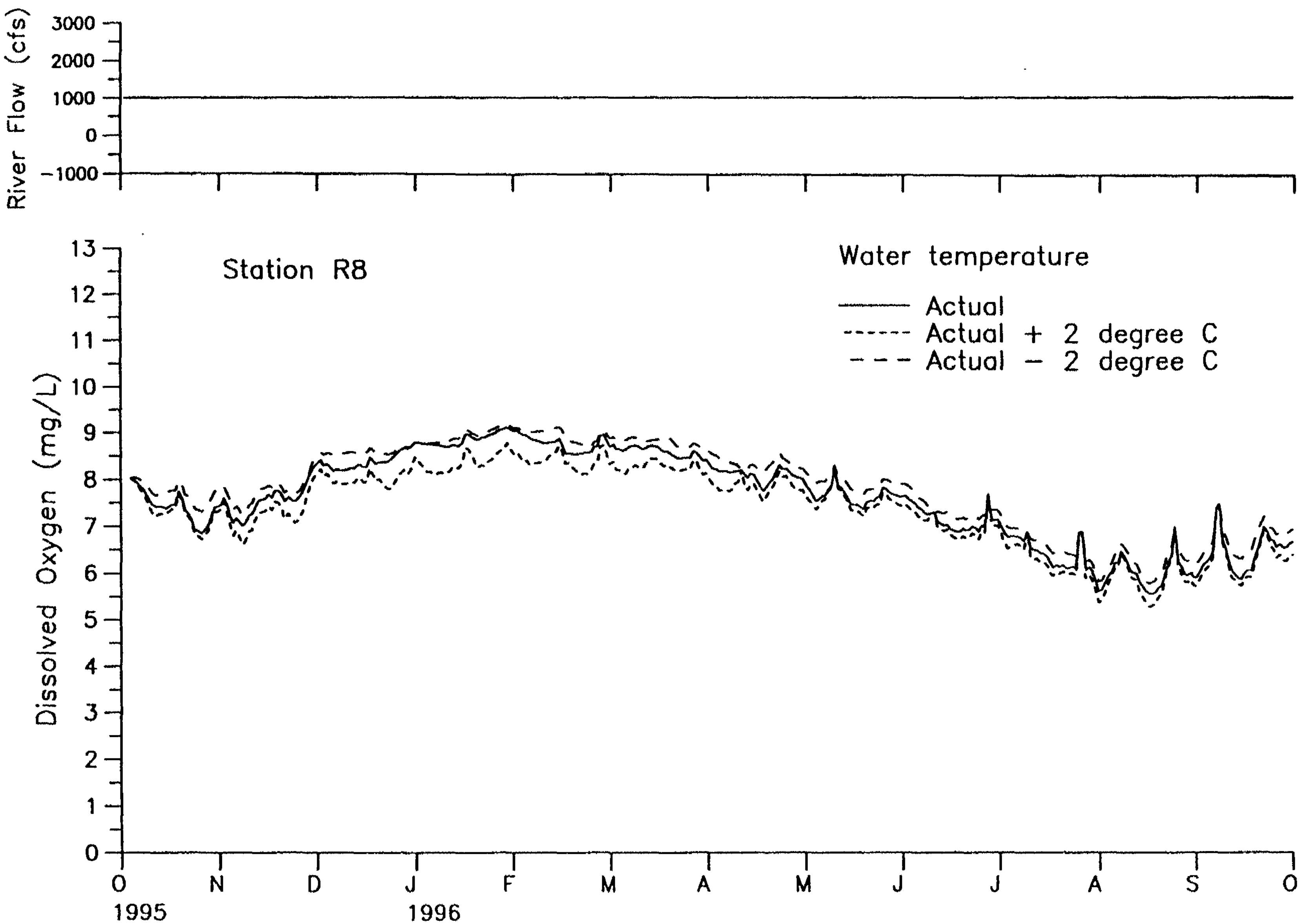
D-041674

D-041674



D-041675

D-041675

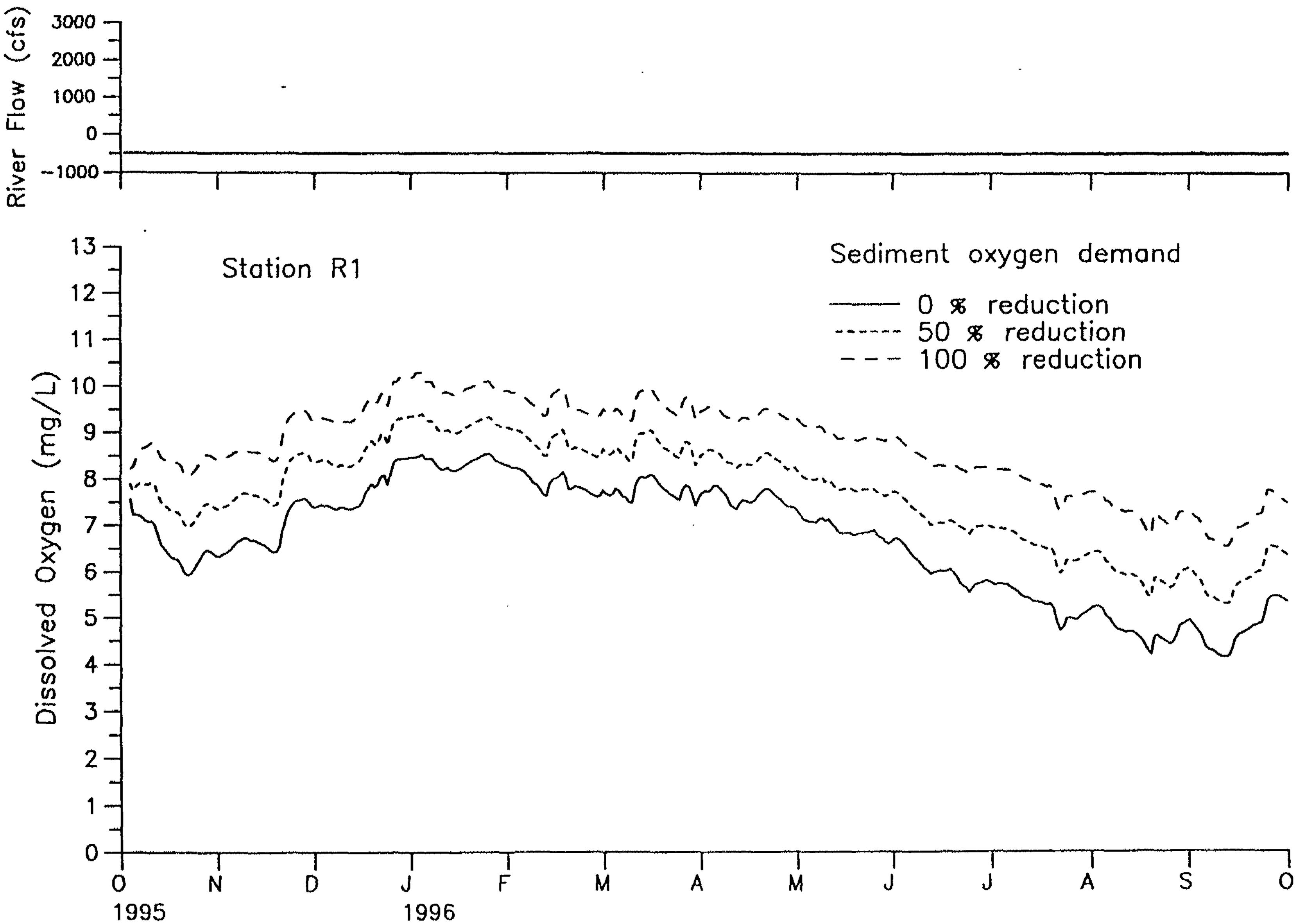


D-041676

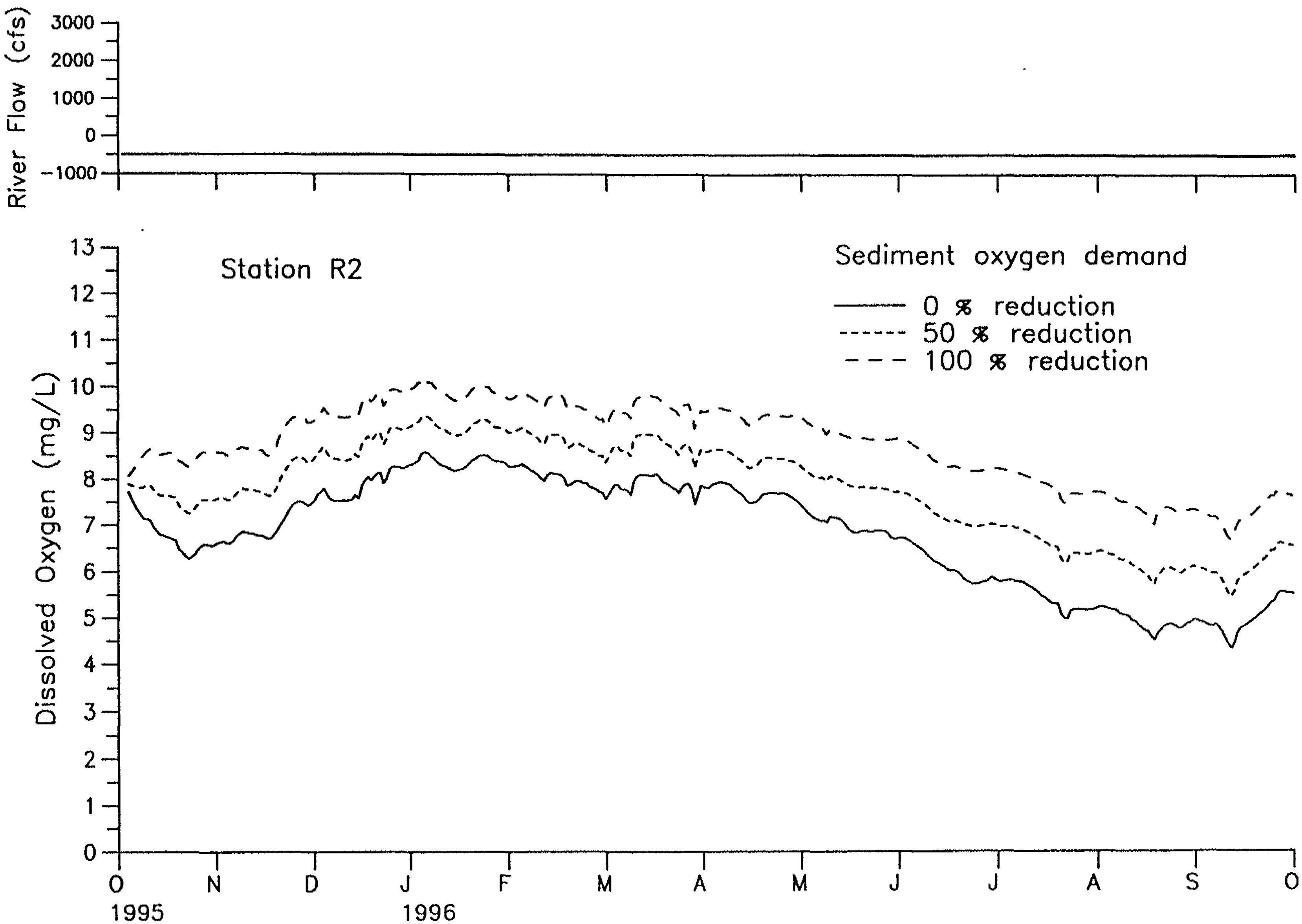
D-041676

Appendix L.

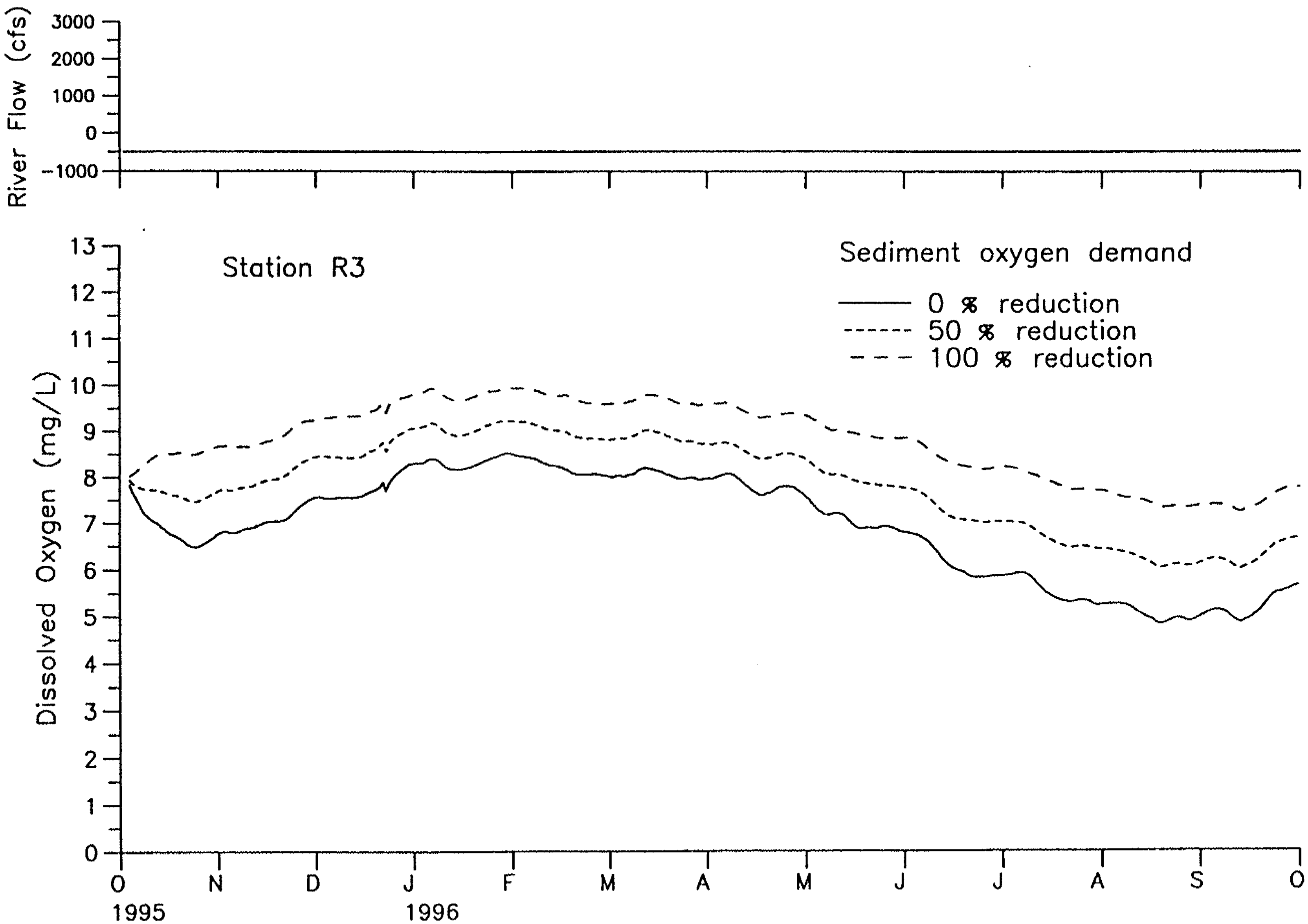
Sensitivity of DO to Sediment Oxygen Demand


River Flow (cfs)
3000
2000
1000
0
−1000
Station R1
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D — 0 4 1 6 7 8


River Flow (cfs)
3000
2000
1000
0
-1000
Station R2
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

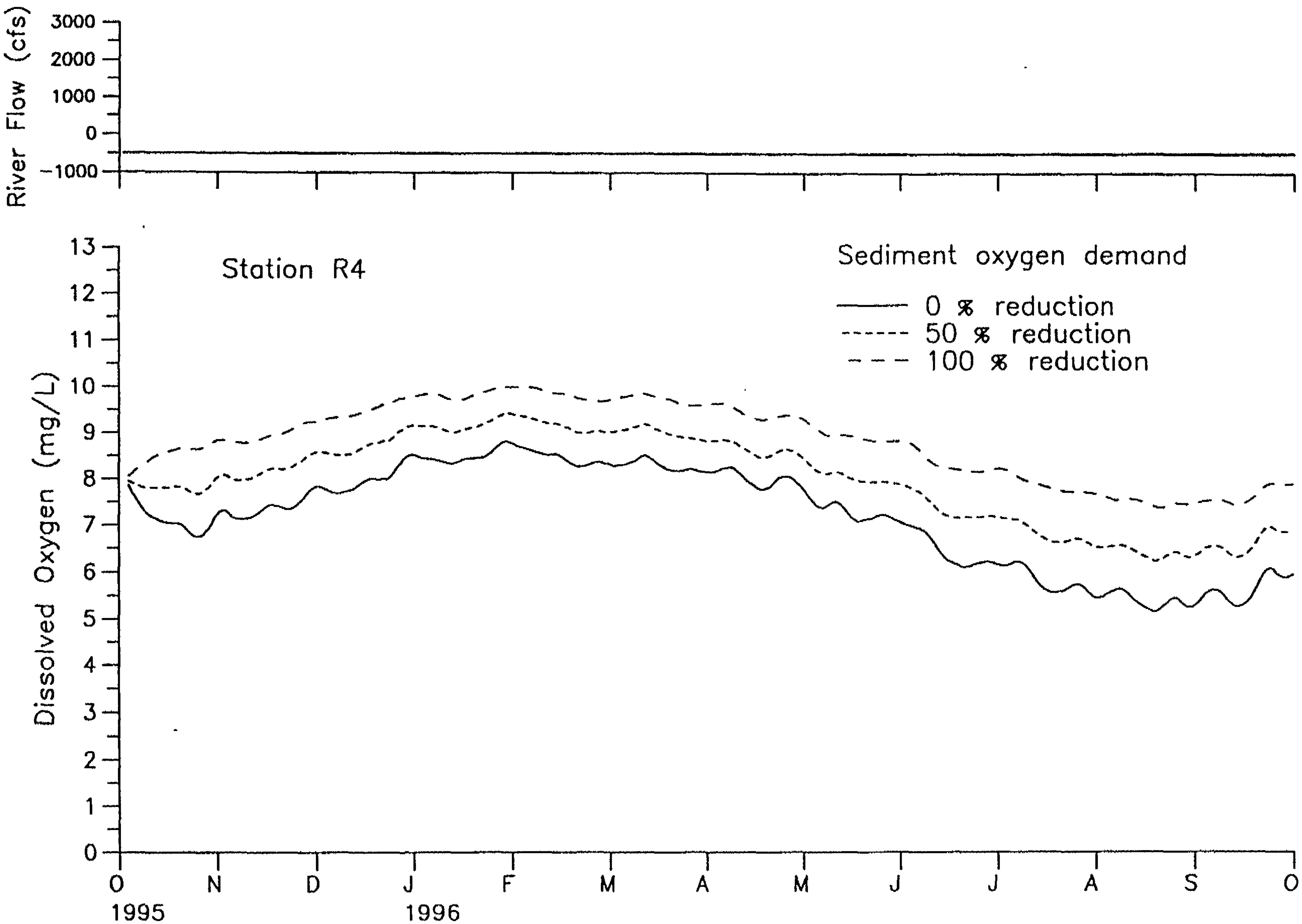
D-041679



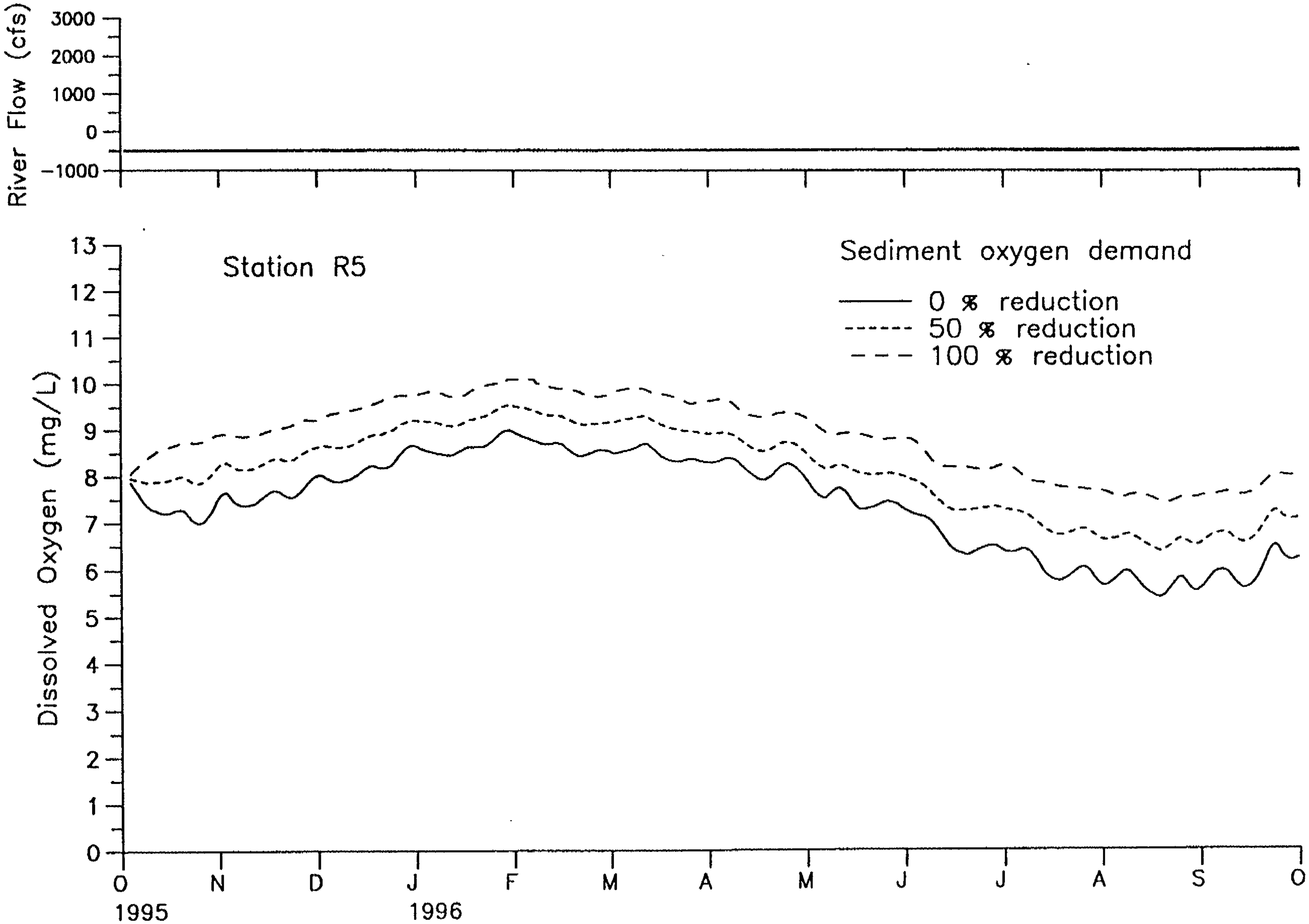
River Flow (cfs)
3000
2000
1000
0
-1000
Station R3
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D-041680

D-041681

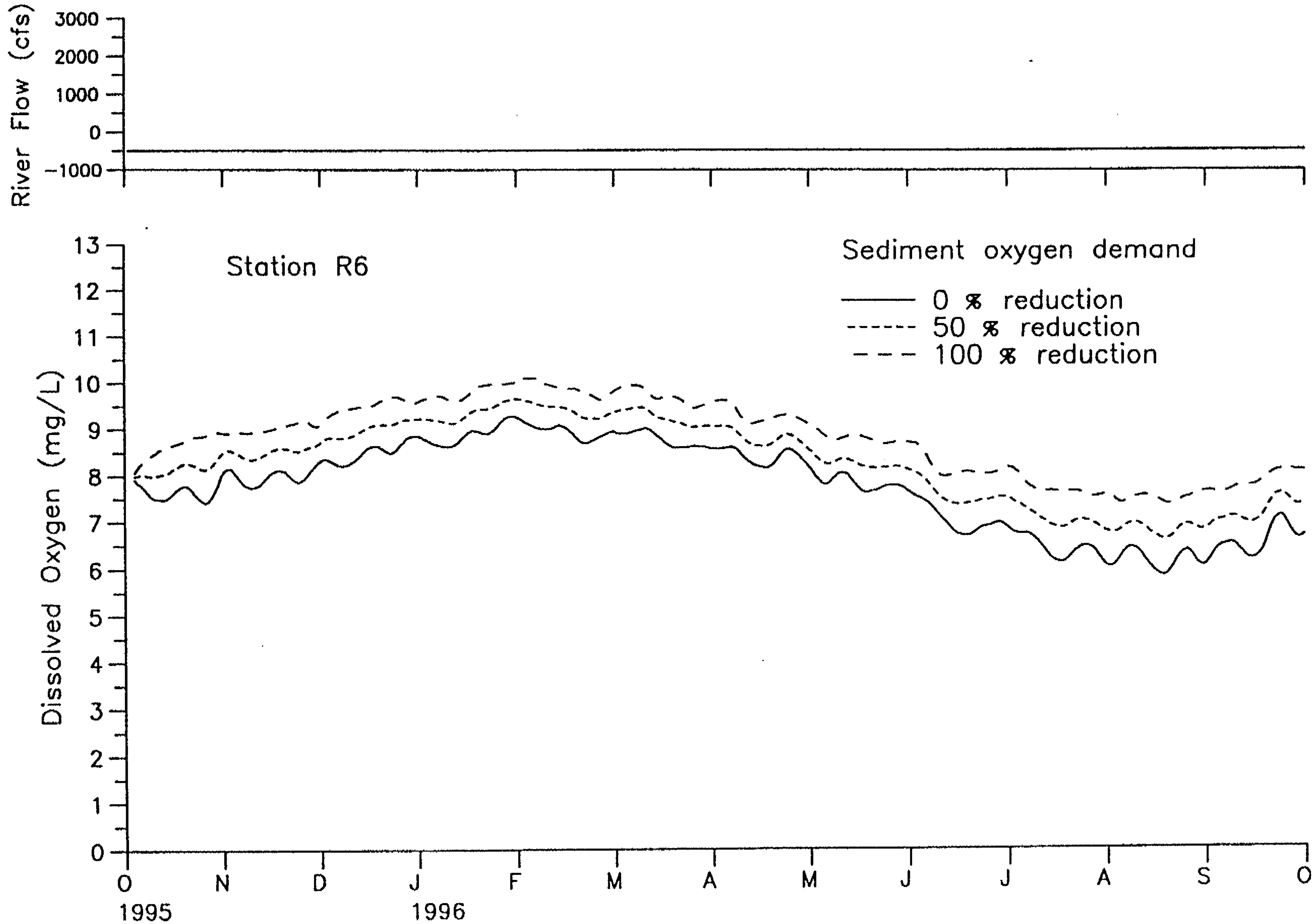


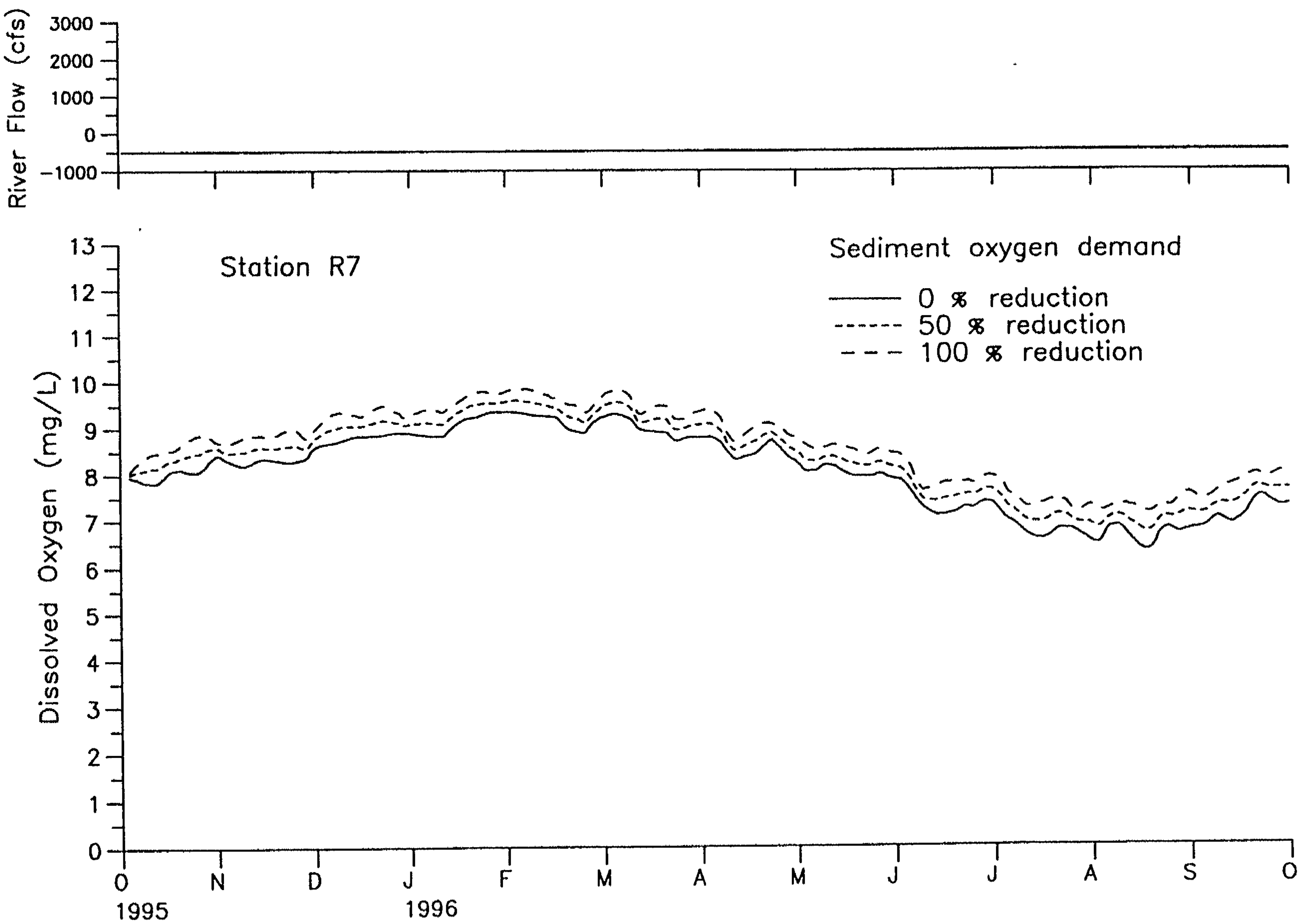
D—041681



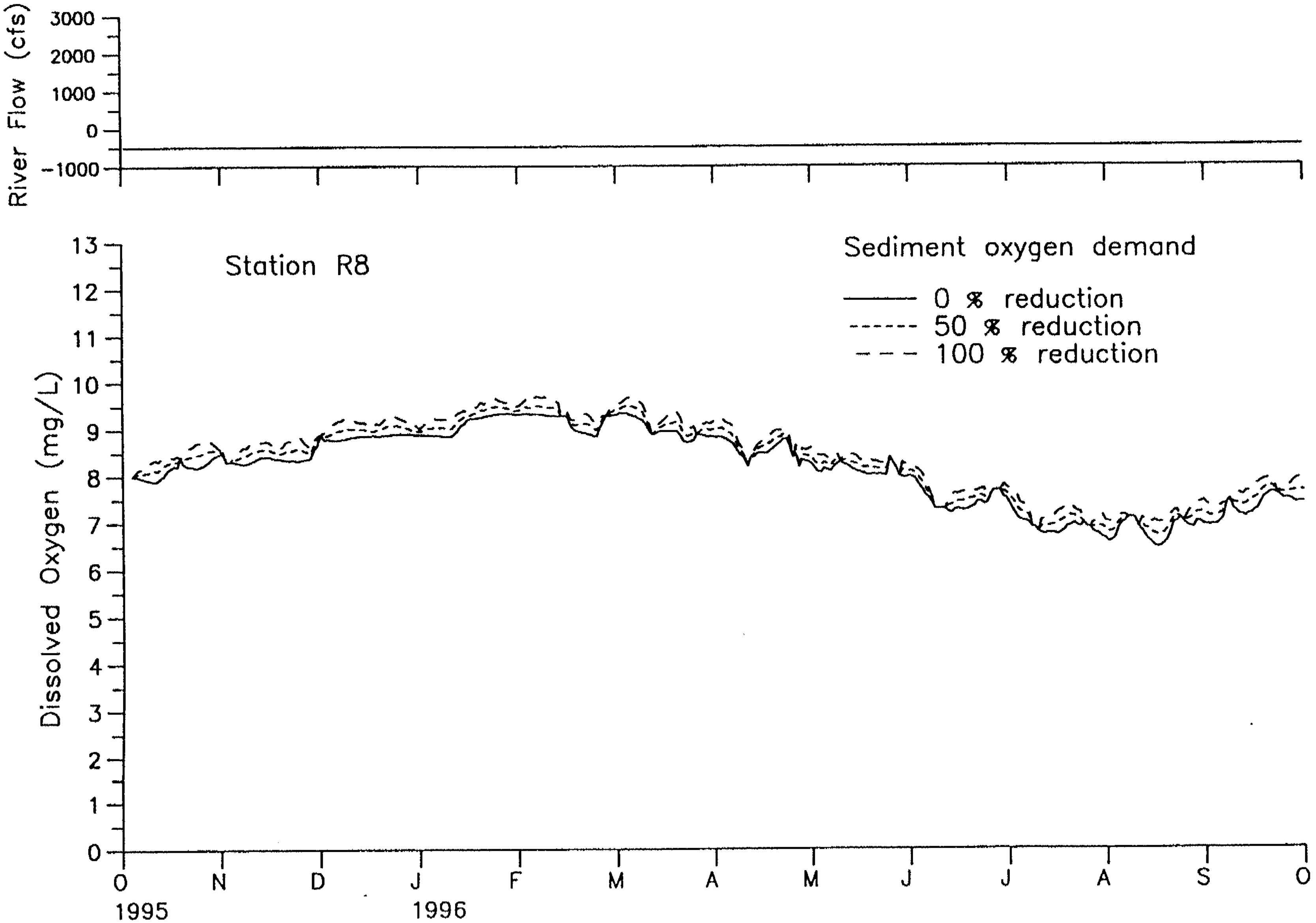
River Flow (cfs)
3000
2000
1000
0
−1000
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Station R5
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D-041682


River Flow (cfs)
3000
2000
1000
0
−1000
Station R6
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

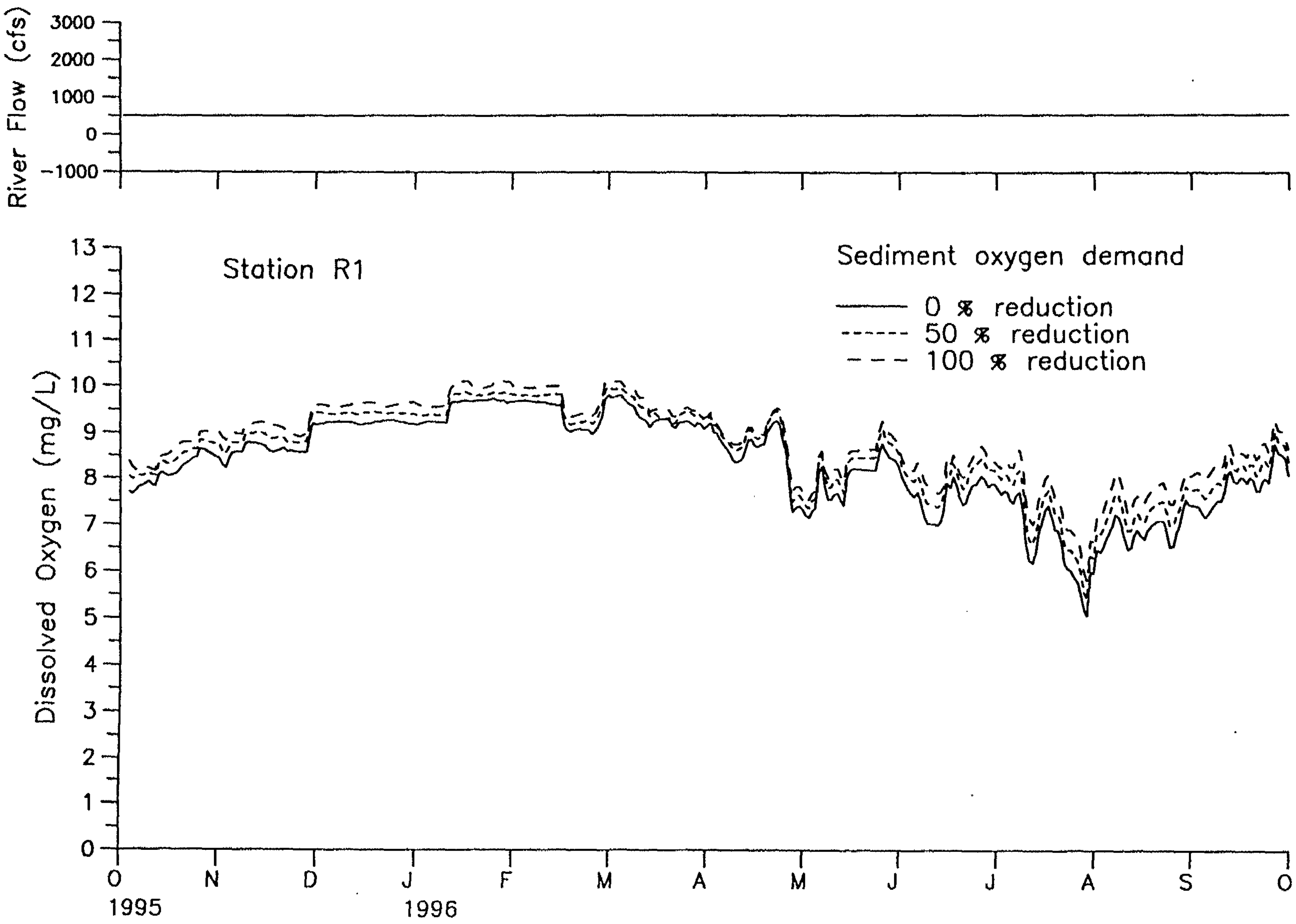

River Flow (cfs)
3000
2000
1000
0
−1000
Station R7
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D-041684

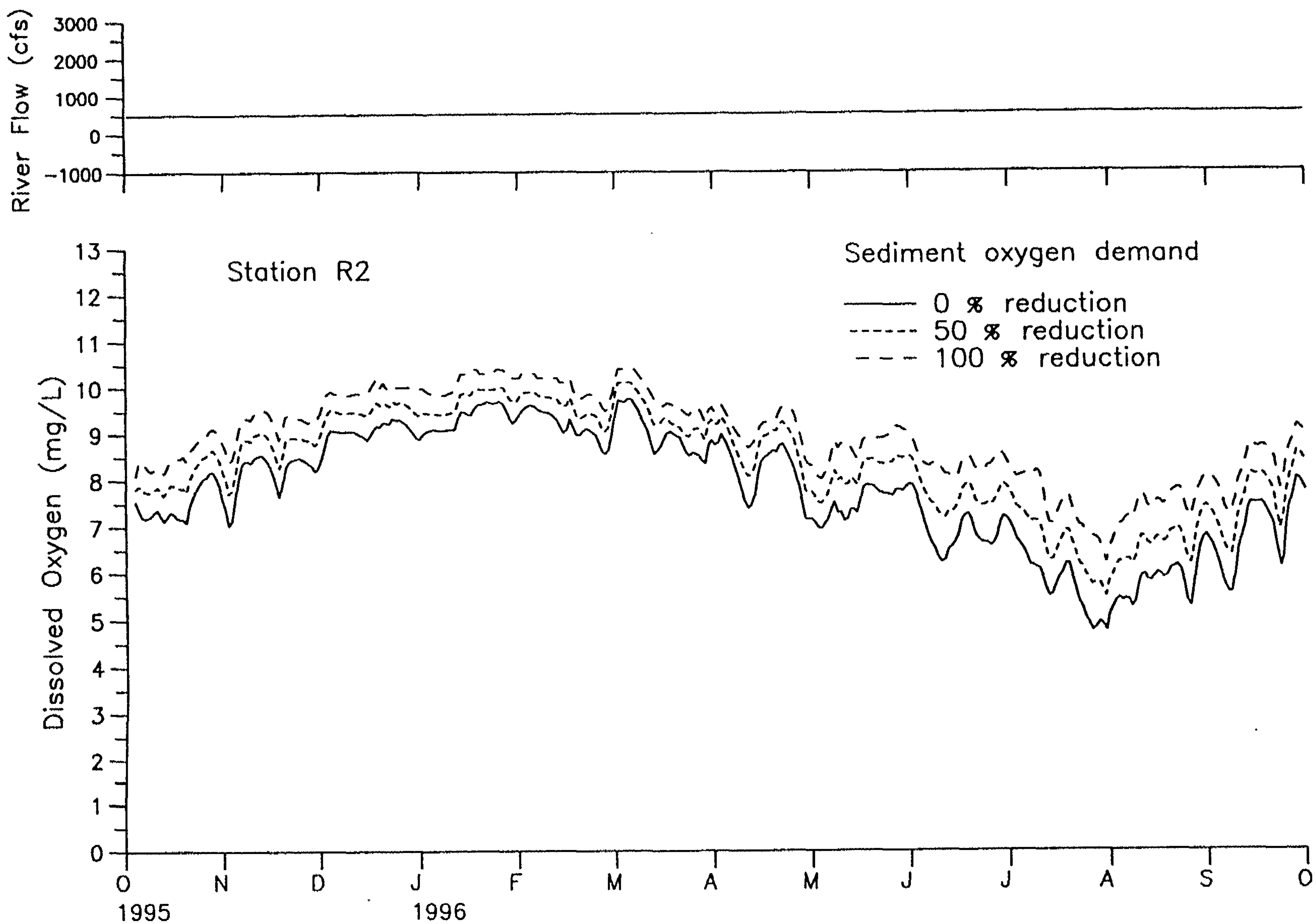


D-041685

D—041685

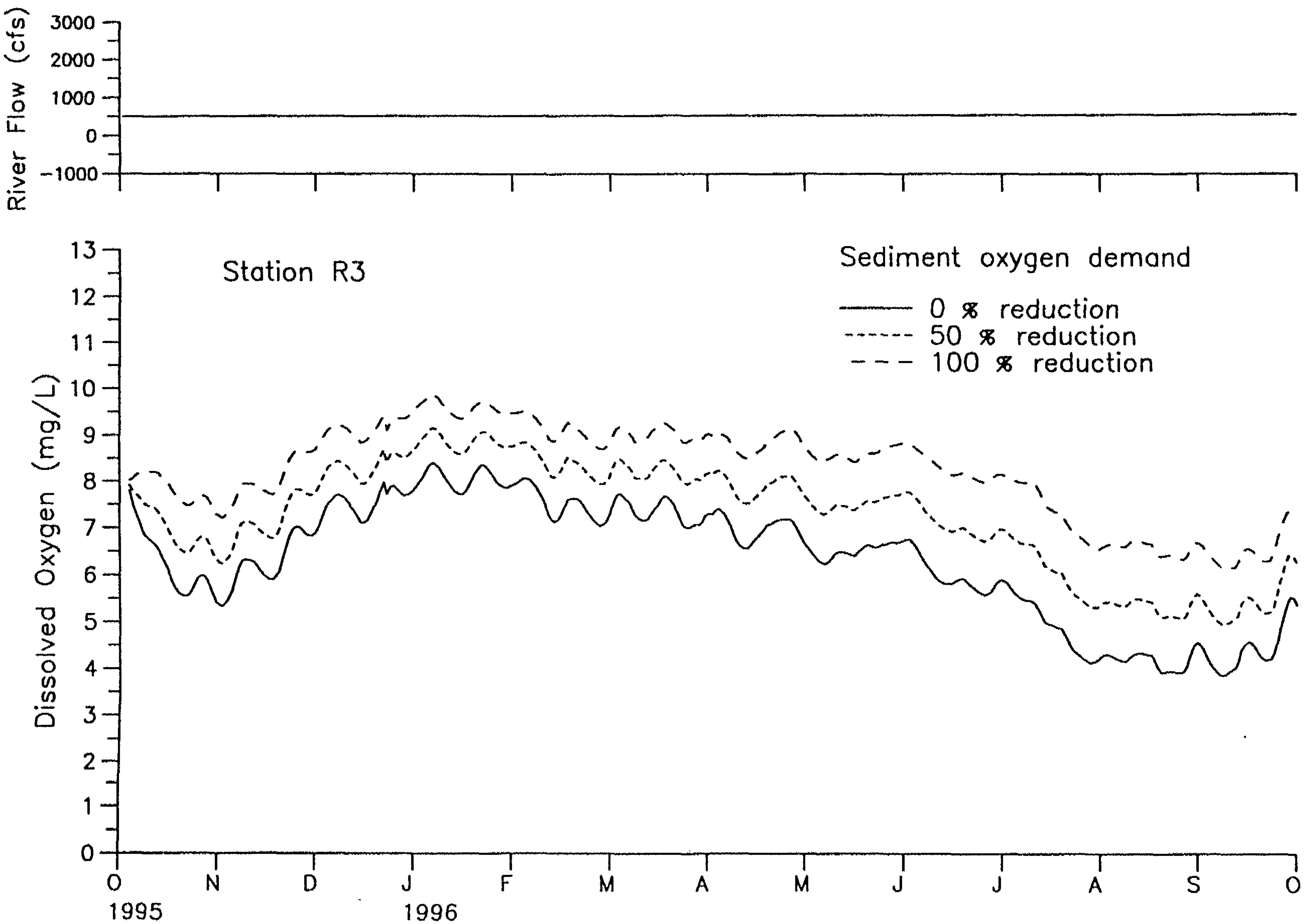

River Flow (cfs)
3000
2000
1000
0
-1000
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Station R1
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

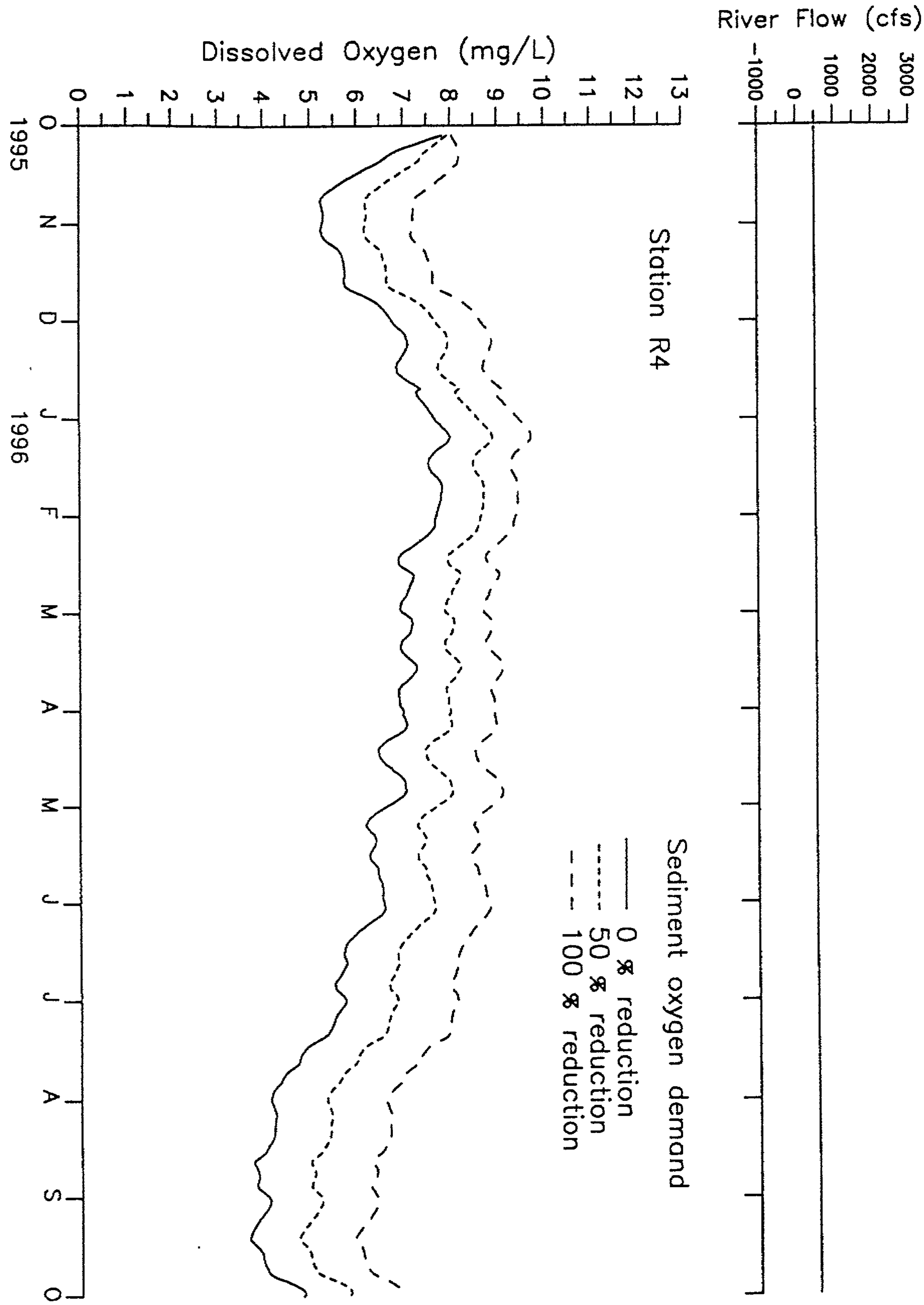
D-041686



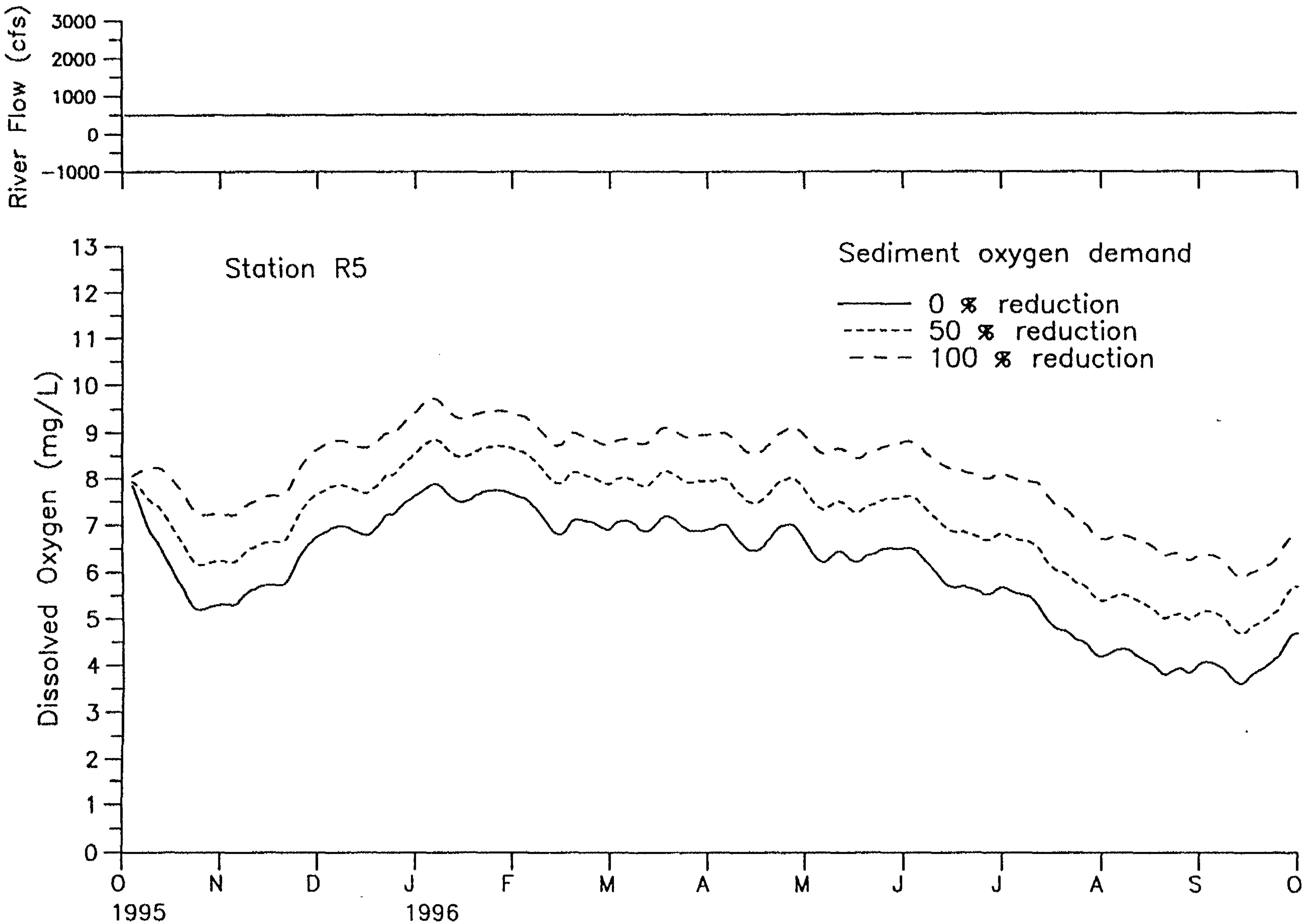
D-041687

D — 0 4 1 6 8 7


River Flow (cfs)
3000
2000
1000
0
-1000
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Station R3
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction
O N D J F M A M J J A S O
1995
1996

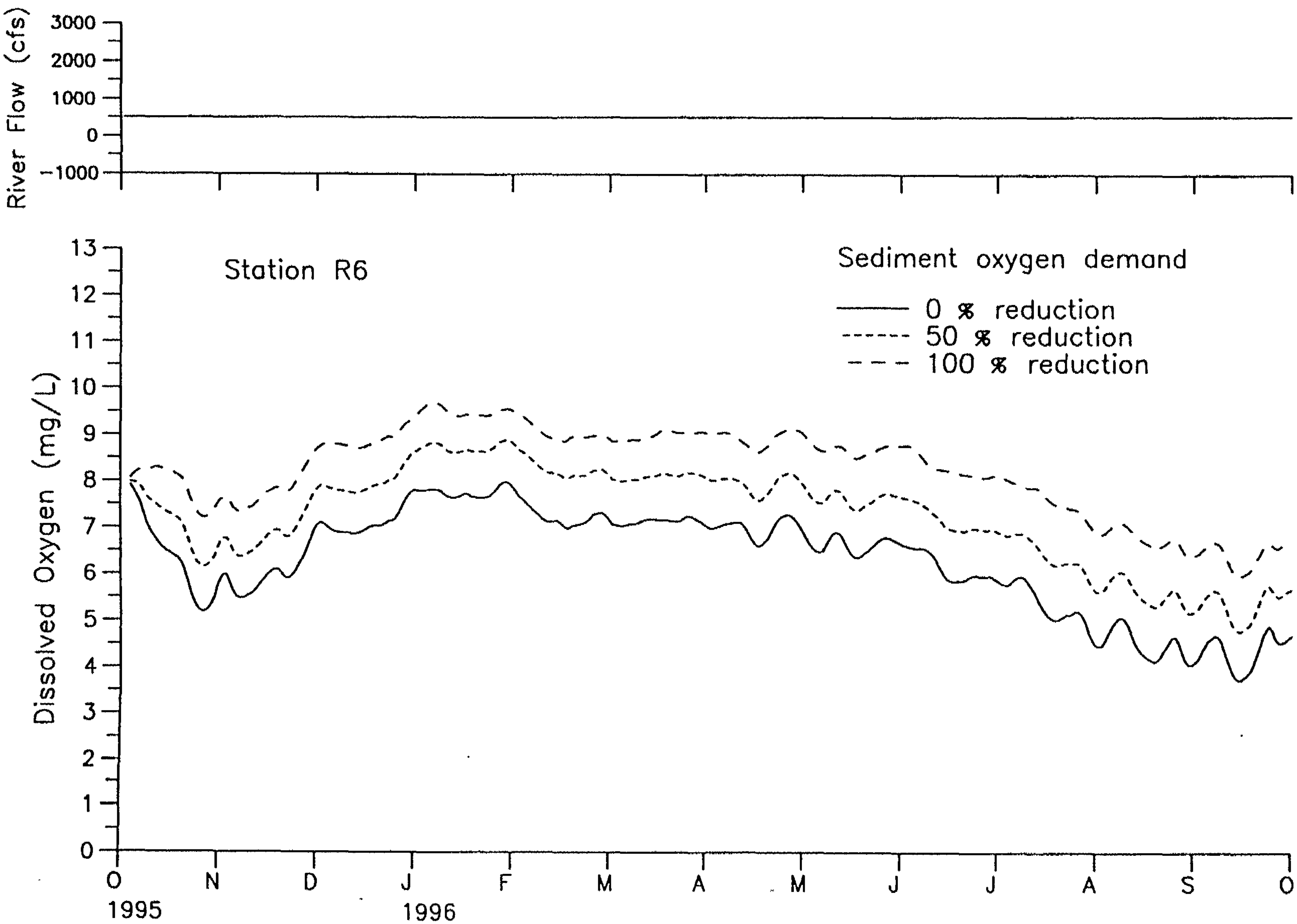


River Flow (cfs)
-1000
0
1000
2000
3000
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
O
1995
N
D
J
1996
F
M
A
M
J
J
A
S
O
Station R4
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction

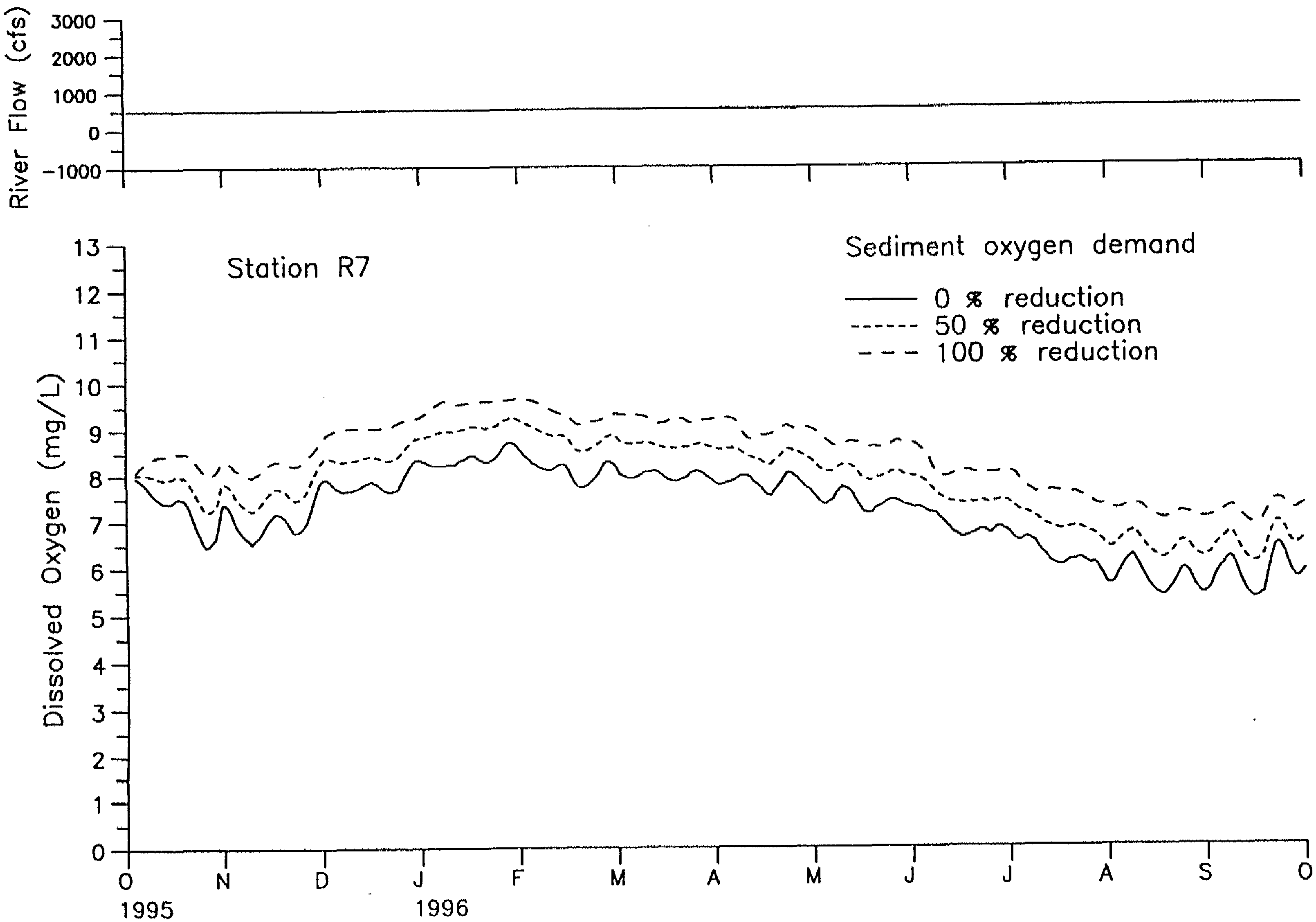


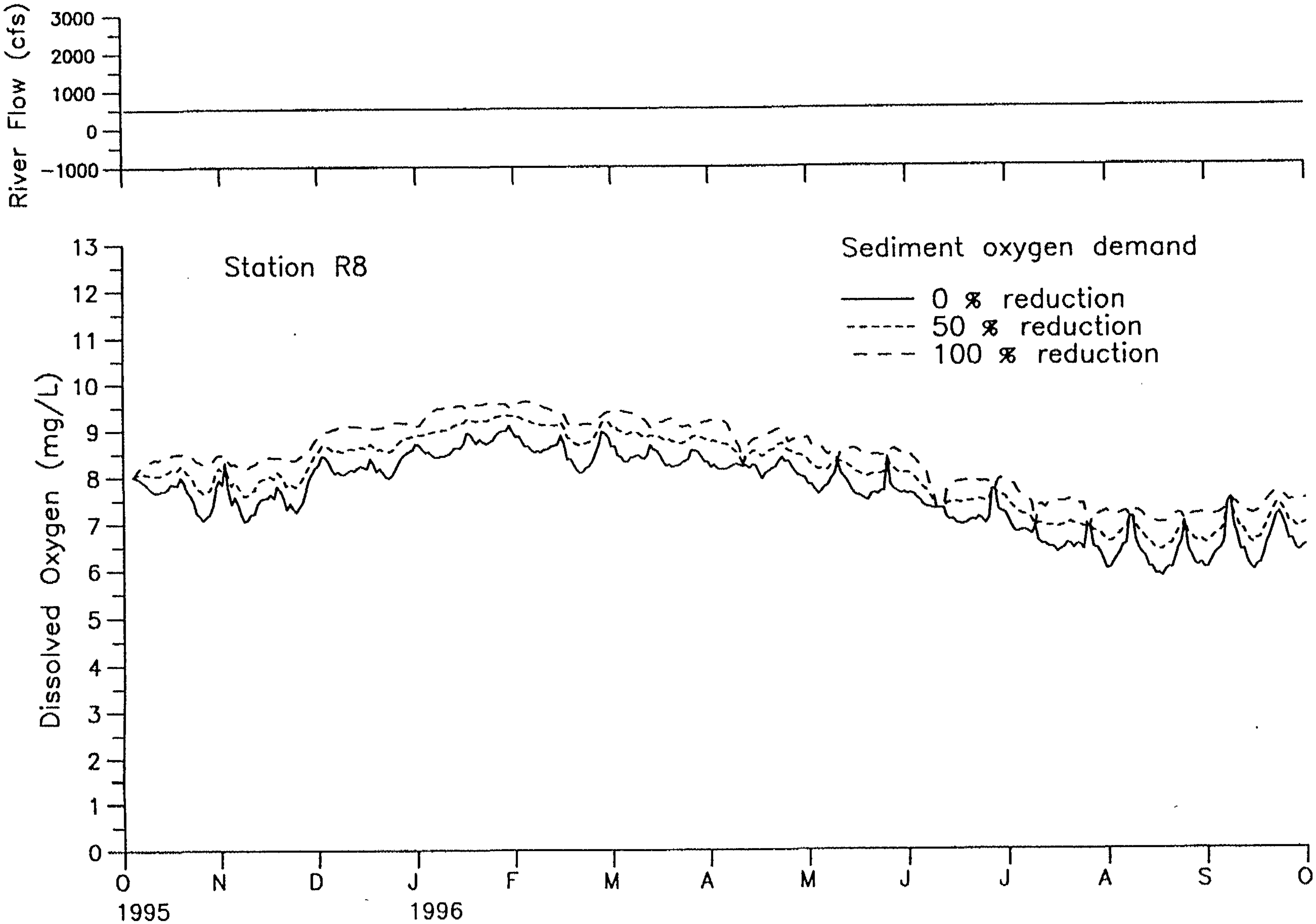
D-041690

D-041690


River Flow (cfs)
3000
2000
1000
0
-1000
Station R6
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D-041691

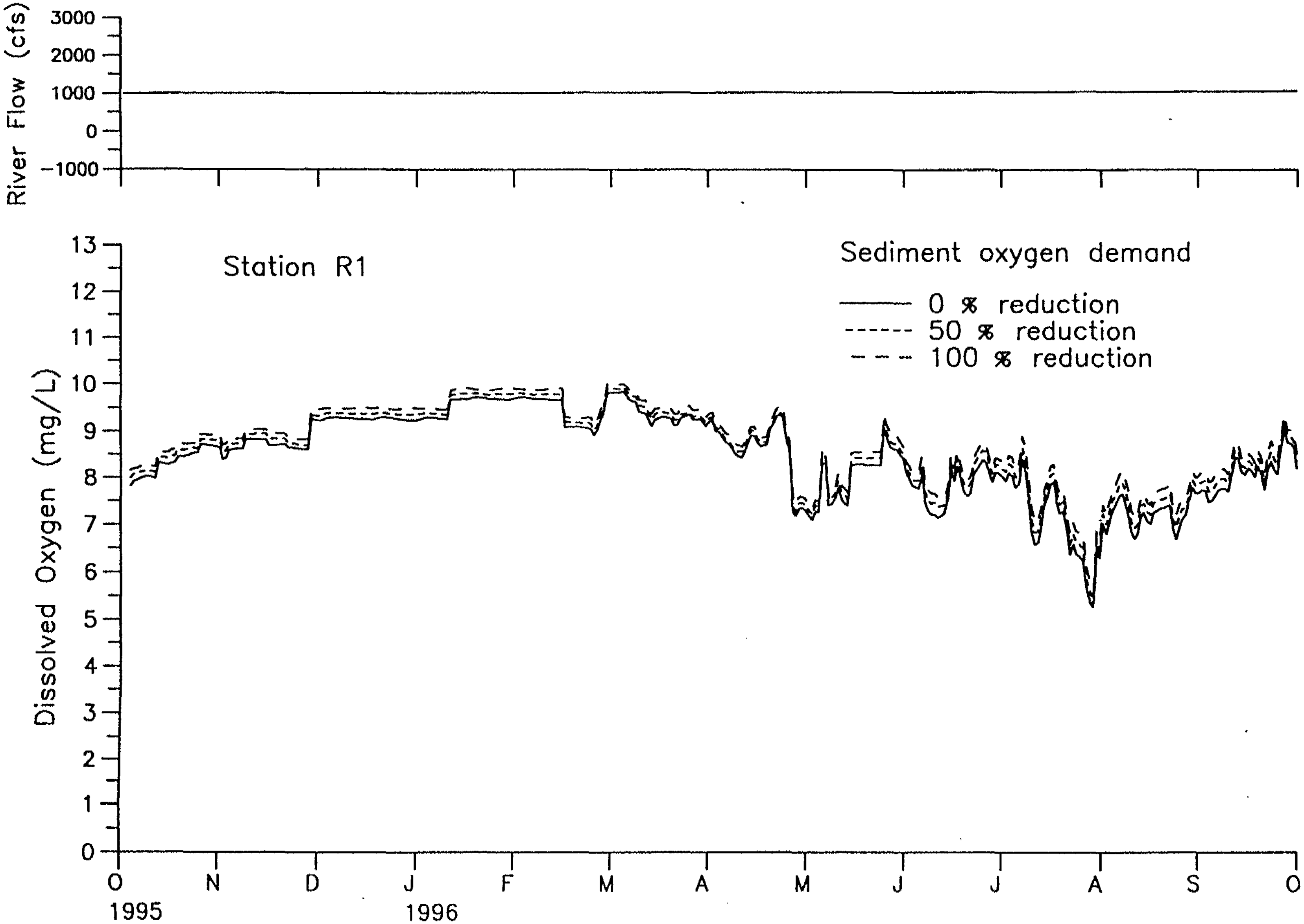

River Flow (cfs)
3000
2000
1000
0
-1000
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Station R7
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996



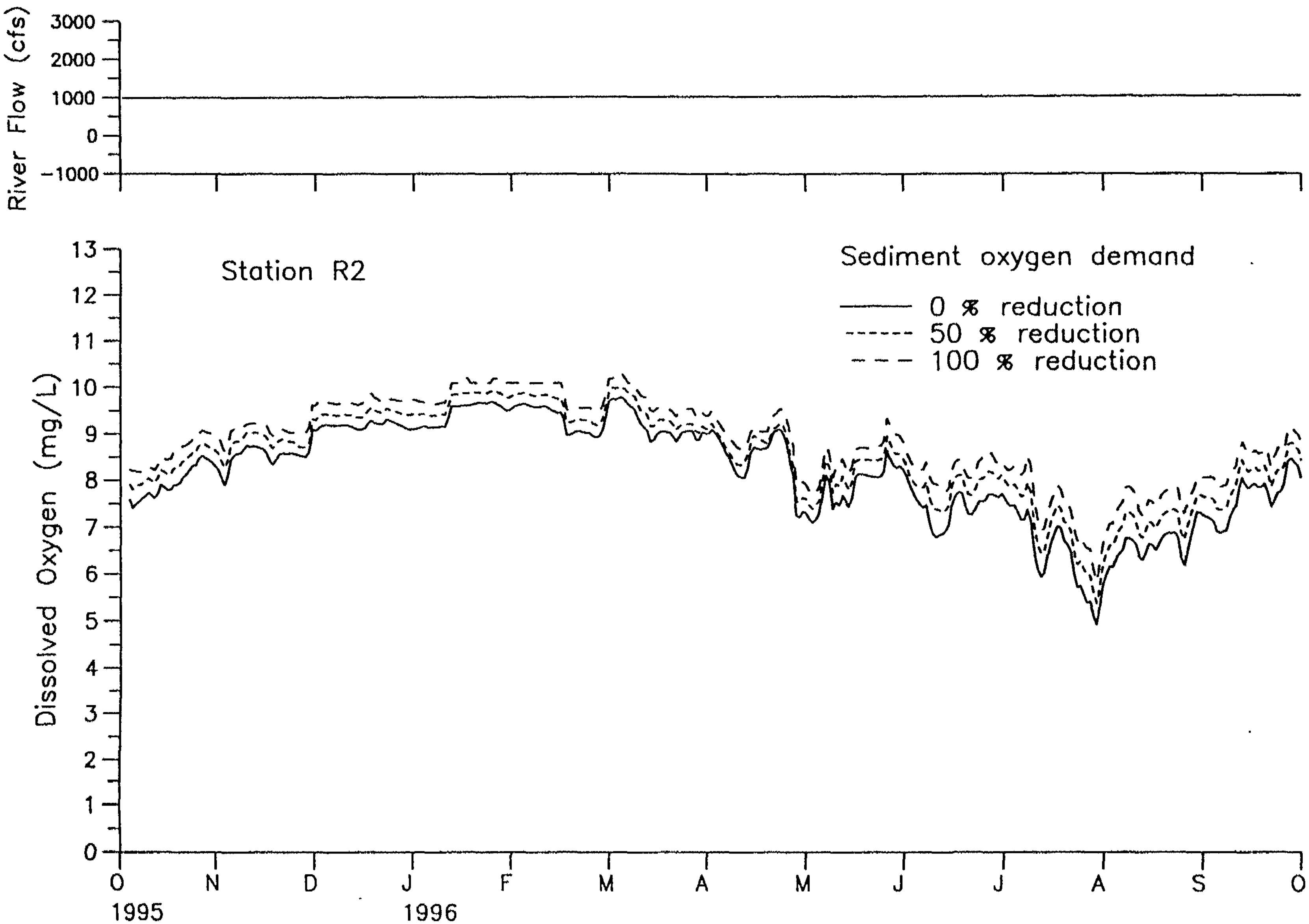
River Flow (cfs)
3000
2000
1000
0
−1000
Station R8
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D-041693

D-041694

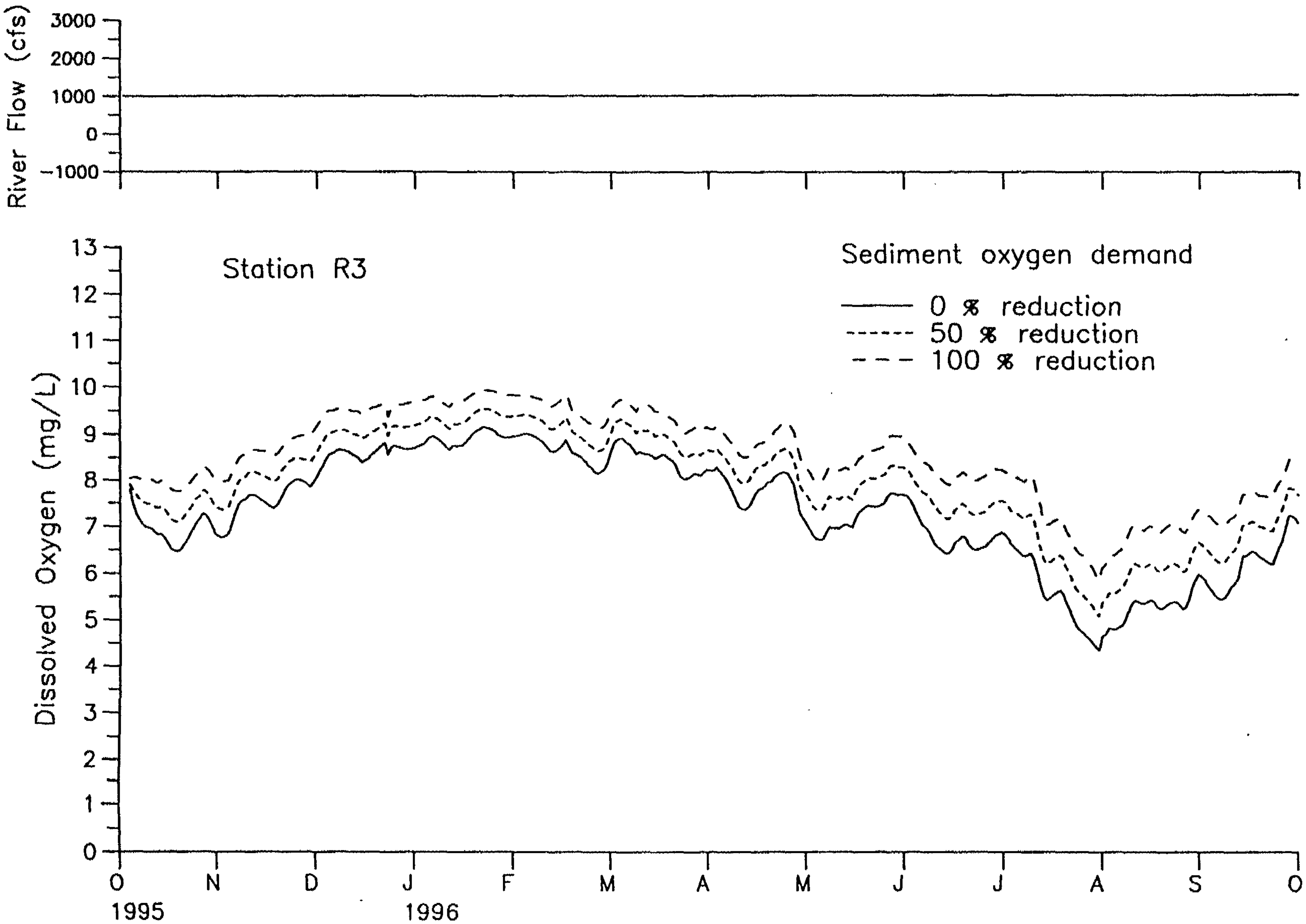


D-041694

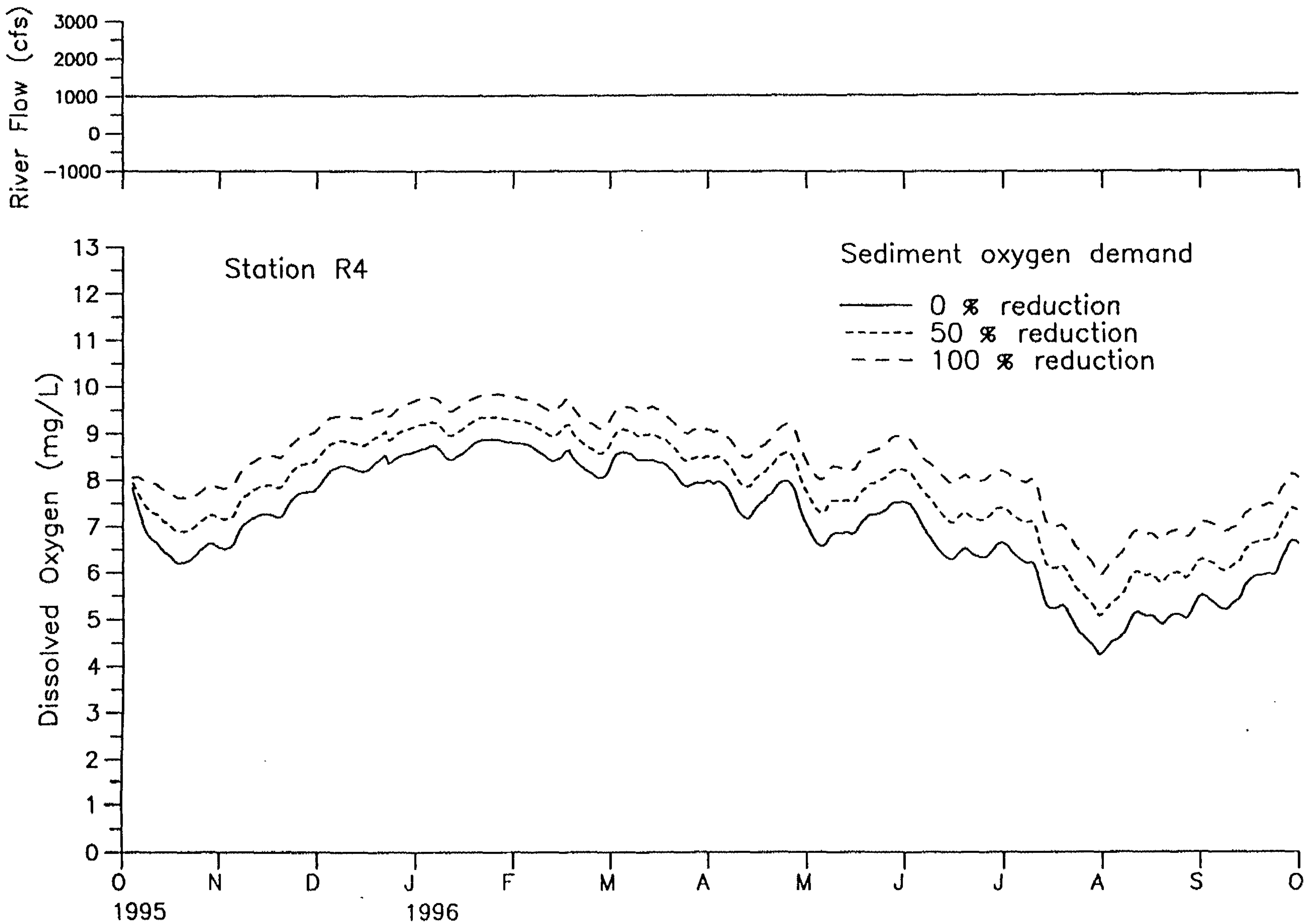


D-041695

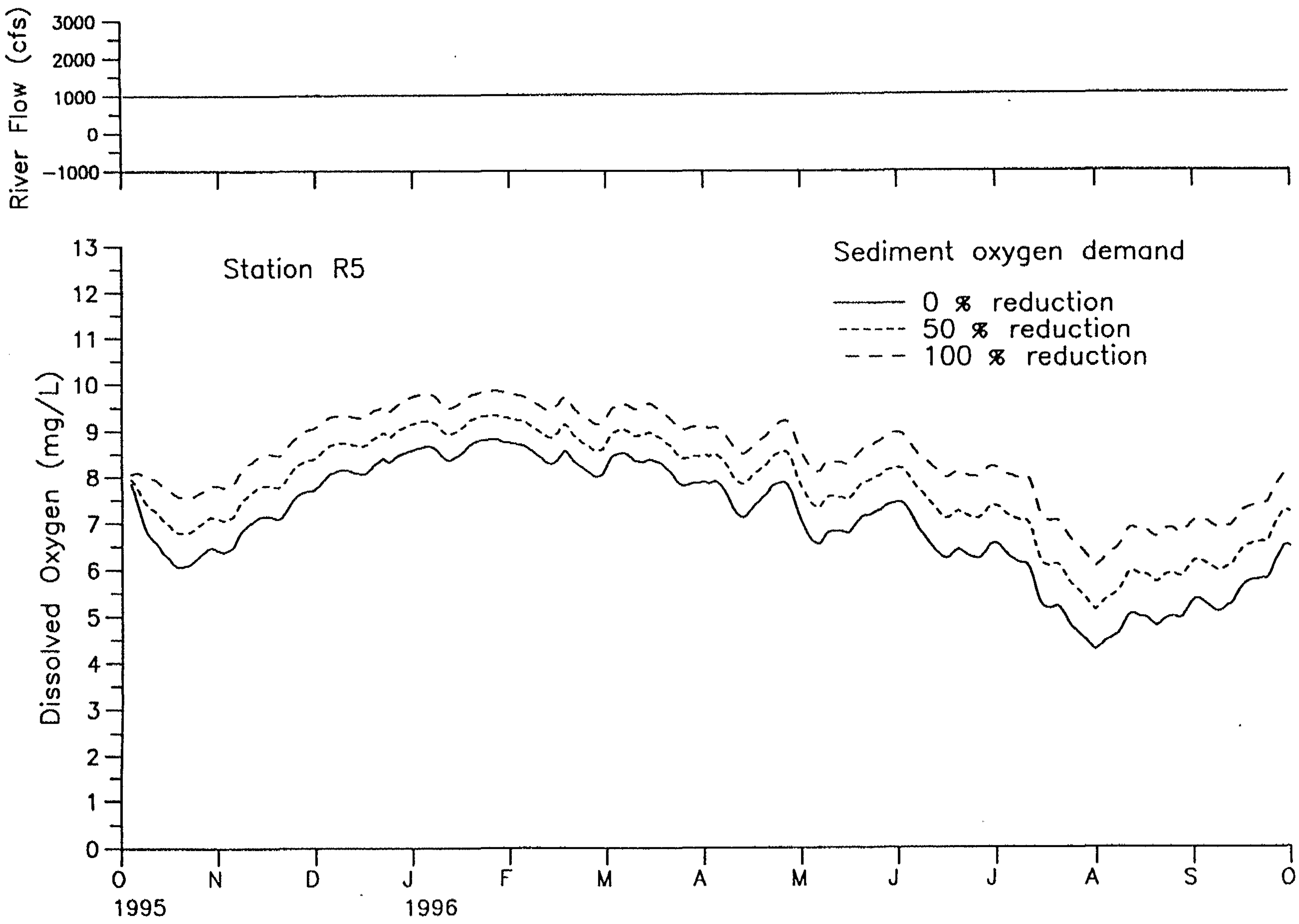
D-041695

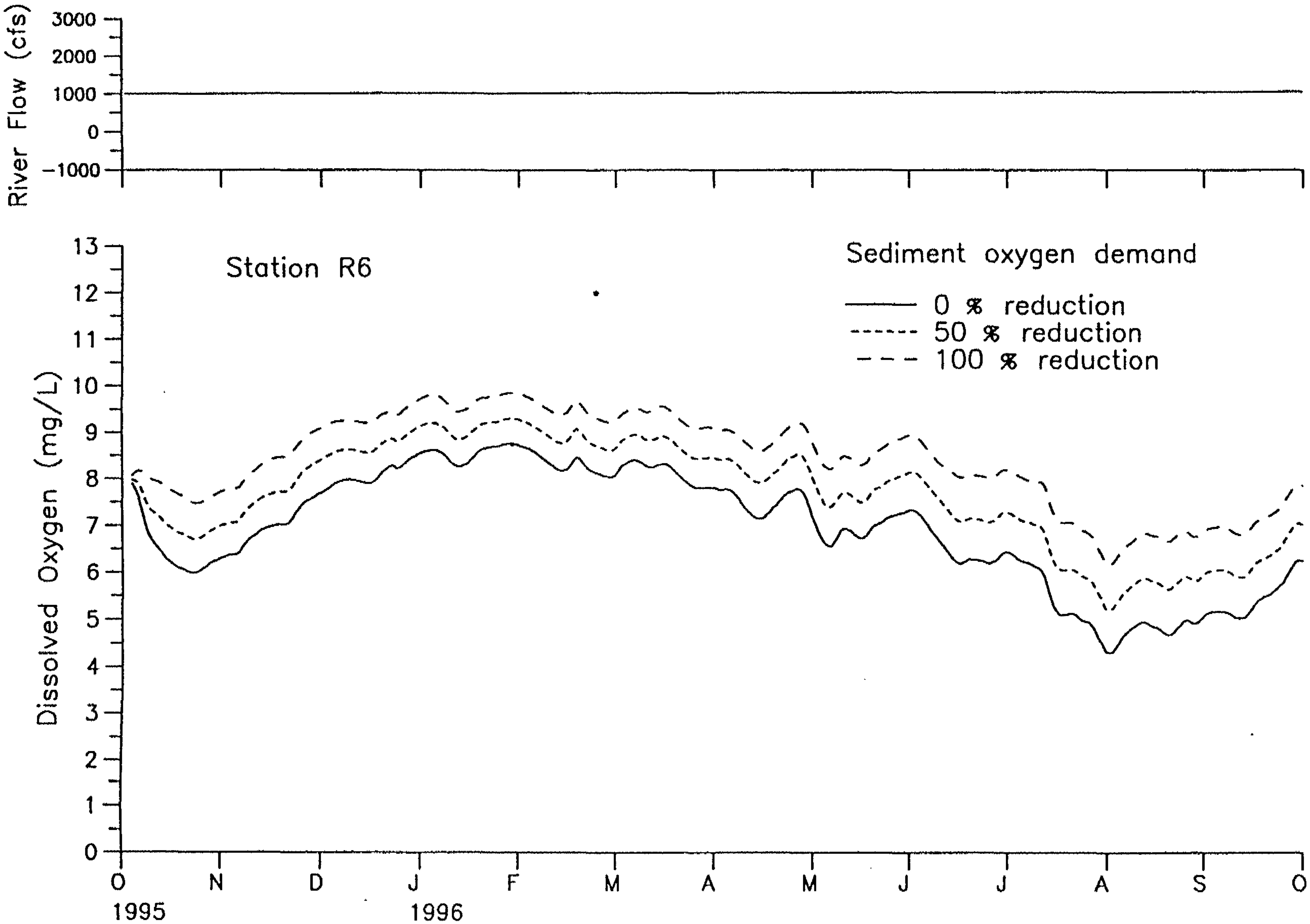

River Flow (cfs)
3000
2000
1000
0
-1000
Station R3
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D-041696


River Flow (cfs)
3000
2000
1000
0
-1000
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Station R4
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

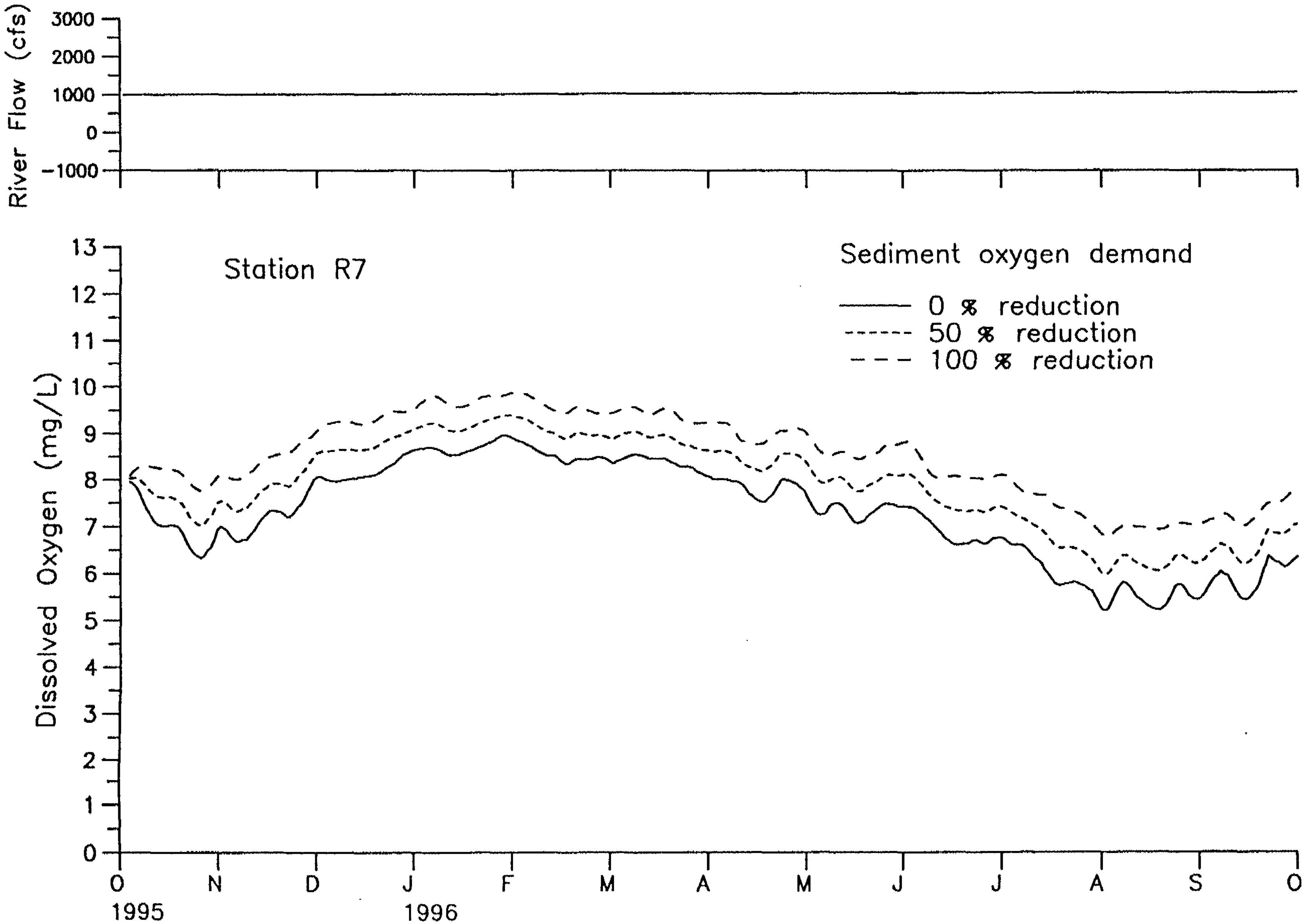
D-041697


River Flow (cfs)
3000
2000
1000
0
−1000
Station R5
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996



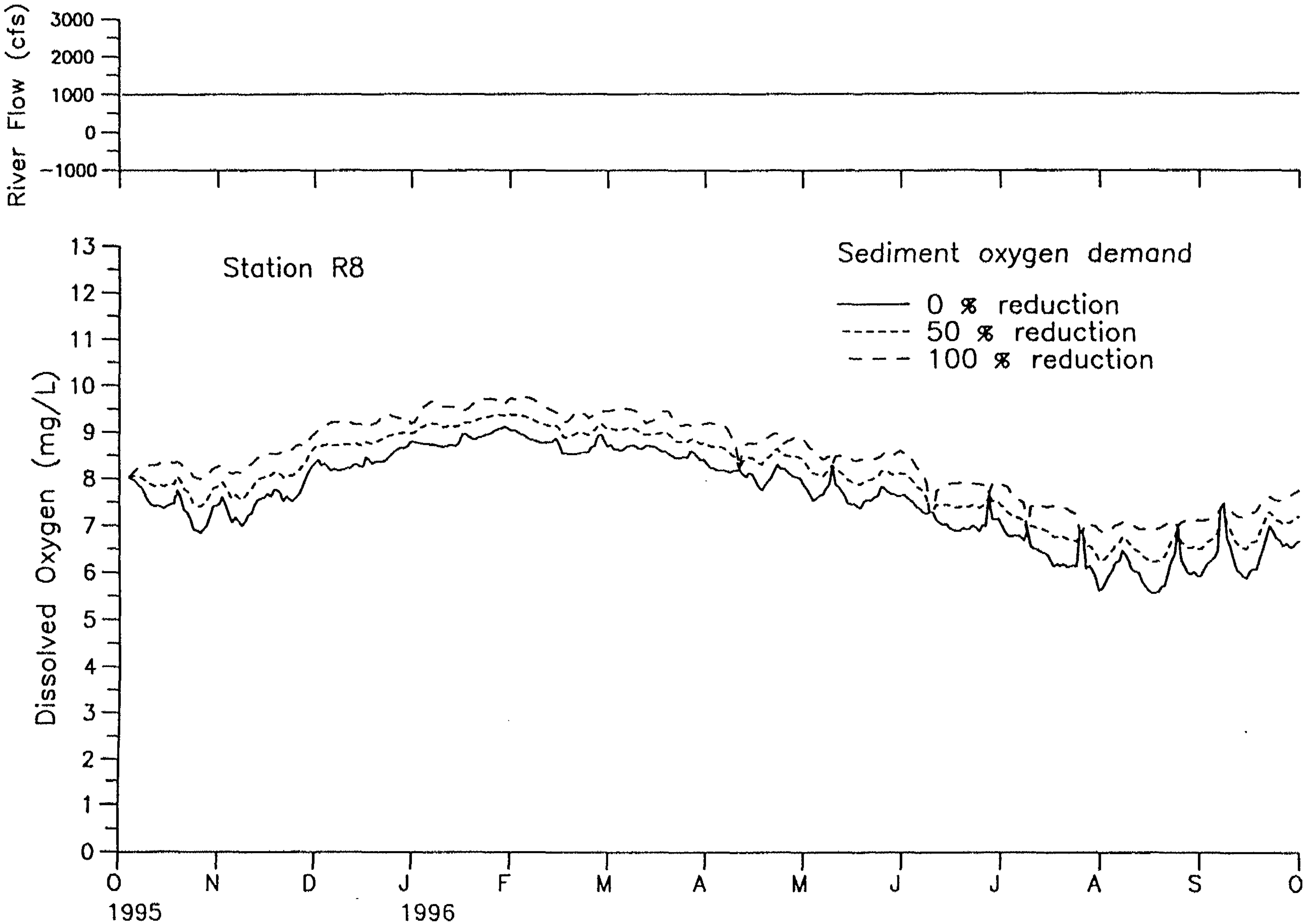
River Flow (cfs)
3000
2000
1000
0
−1000
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Station R6
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D—041699



River Flow (cfs)
3000
2000
1000
0
-1000
Station R7
Sediment oxygen demand
0 % reduction
50 % reduction
100 % reduction
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D-041700

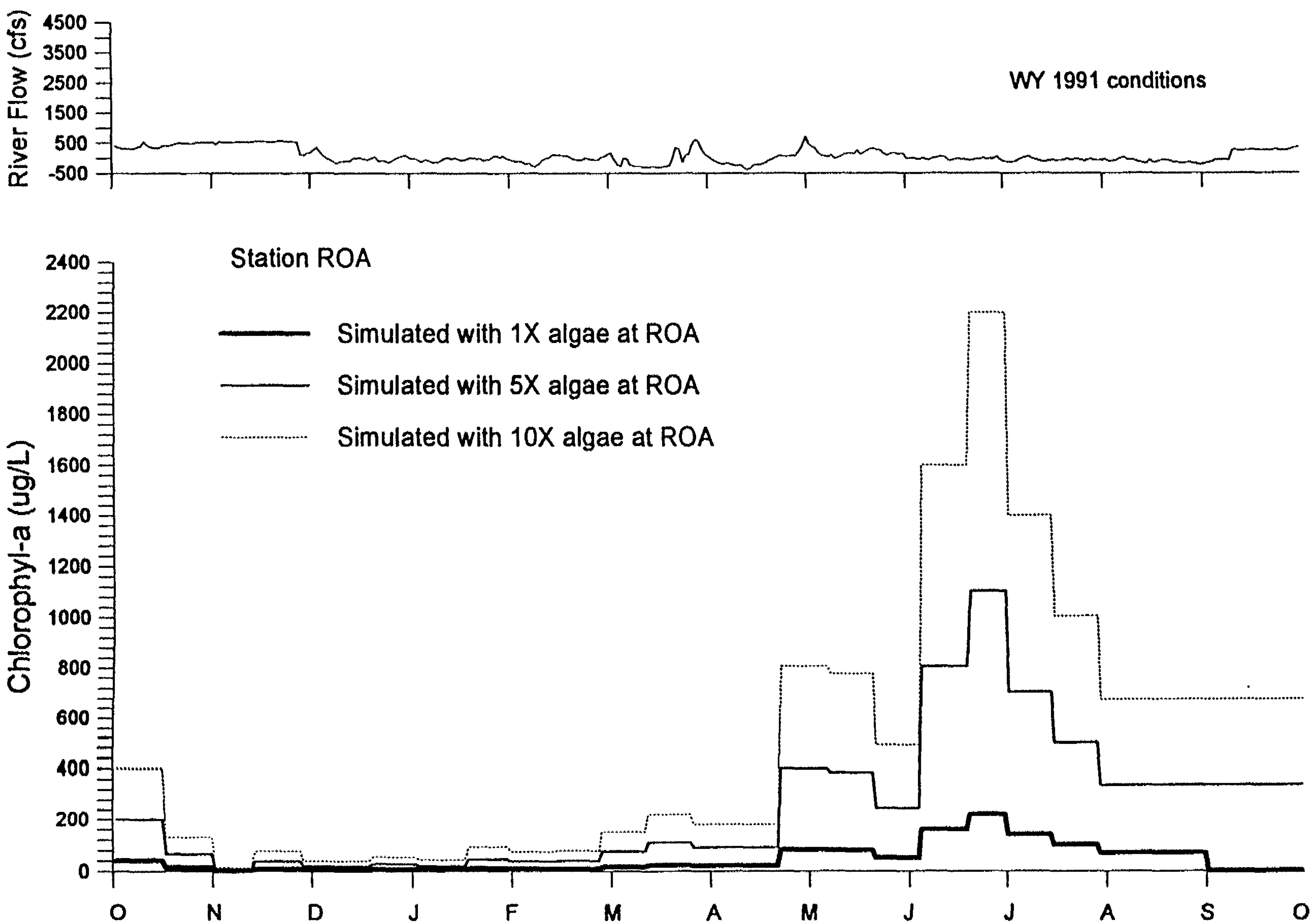


D-041701

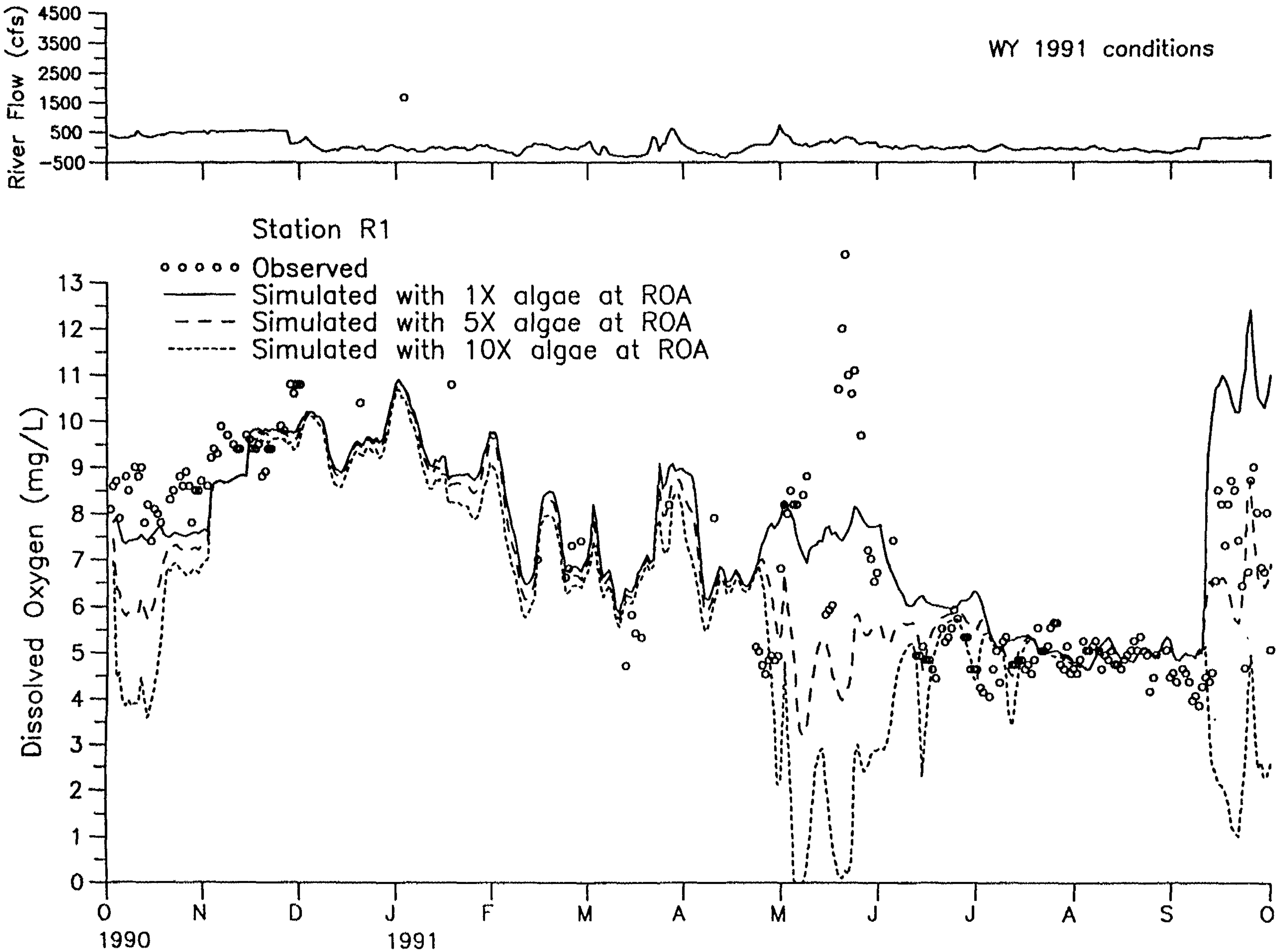
D-041701

Appendix M.

Sensitivity of DO to Algal Blooms at Mossdale

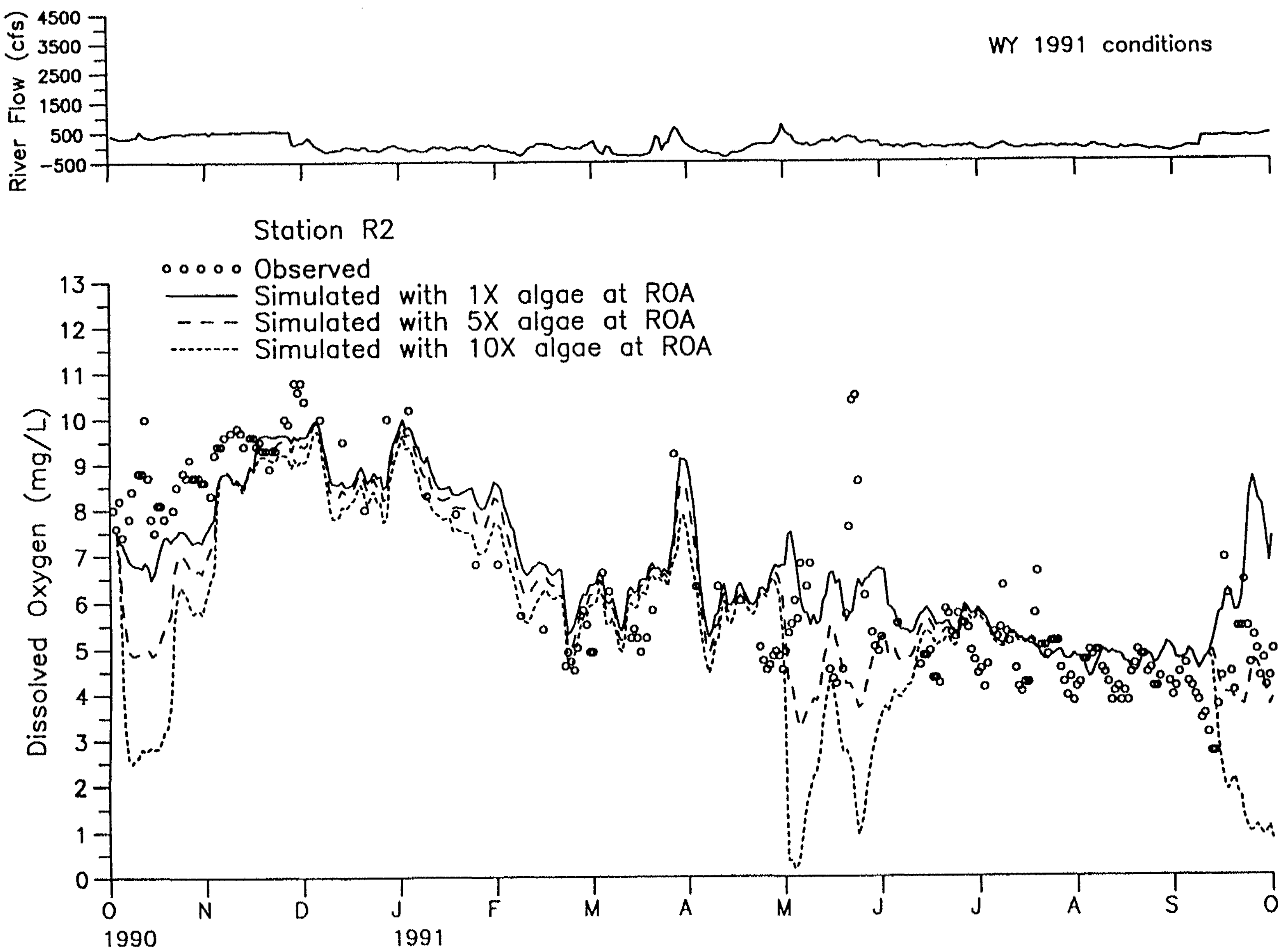


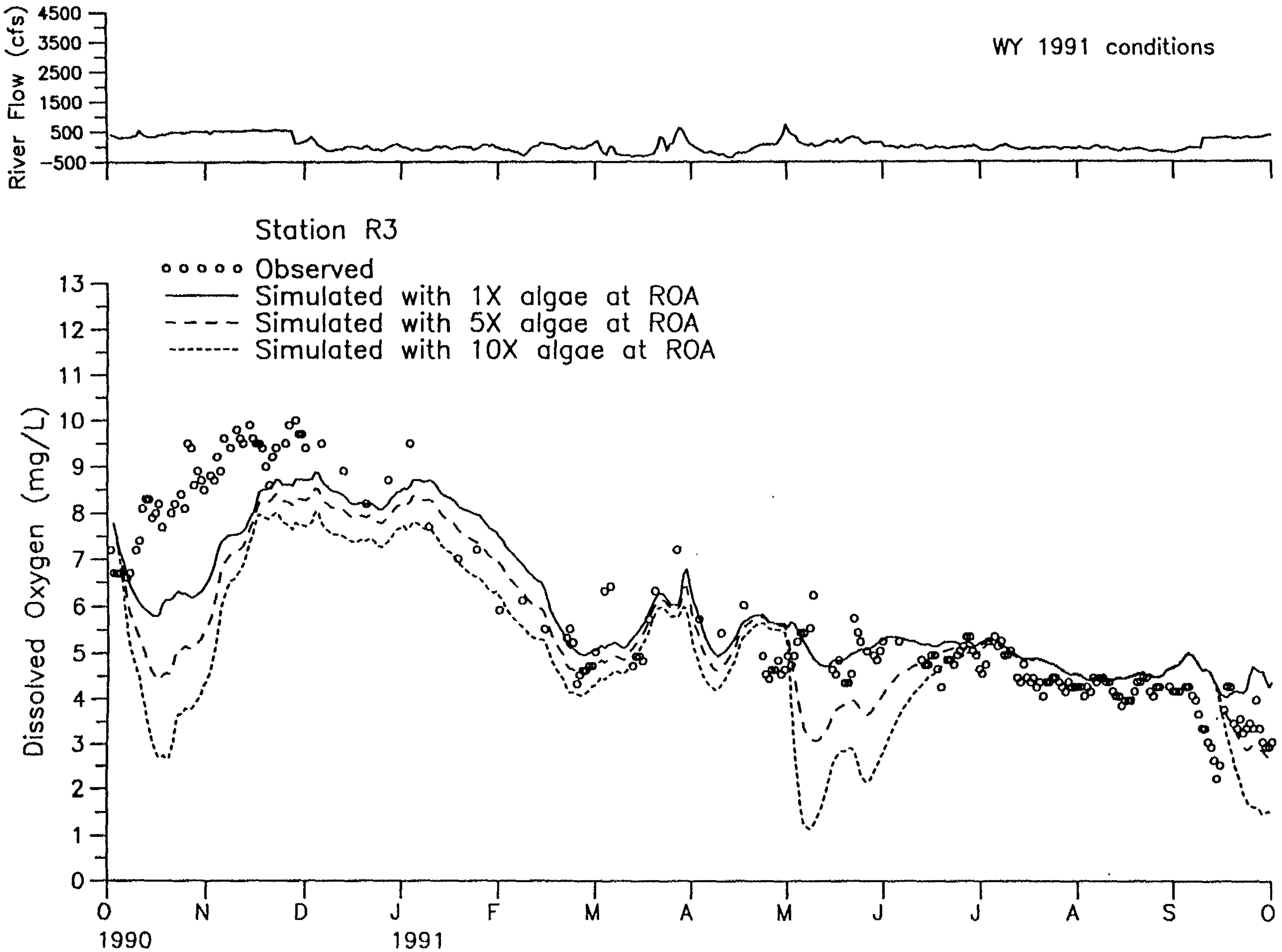
River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Station ROA
Simulated with 1X algae at ROA
Simulated with 5X algae at ROA
Simulated with 10X algae at ROA
Chlorophyl-a (ug/L)
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
O
N
D
J
F
M
A
M
J
J
A
S
O



River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Station R1
Observed
Simulated with 1X algae at ROA
Simulated with 5X algae at ROA
Simulated with 10X algae at ROA
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1990
1991

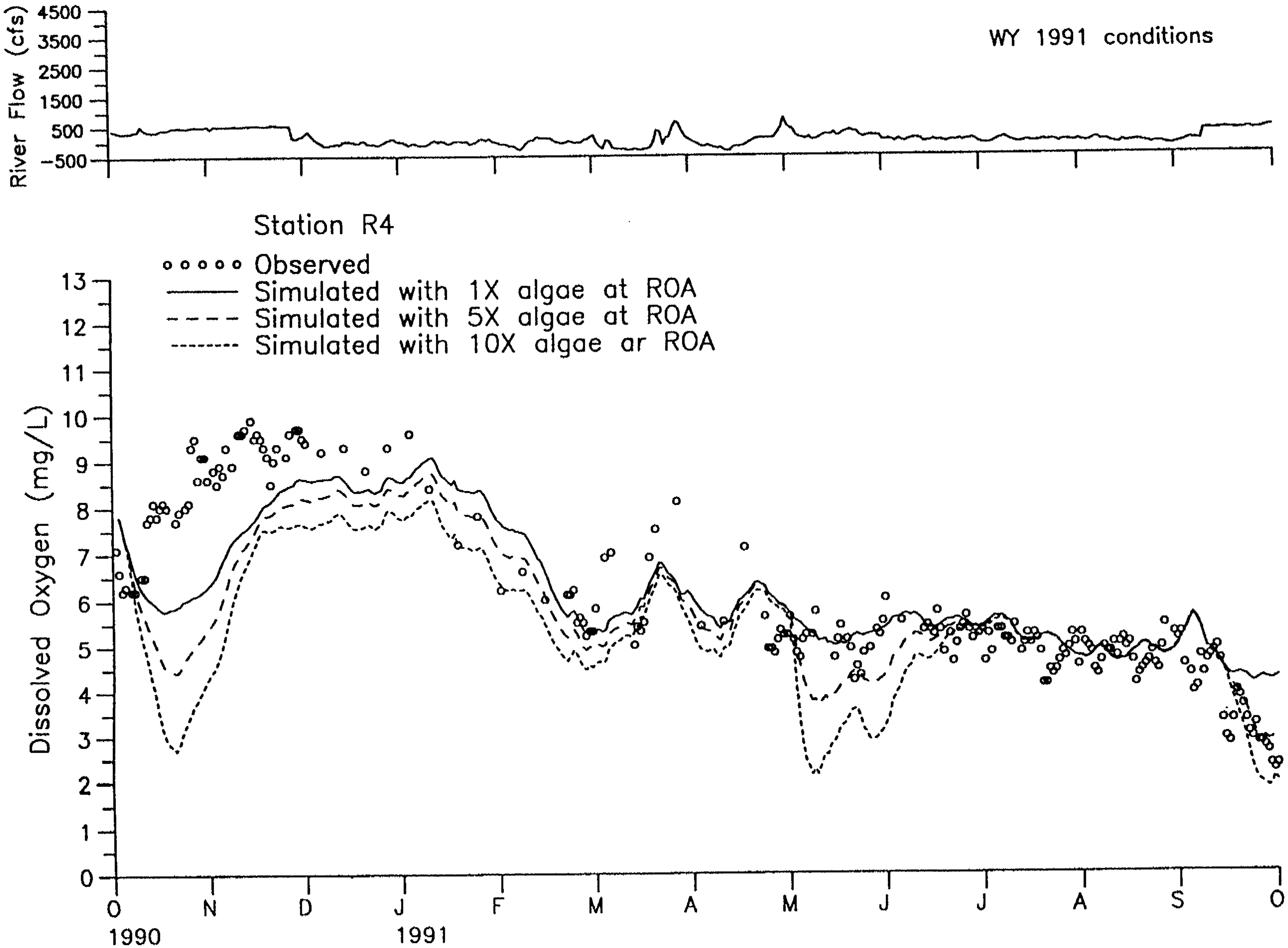
D-041704


WY 1991 conditions
River Flow (cfs)
4500
3500
2500
1500
500
-500
Station R2
Observed
Simulated with 1X algae at ROA
Simulated with 5X algae at ROA
Simulated with 10X algae at ROA
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991



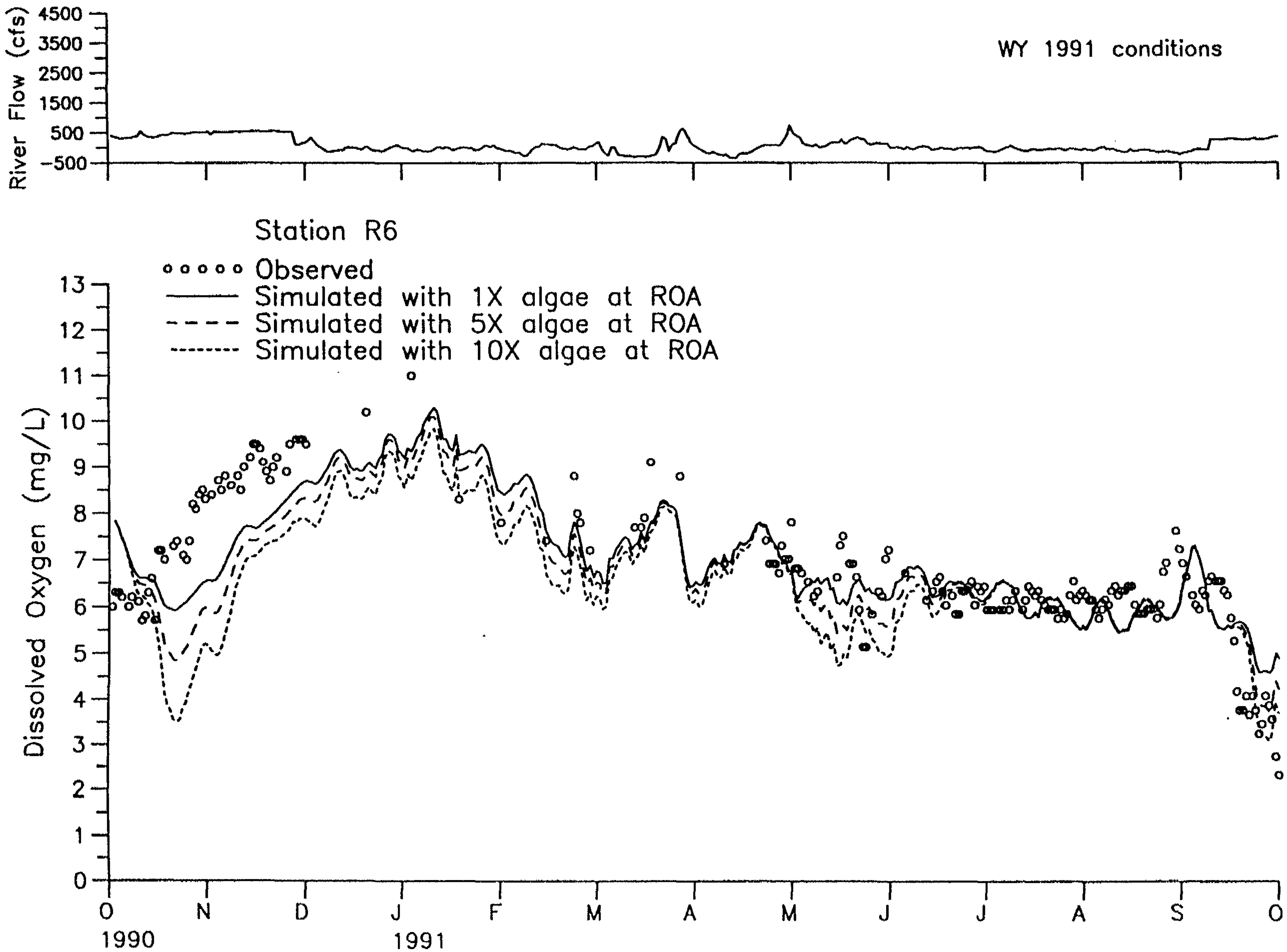
D-041706

D-041706

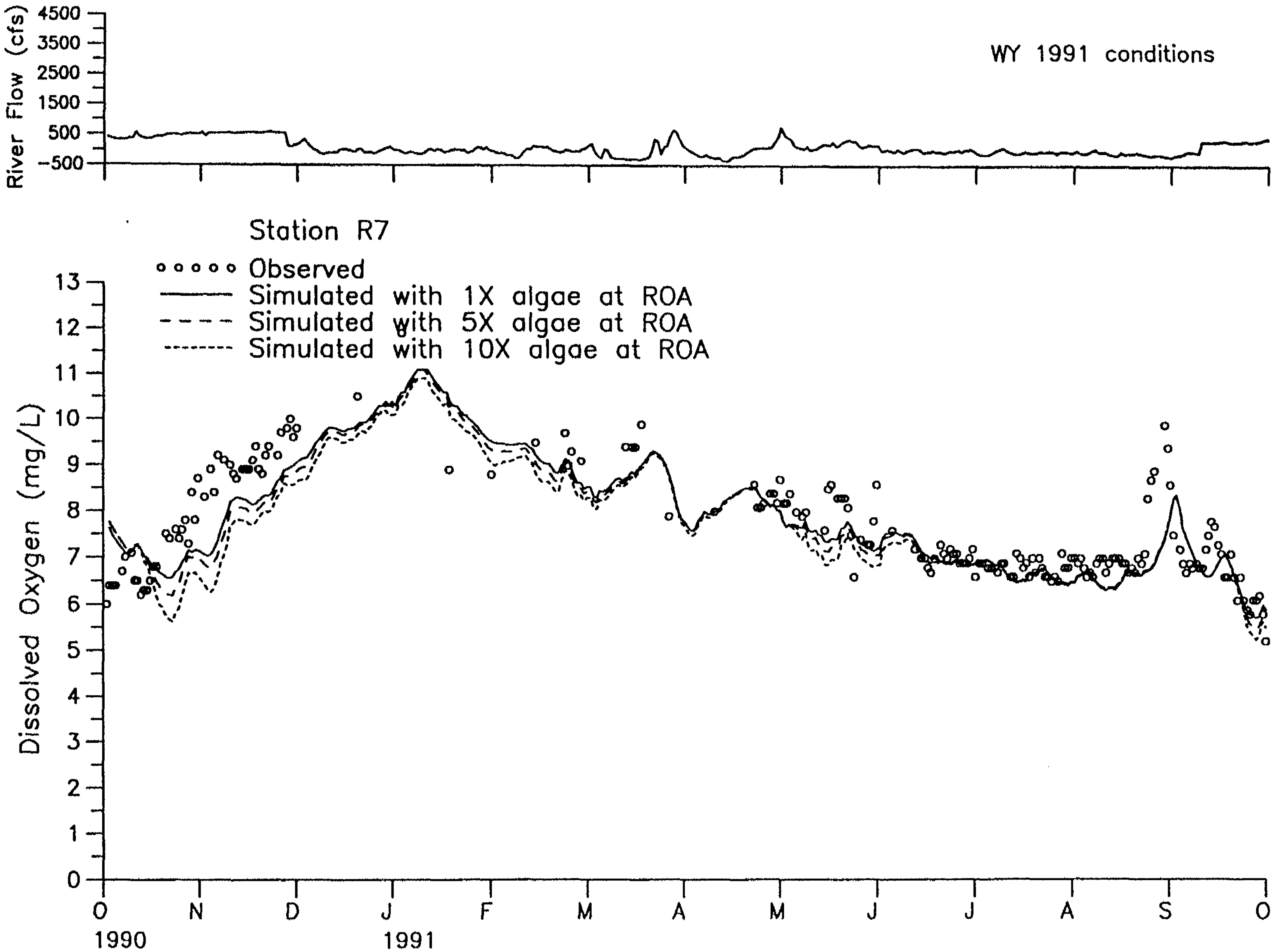


D-041707

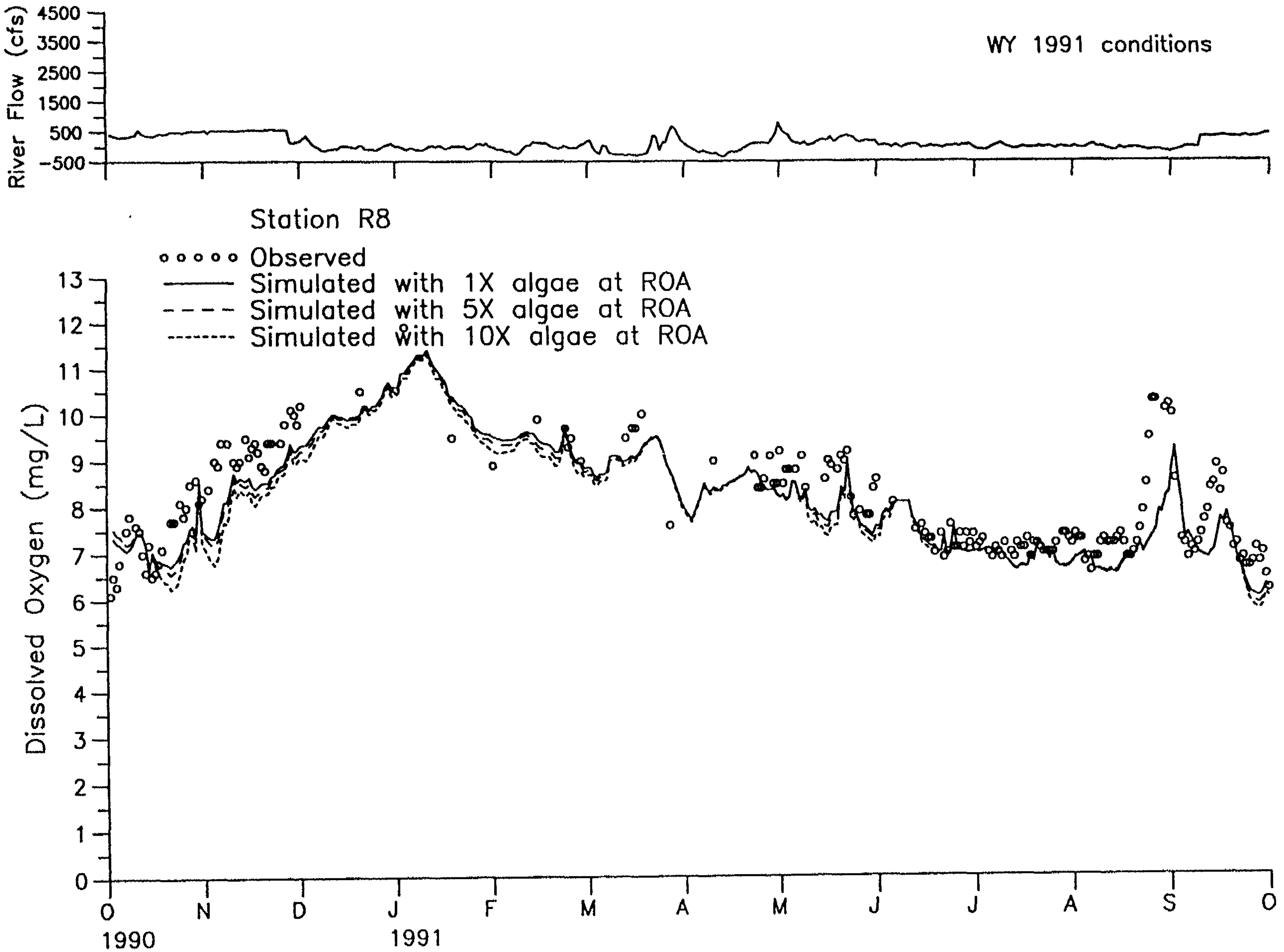
D-041707



River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Station R6
Observed
Simulated with 1X algae at ROA
Simulated with 5X algae at ROA
Simulated with 10X algae at ROA
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991



River Flow (cfs)
4500
3500
2500
1500
500
-500
WY 1991 conditions
Station R7
Observed
Simulated with 1X algae at ROA
Simulated with 5X algae at ROA
Simulated with 10X algae at ROA
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1990
1991

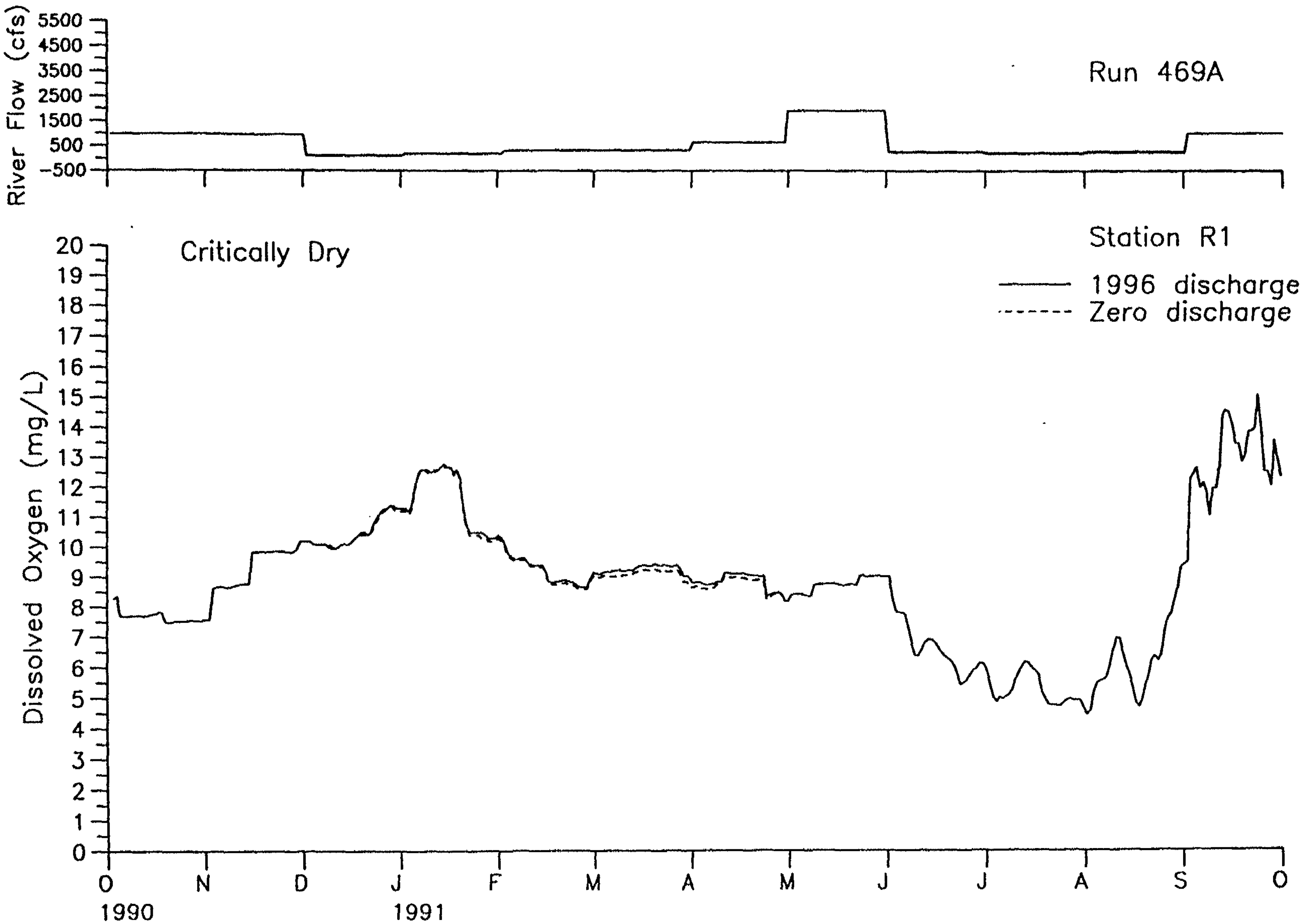


D — 0 4 1 7 1 0

D-041710

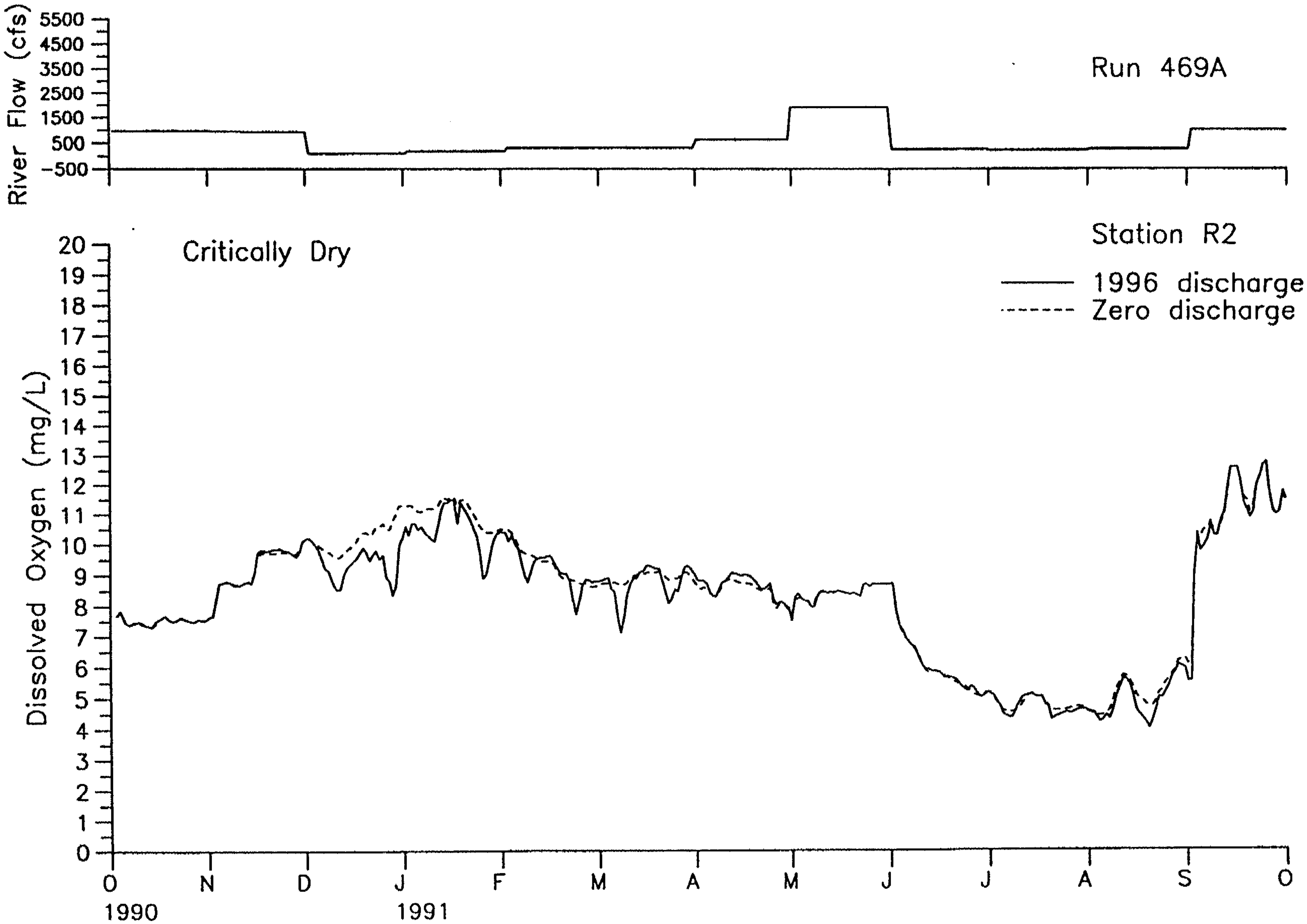
Appendix N.

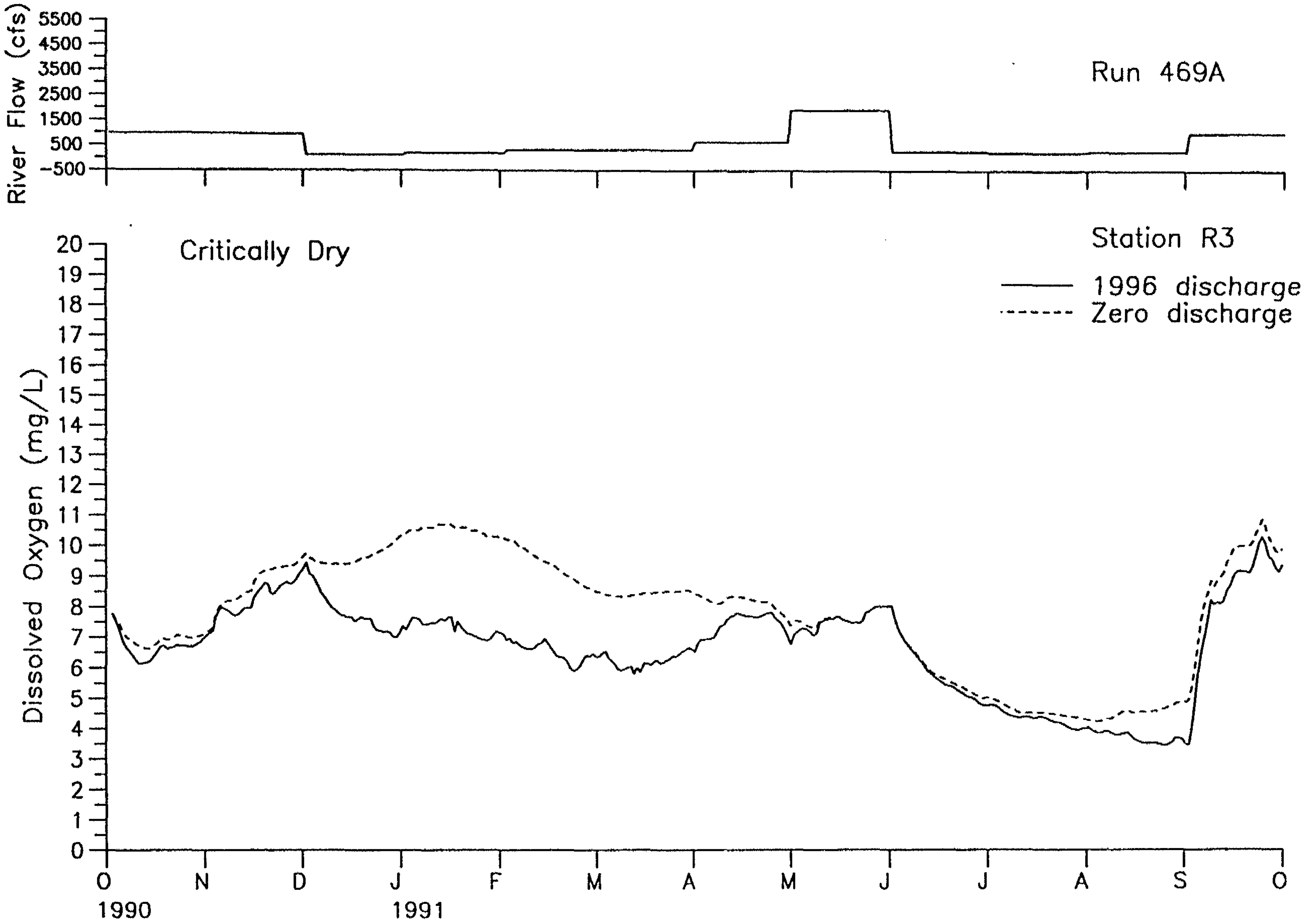
Sensitivity of DO to Waste Load



River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 469A
Station R1
Critically Dry
1996 discharge
Zero discharge
Dissolved Oxygen (mg/L)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

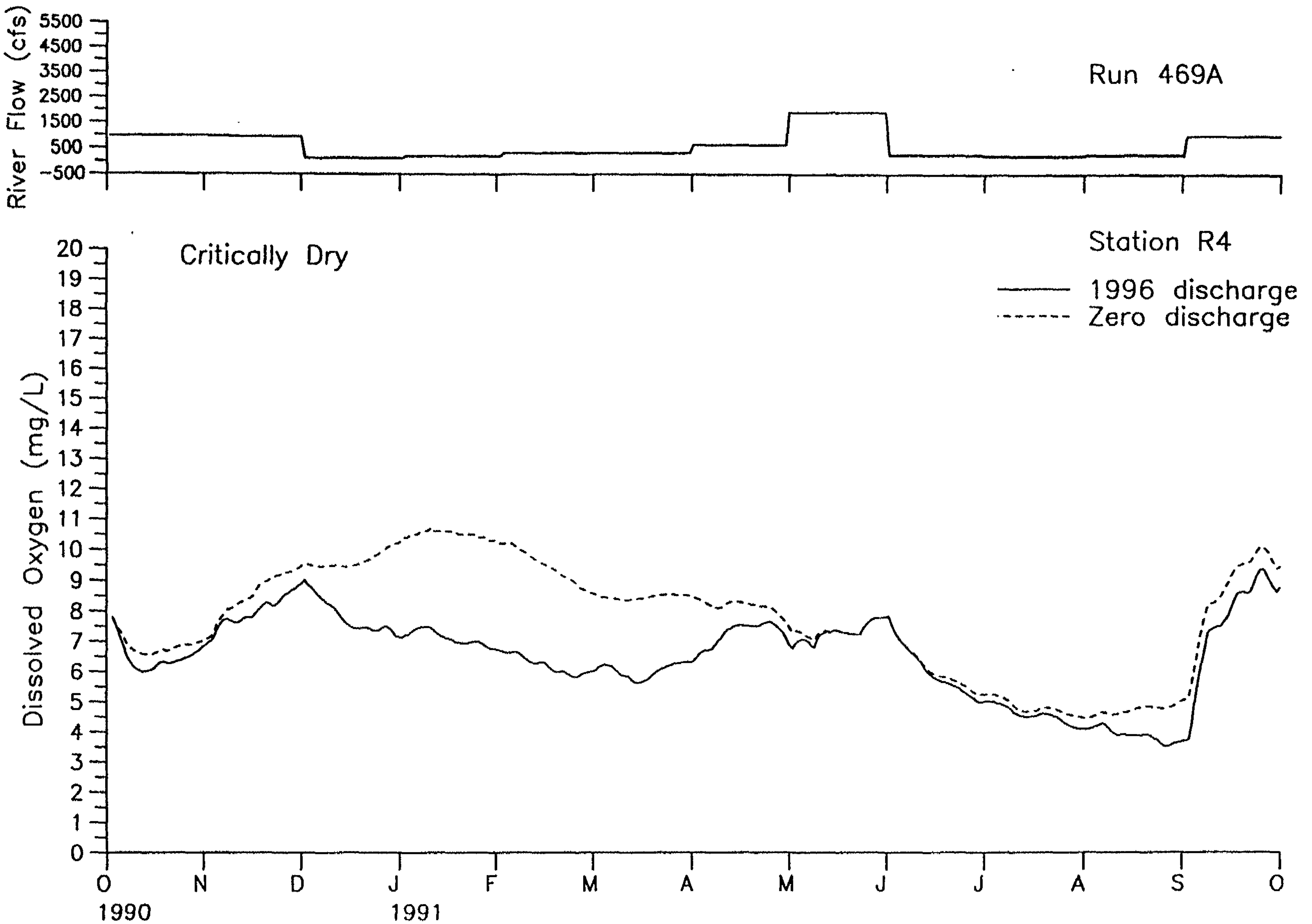
D-041712


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 469A
Station R2
1996 discharge
Zero discharge
Critically Dry
Dissolved Oxygen (mg/L)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991

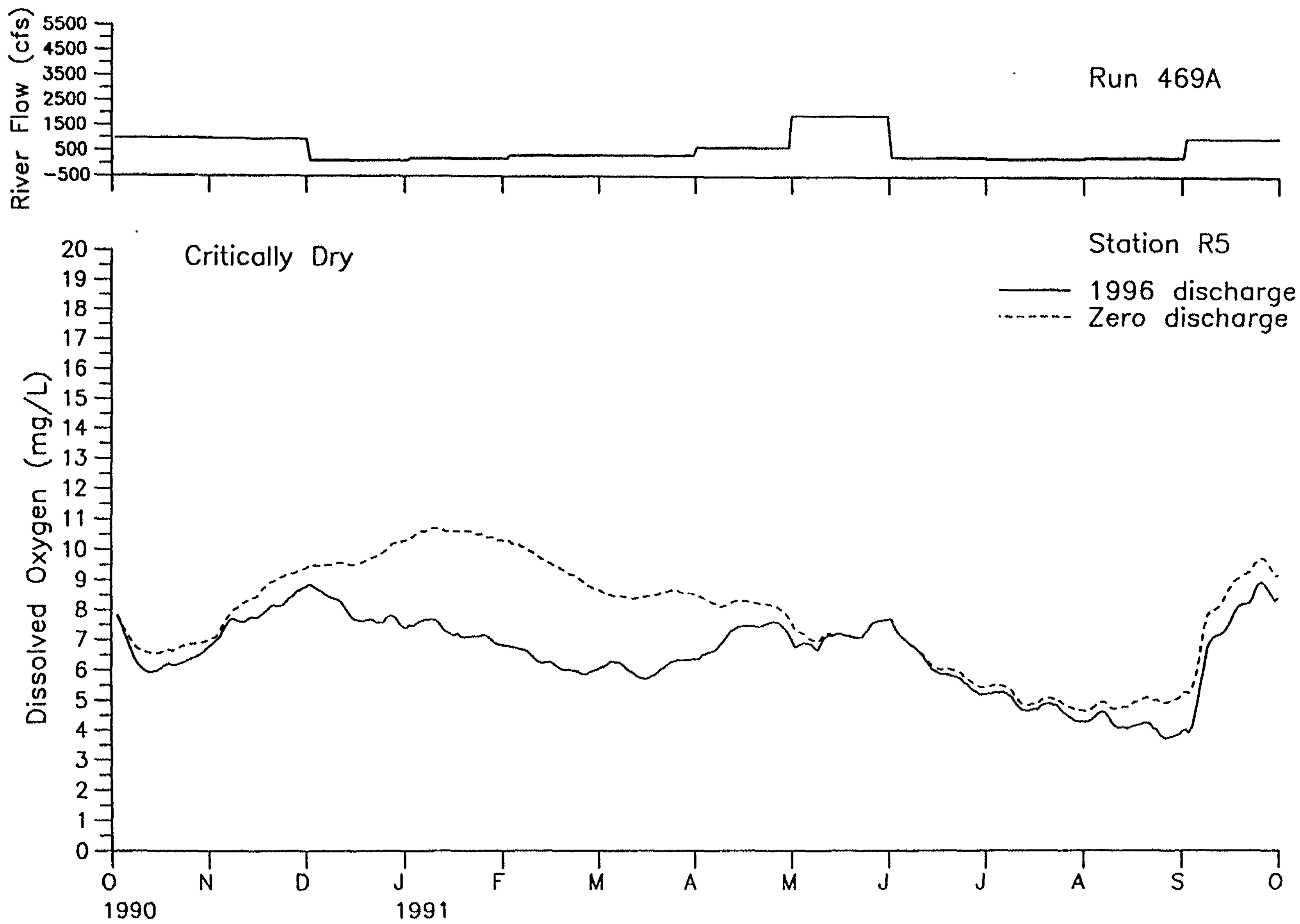


D-041714

D-041714

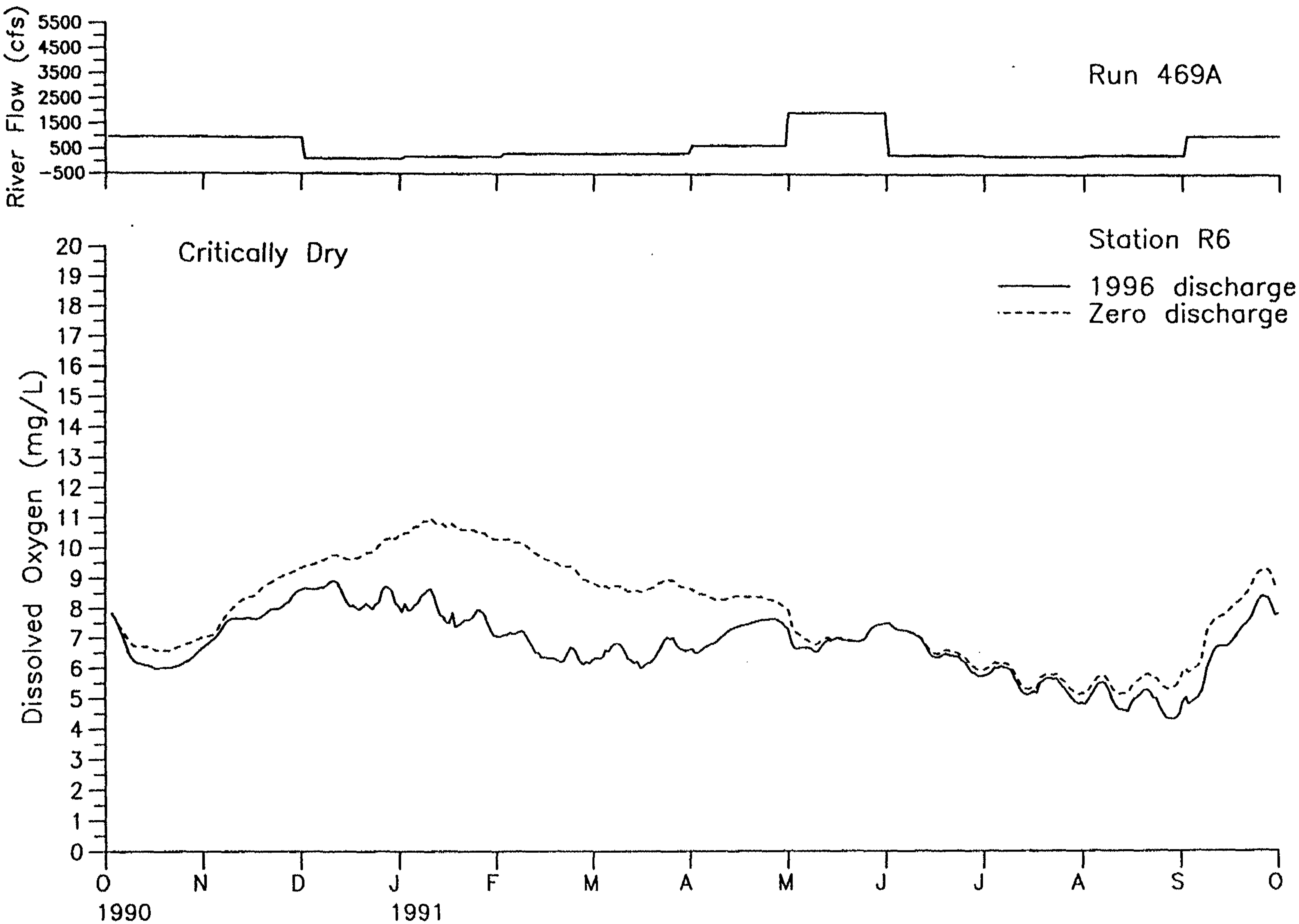


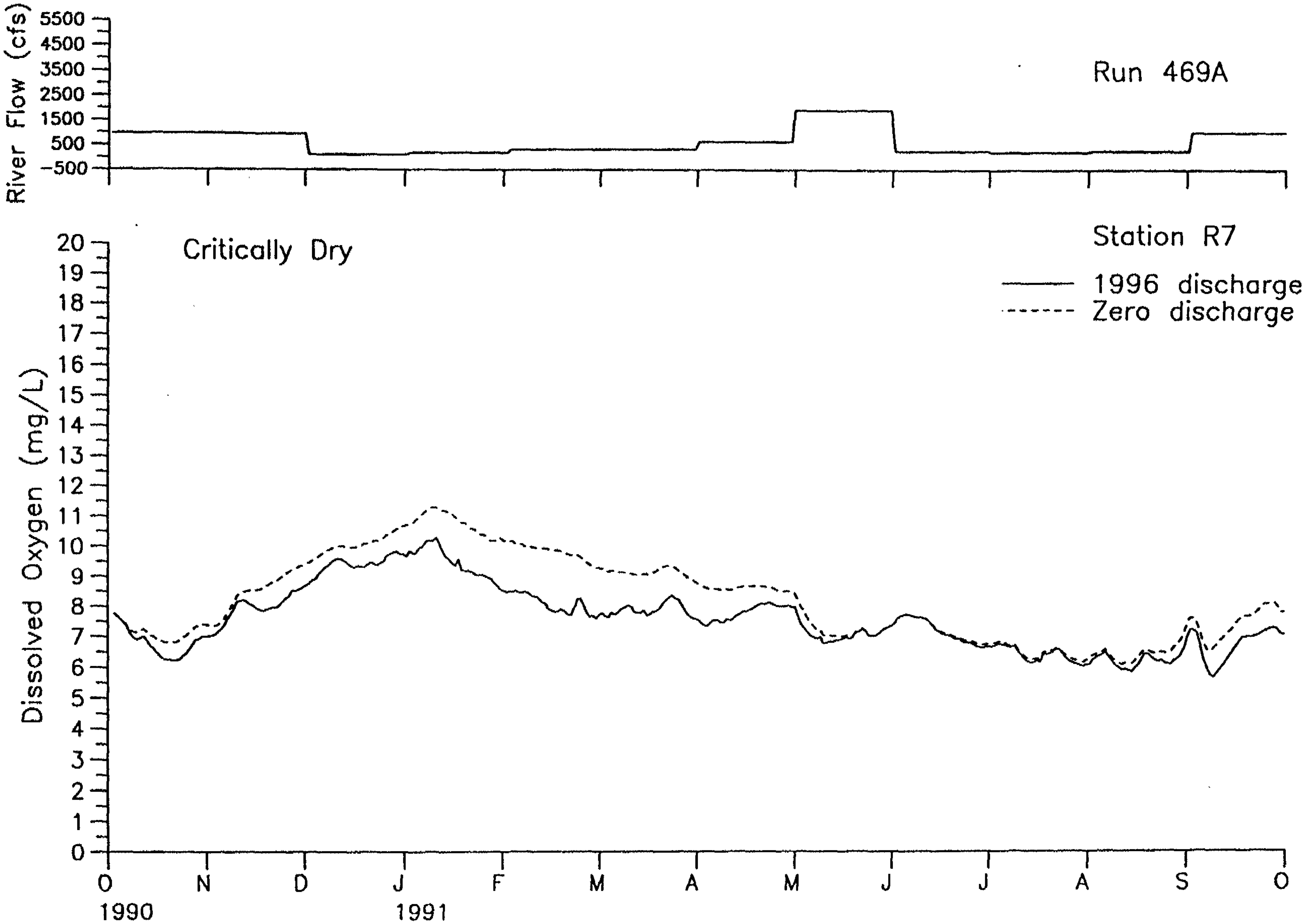
Run 469A
River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Station R4
Critically Dry
1996 discharge
Zero discharge
Dissolved Oxygen (mg/L)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1990
1991



D-041716

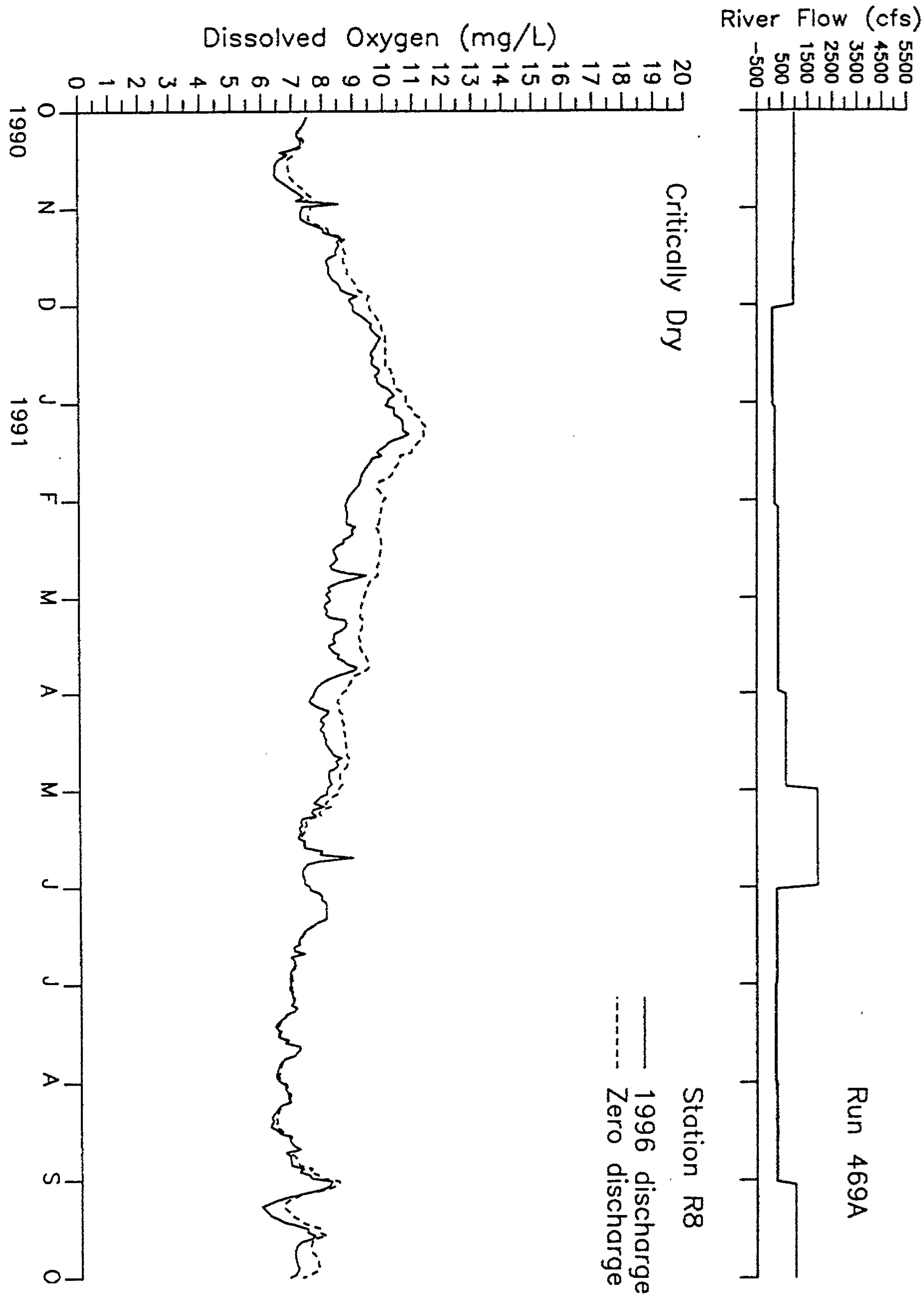
D-041716


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 469A
Station R6
Critically Dry
1996 discharge
Zero discharge
Dissolved Oxygen (mg/L)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1990
1991



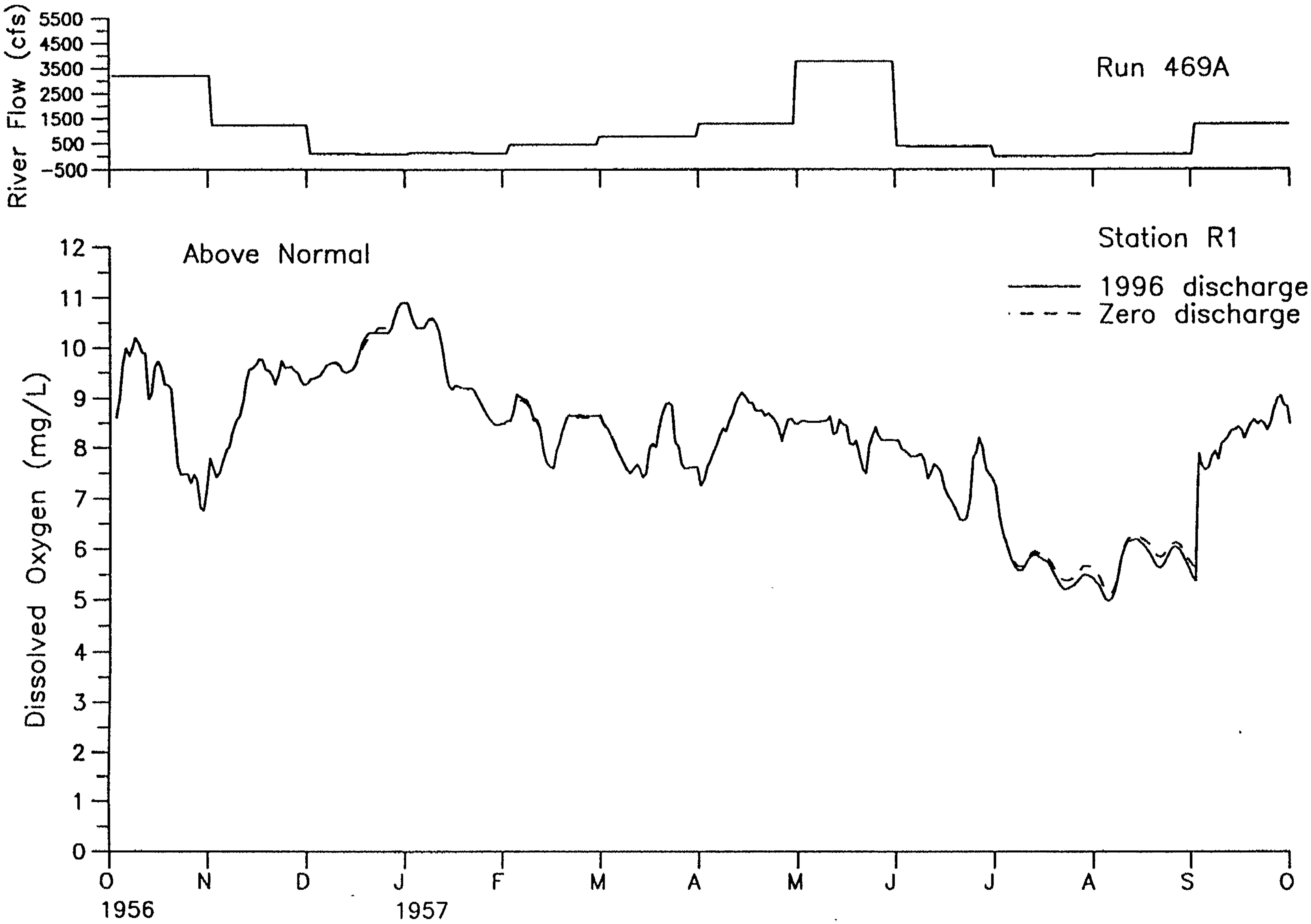
D-041718

D-041718



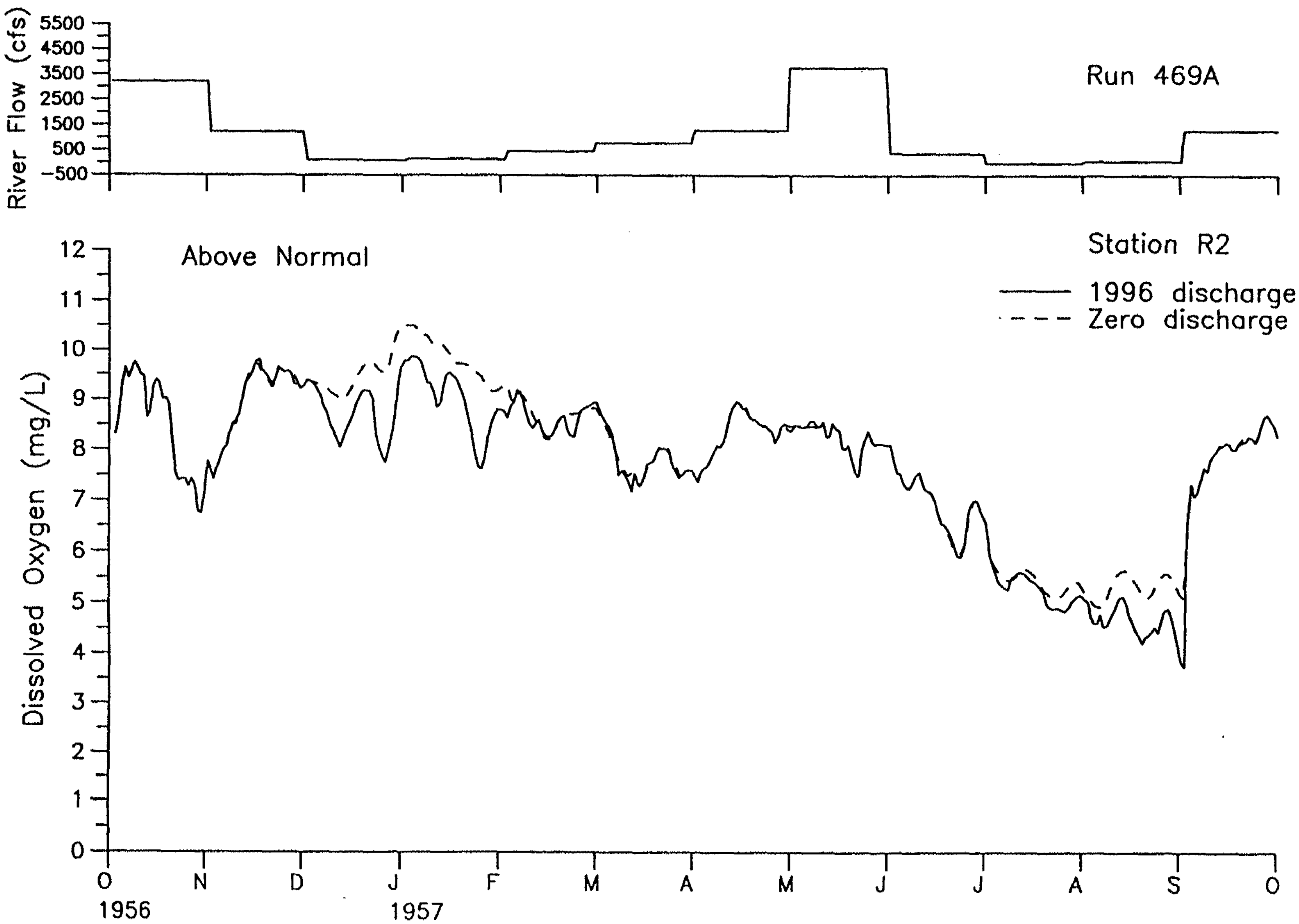
River Flow (cfs)
-500 500 1500 2500 3500 4500 5500
Dissolved Oxygen (mg/L)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Critically Dry
Run 469A
Station R8
1996 discharge
Zero discharge
O N D J F M A M J J A S O
1990
1991

D —0 4 1 7 1 9

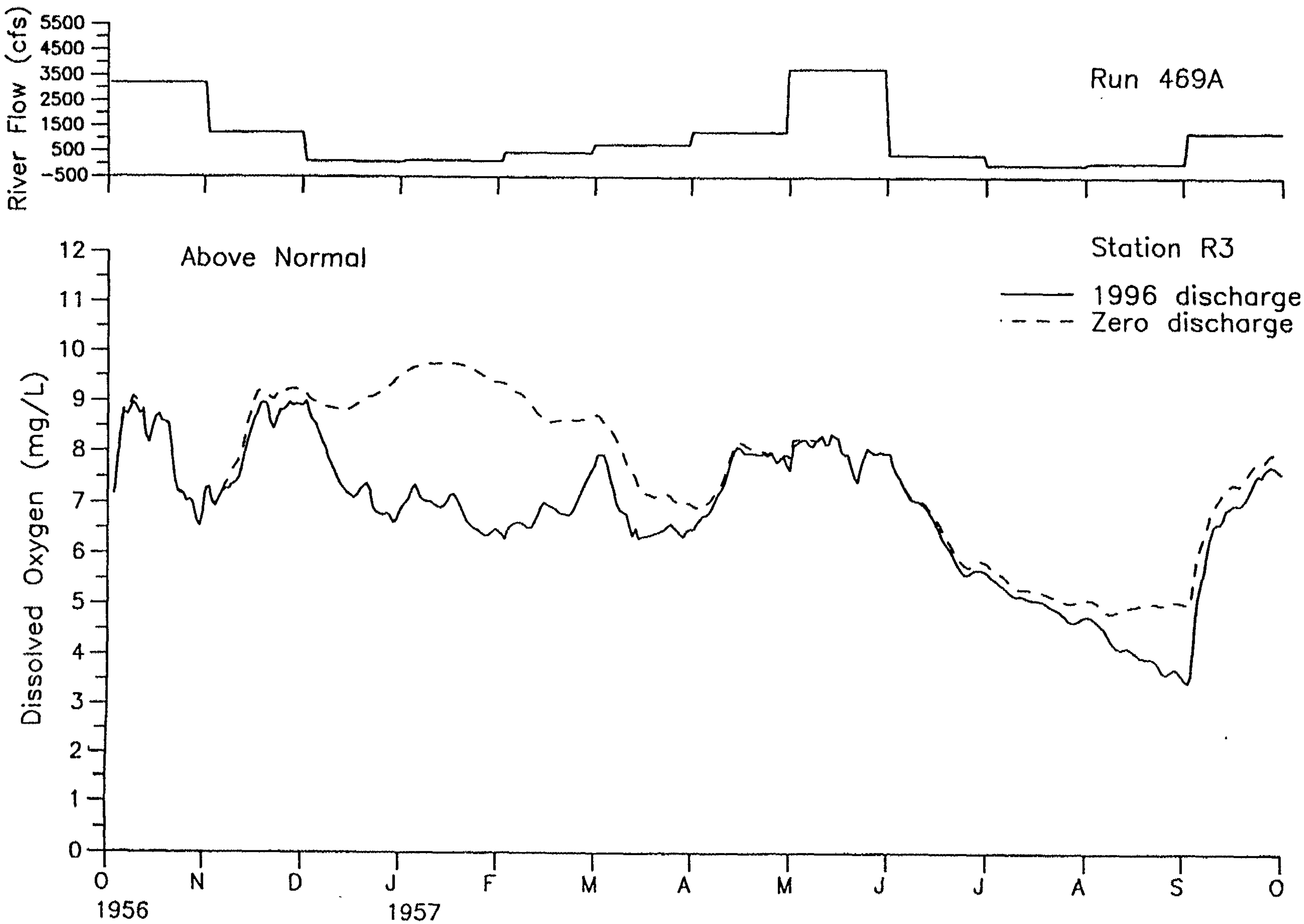


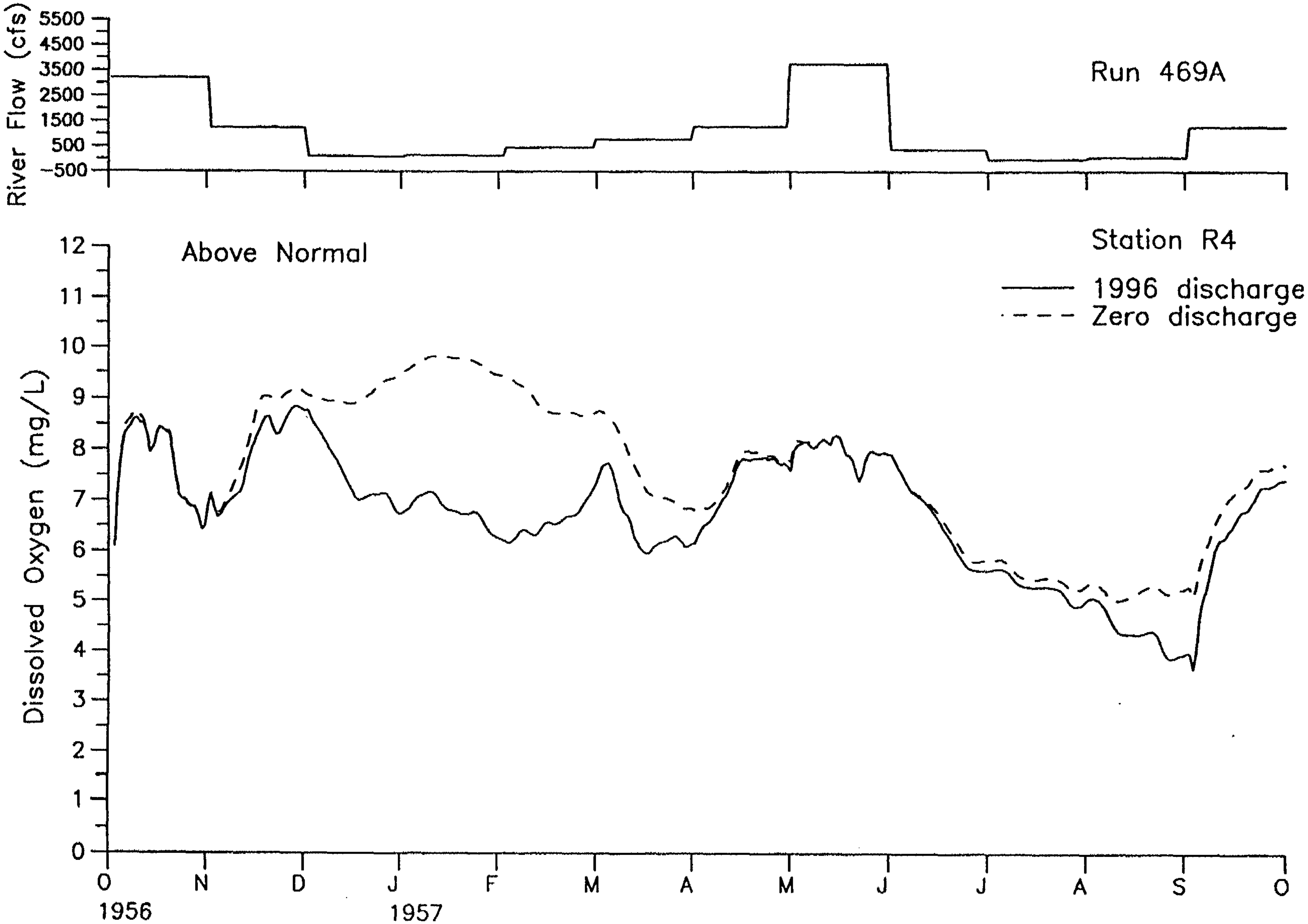
River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 469A
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
Above Normal
Station R1
1996 discharge
Zero discharge
O N D J F M A M J J A S O
1956
1957

D — 0 4 1 7 2 0


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 469A
Station R2
1996 discharge
Zero discharge
Above Normal
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957

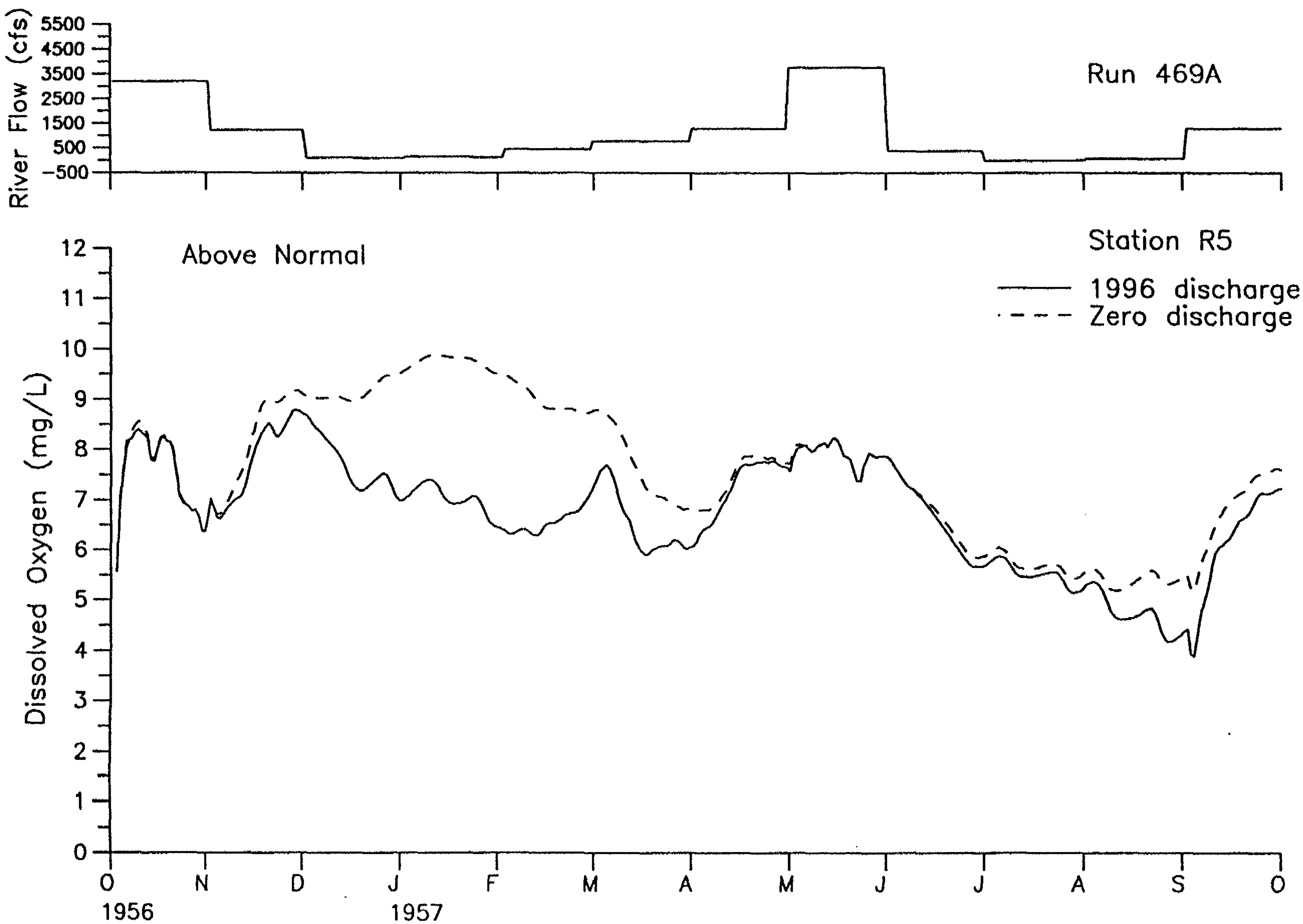
D-041721


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 469A
Dissolved Oxygen (mg/L)
Above Normal
Station R3
1996 discharge
Zero discharge
O N D J F M A M J J A S O
1956
1957

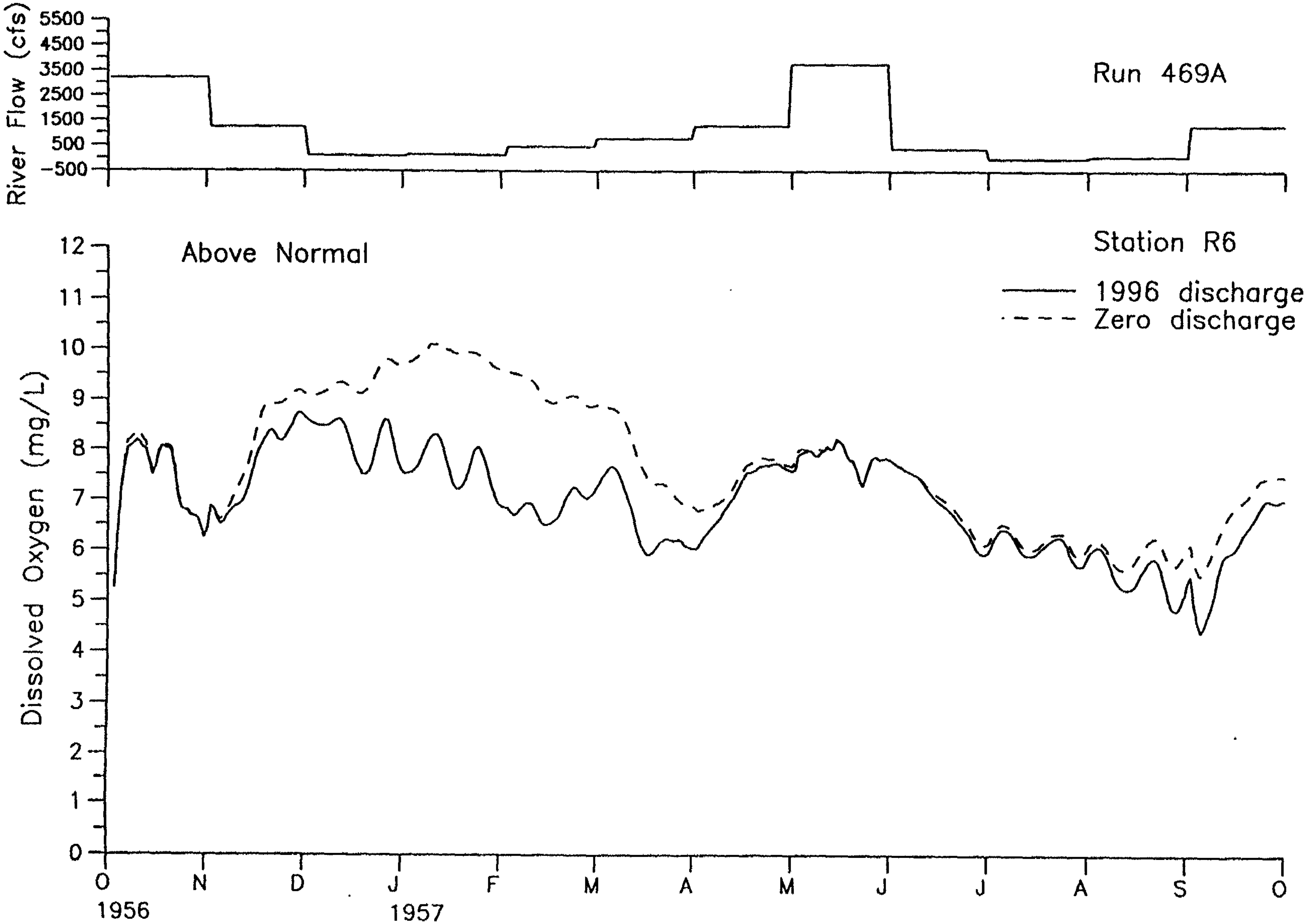


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 469A
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
Above Normal
Station R4
1996 discharge
Zero discharge
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957

D-041723

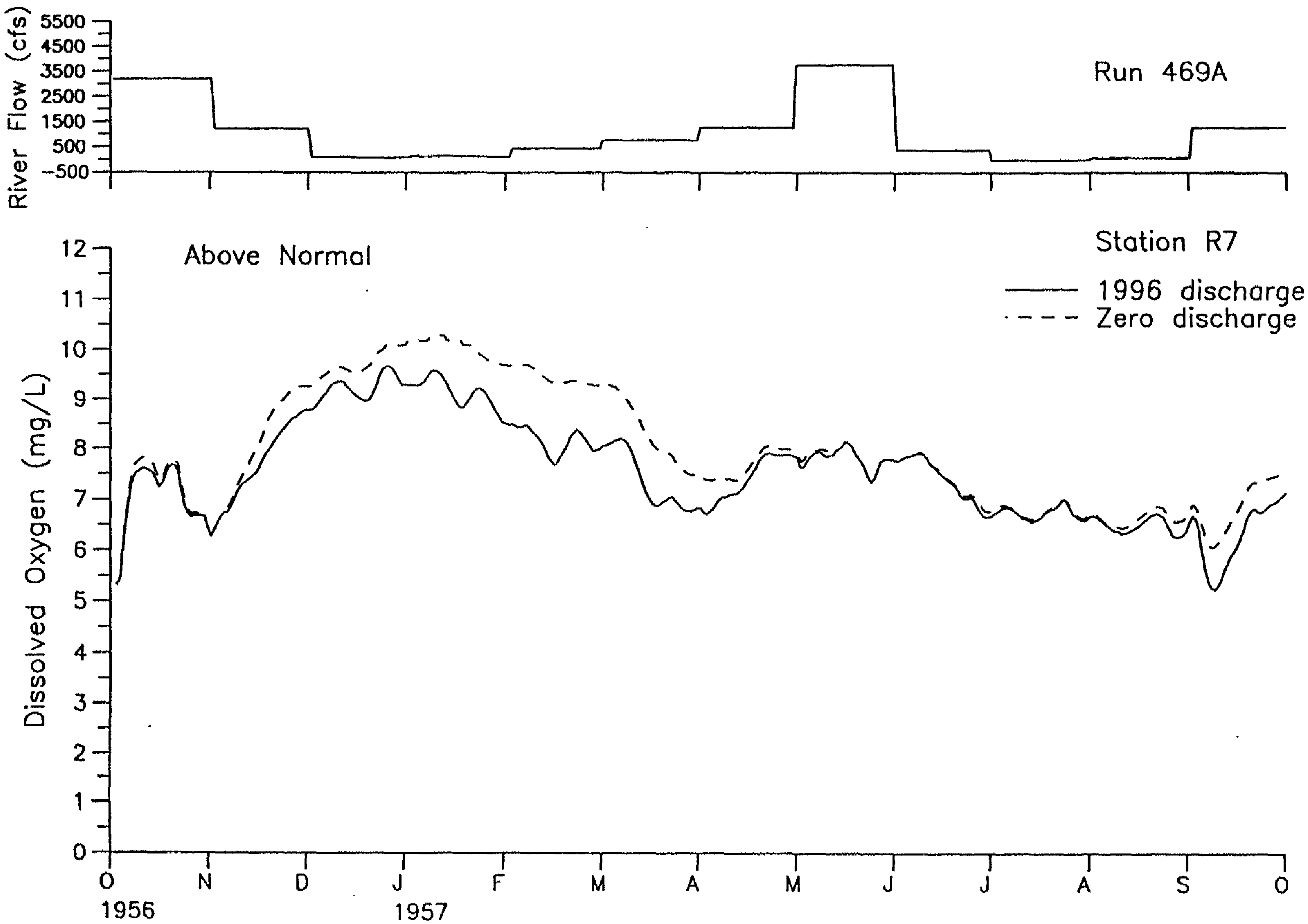


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 469A
Station R5
1996 discharge
Zero discharge
Above Normal
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957

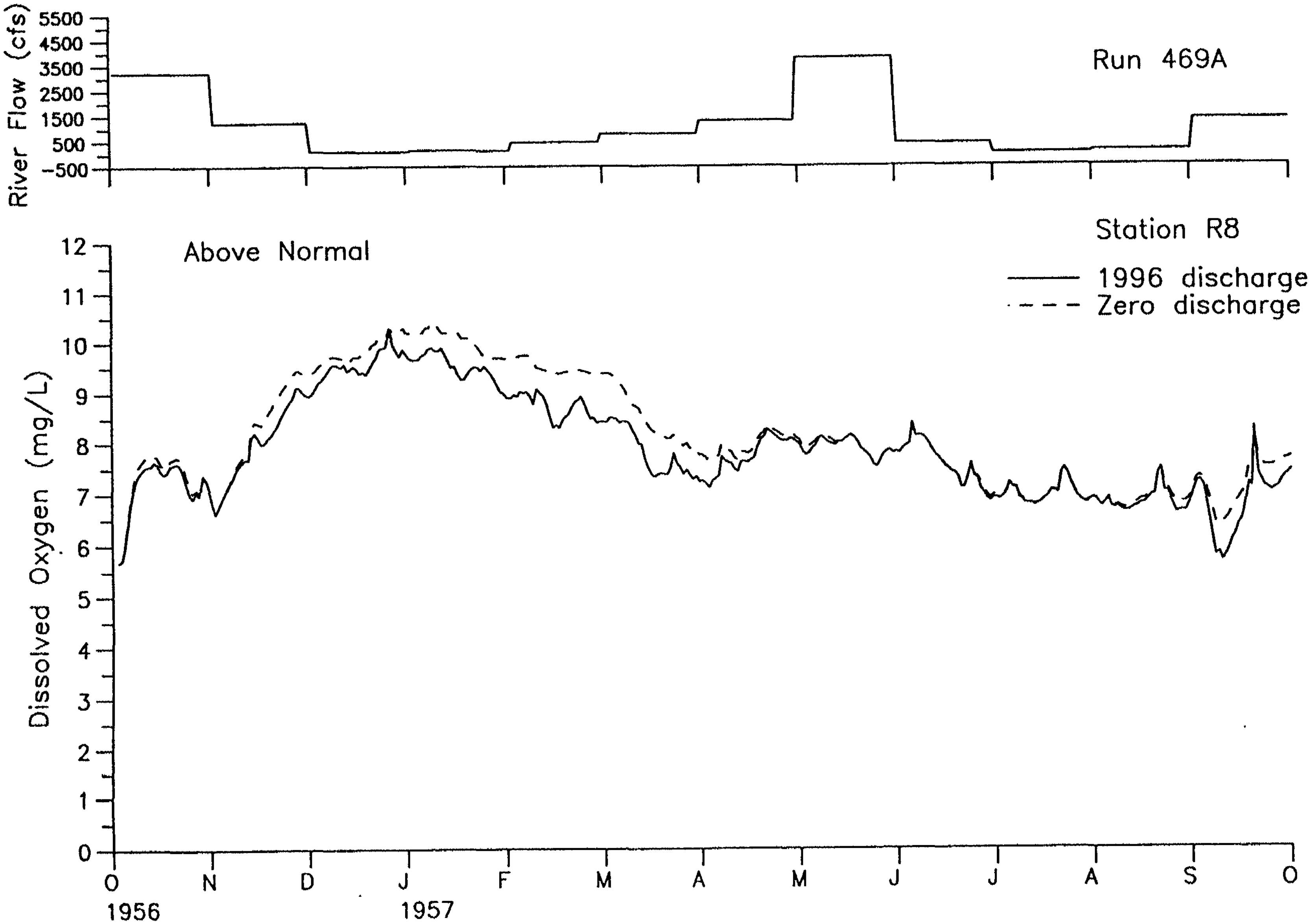


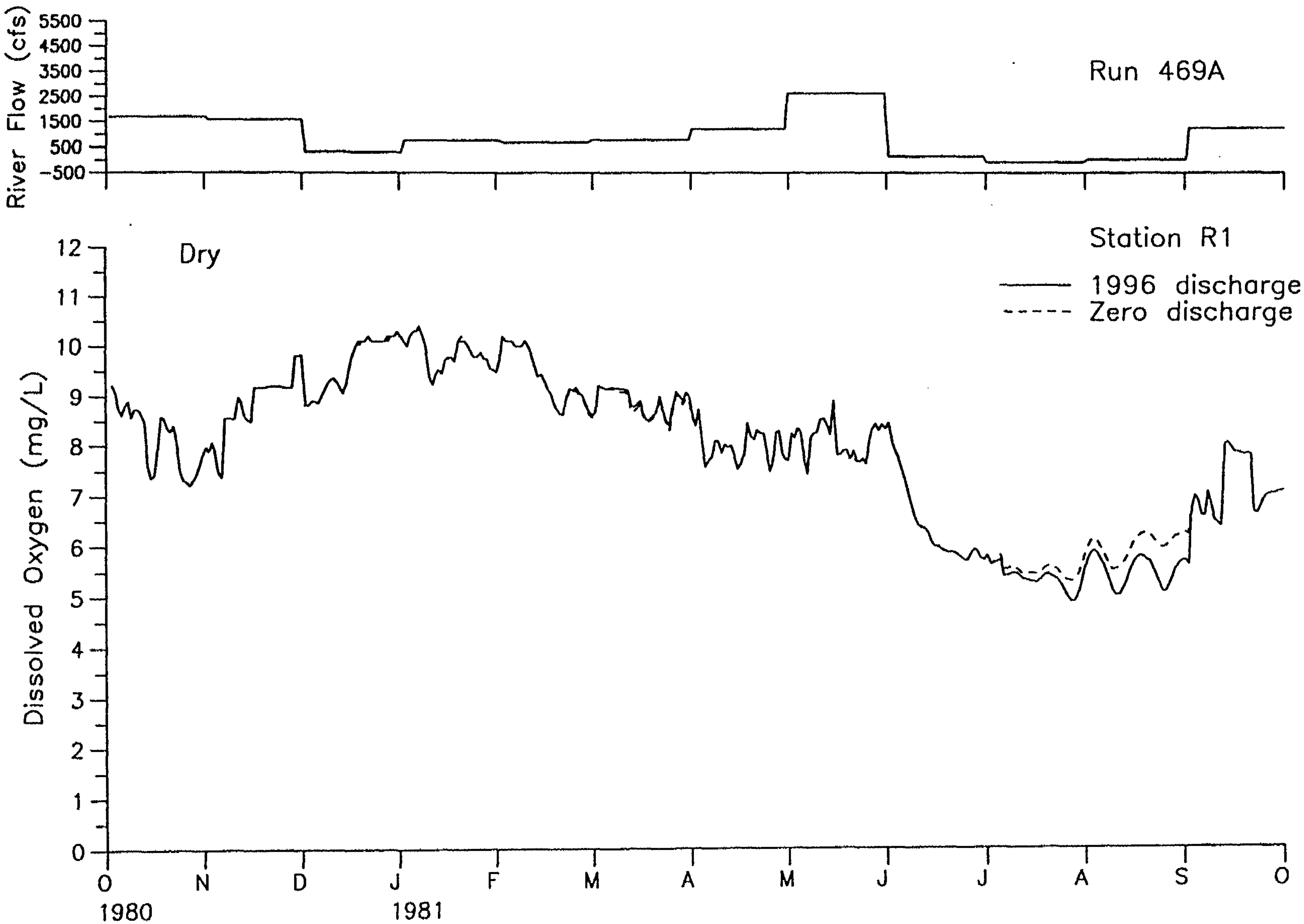
Run 469A
River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Station R6
Above Normal
1996 discharge
Zero discharge
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957

D-041725


River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 469A
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
Above Normal
Station R7
1996 discharge
Zero discharge
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957

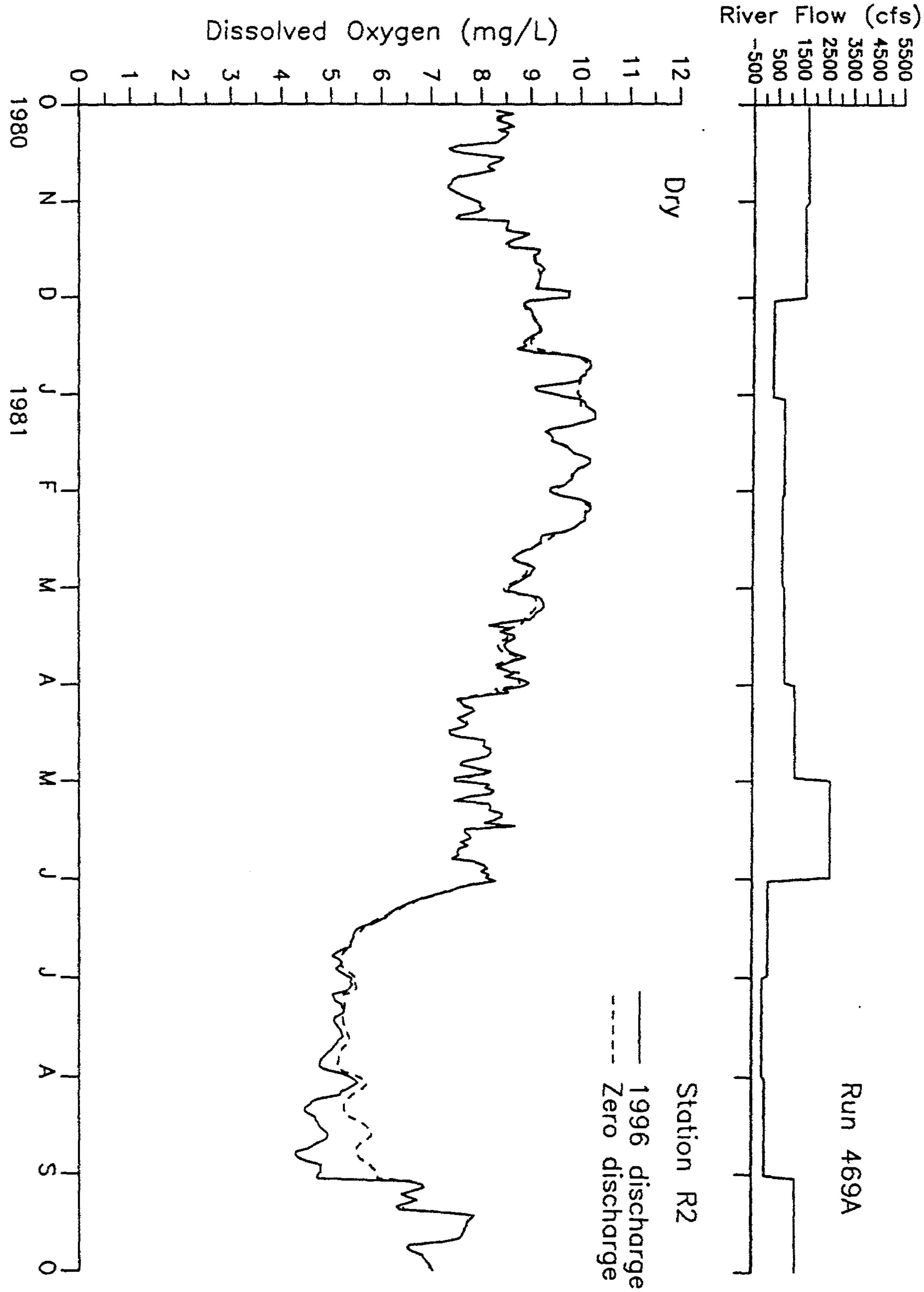
D—041726


Run 469A
River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Station R8
1996 discharge
Zero discharge
Above Normal
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1956
1957



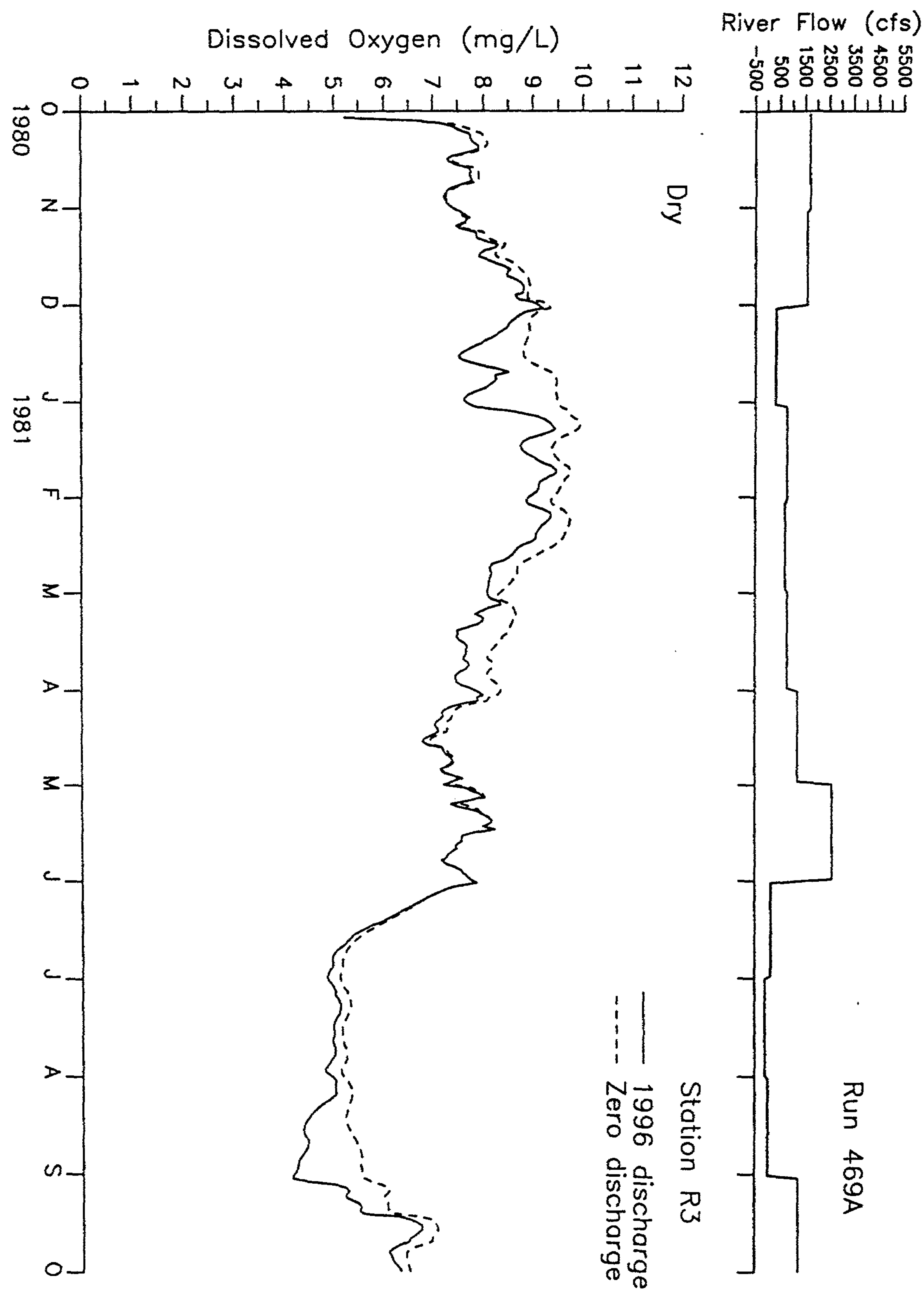
D—041728

D-041728



D-041729

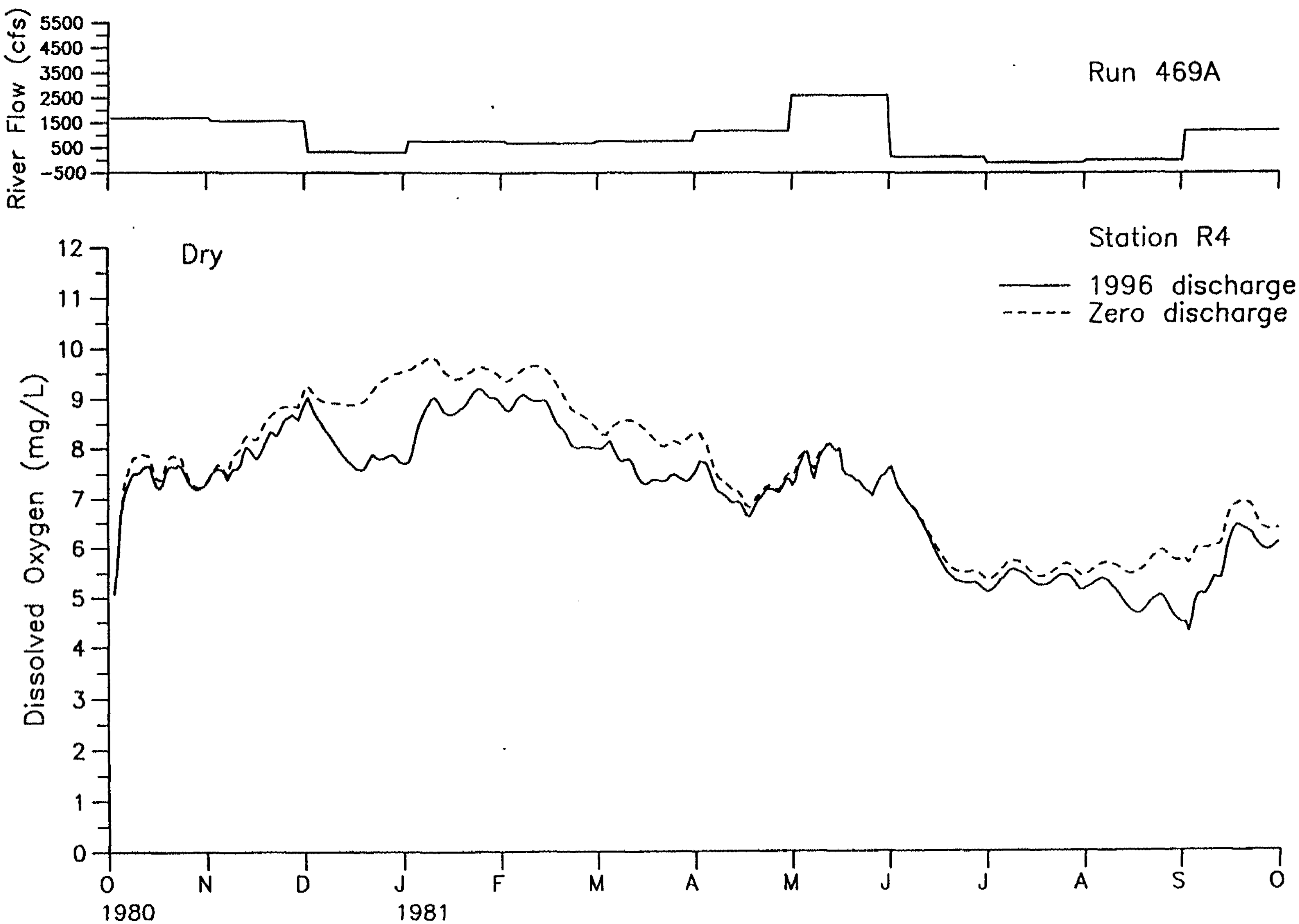
D-041729



D —0 4 1 7 3 0

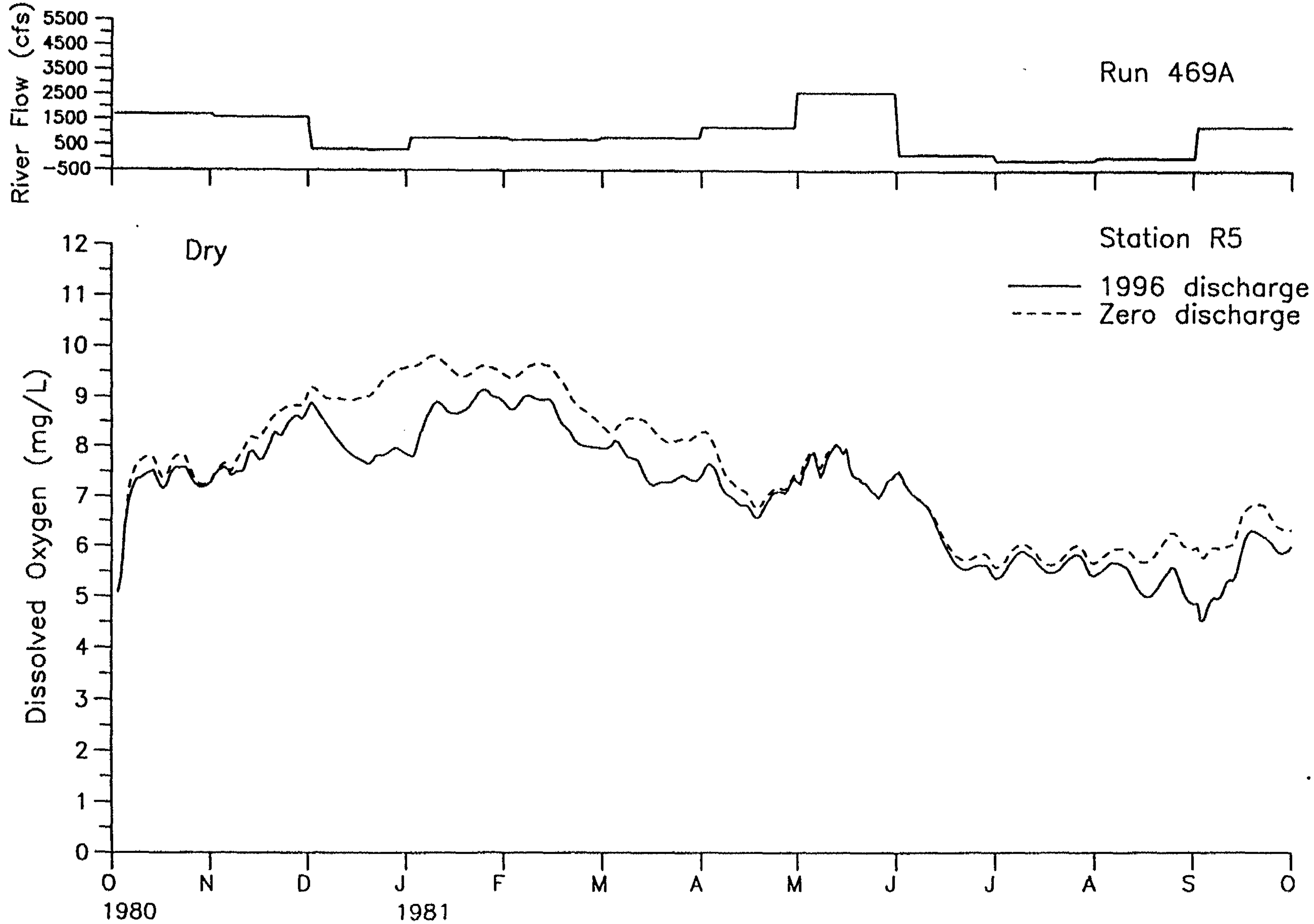
D-041730

D-041731

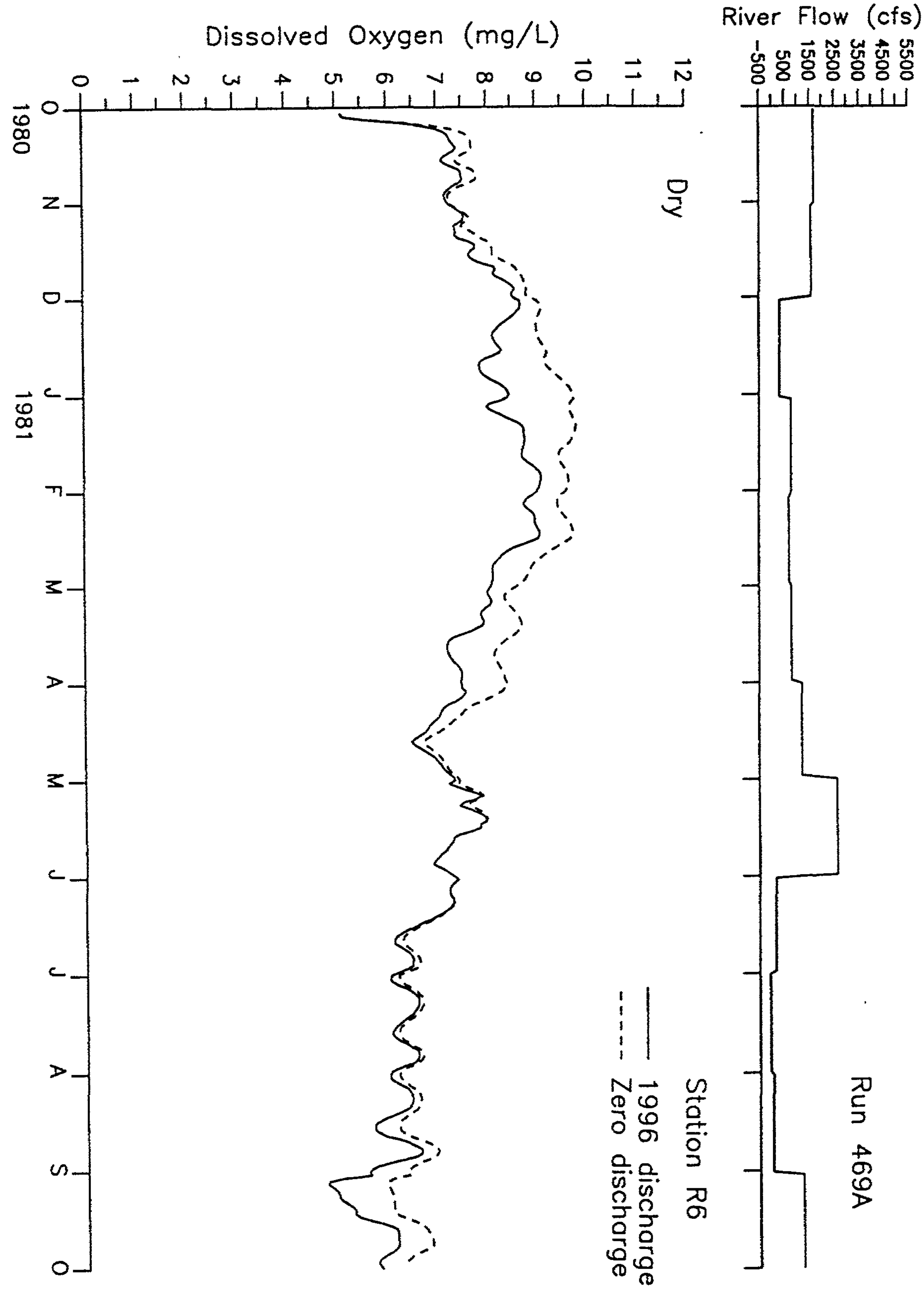


D-041731

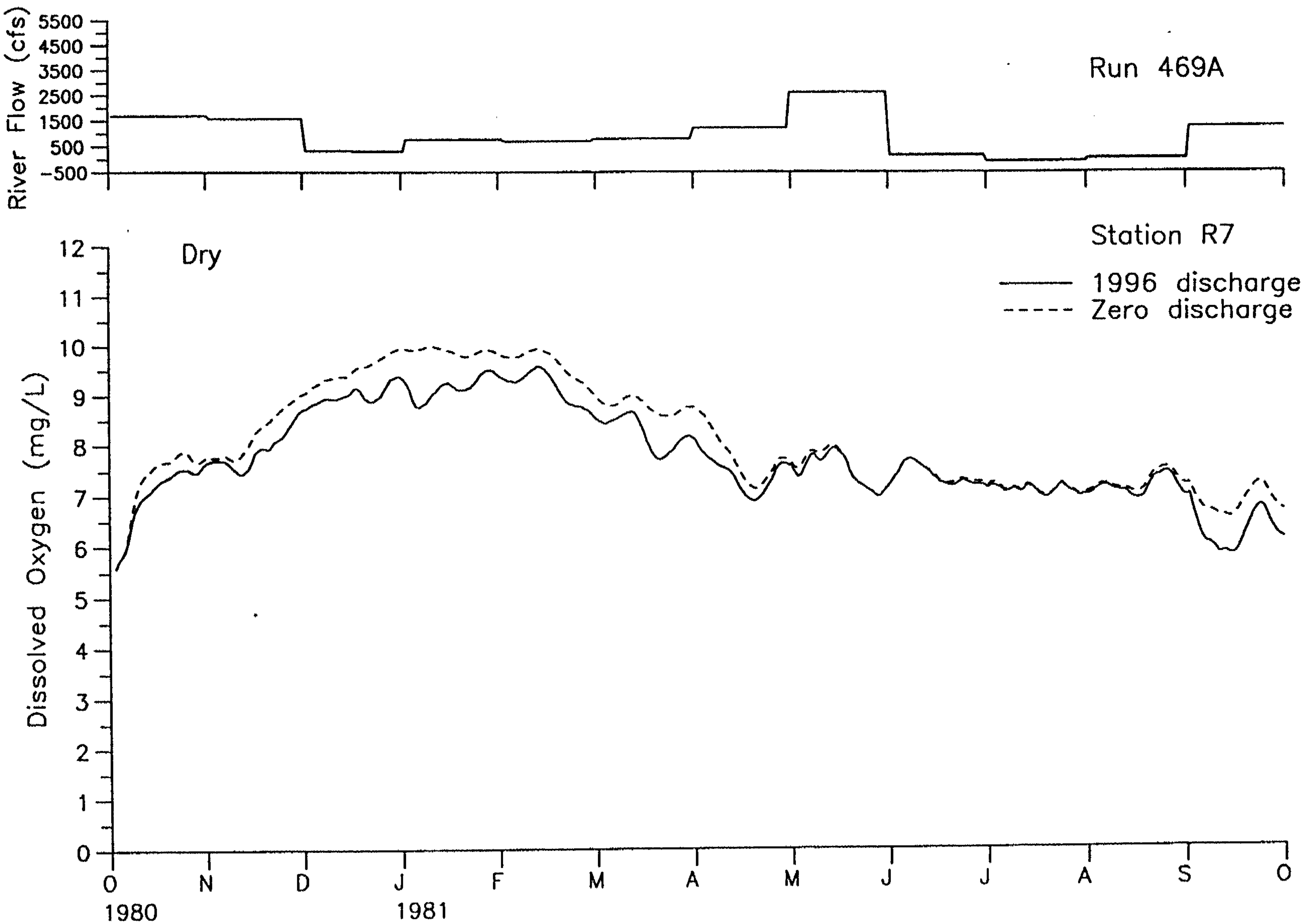
D-041732



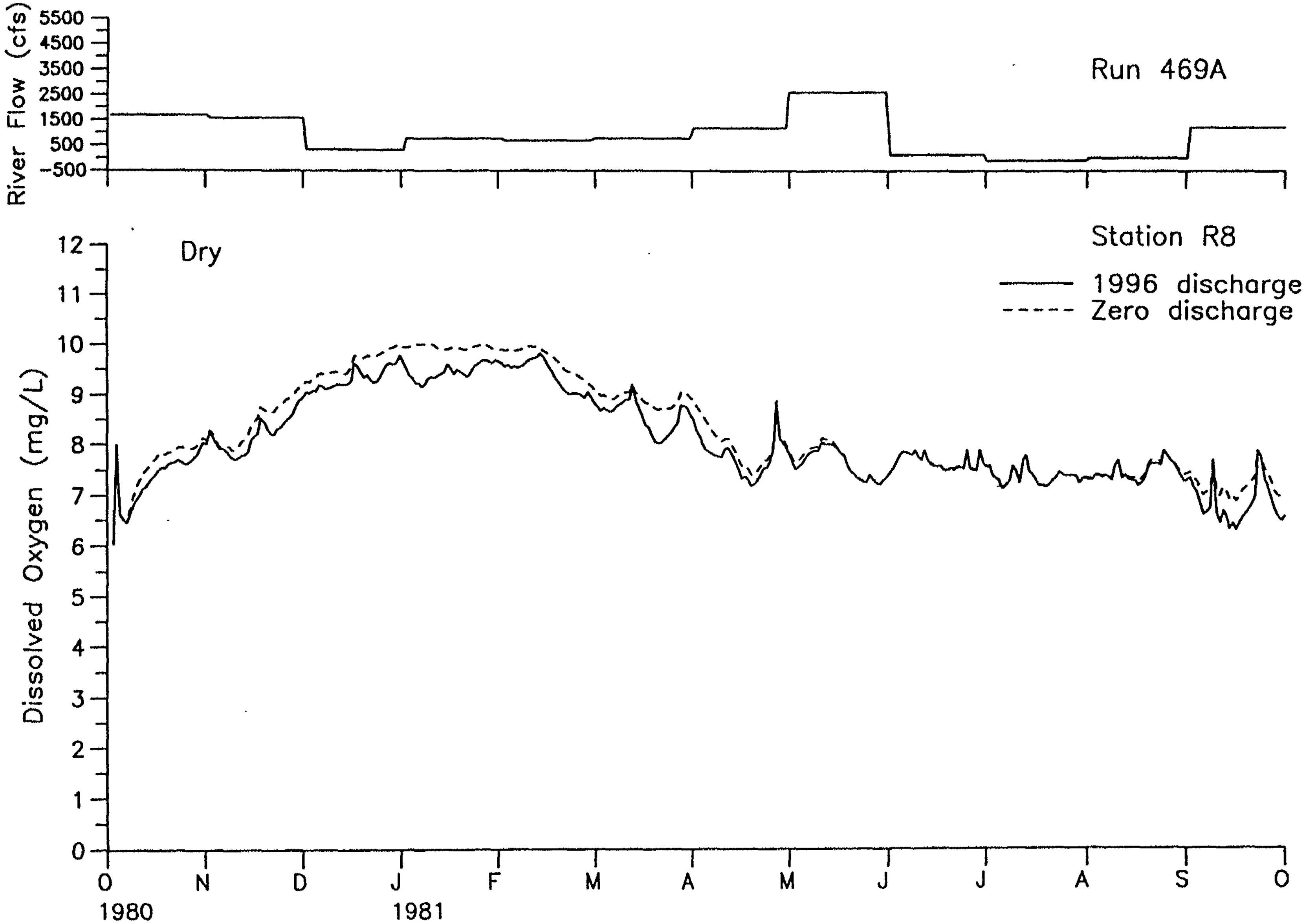
D—041732

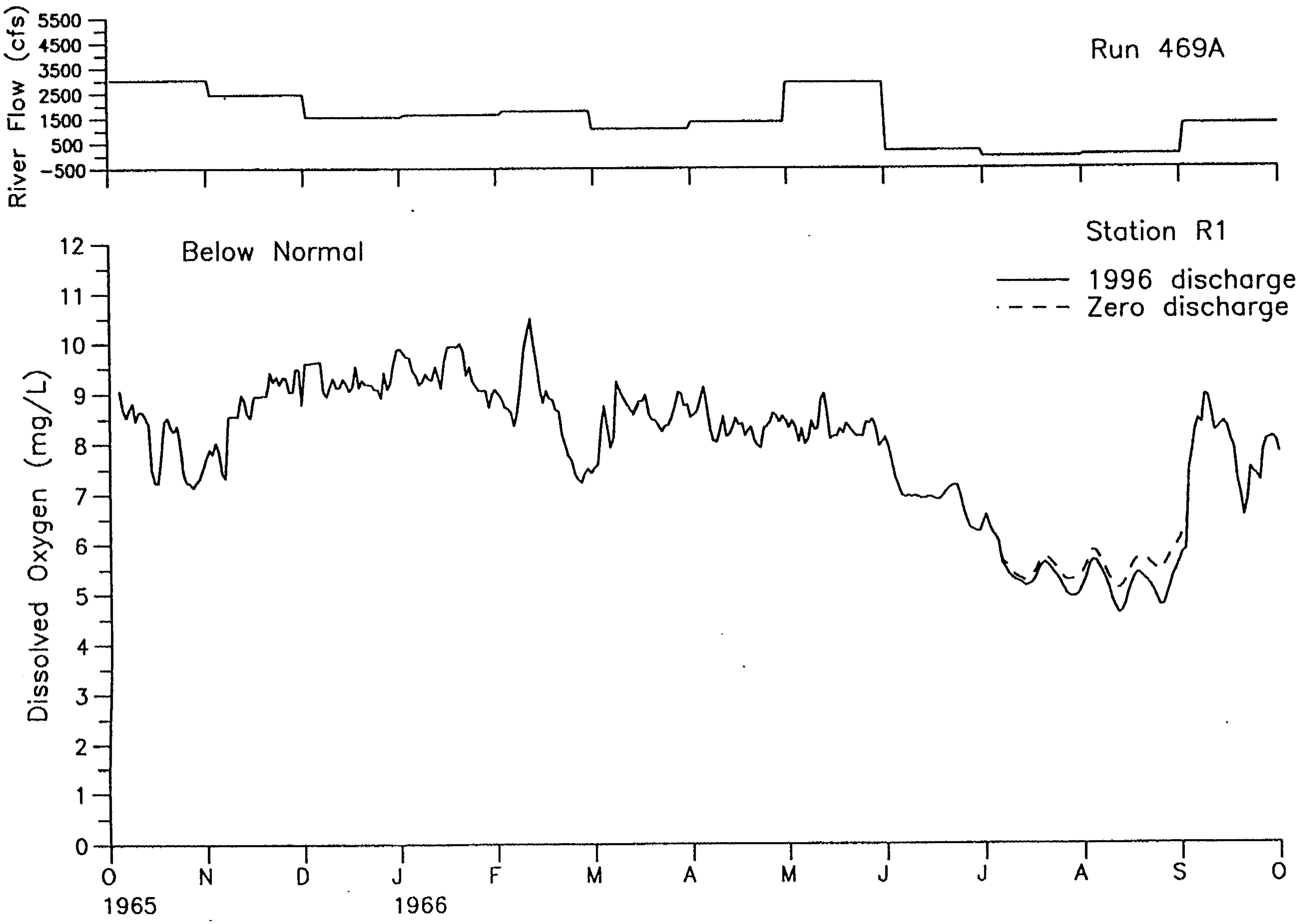


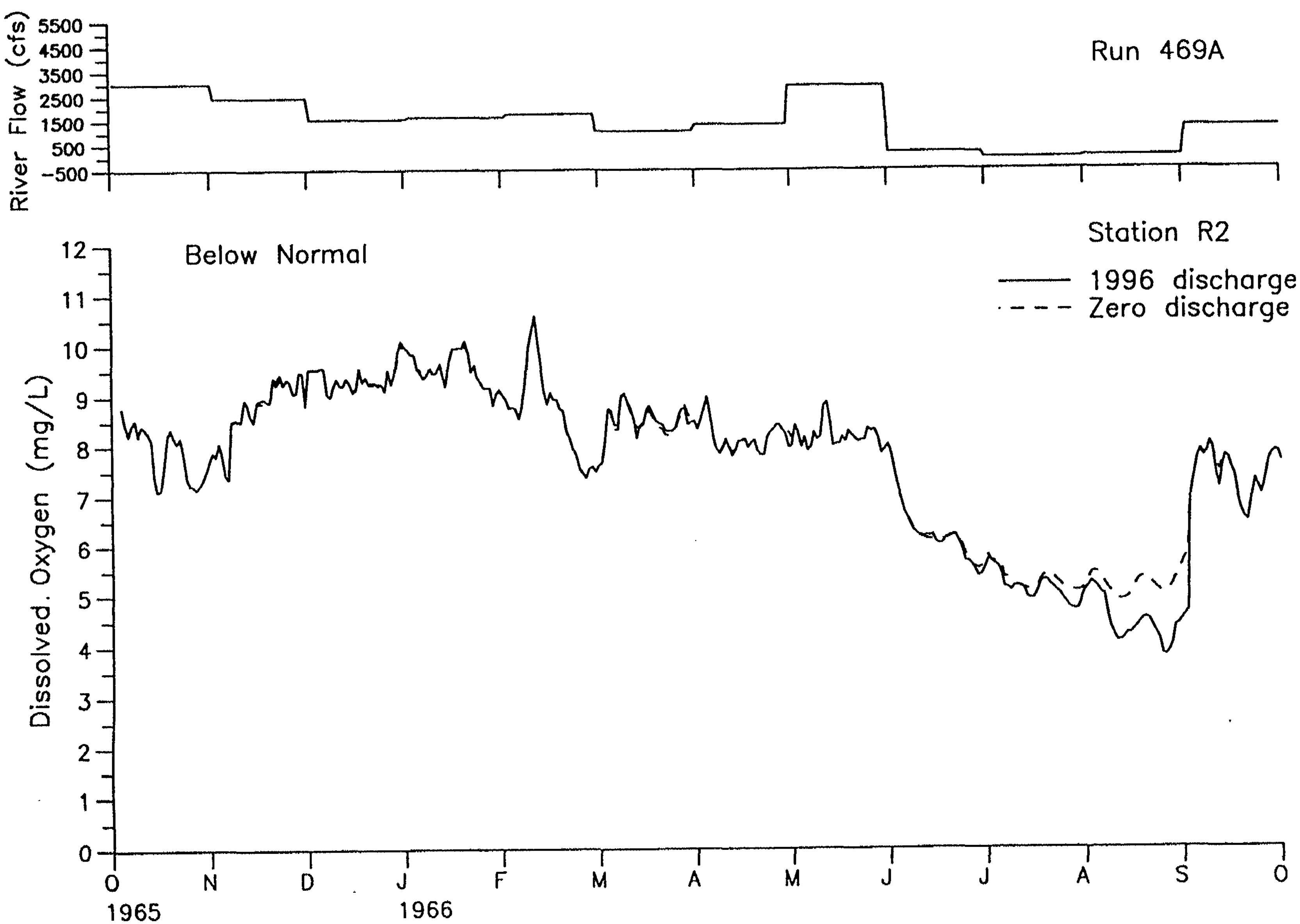
Dissolved Oxygen (mg/L)
River Flow (cfs)
Dry
Station R6
1996 discharge
Zero discharge
Run 469A
1980
1981


Run 469A
River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Station R7
Dry
1996 discharge
Zero discharge
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1980
1981

D-041734


Run 469A
River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Station R8
1996 discharge
Zero discharge
Dry
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1980
1981

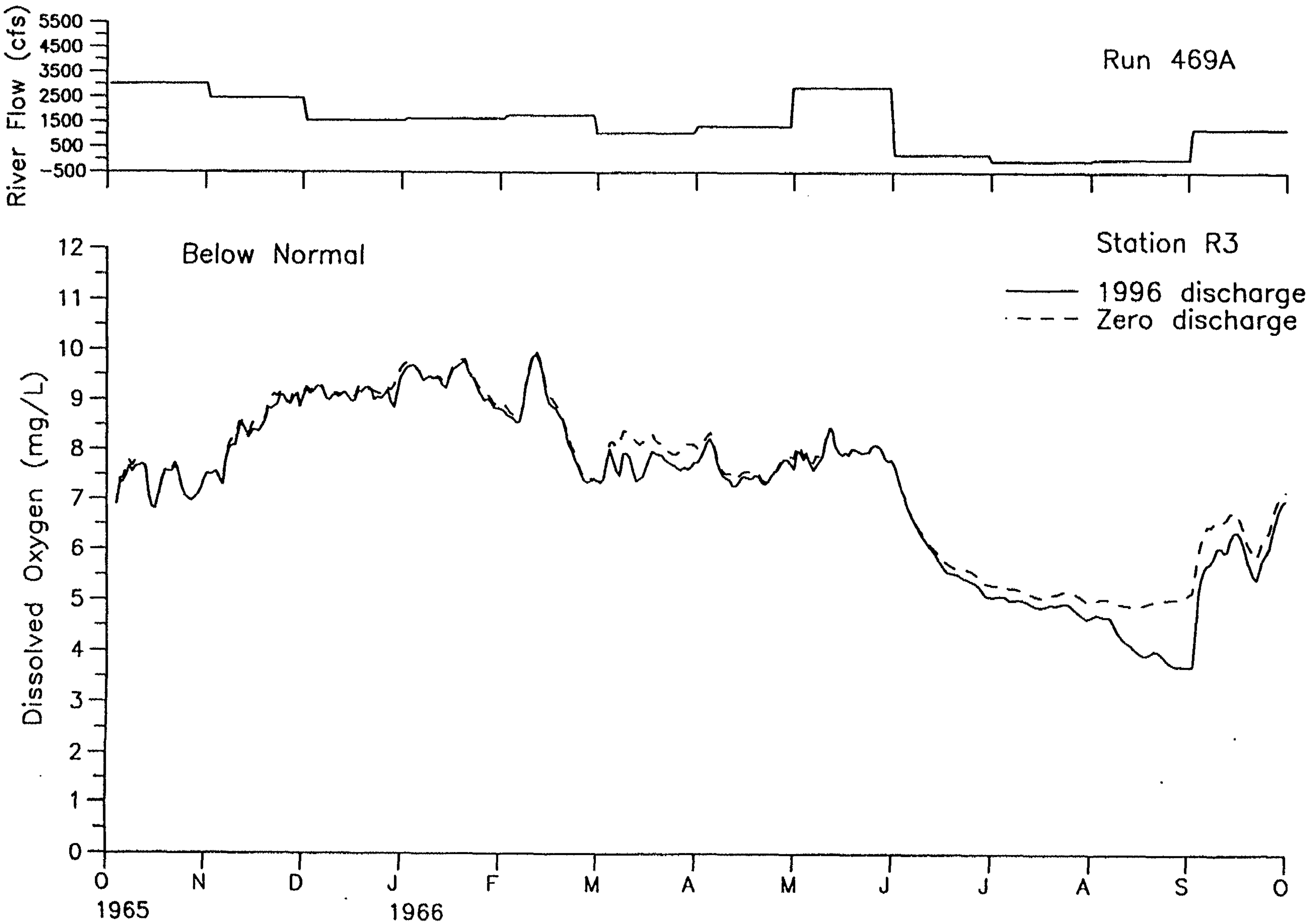

River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Run 469A
Station R1
Below Normal
1996 discharge
Zero discharge
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1965
1966



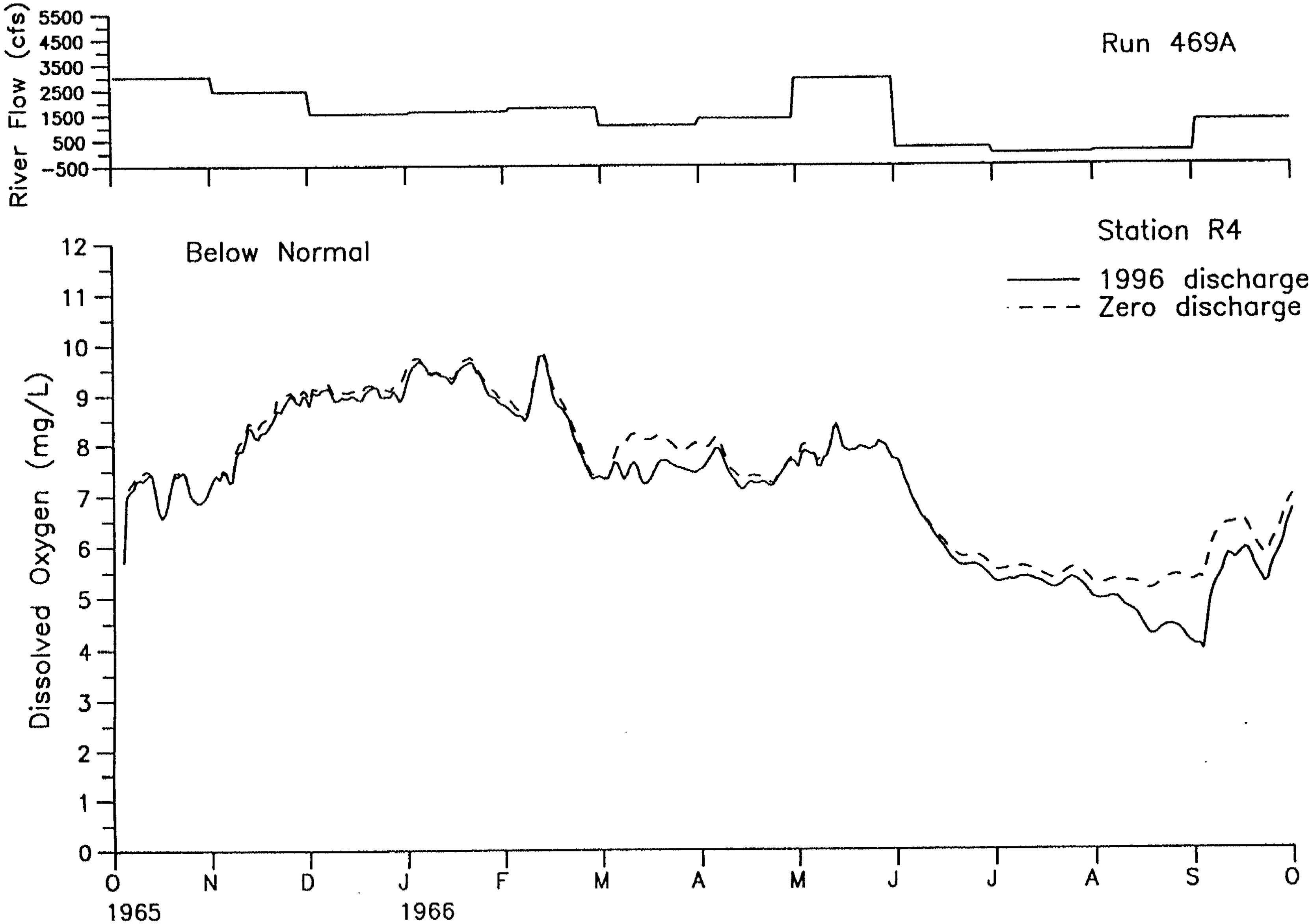
D-041737

D-041737

D-041738

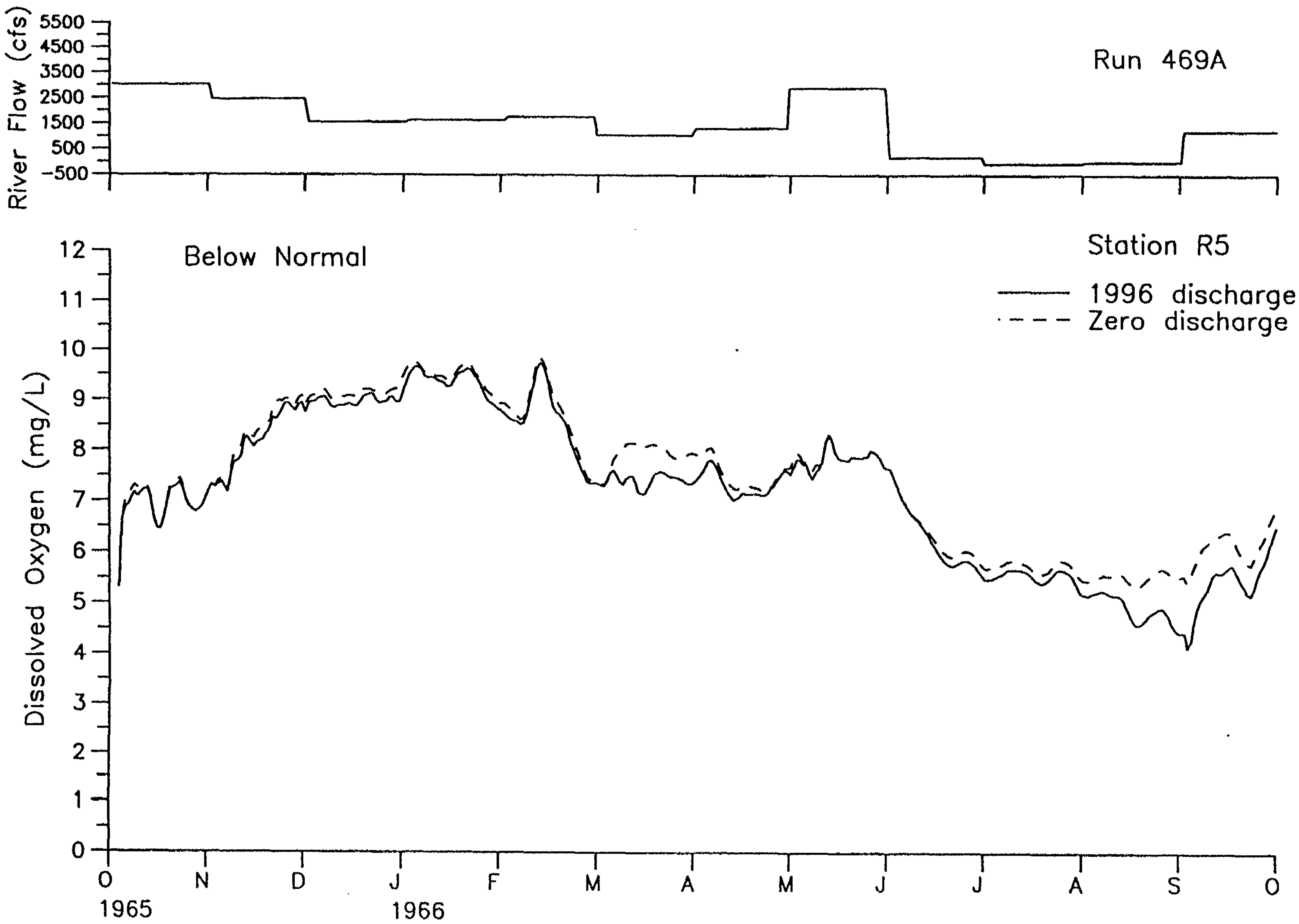


D-041738

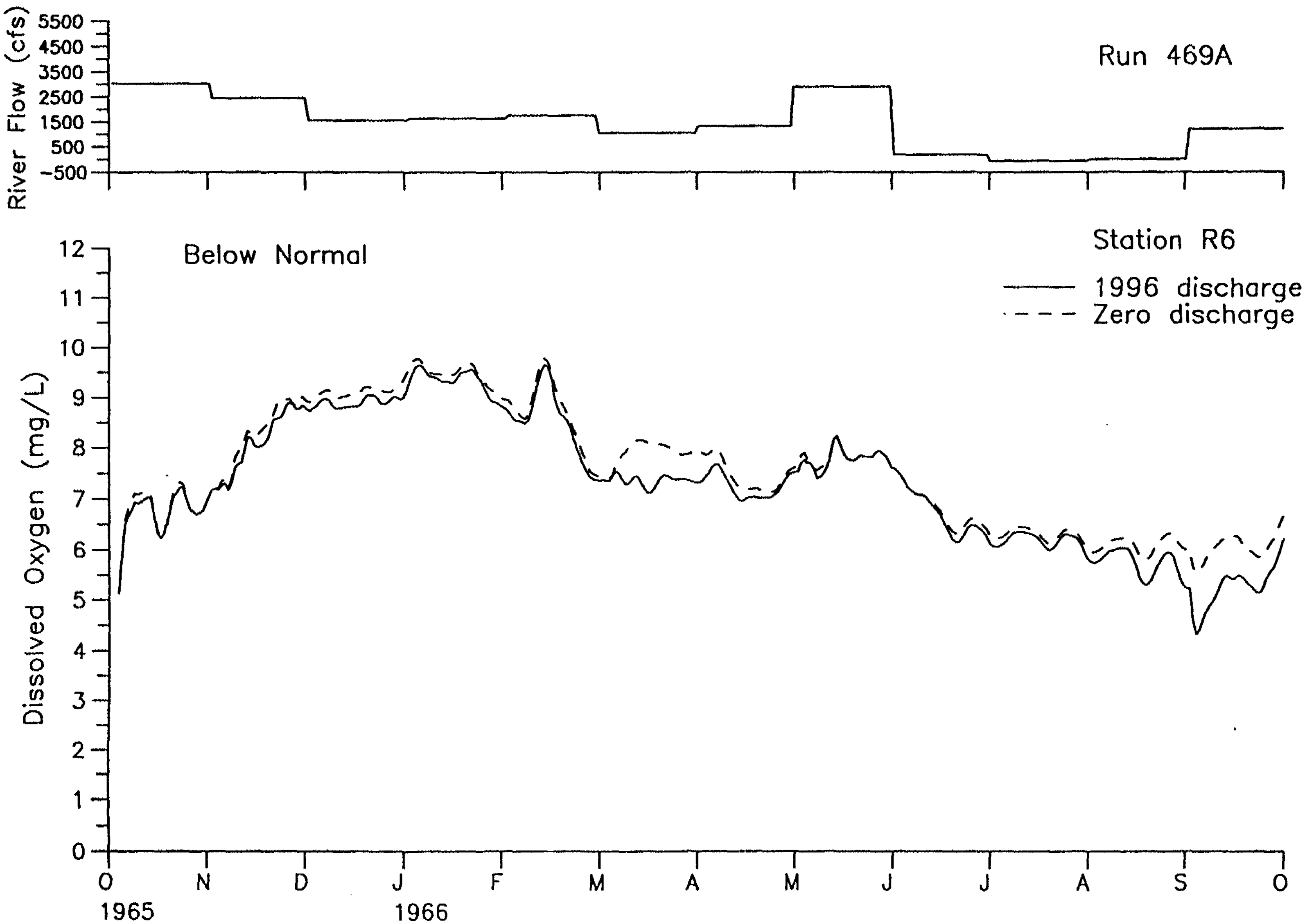


Run 469A
River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Station R4
Below Normal
1996 discharge
Zero discharge
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1965
1966

D—041739

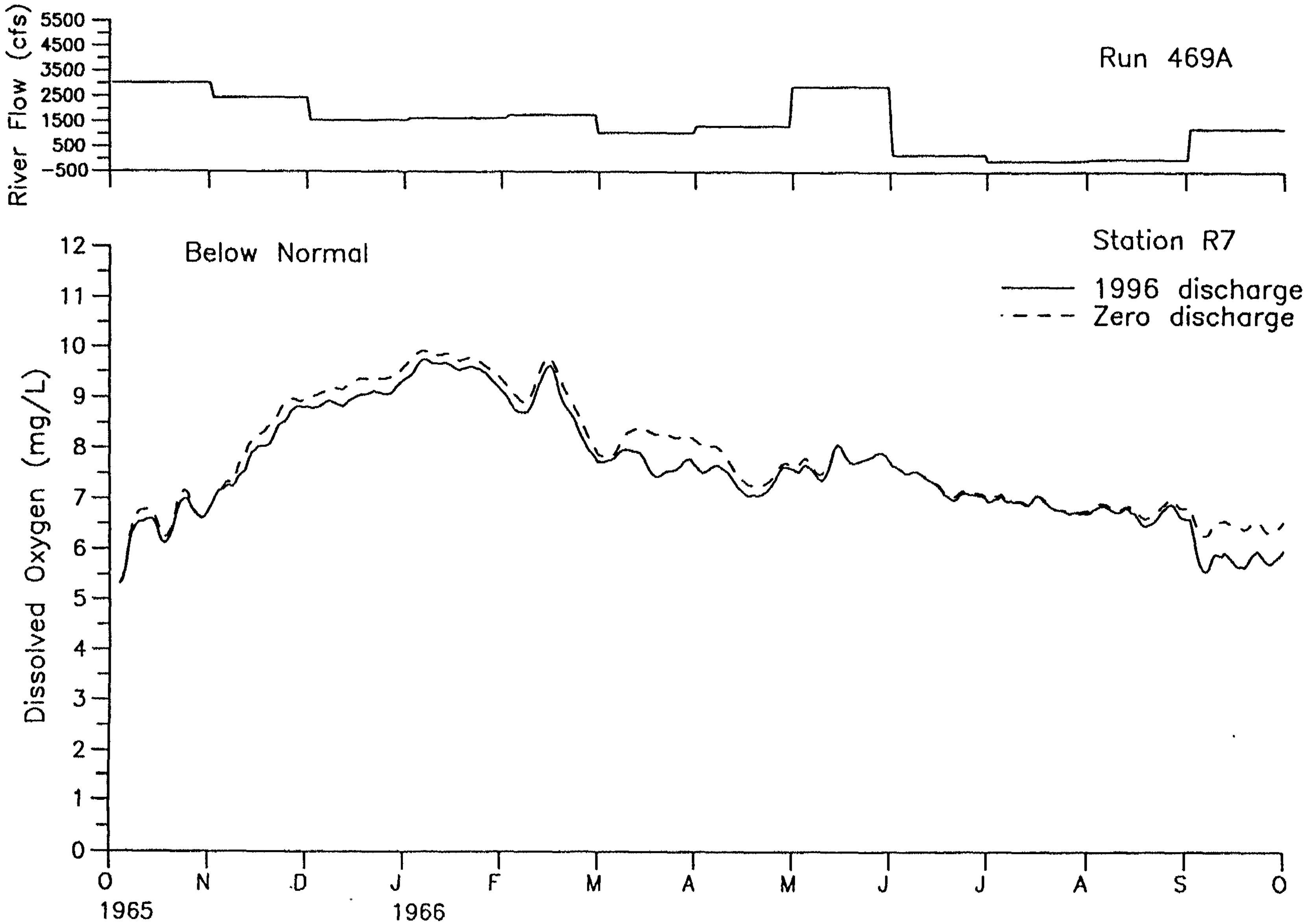


Run 469A
River Flow (cfs)
5500
4500
3500
2500
1500
500
-500
Below Normal
Station R5
1996 discharge
Zero discharge
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1965
1966



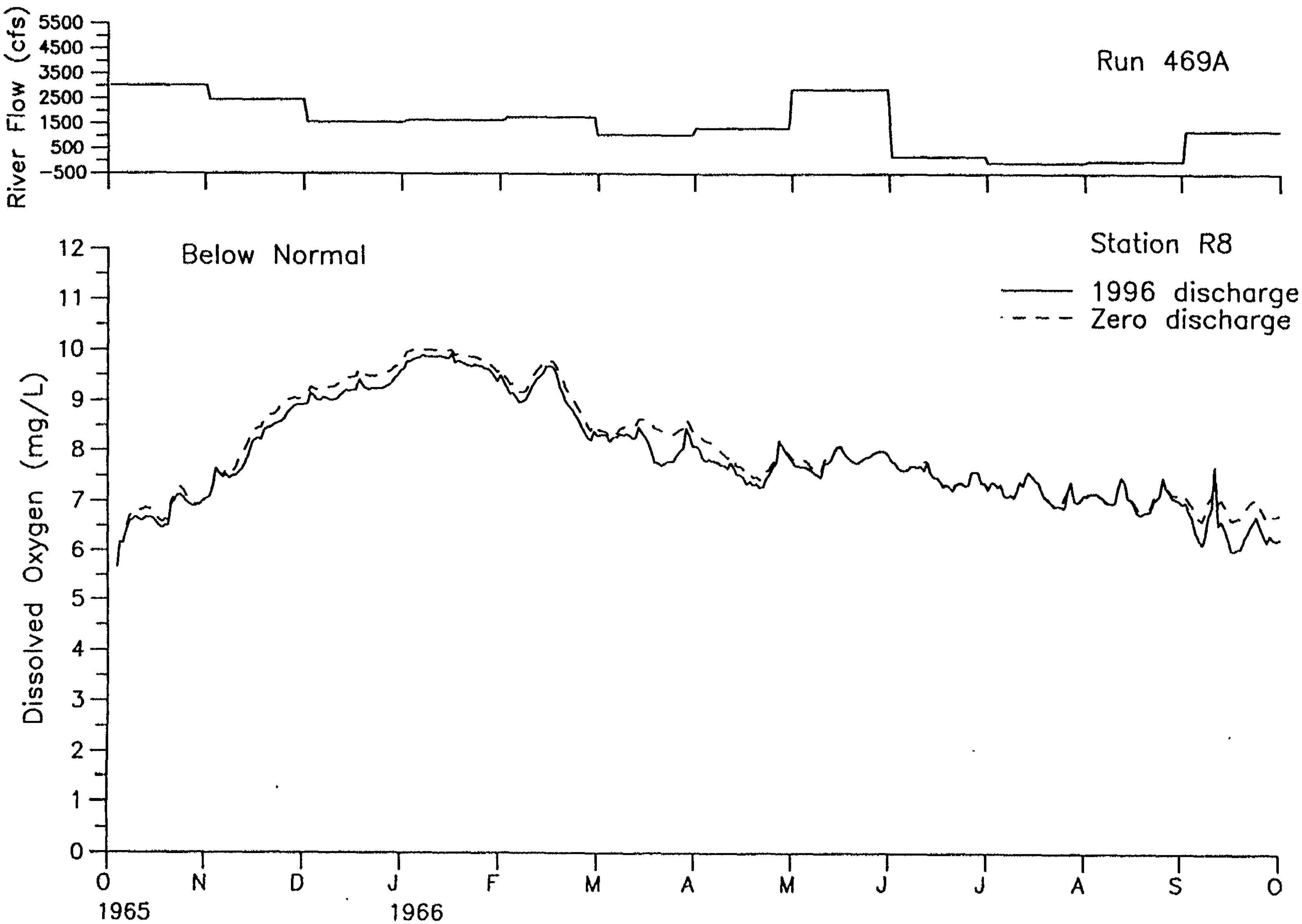
D-0 4 1 7 4 1

D-041741



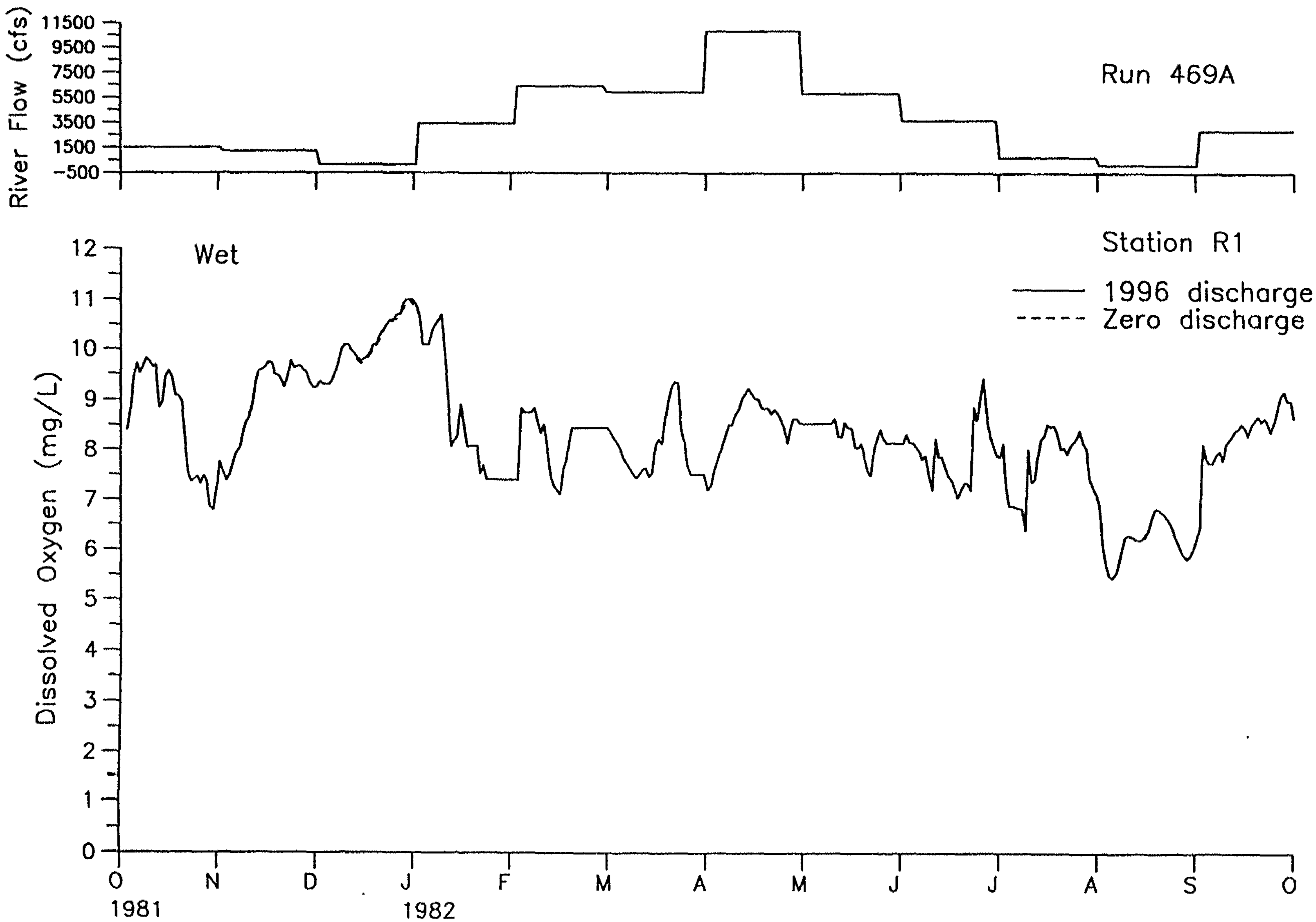
D-041742

D-041742



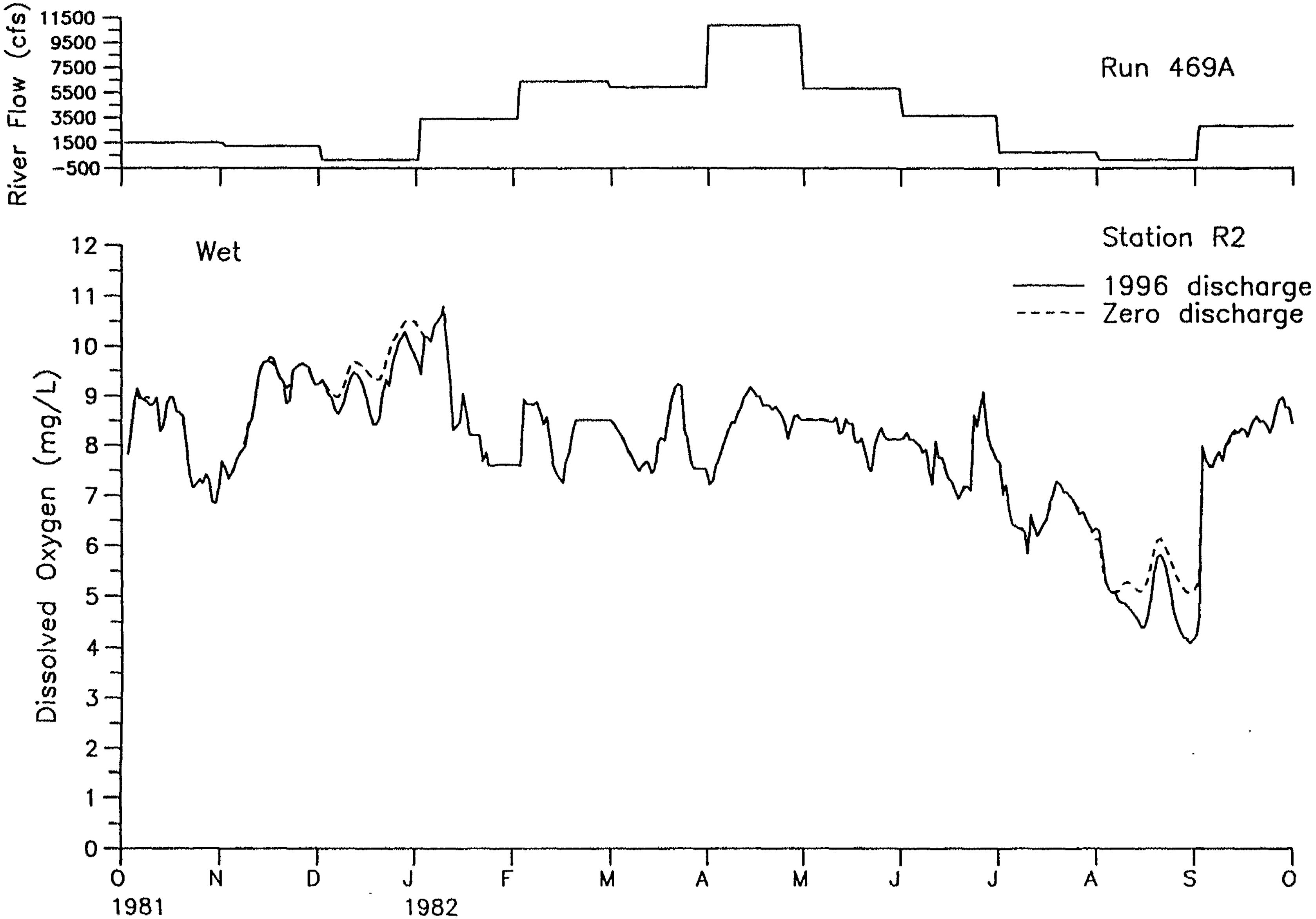
D-041743

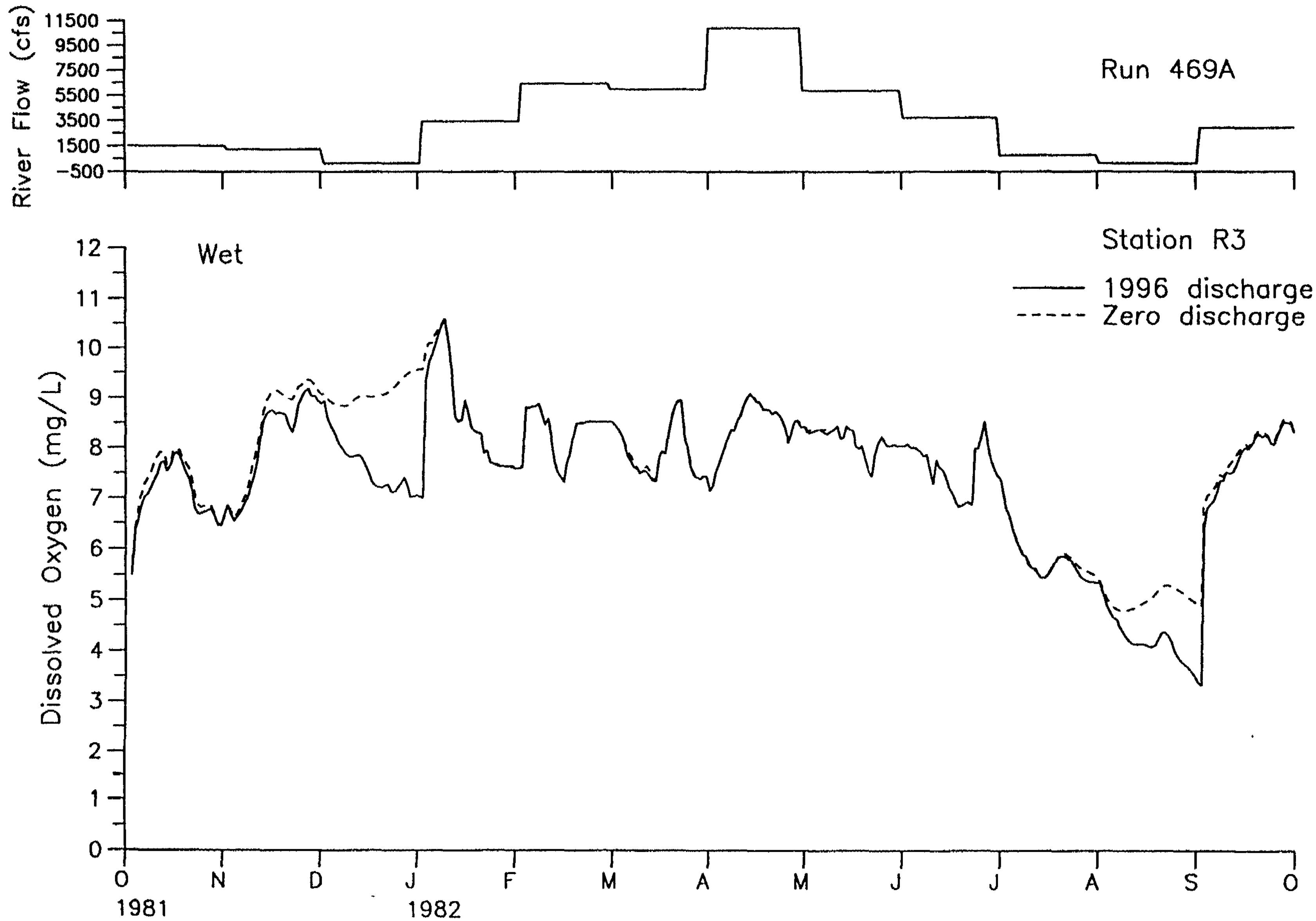
D-041743



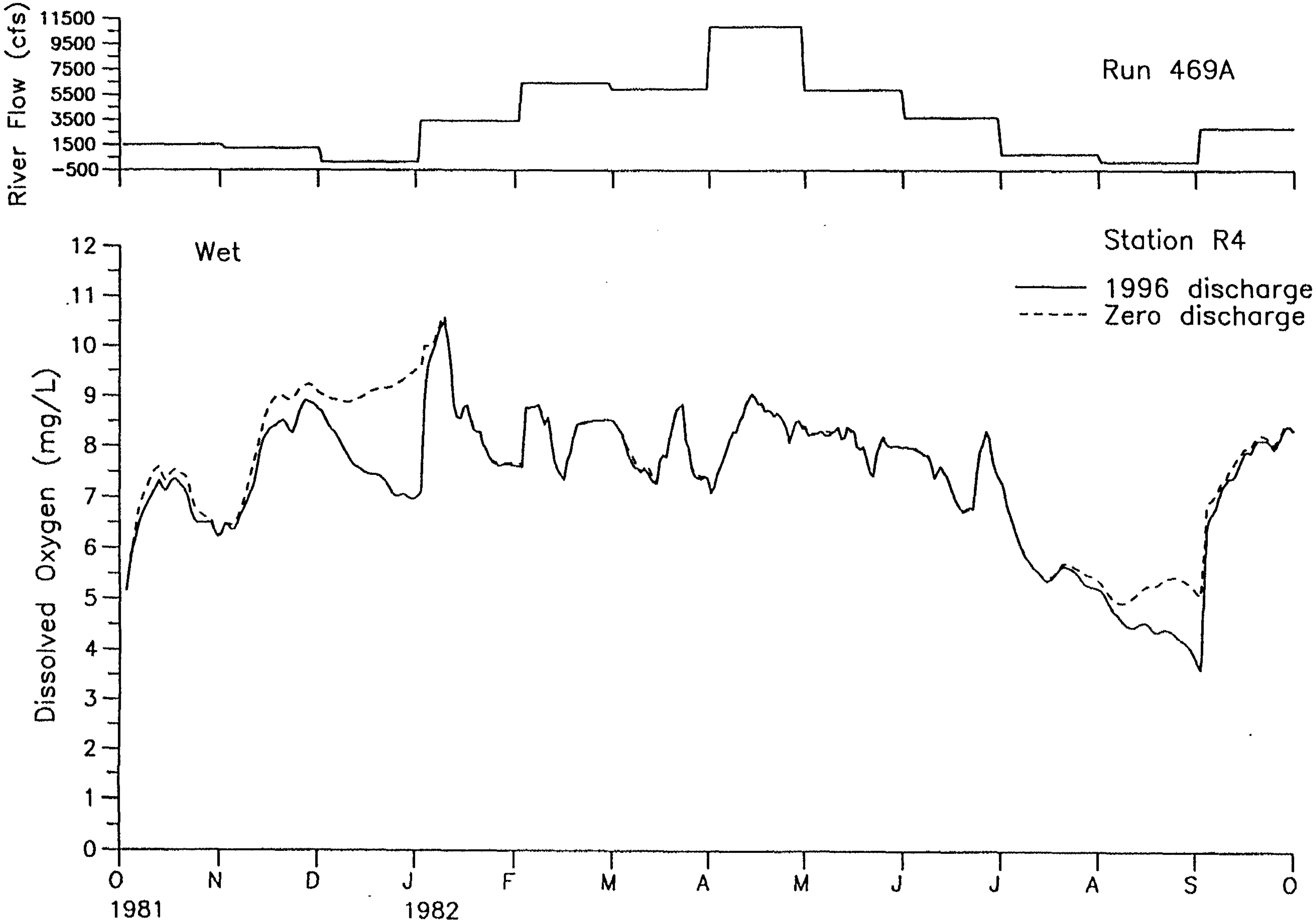
Run 469A
River Flow (cfs)
11500
9500
7500
5500
3500
1500
-500
Station R1
Wet
1996 discharge
Zero discharge
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1981
1982

D—041744

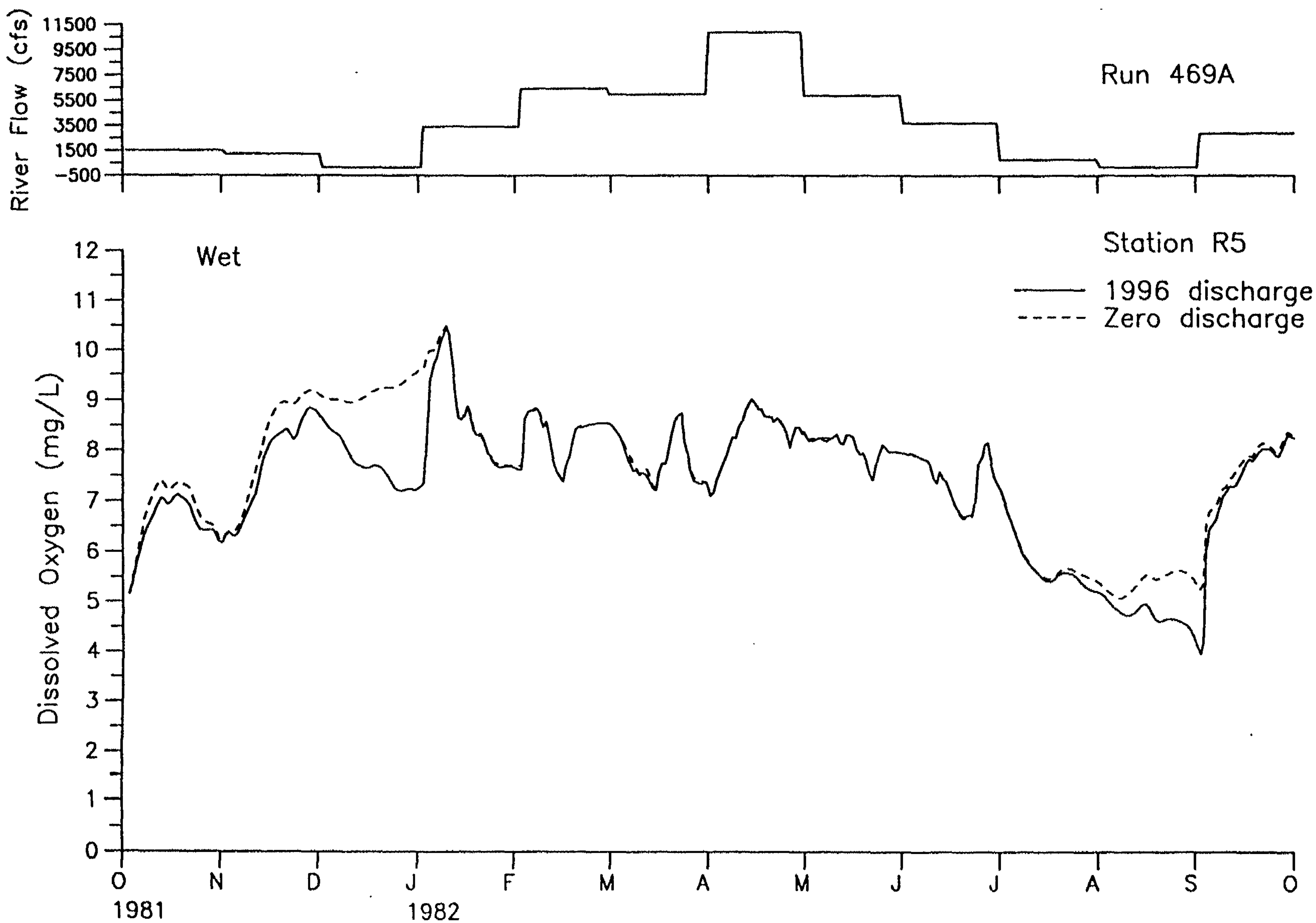

River Flow (cfs)
11500
9500
7500
5500
3500
1500
-500
Run 469A
Station R2
Wet
1996 discharge
Zero discharge
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1981
1982

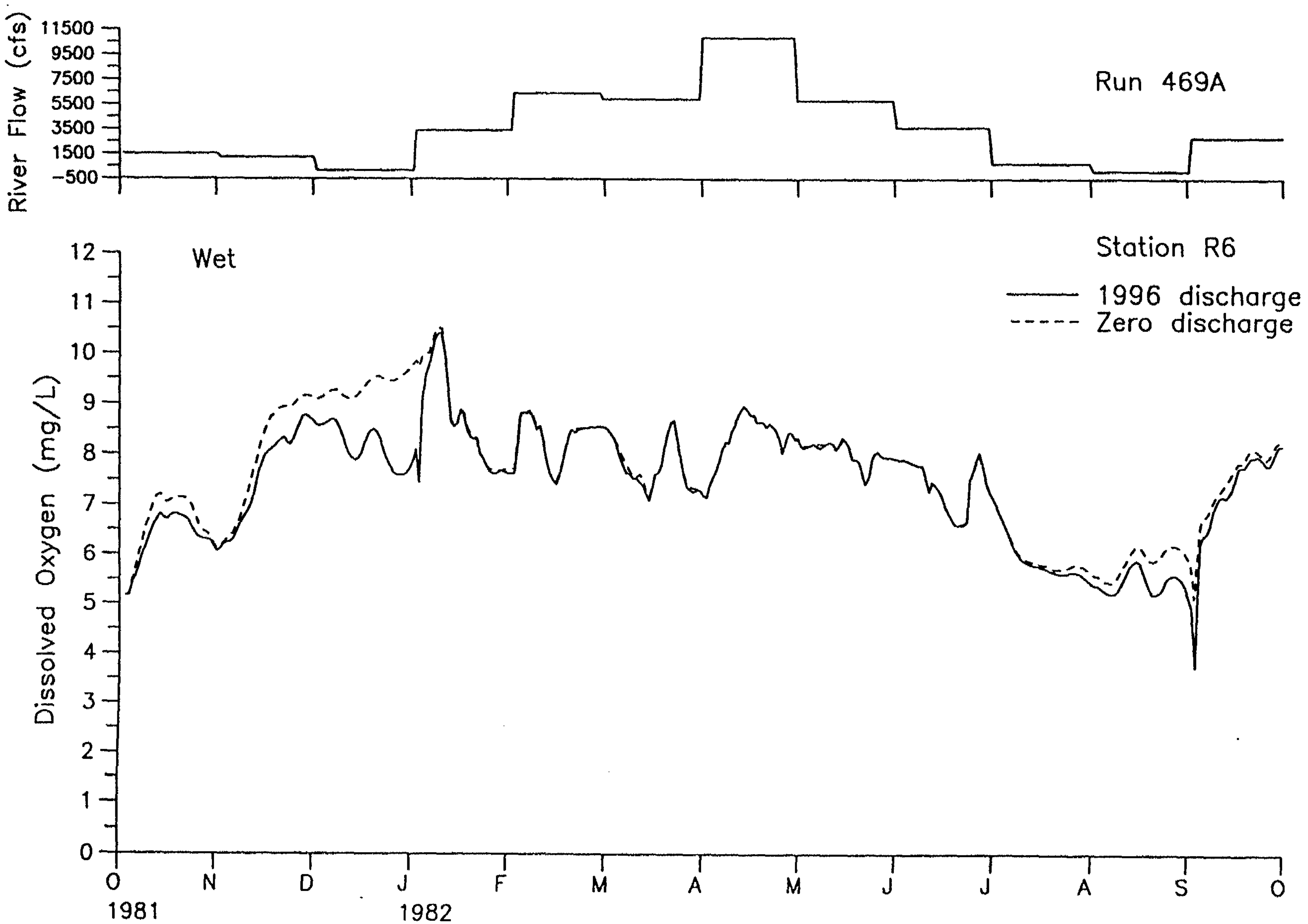

River Flow (cfs)
11500
9500
7500
5500
3500
1500
-500
Run 469A
Station R3
1996 discharge
Zero discharge
Wet
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1981
1982

D-041746

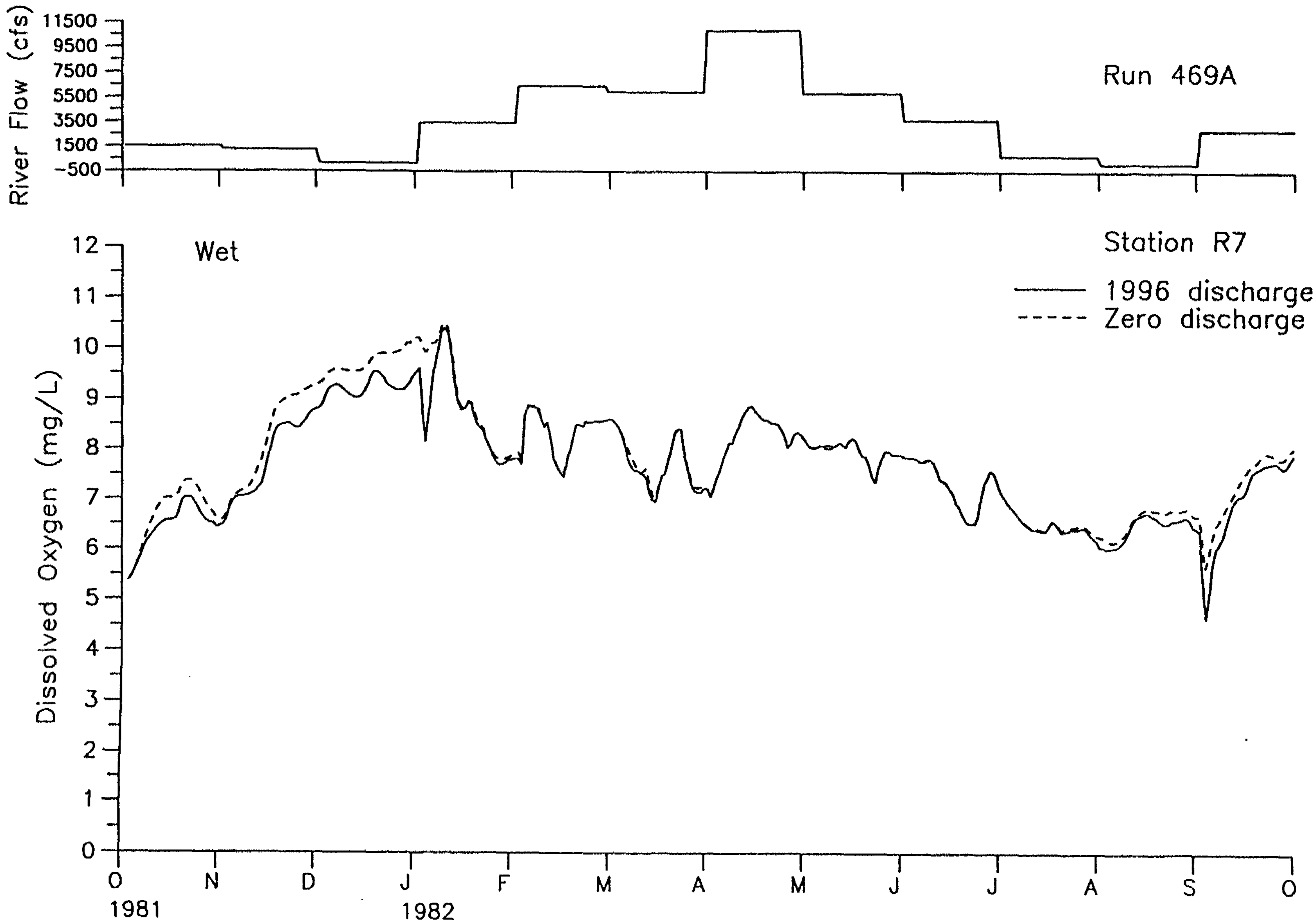

River Flow (cfs)
11500
9500
7500
5500
3500
1500
-500
Run 469A
Station R4
1996 discharge
Zero discharge
Wet
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1981
1982

D-041747


River Flow (cfs)
11500
9500
7500
5500
3500
1500
-500
Run 469A
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
Wet
Station R5
1996 discharge
Zero discharge
O
N
D
J
F
M
A
M
J
J
A
S
O
1981
1982

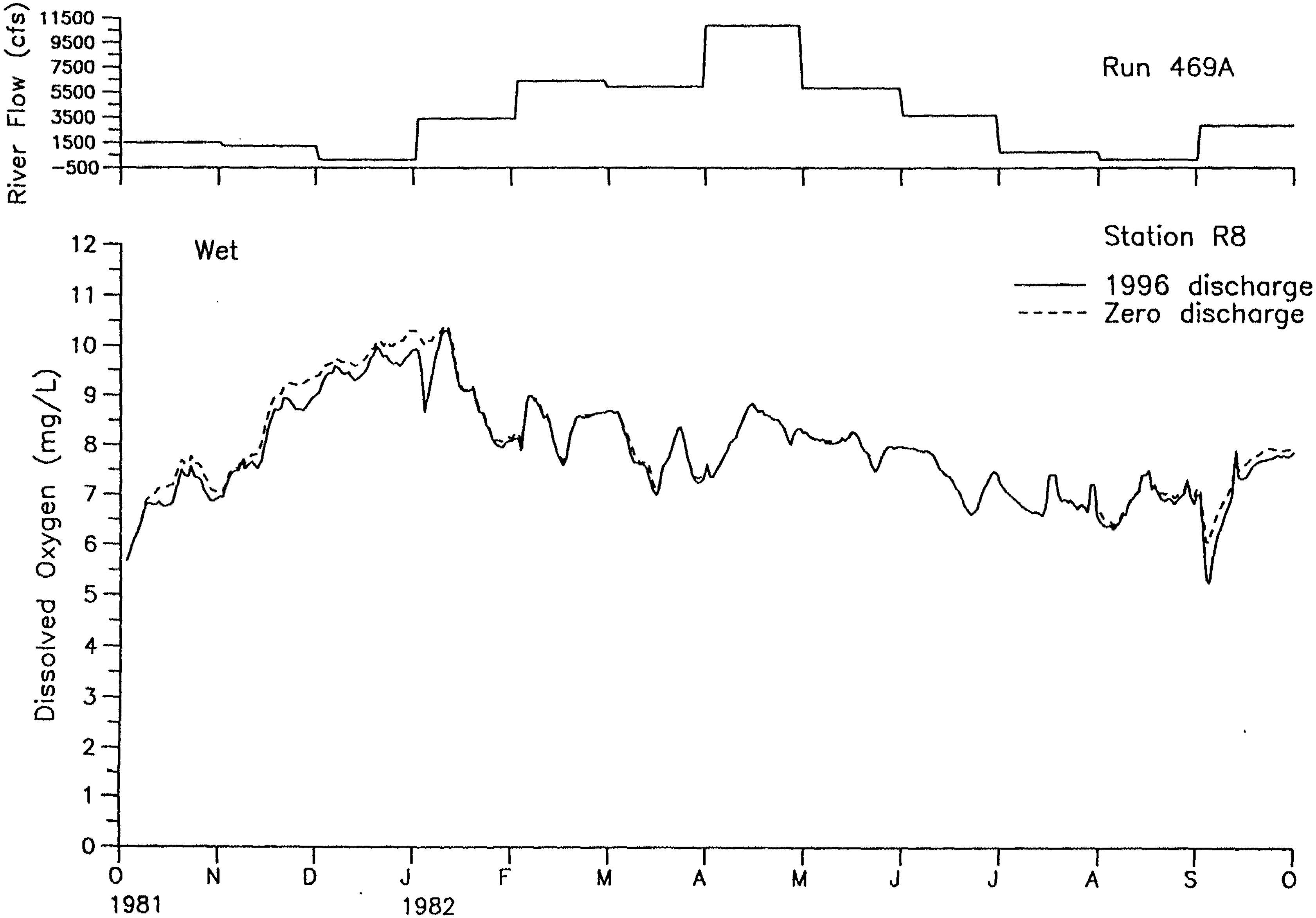

River Flow (cfs)
11500
9500
7500
5500
3500
1500
-500
Run 469A
Station R6
Wet
1996 discharge
Zero discharge
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1981
1982

D-041749



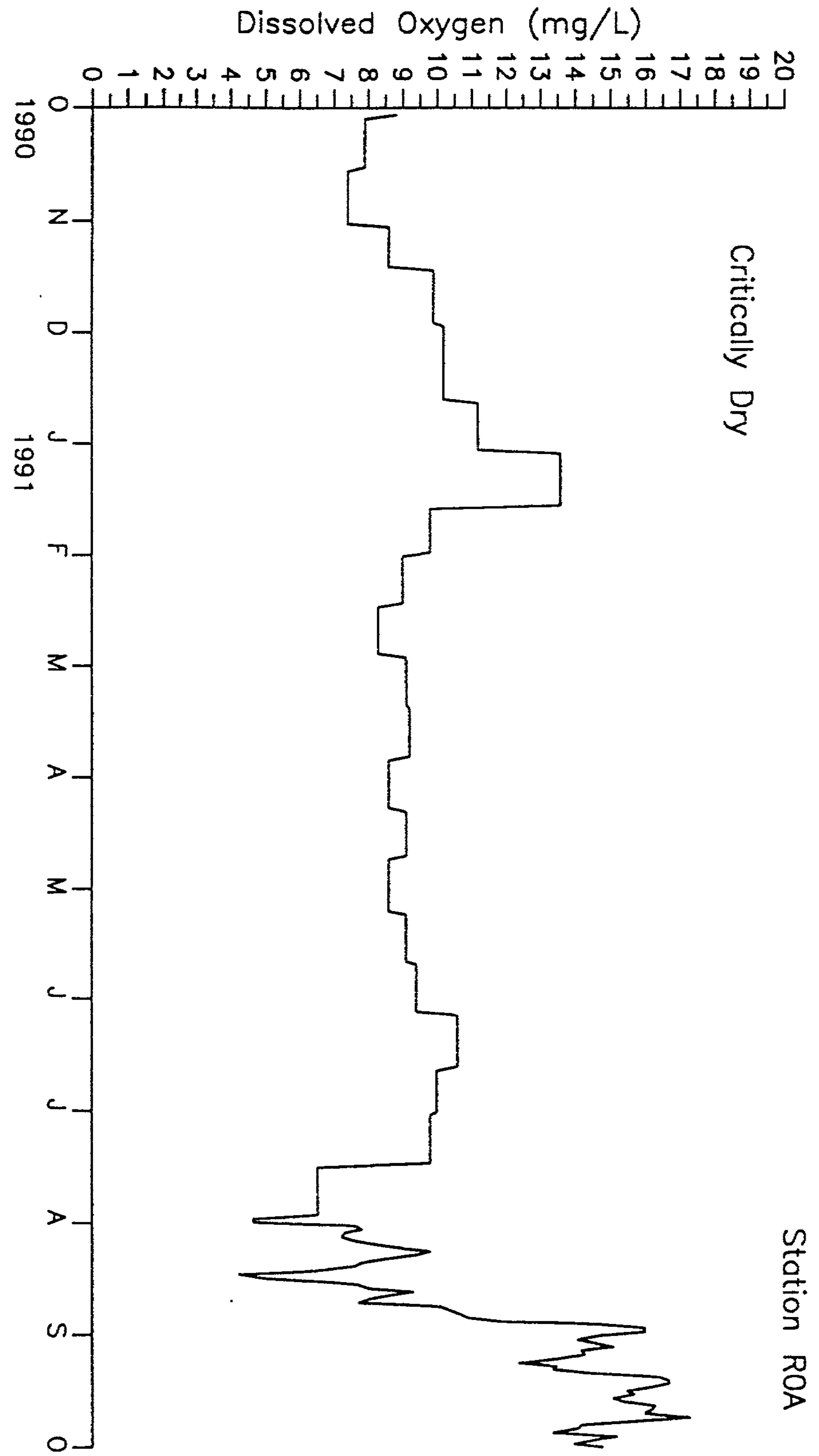
D—041750

D-041750

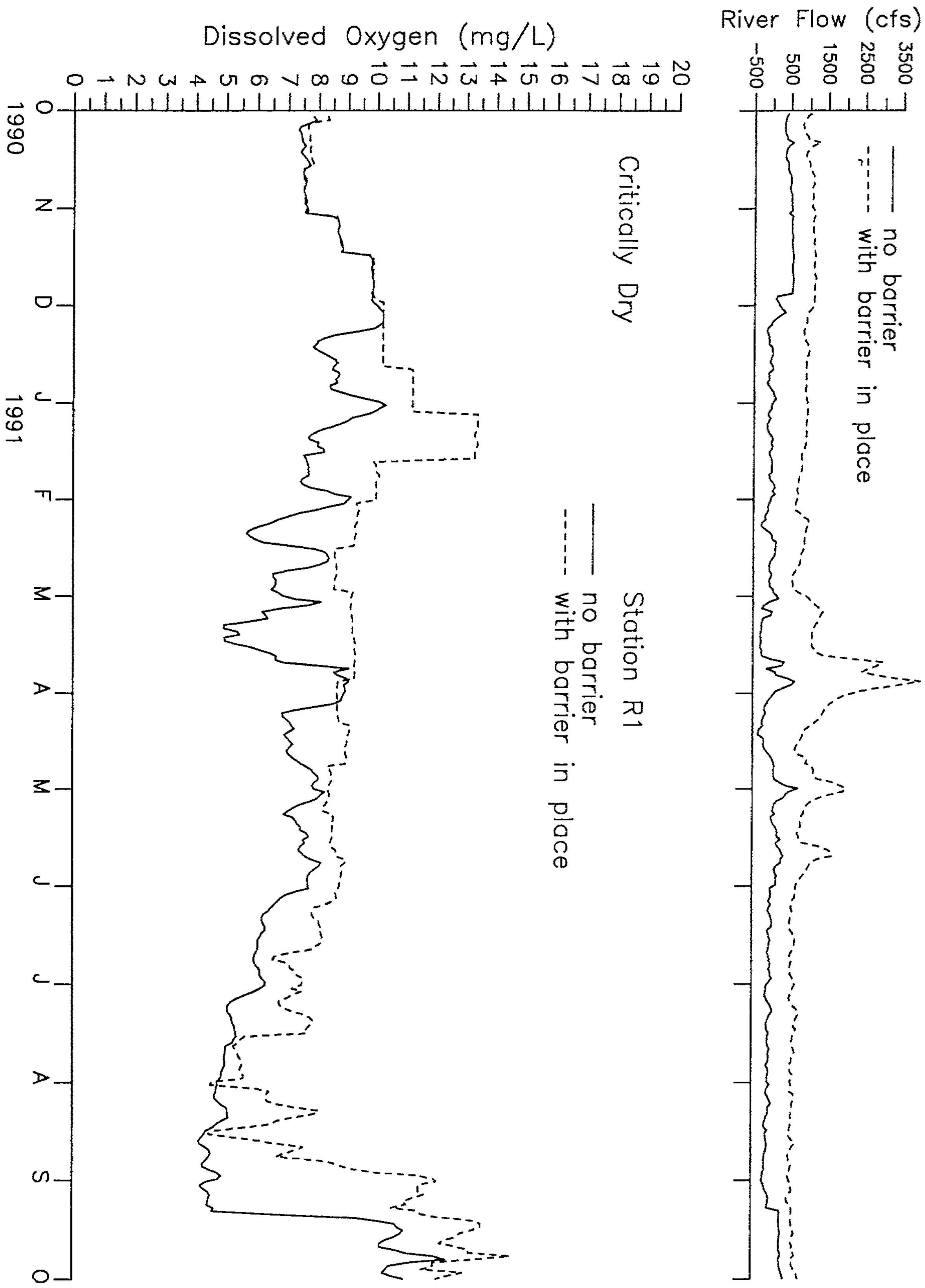

River Flow (cfs)
11500
9500
7500
5500
3500
1500
-500
Run 469A
Station R8
Wet
1996 discharge
Zero discharge
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1981
1982

Appendix O.

DO Without Flow Diversion to the Old River

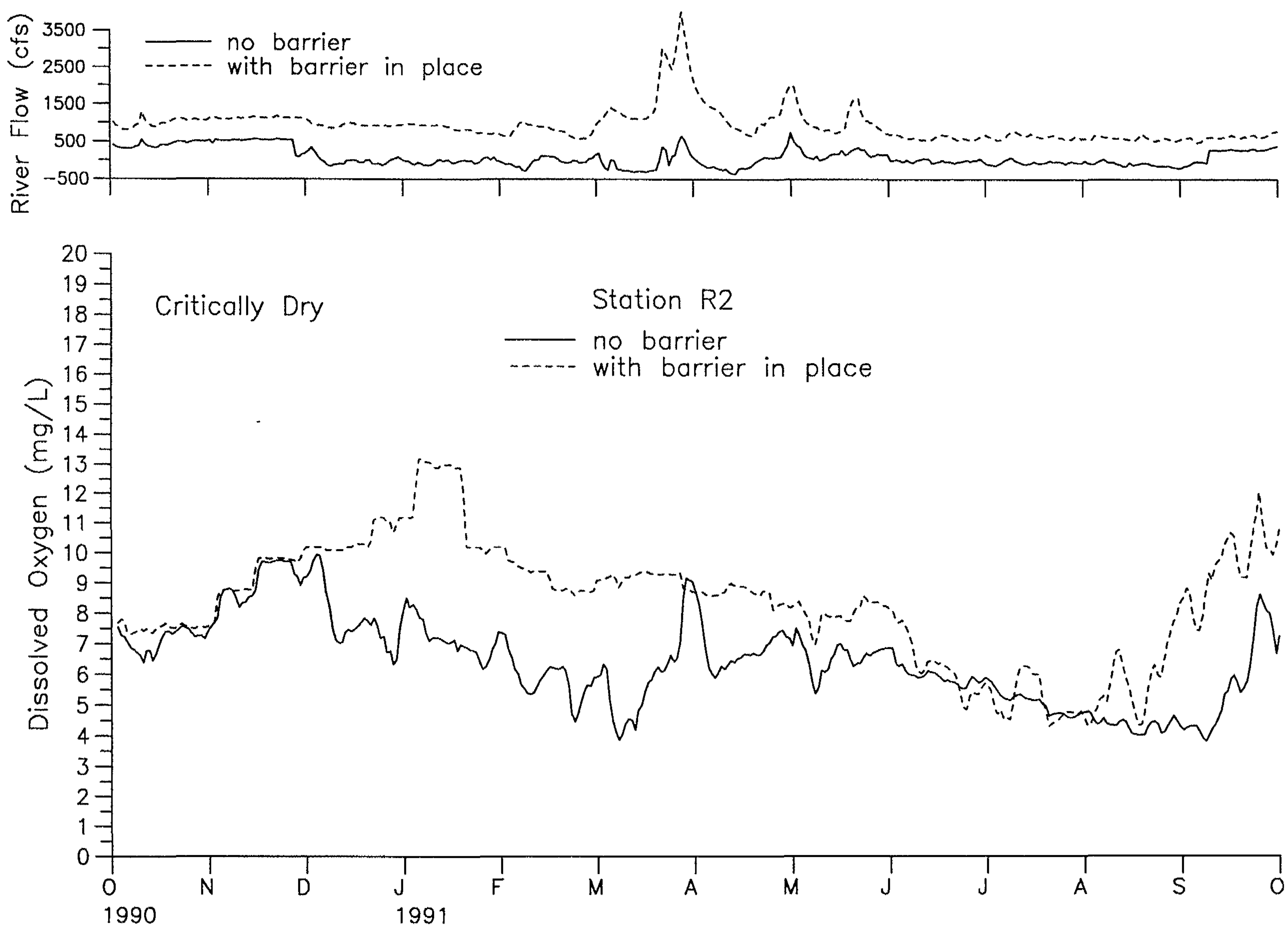

Dissolved Oxygen (mg/L)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
O N D J F M A M J J A S O
1990
1991
Critically Dry
Station ROA

D-041753



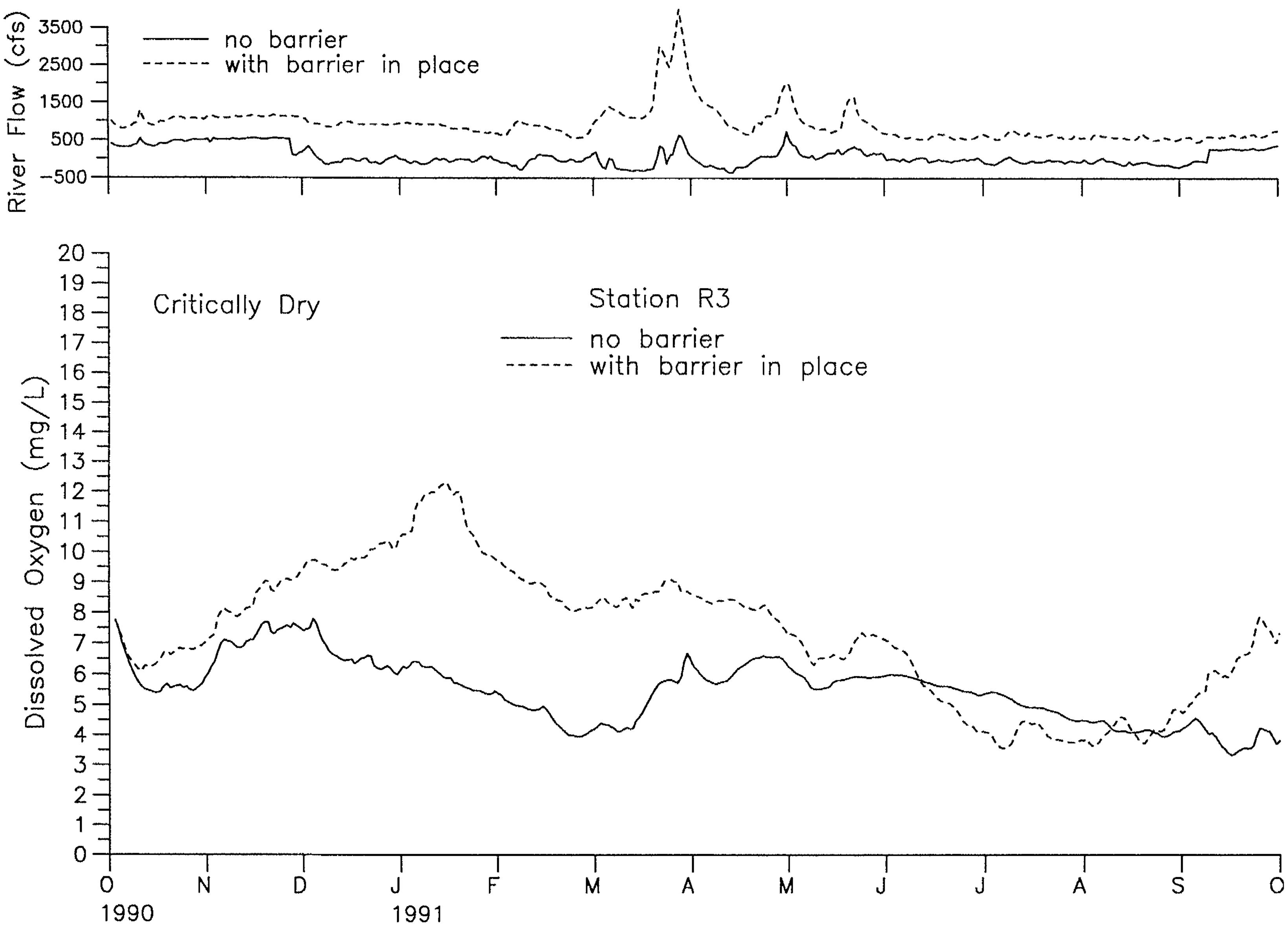
D-041754

D-041754



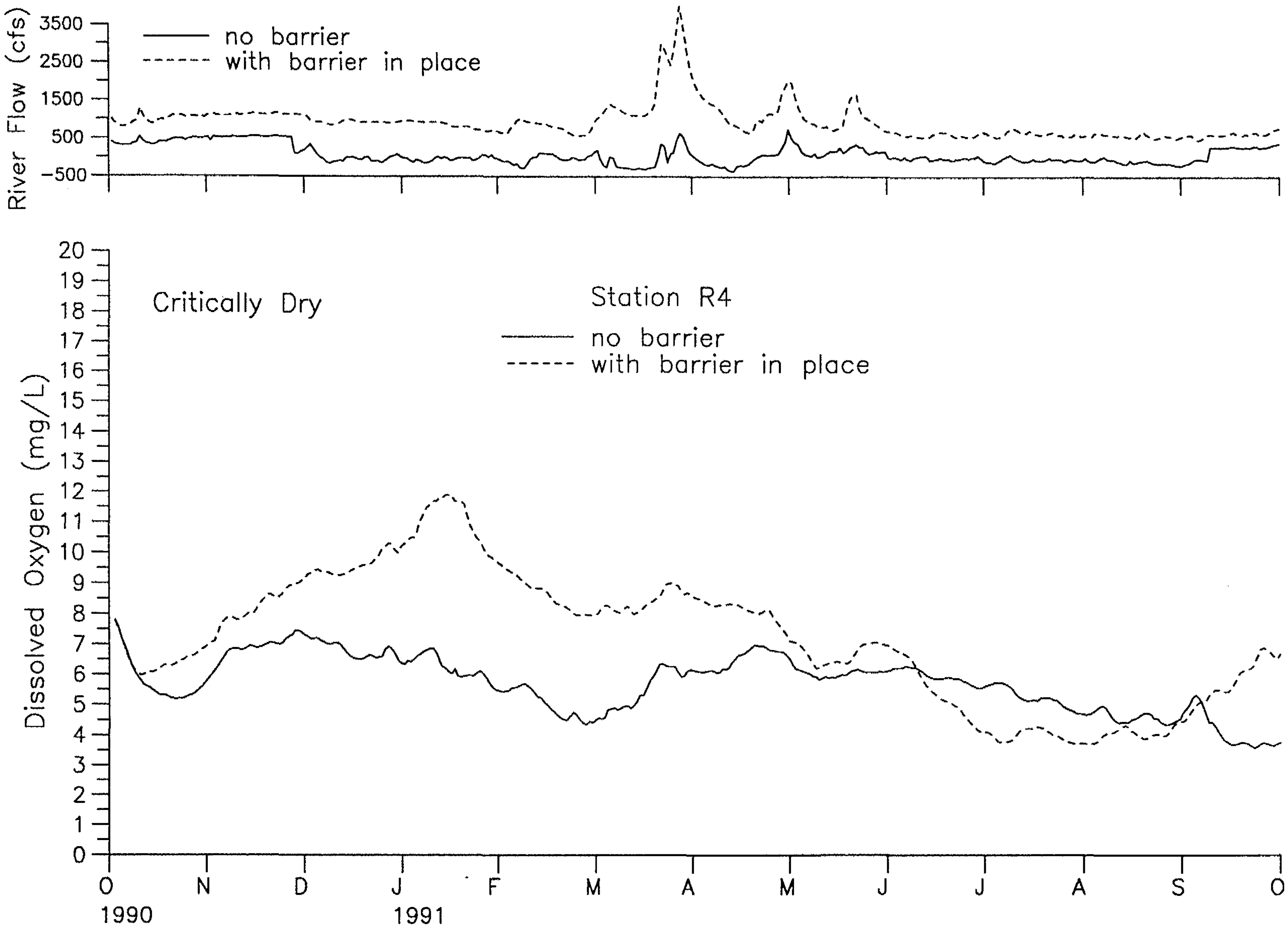
D-041755

D-041755



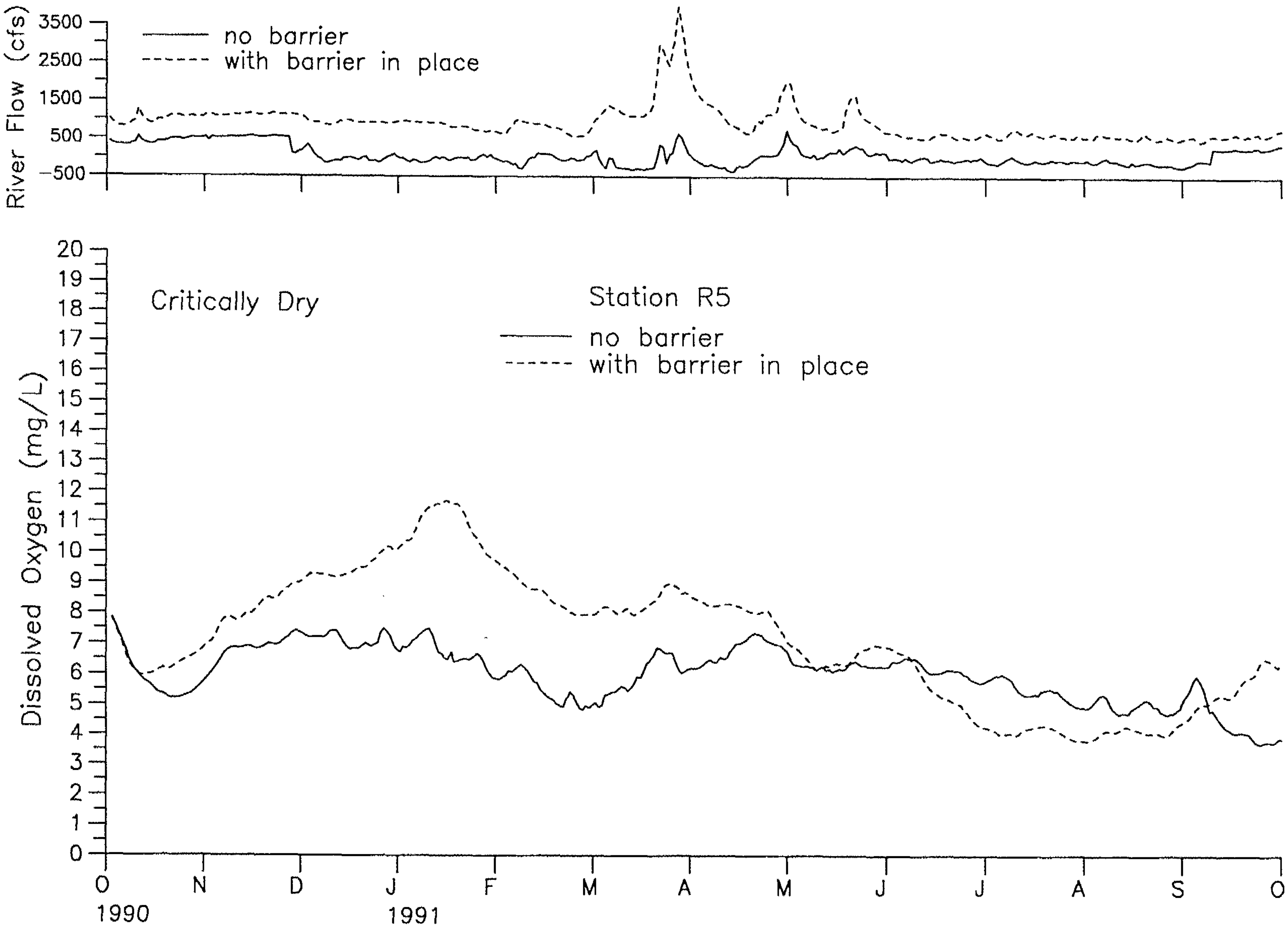
D-041756

D — 0 4 1 7 5 6

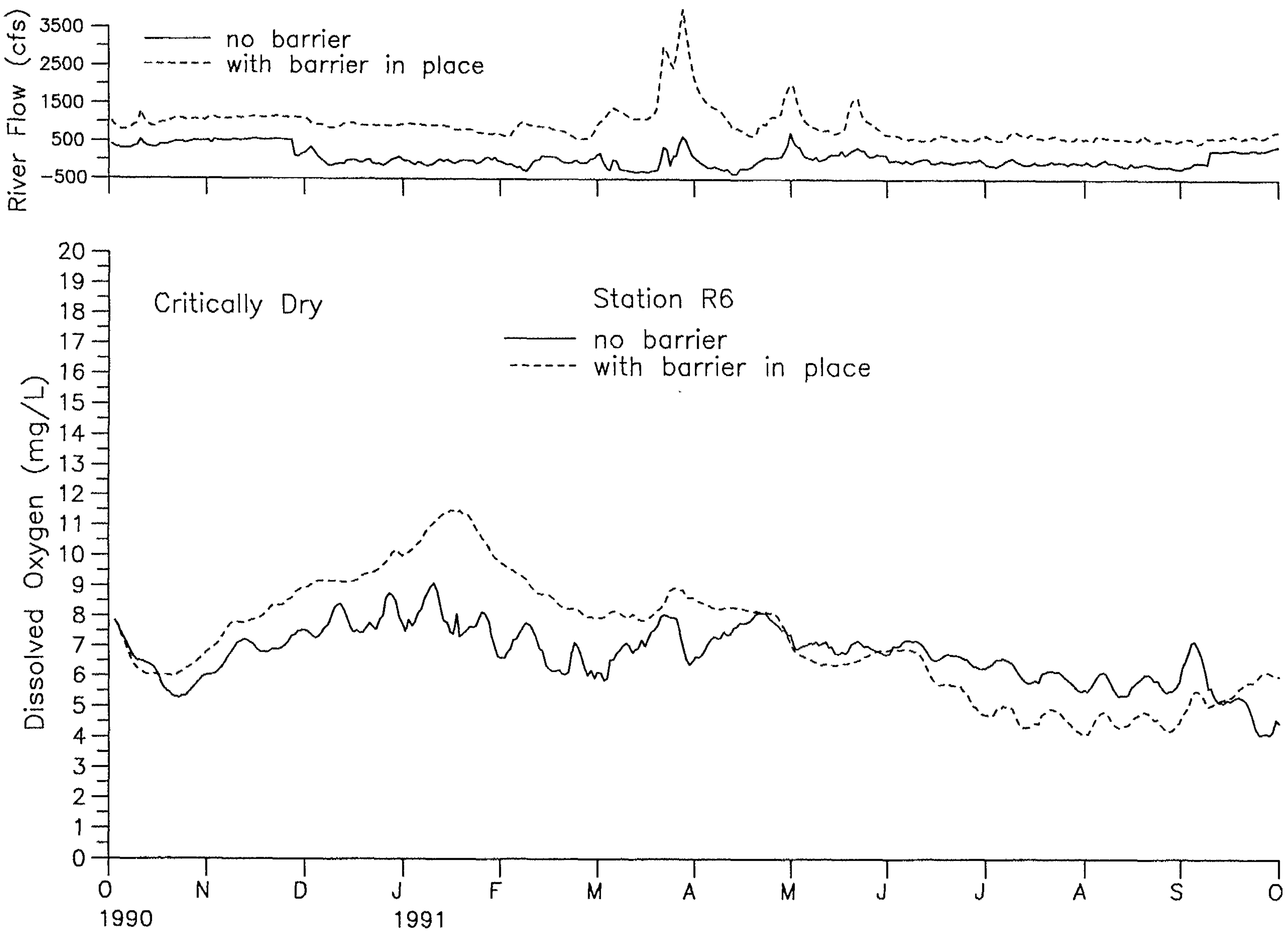


D-041757

D-041757

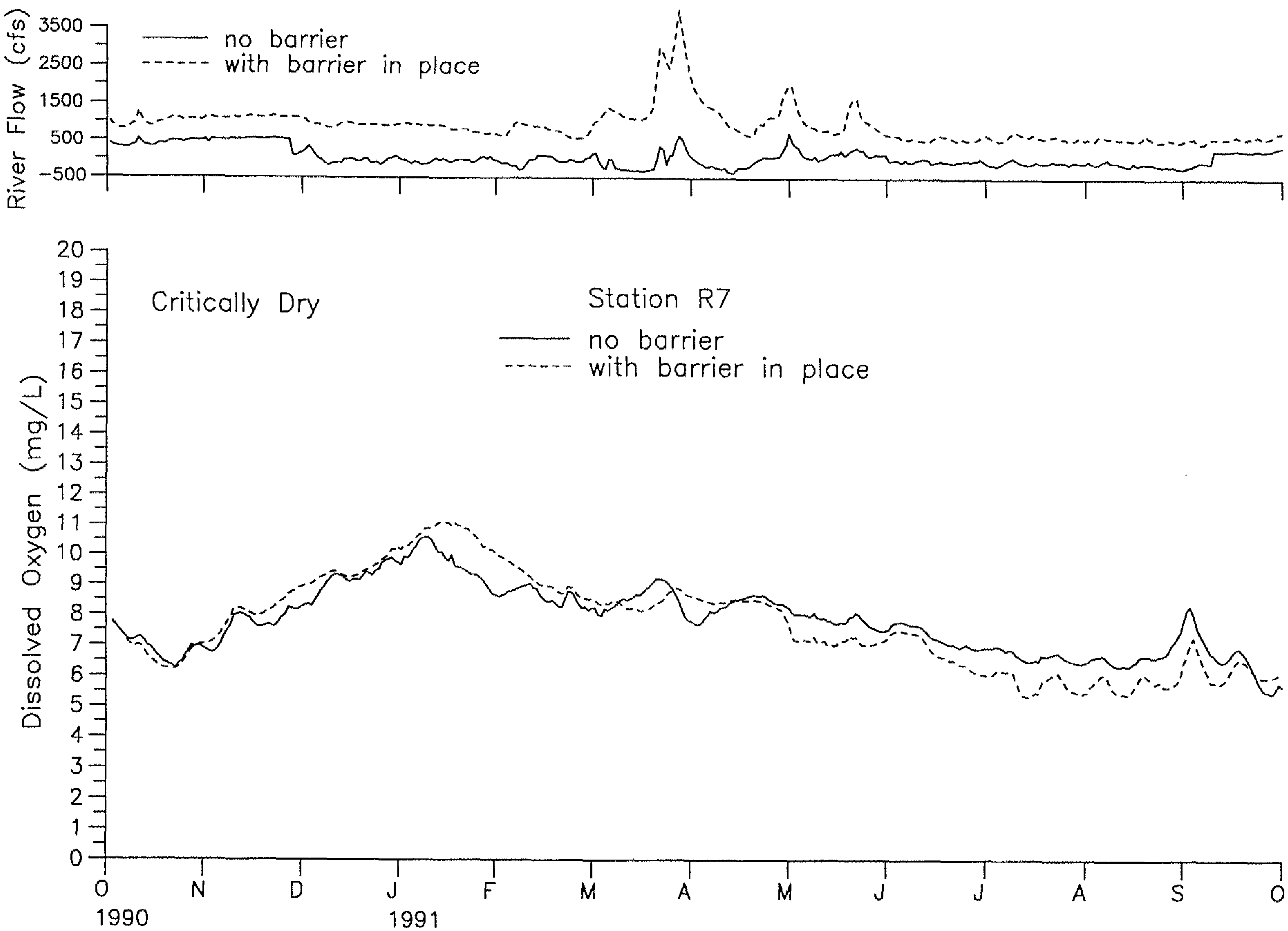

River Flow (cfs)
3500
2500
1500
500
-500
no barrier
with barrier in place
Dissolved Oxygen (mg/L)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Critically Dry
Station R5
no barrier
with barrier in place
O N D J F M A M J J A S O
1990
1991

D-041758



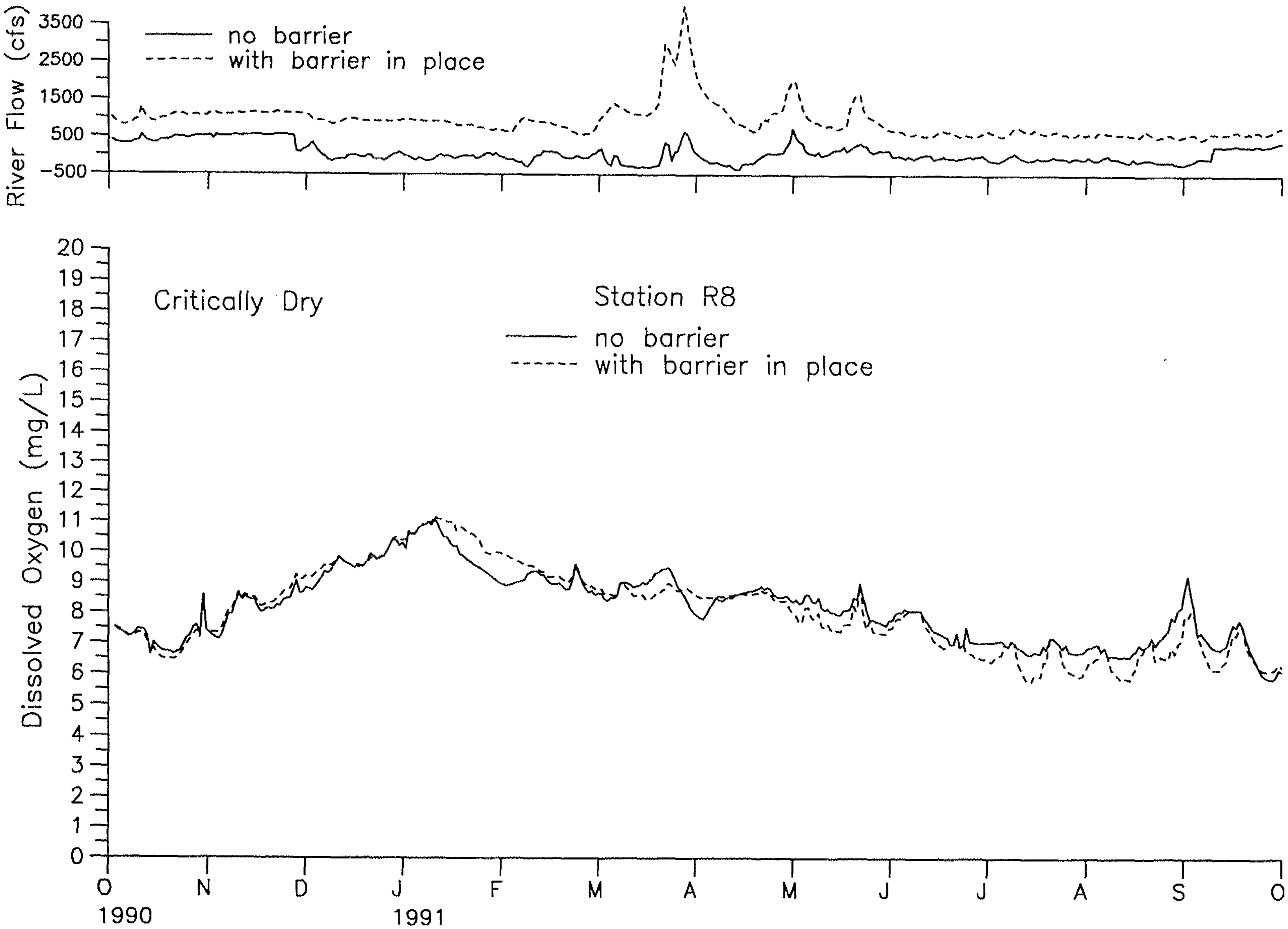
D-041759

D-041759



D—041760

D-041760



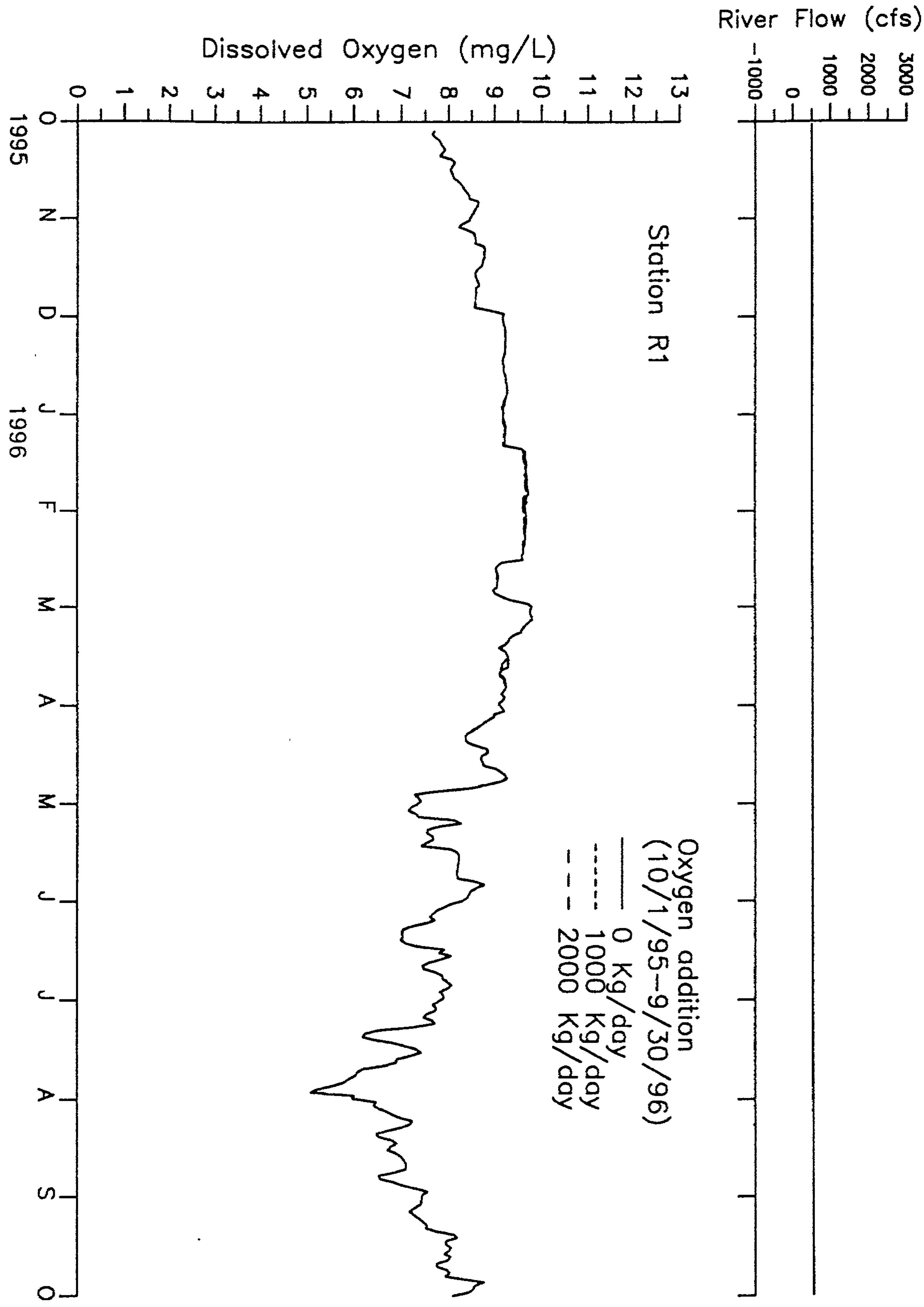
D-041761

D-041761

Appendix P.

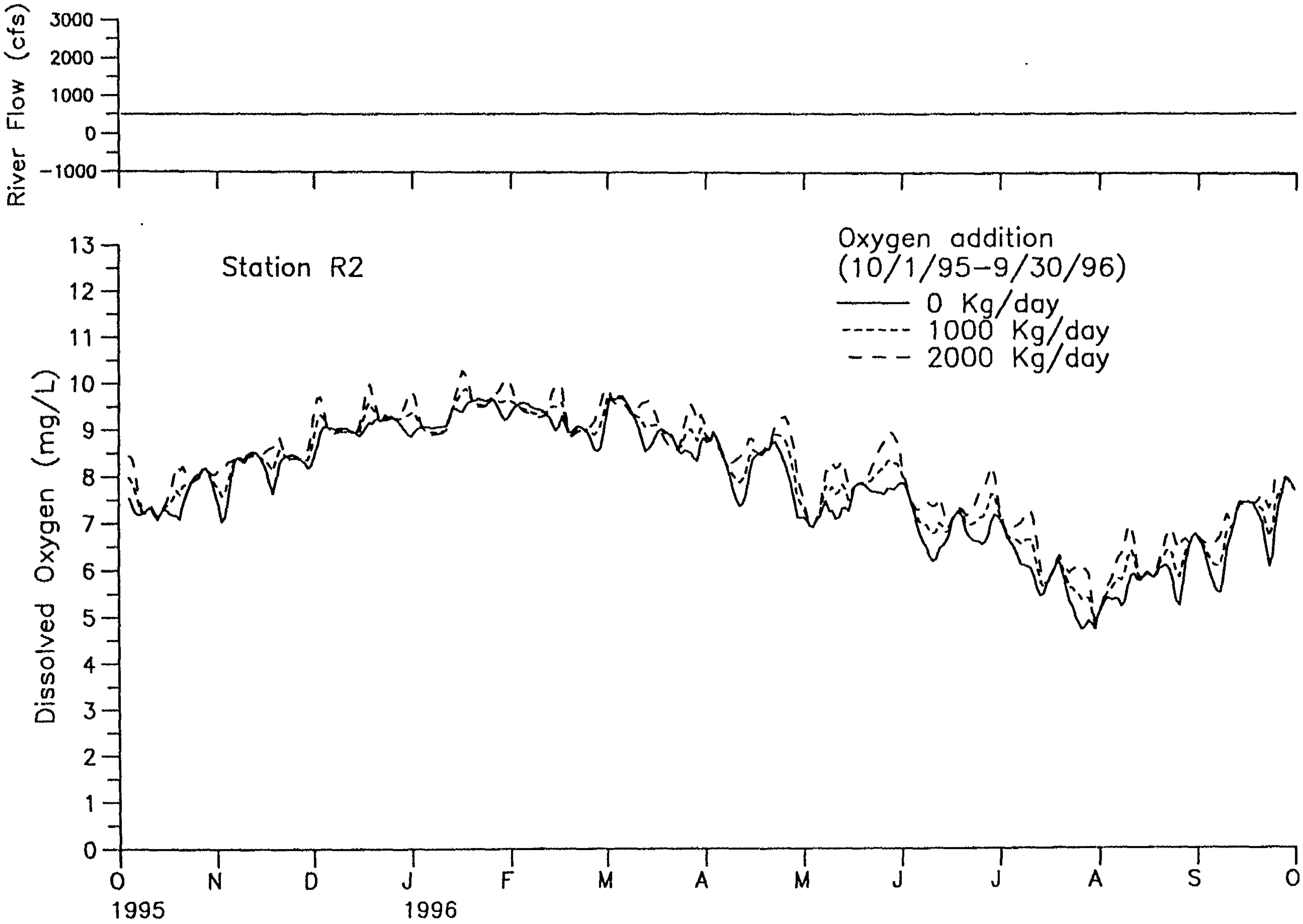
DO With Oxygen Addition

D-041762



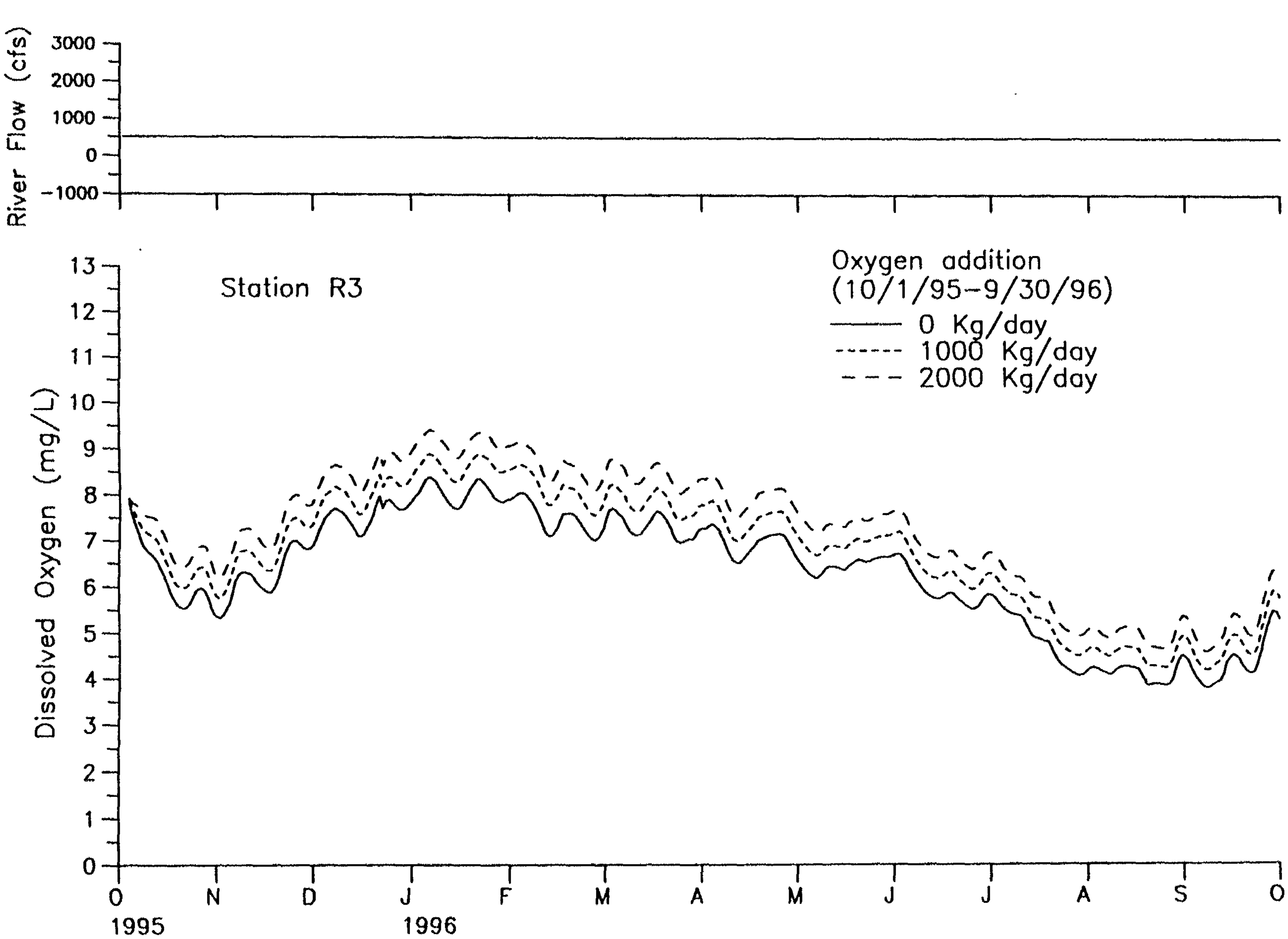
River Flow (cfs)
-1000
0
1000
2000
3000
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Station R1
Oxygen addition
(10/1/95–9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
O
1995
N
D
J
1996
F
M
A
M
J
J
A
S
O

D-041763



D-041764

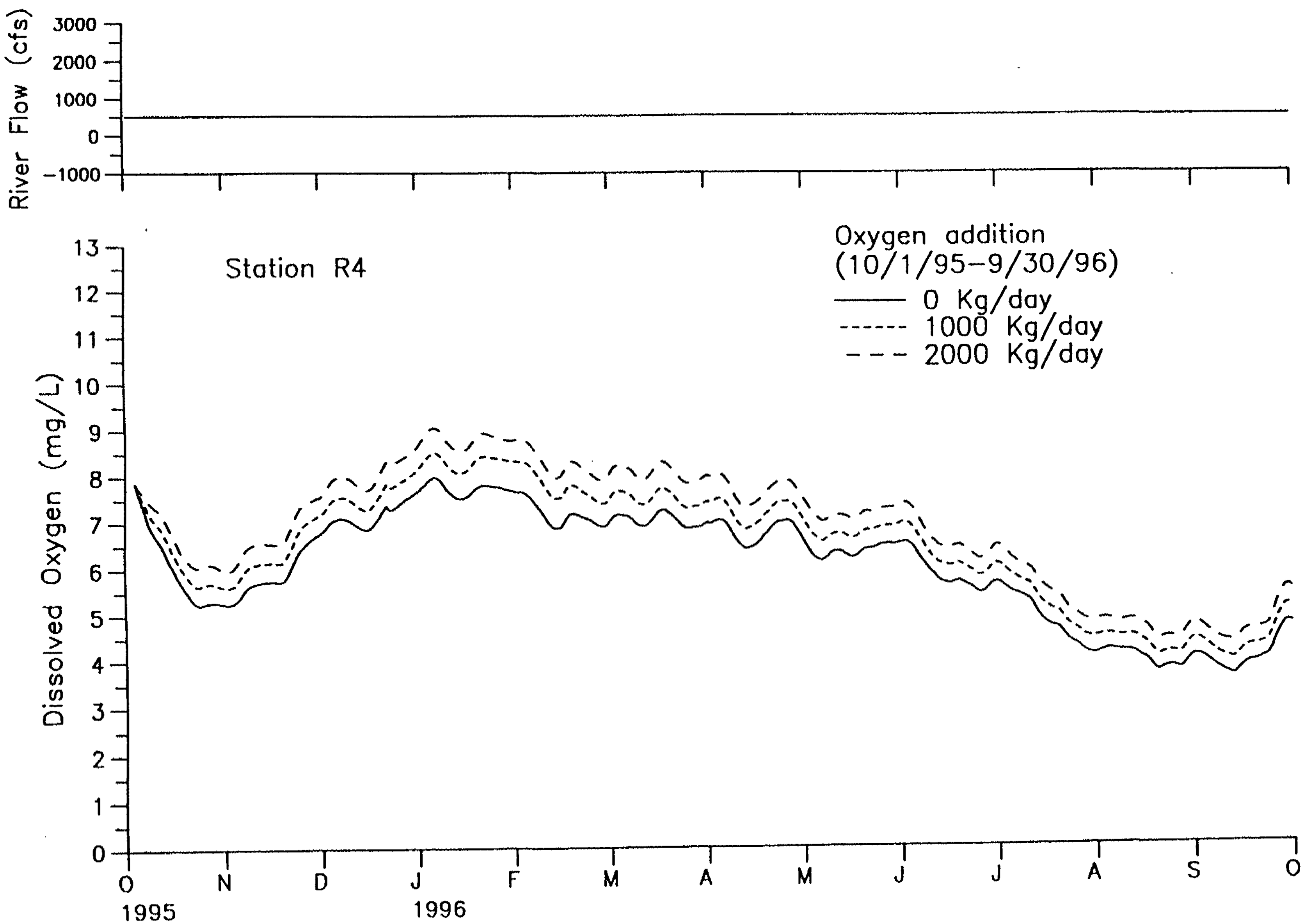
D-041764



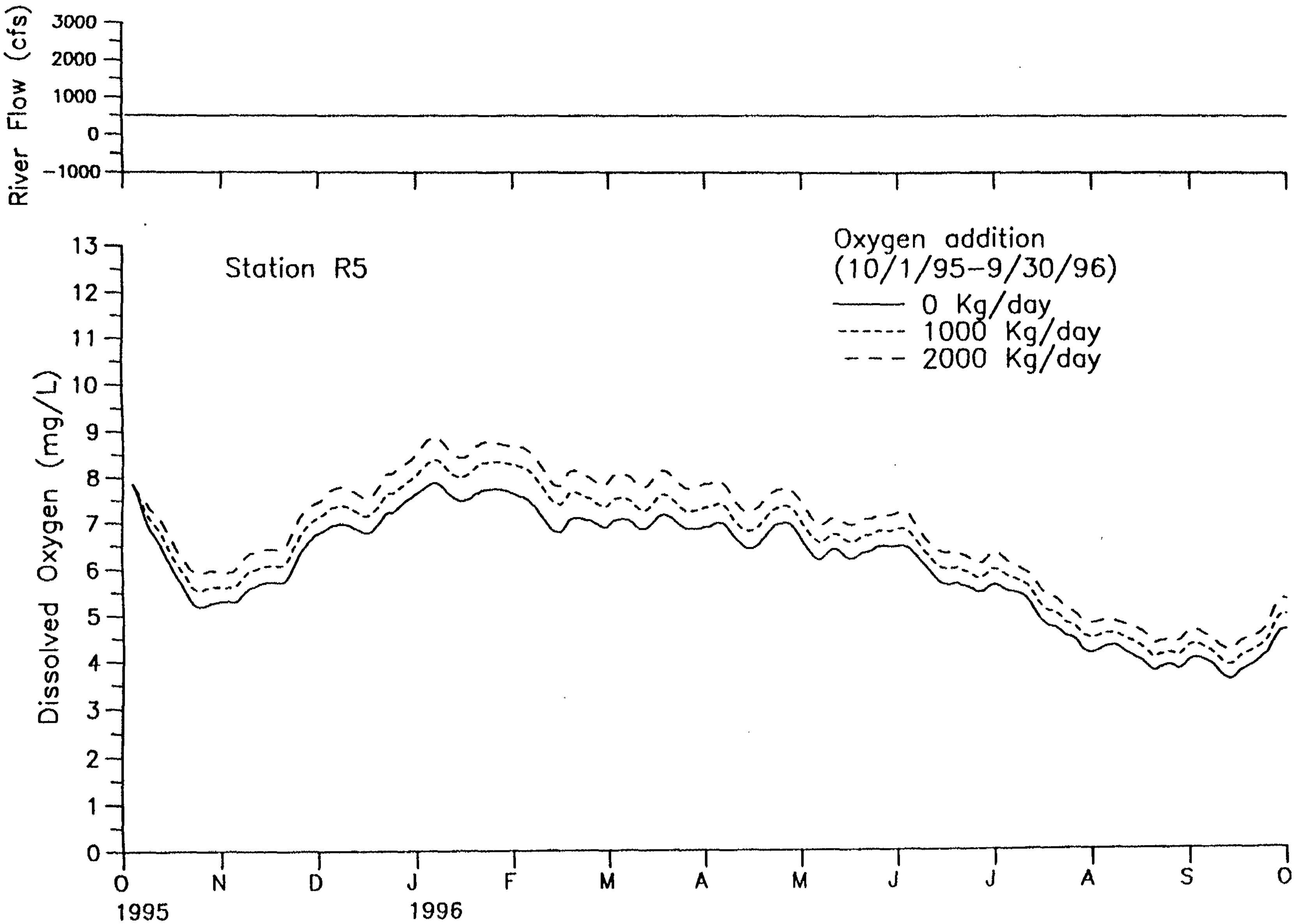
River Flow (cfs)
3000
2000
1000
0
-1000
Dissolved Oxygen (mg/L)
Station R3
Oxygen addition
(10/1/95-9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
O N D J F M A M J J A S O
1995
1996

D-041765

D-041766

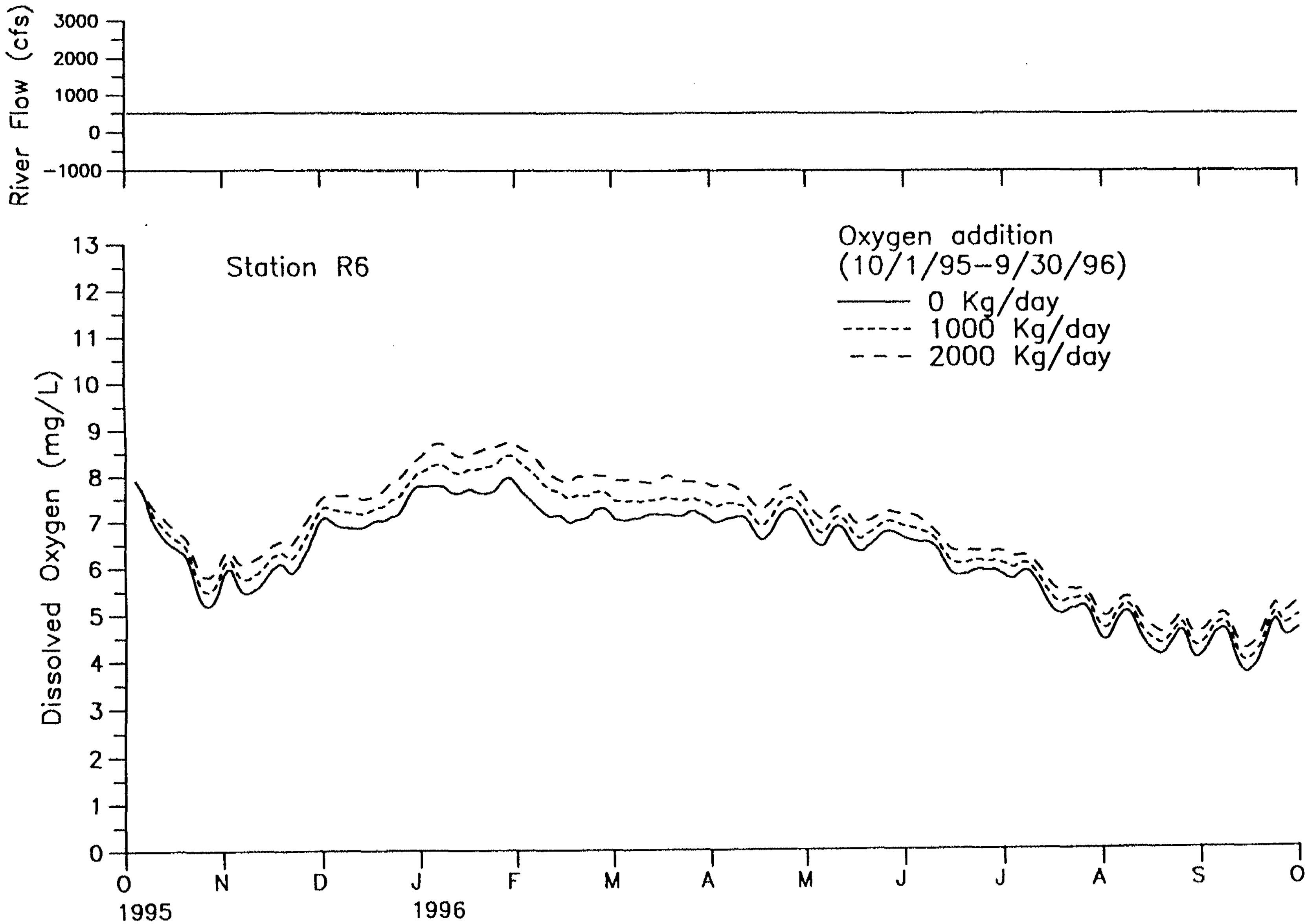


D-041766



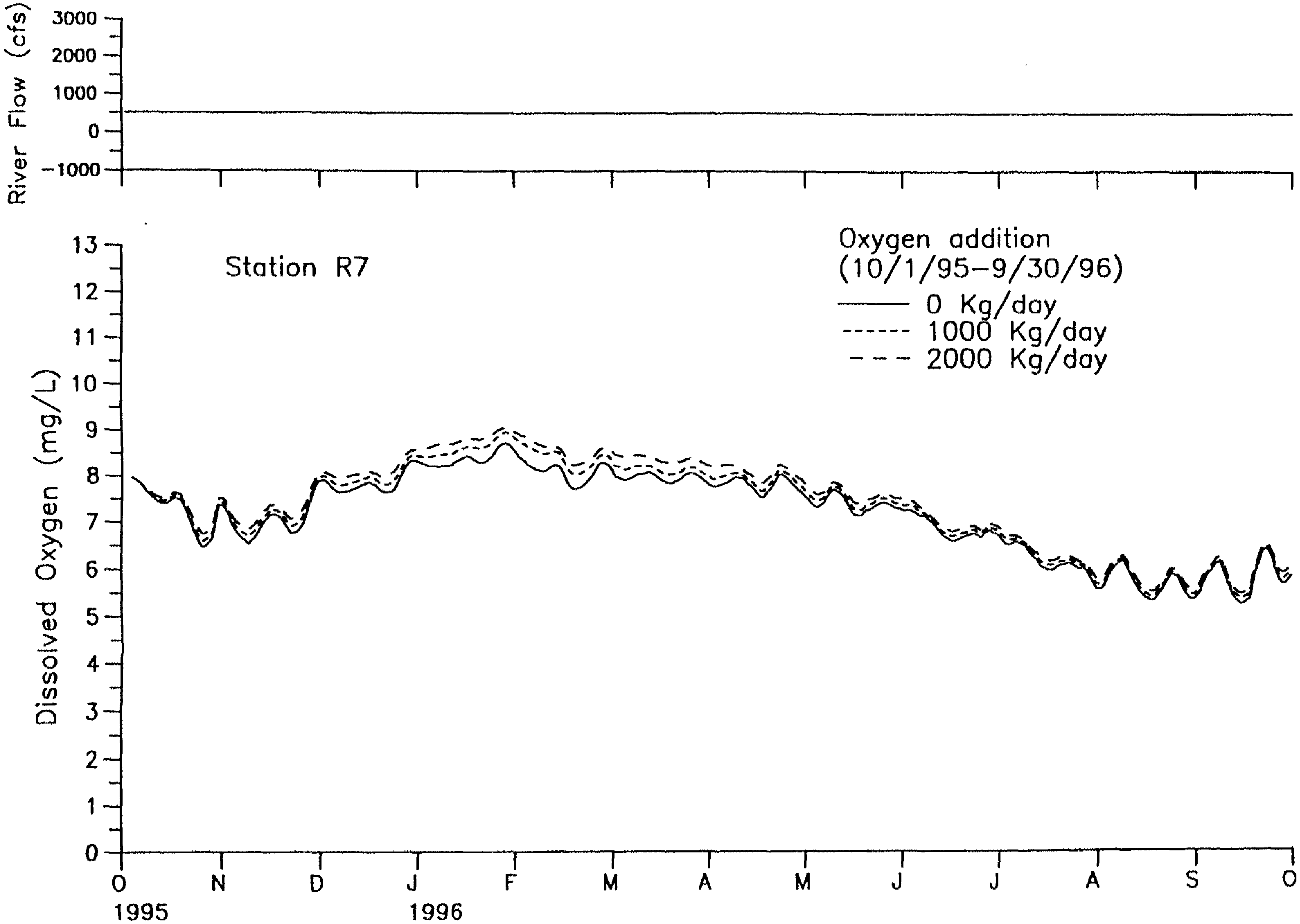
D-041767

D-041767



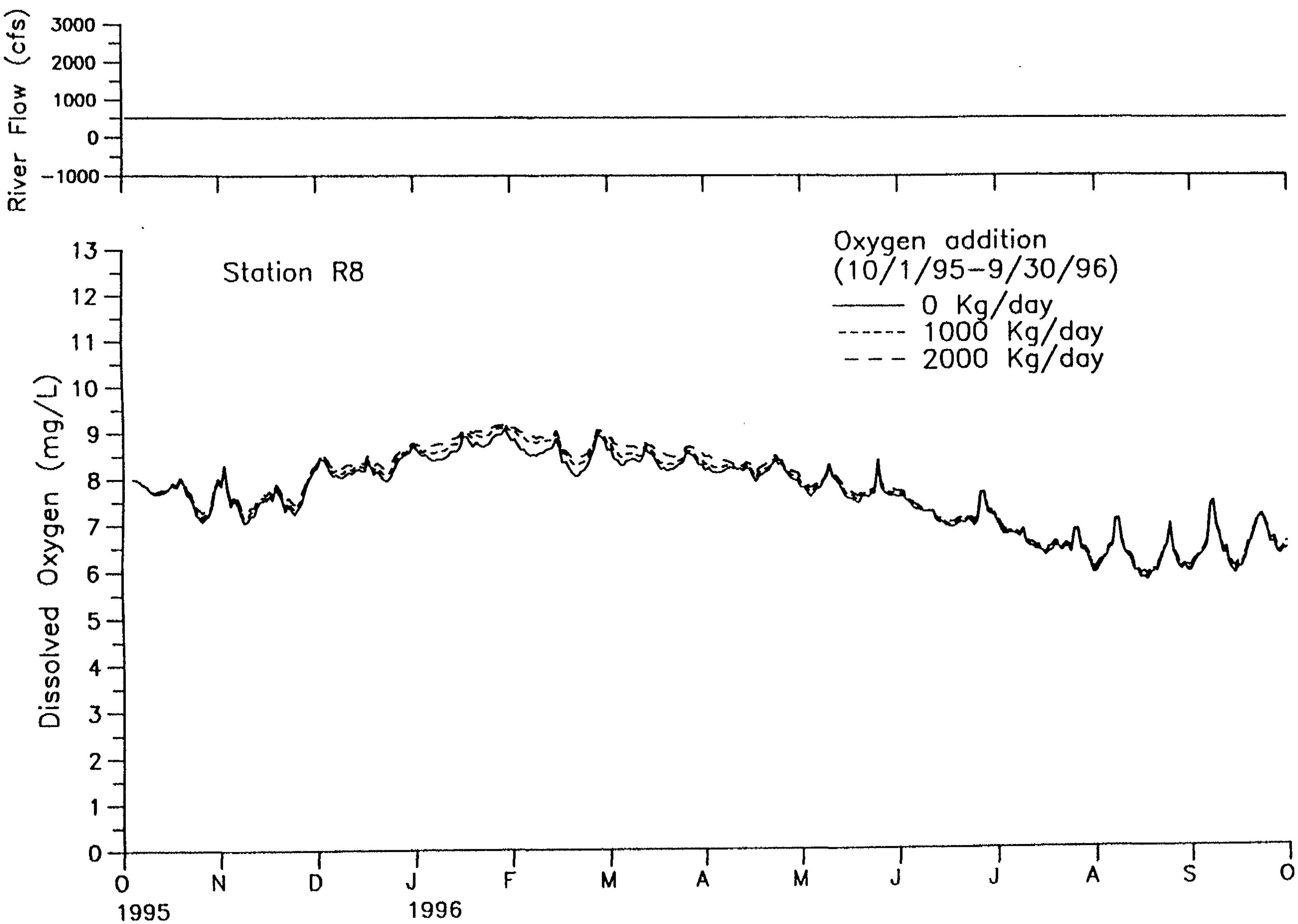
D-041768

D-041768



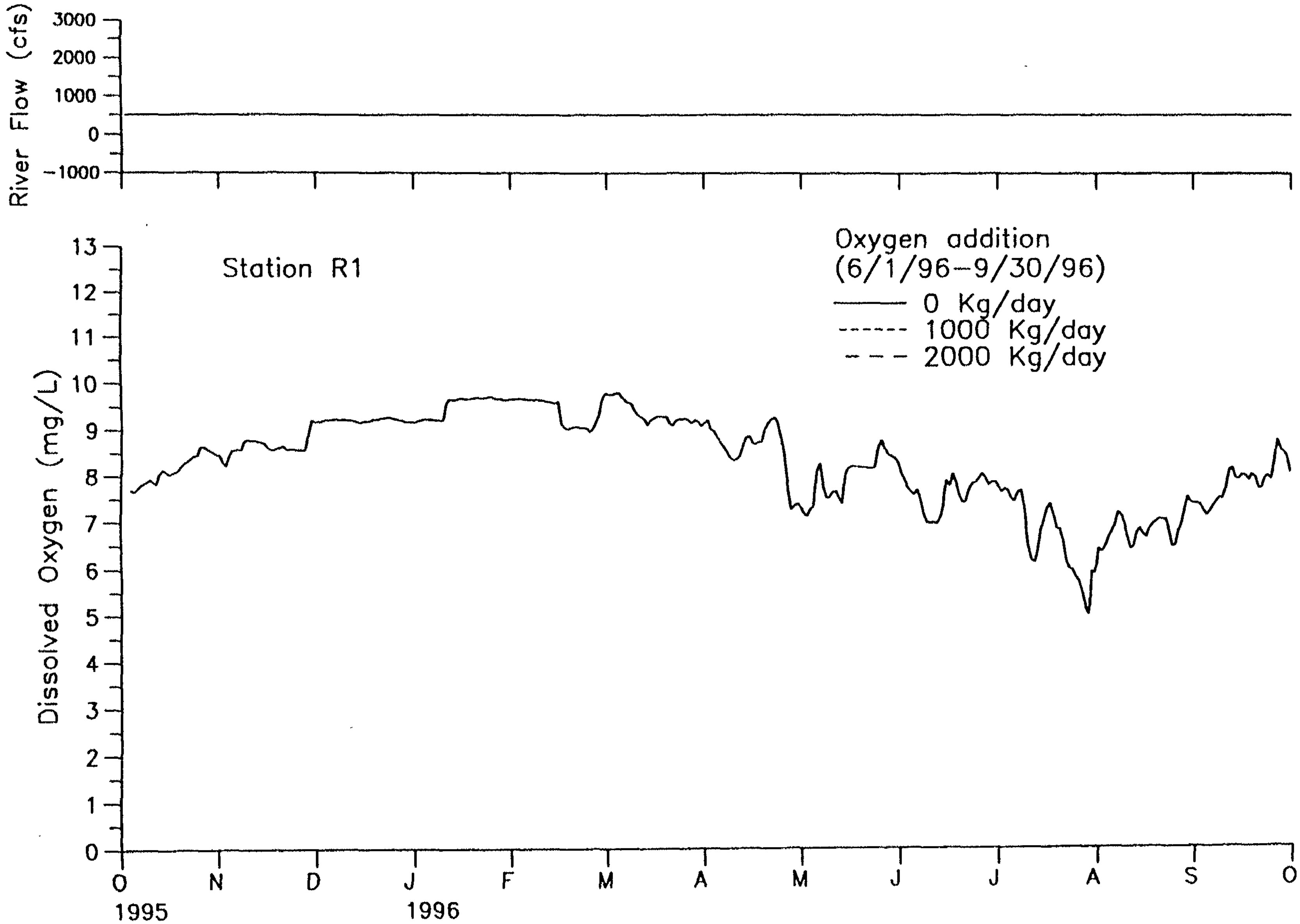
D - 0 4 1 7 6 9

D-041769

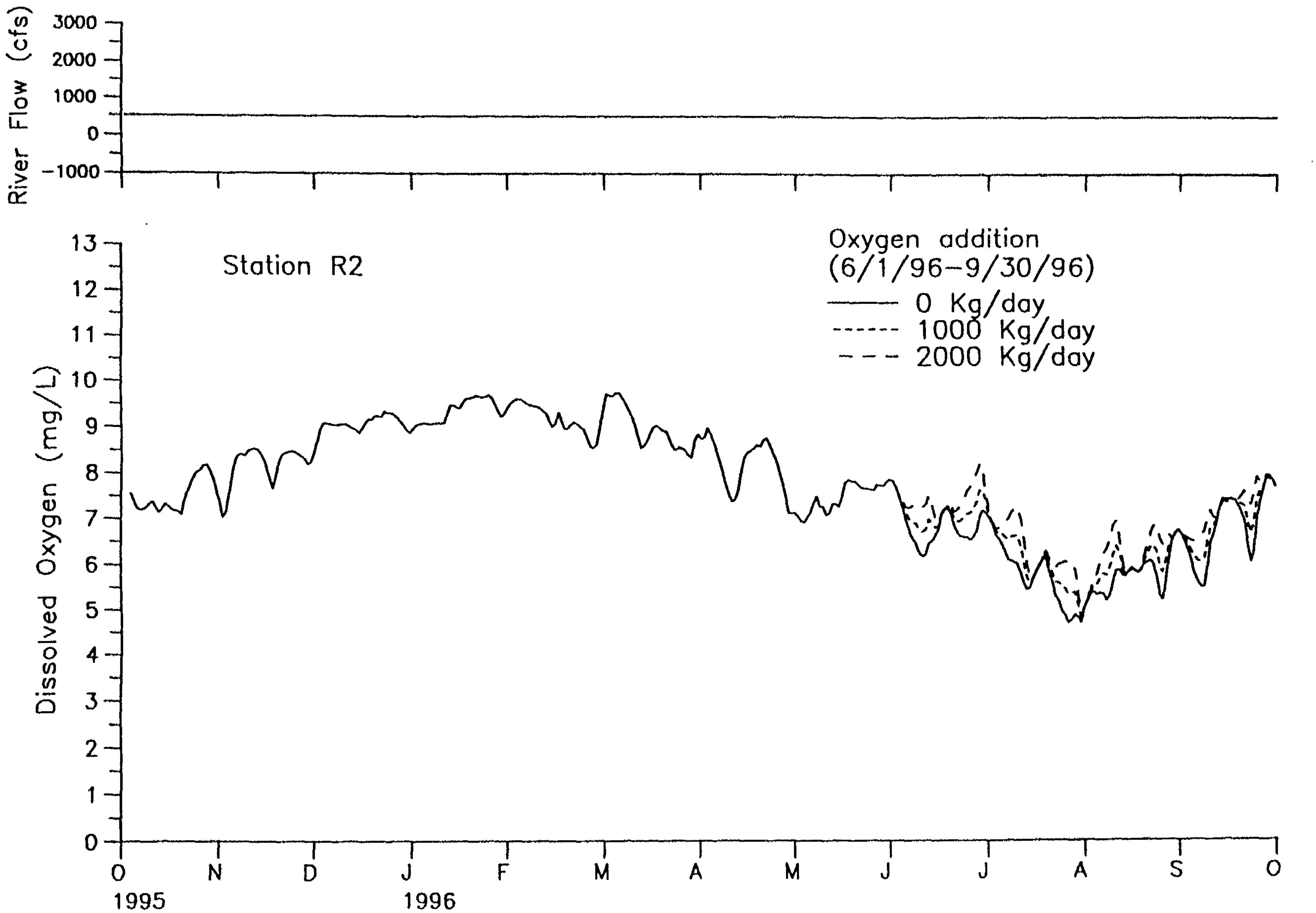


D-041770

D-041770

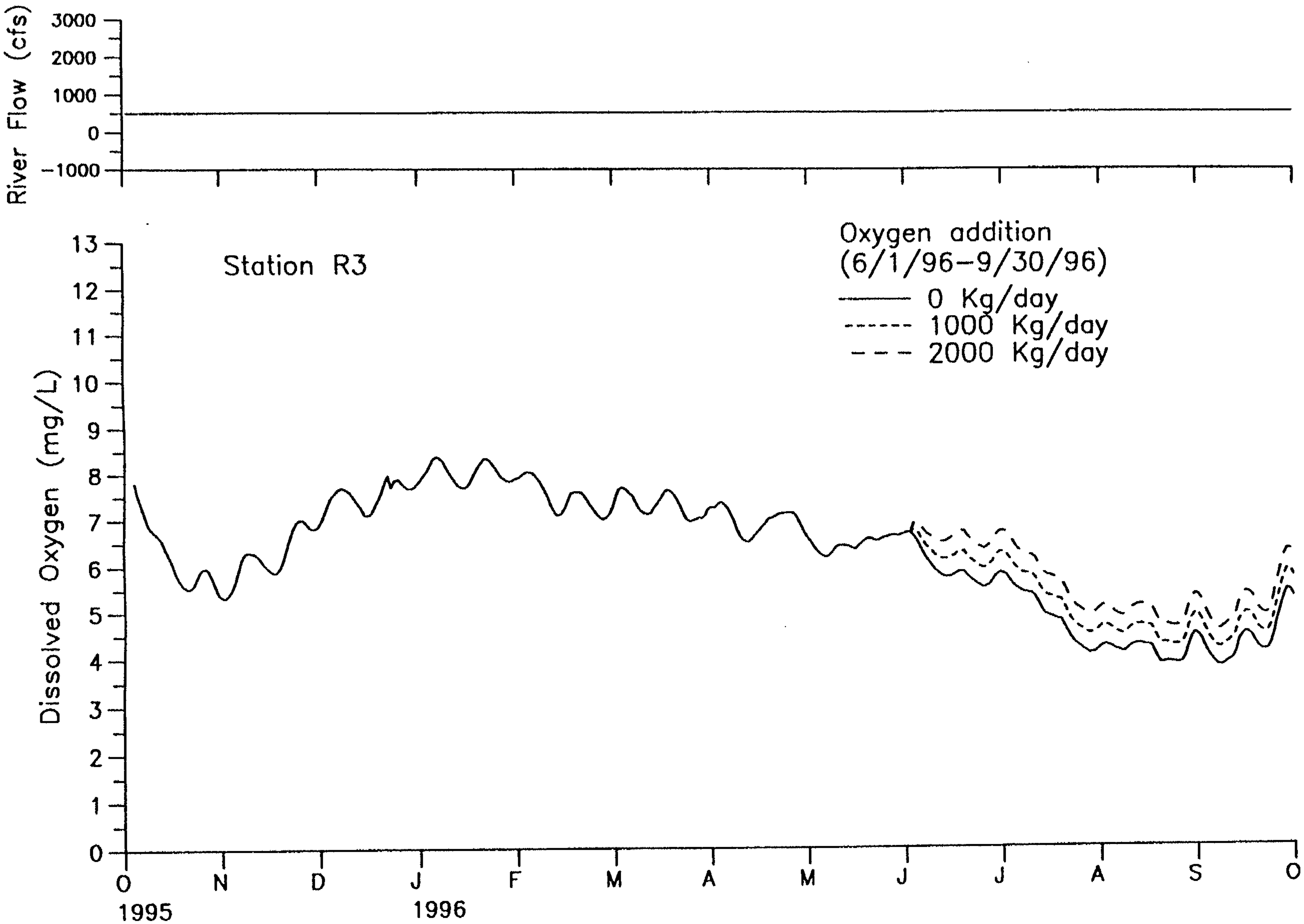

River Flow (cfs)
3000
2000
1000
0
-1000
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Station R1
Oxygen addition
(6/1/96-9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D-041771



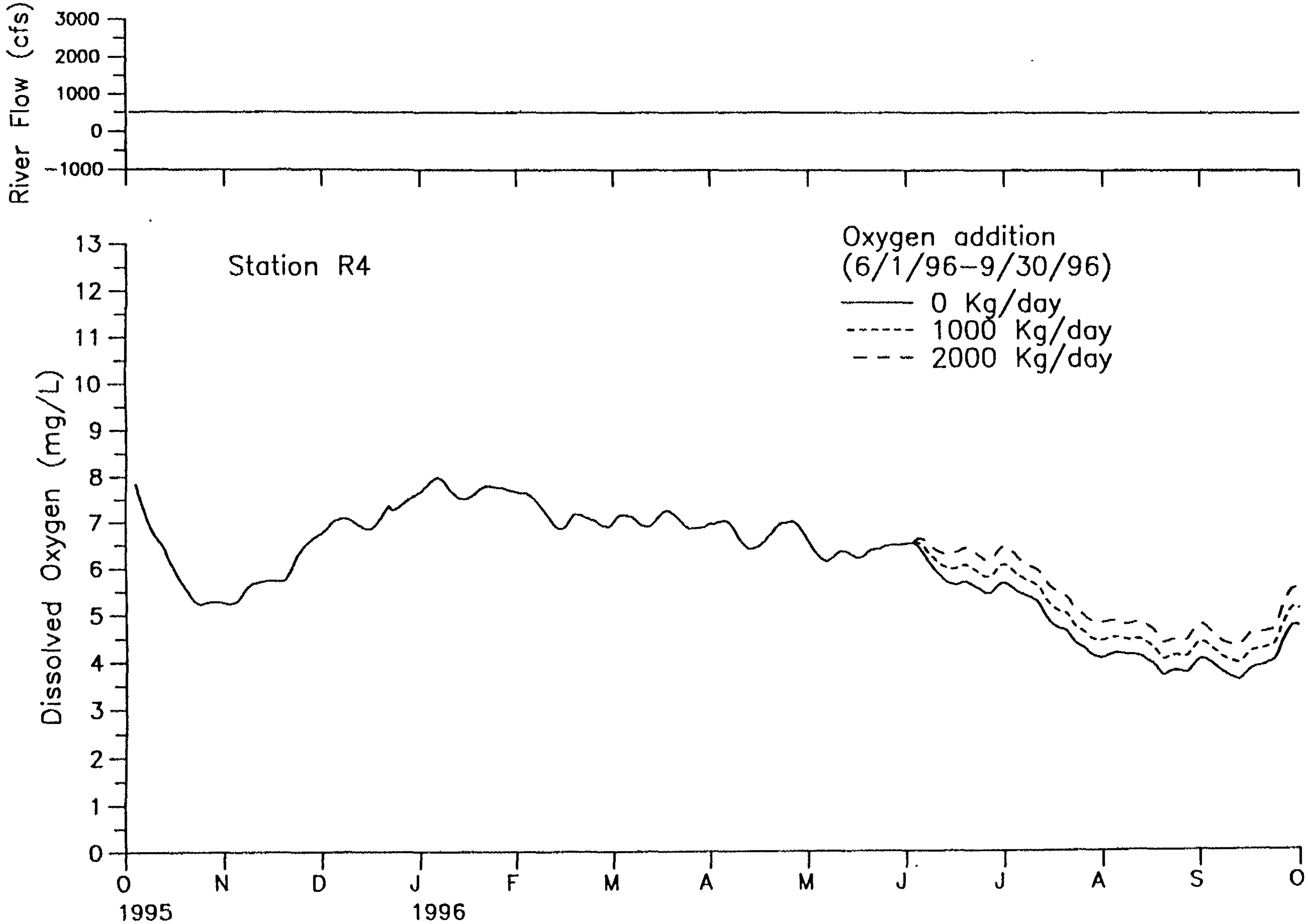
D-041772

D-041772



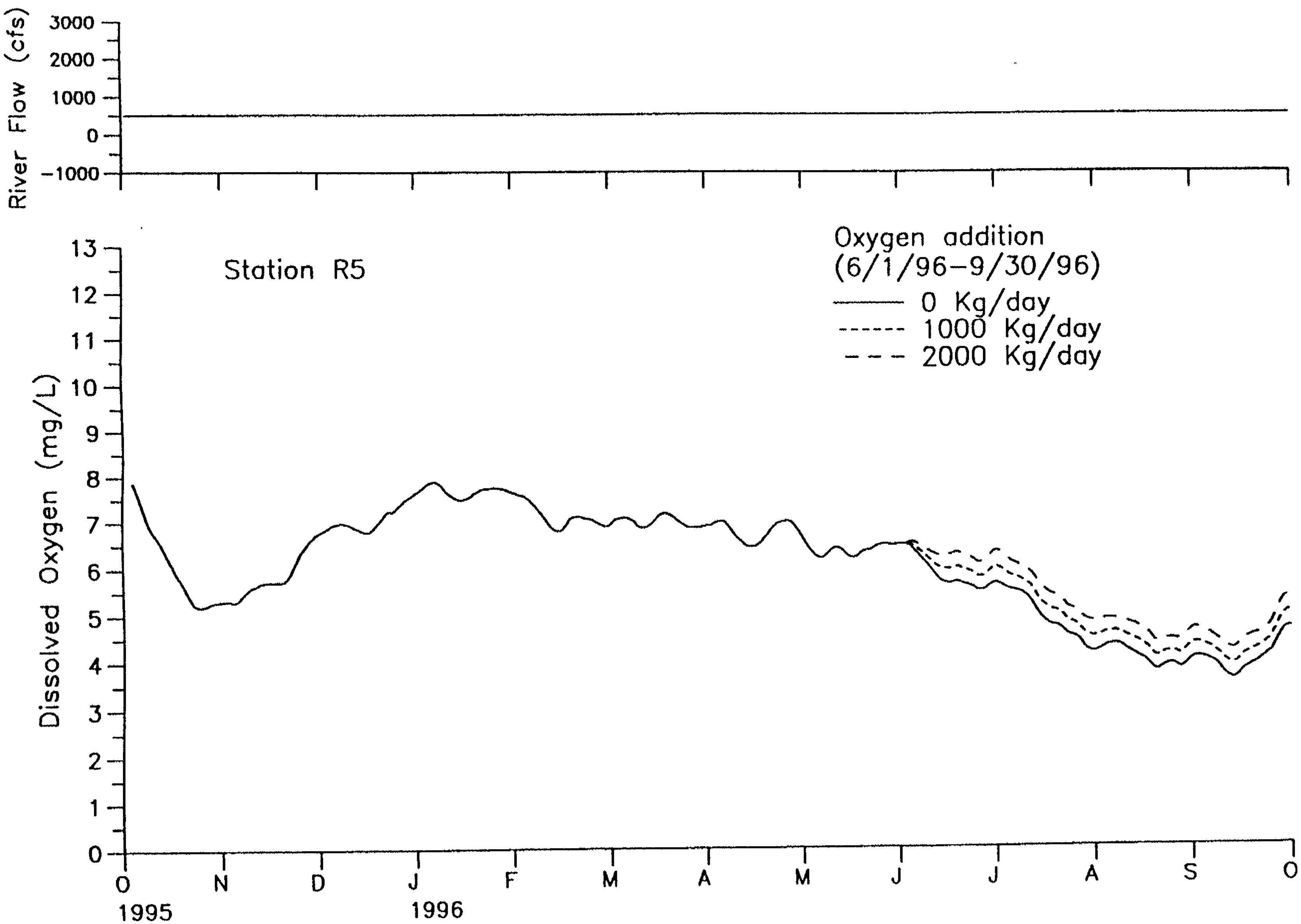
River Flow (cfs)
3000
2000
1000
0
-1000
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Station R3
Oxygen addition
(6/1/96-9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D-041773



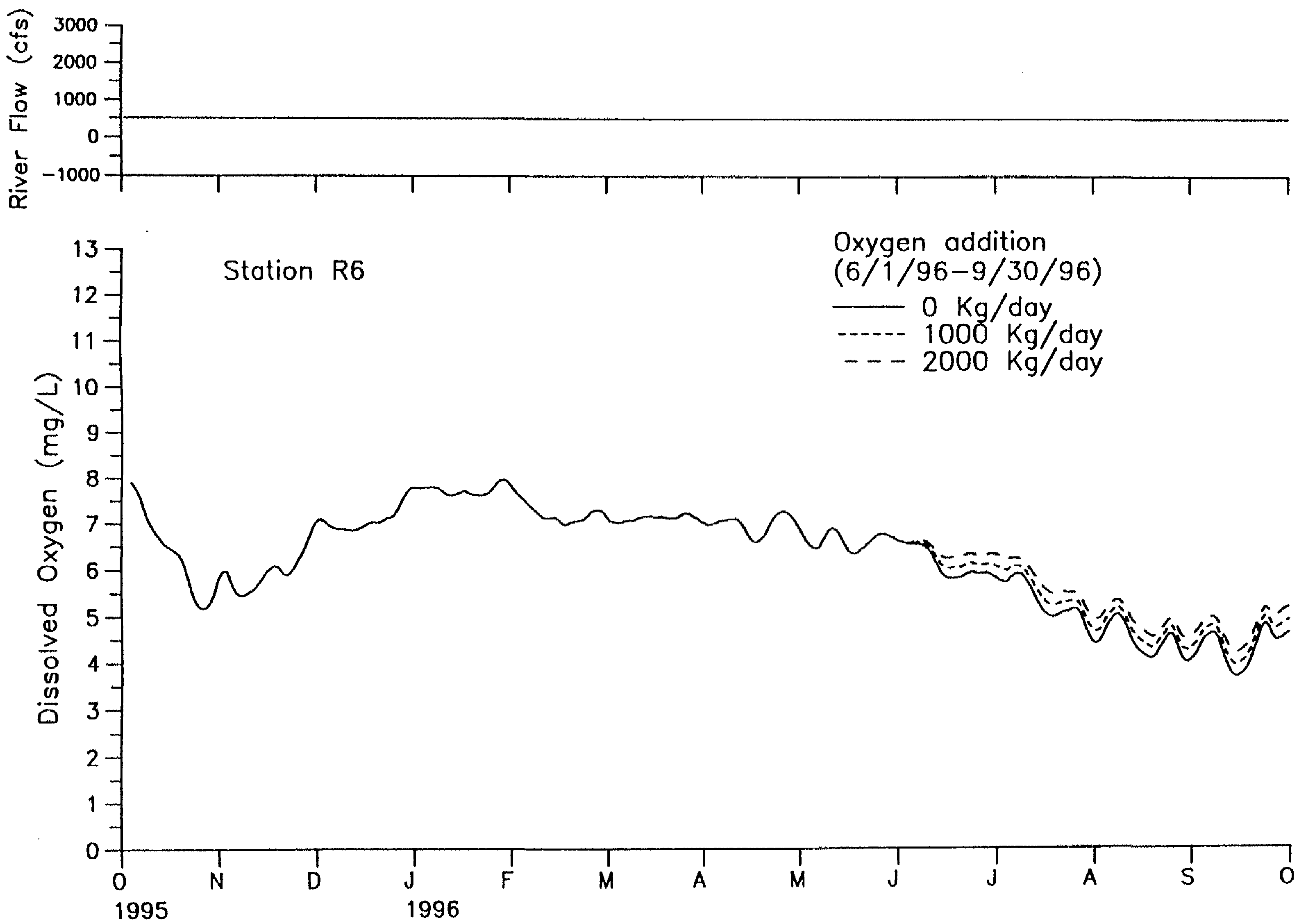
D —0 4 1 7 7 4

D-041774

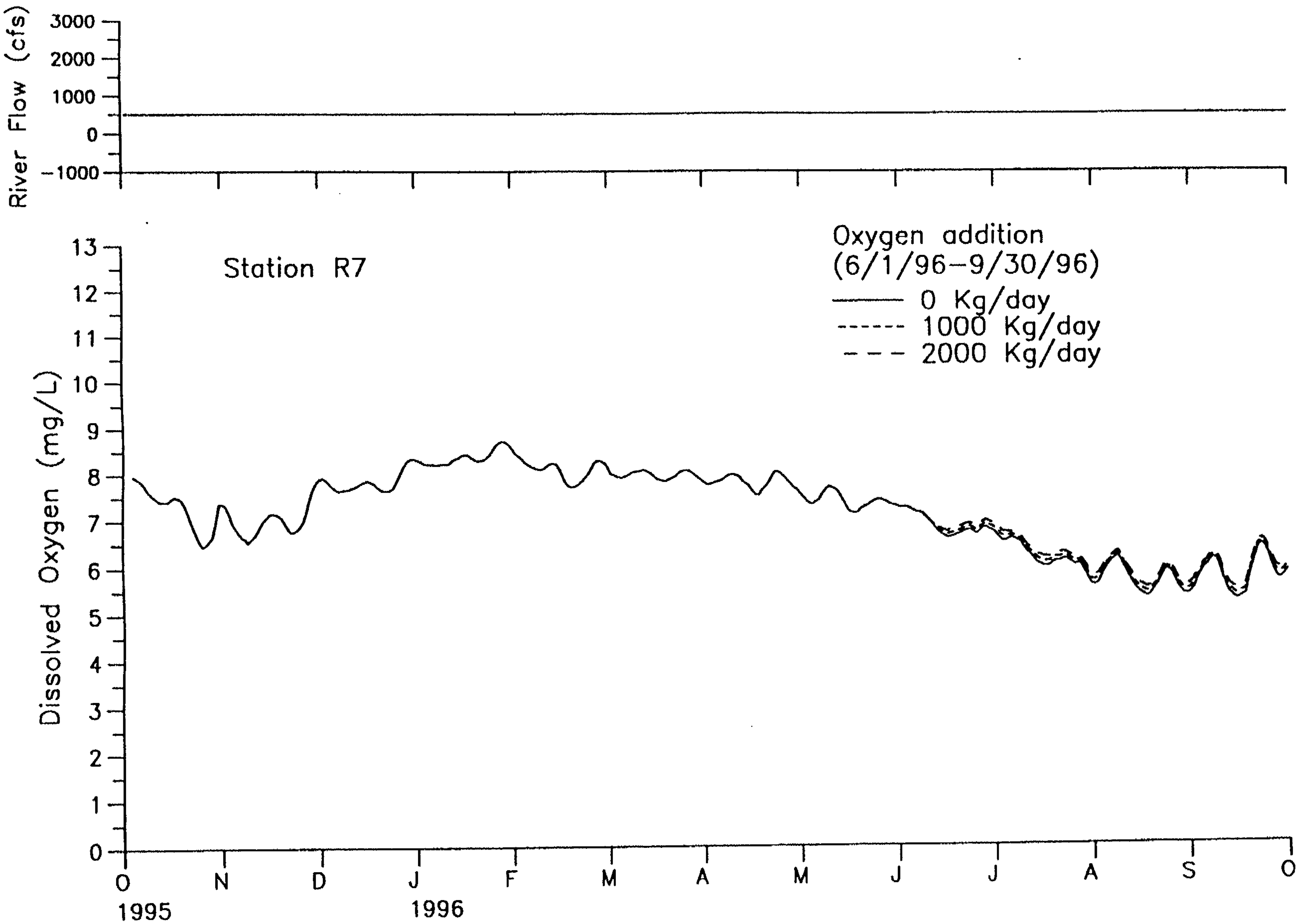


D-041775

D-041775

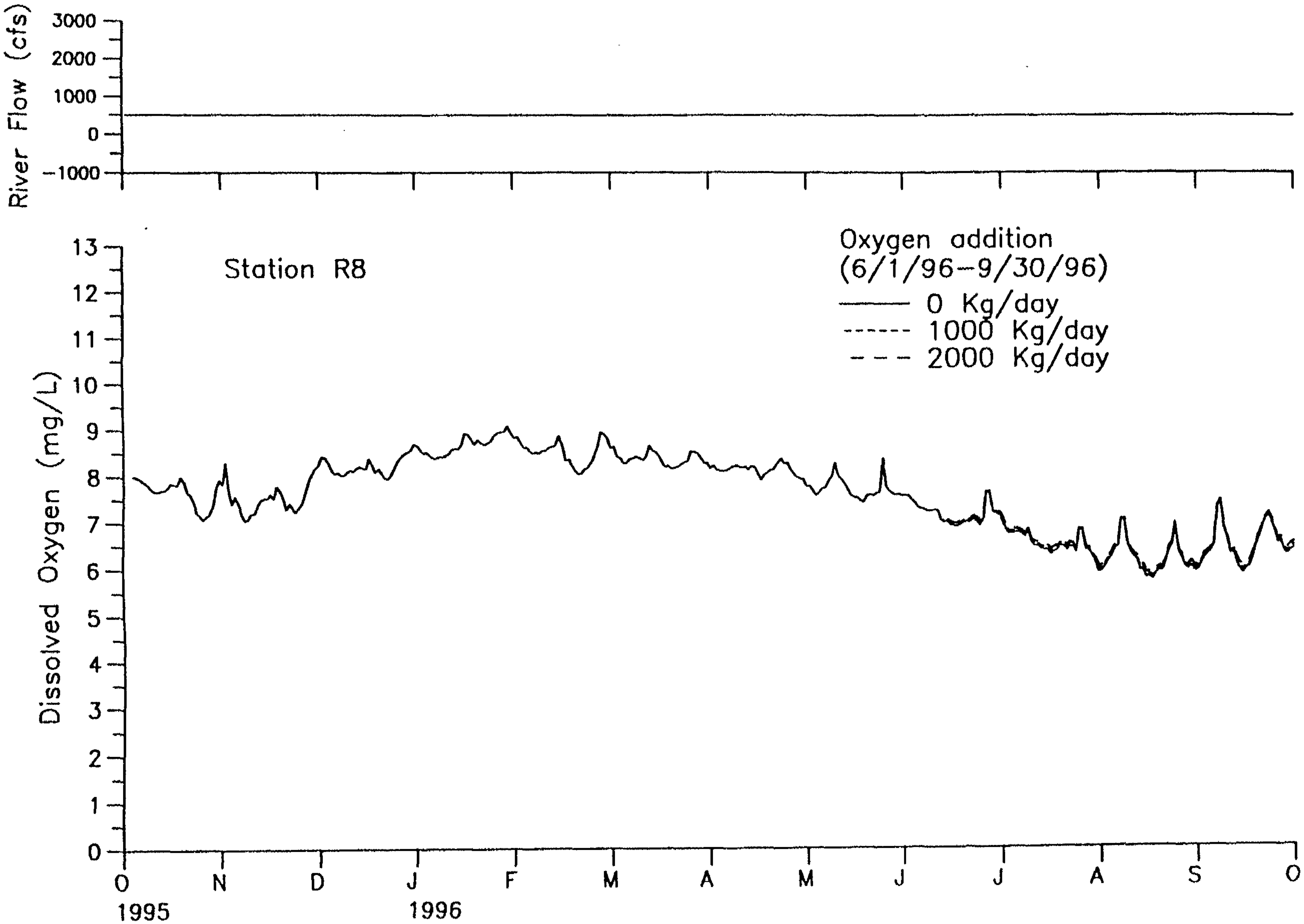


River Flow (cfs)
3000
2000
1000
0
−1000
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Station R6
Oxygen addition
(6/1/96–9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

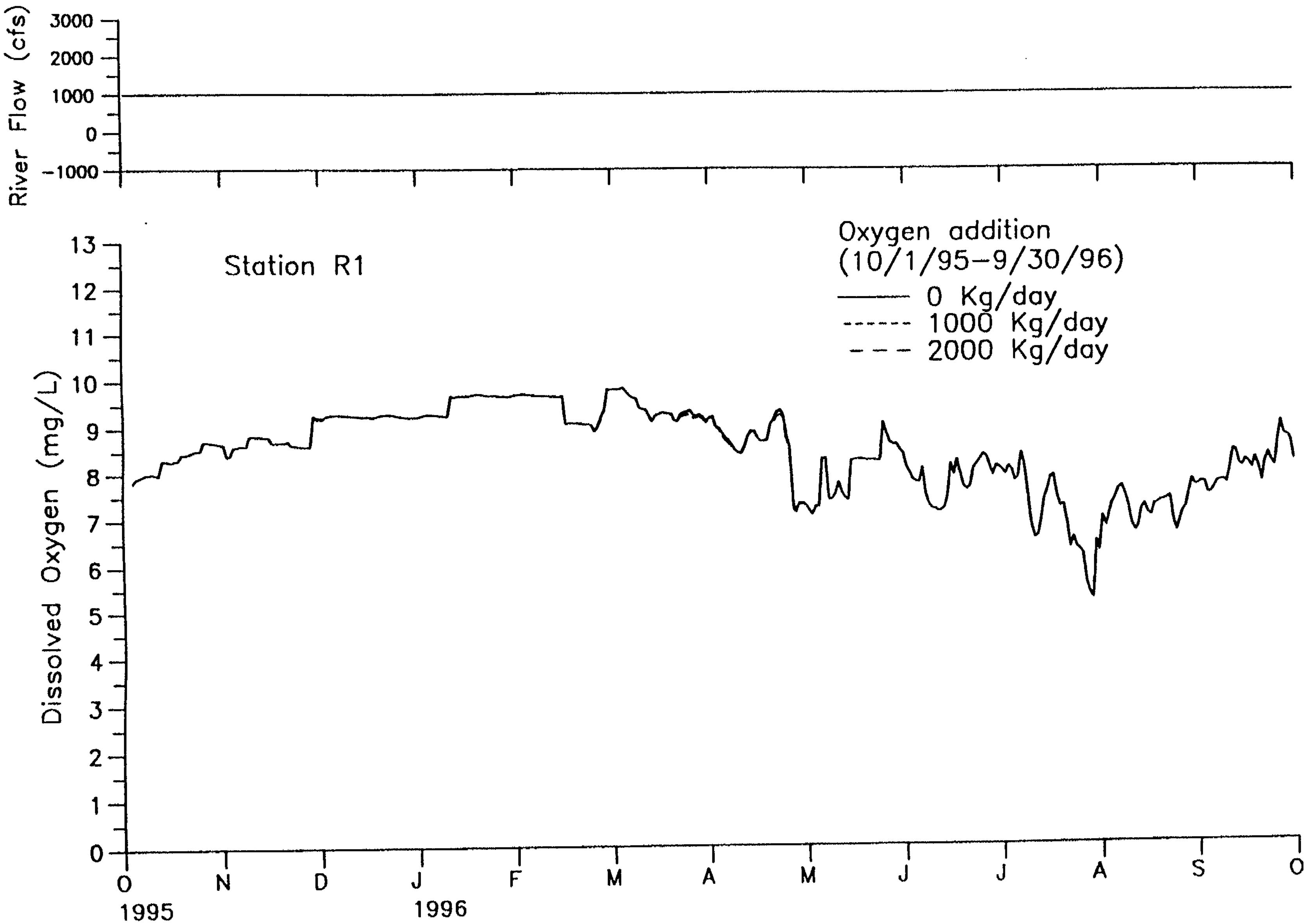


D-041777

D-041777

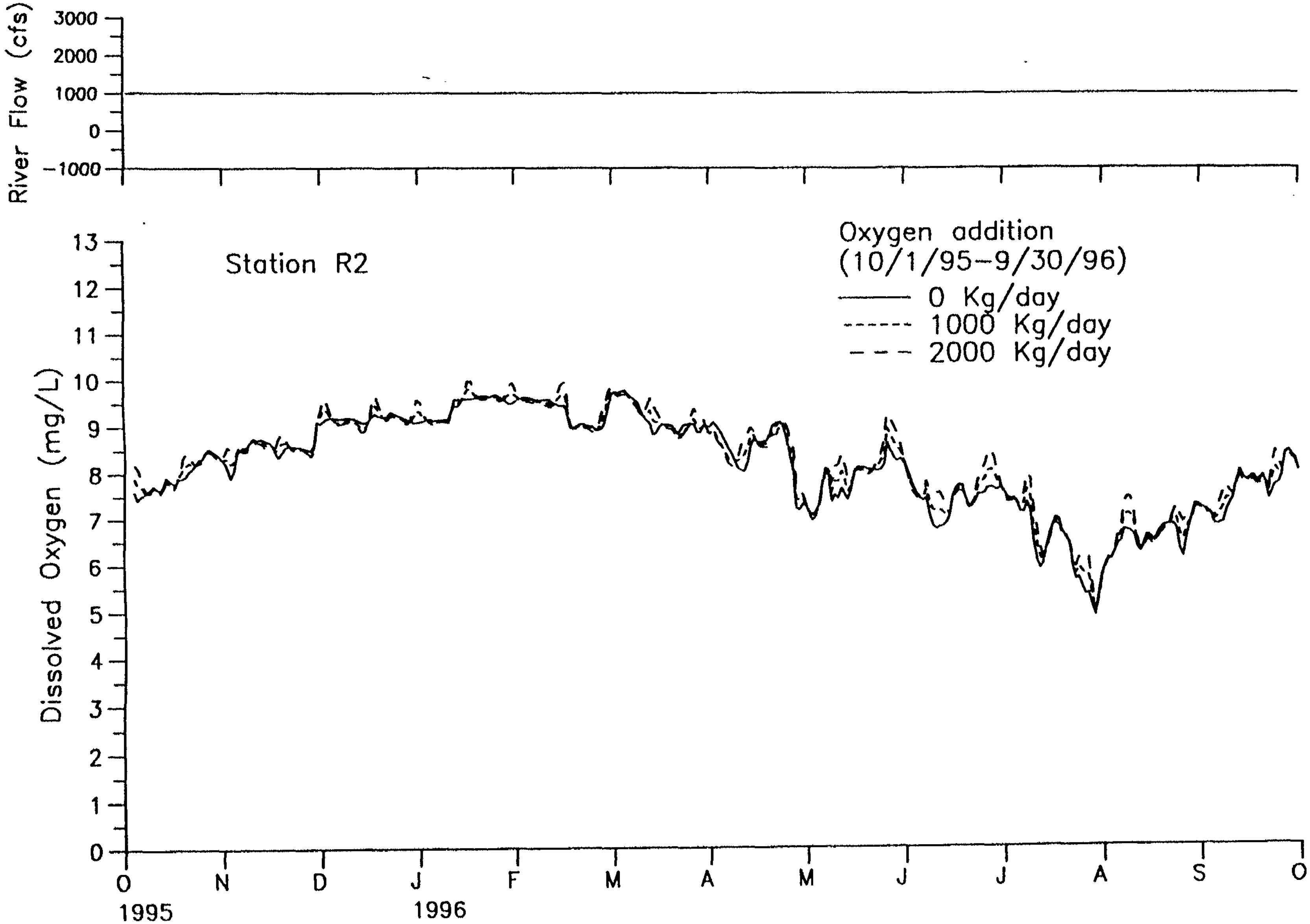


River Flow (cfs)
3000
2000
1000
0
−1000
Station R8
Oxygen addition
(6/1/96−9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996



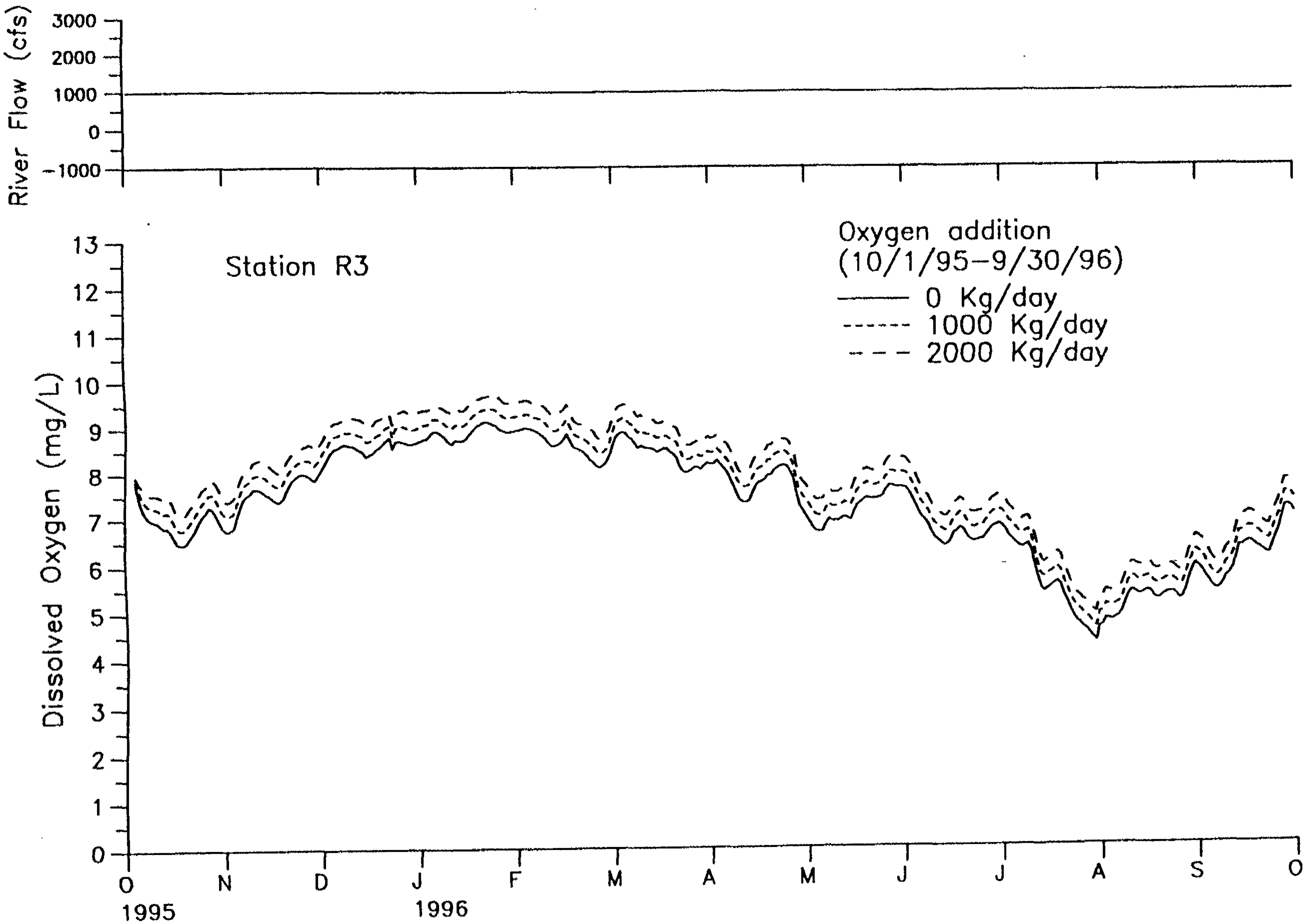
D-041779

D-041779



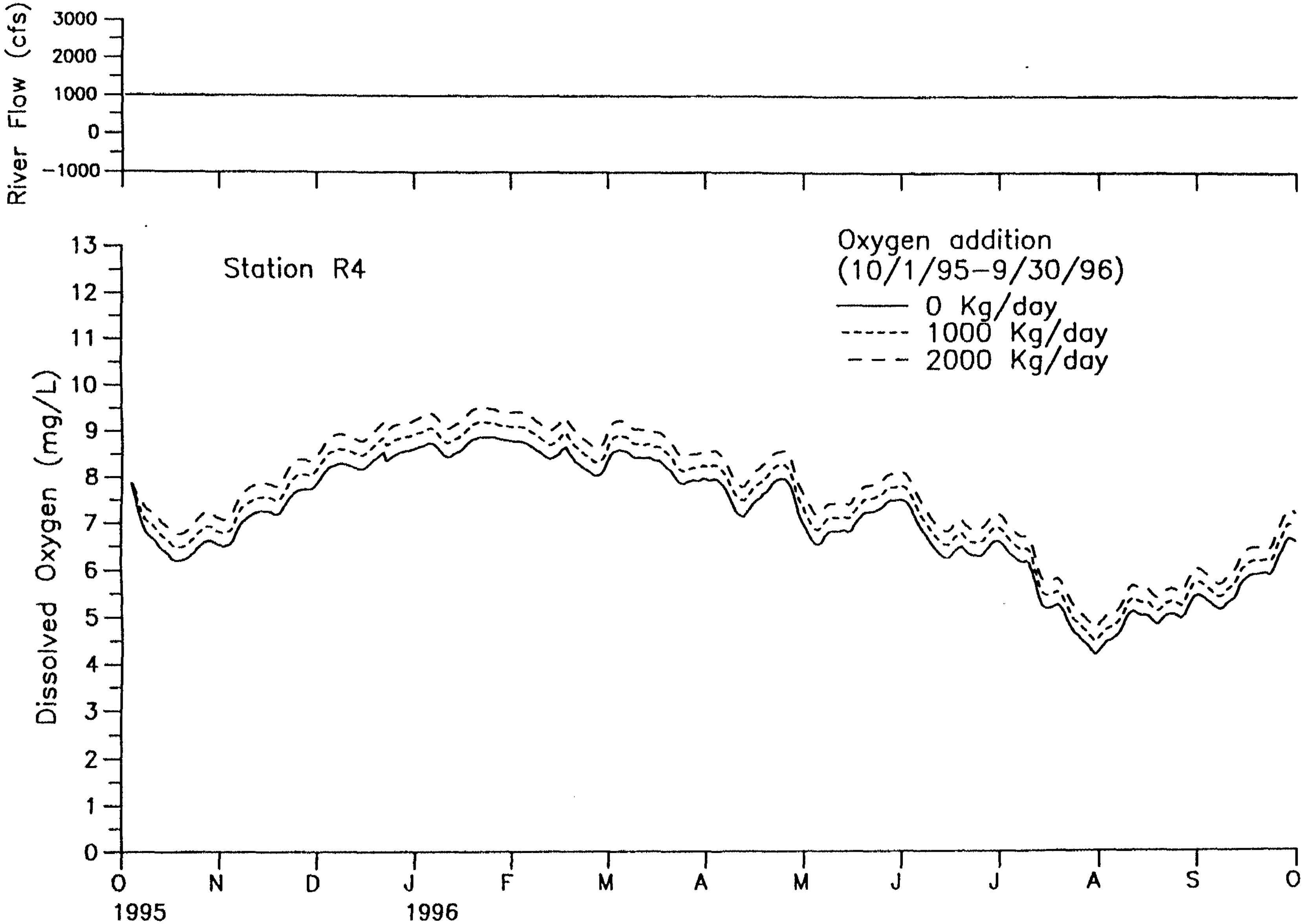
D—041780

D-041780

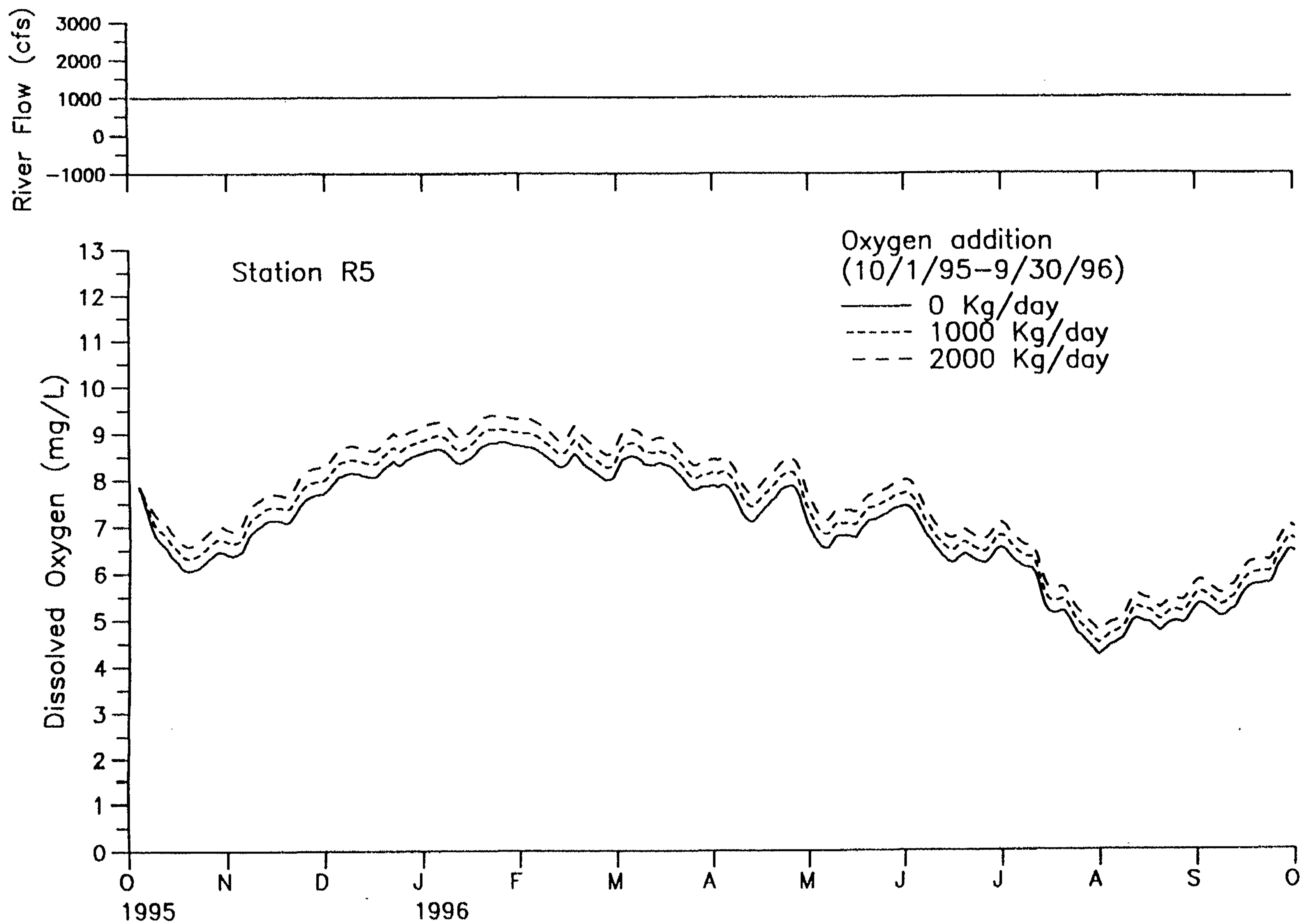


D-041781

D-041781

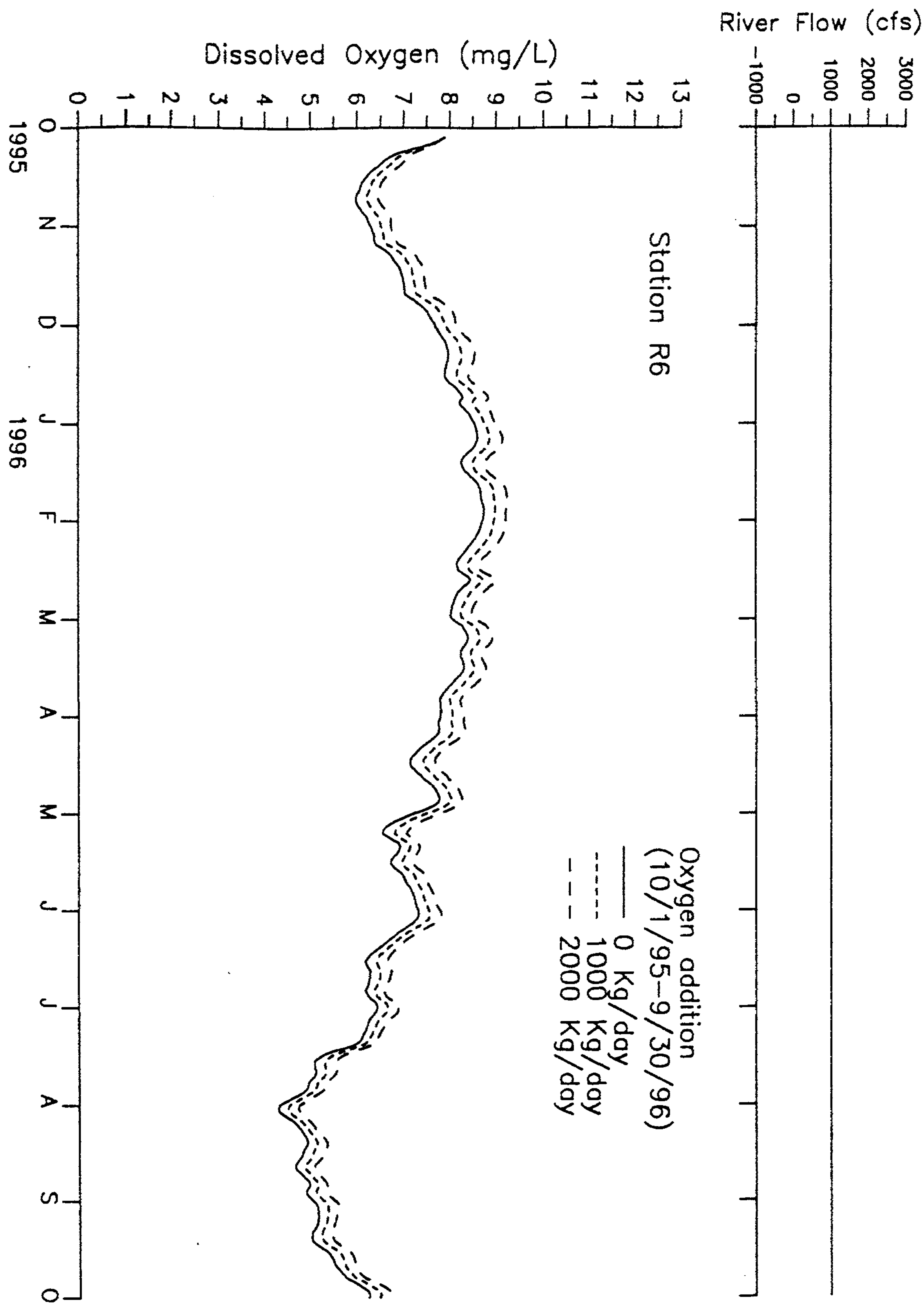

River Flow (cfs)
3000
2000
1000
0
-1000
Station R4
Oxygen addition
(10/1/95-9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1995
1996

D-0 4 1 7 8 2

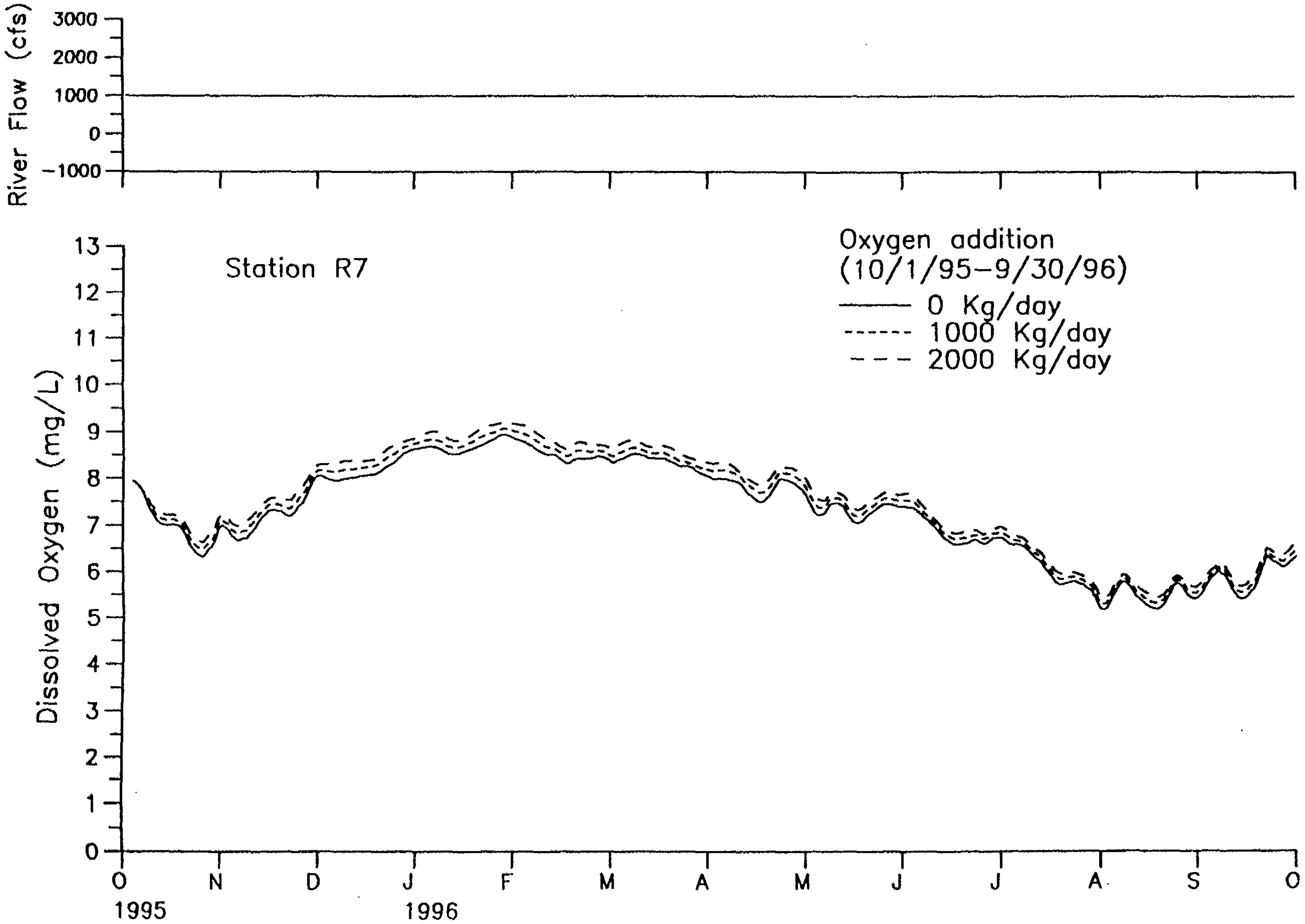


D–041783

D-041783

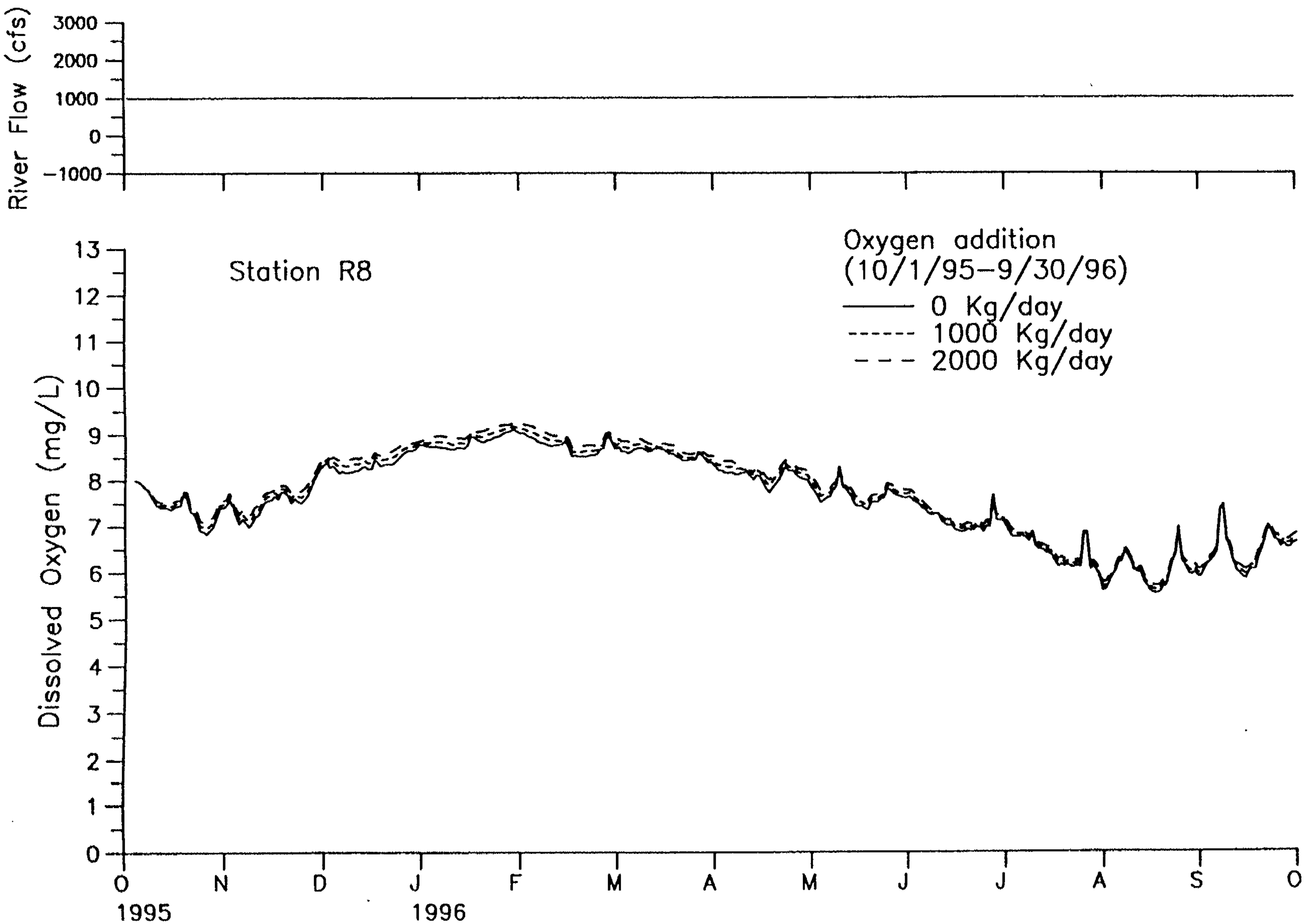

Dissolved Oxygen (mg/L)
River Flow (cfs)
Station R6
Oxygen addition
(10/1/95–9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
1995
1996
O N D J F M A M J J A S O

D –0 4 1 7 8 4



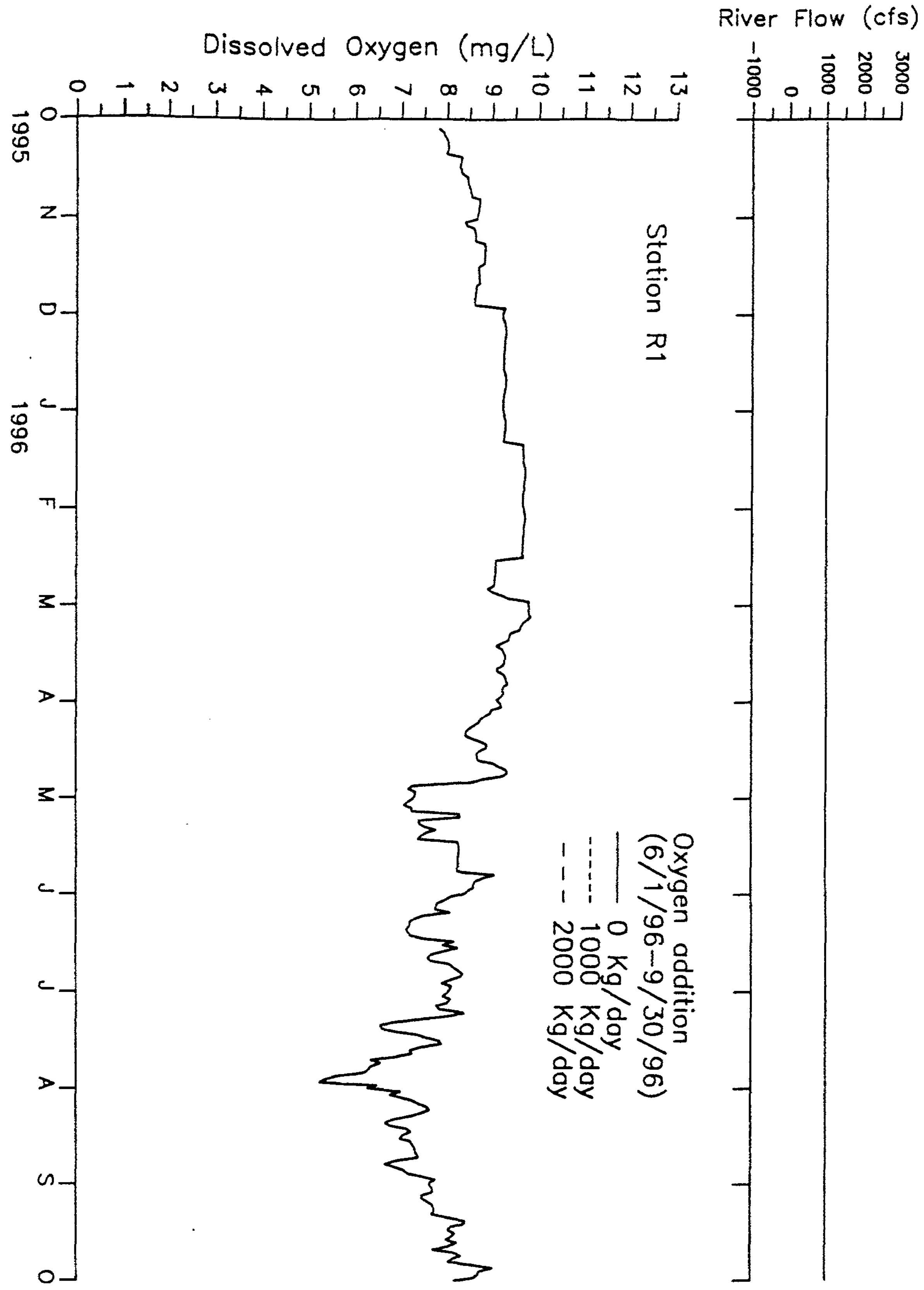
D-041785

D-041785



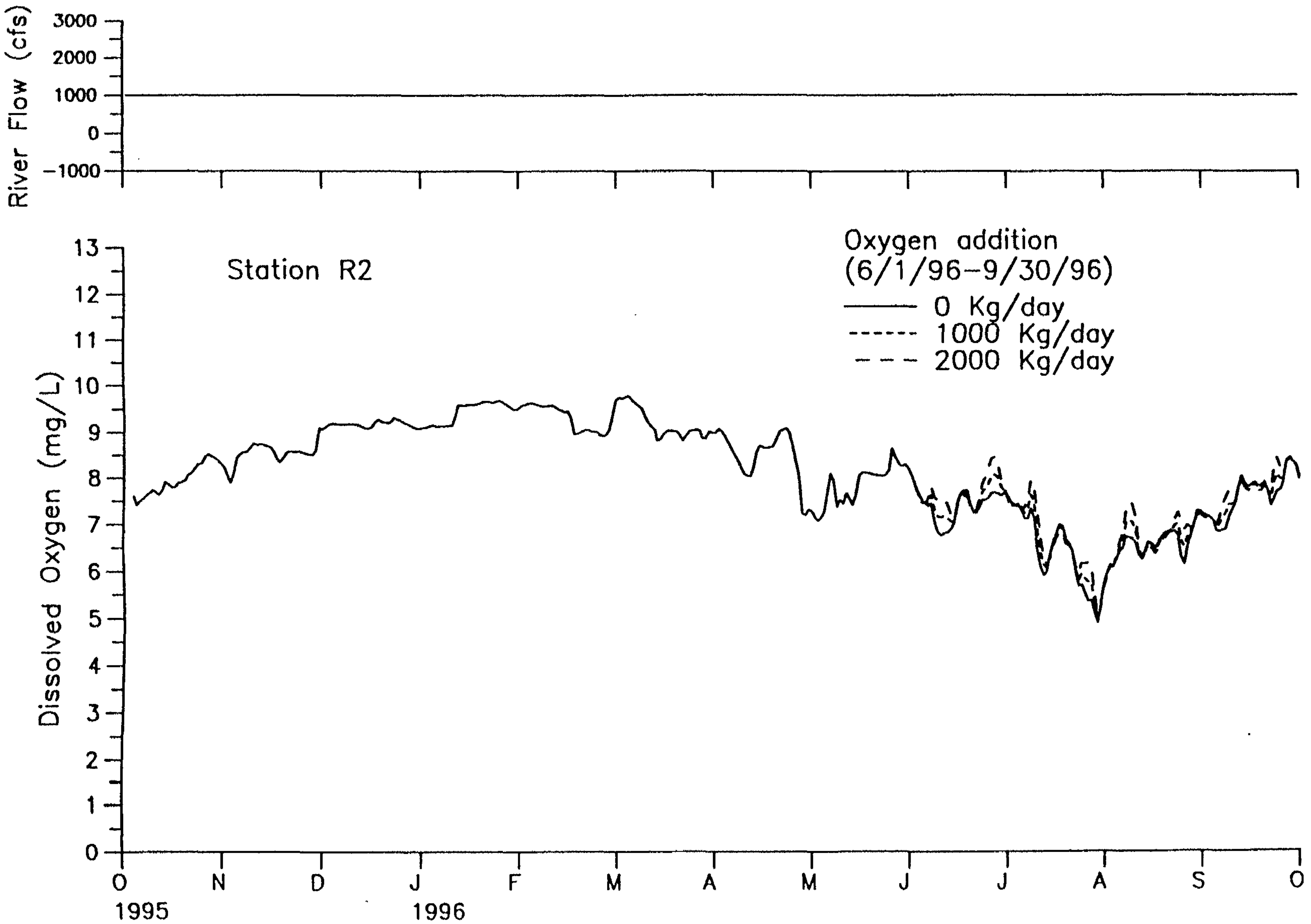
D-041786

D-041786



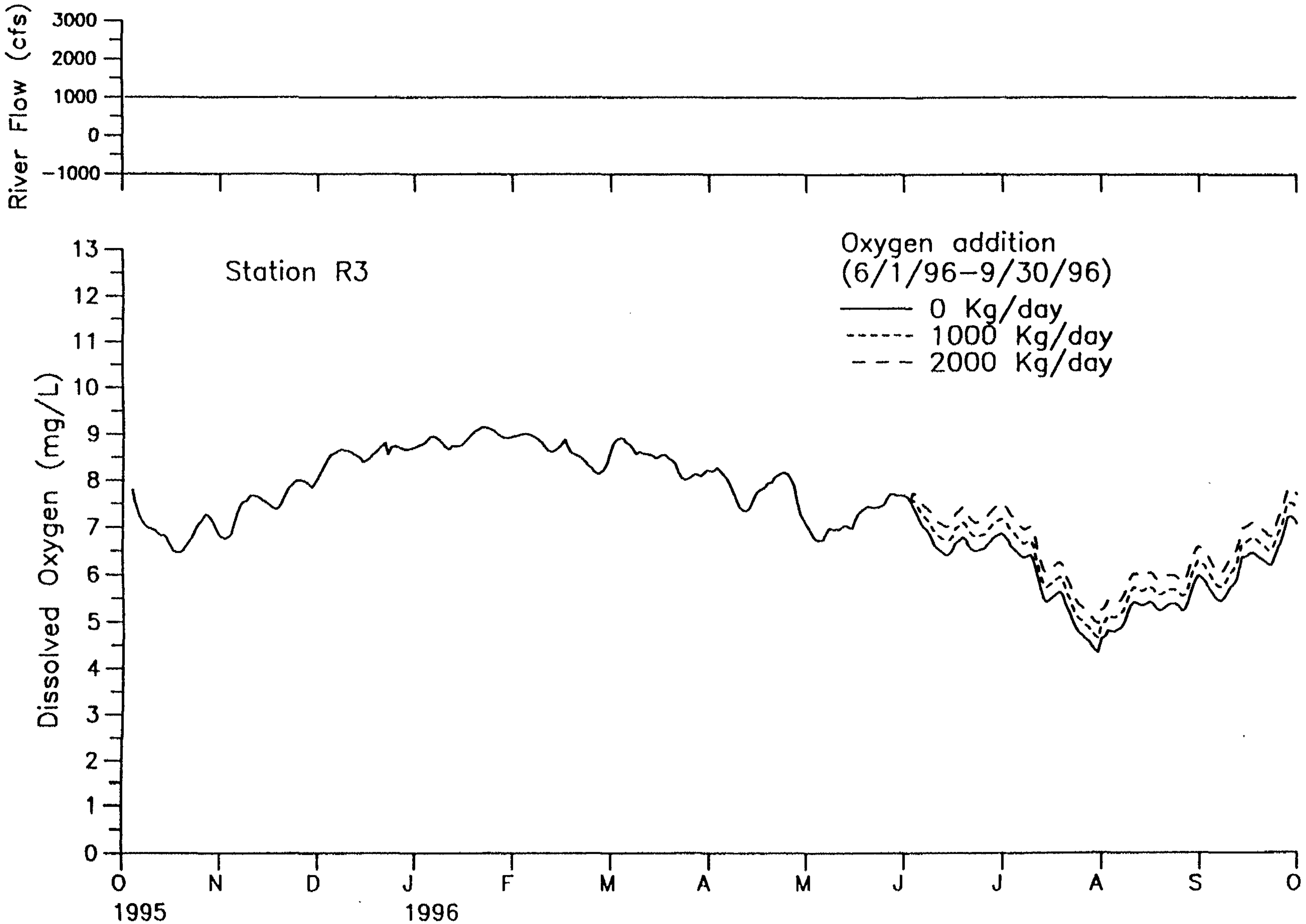
D–041787

D-041787

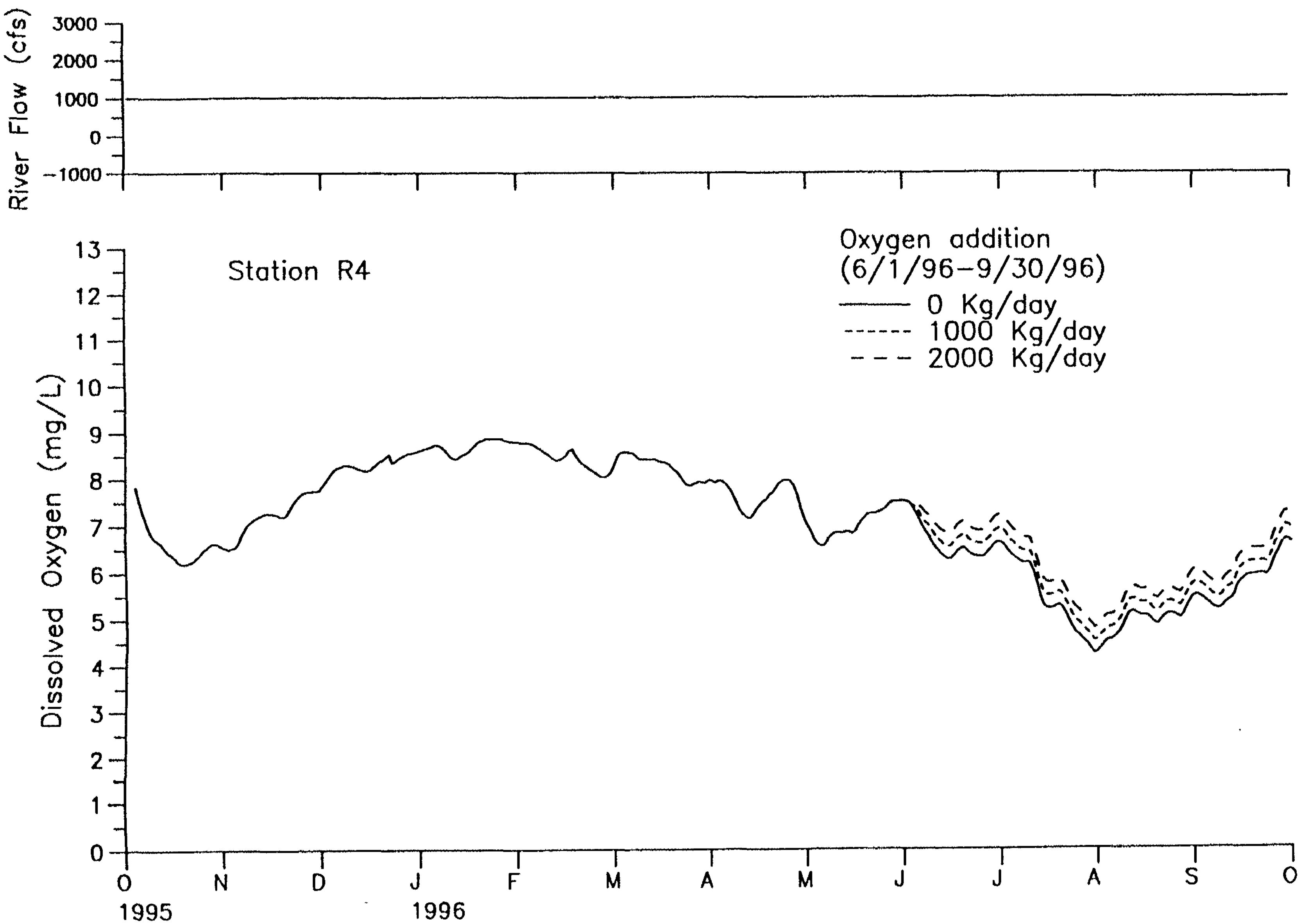


D-041788

D-041788

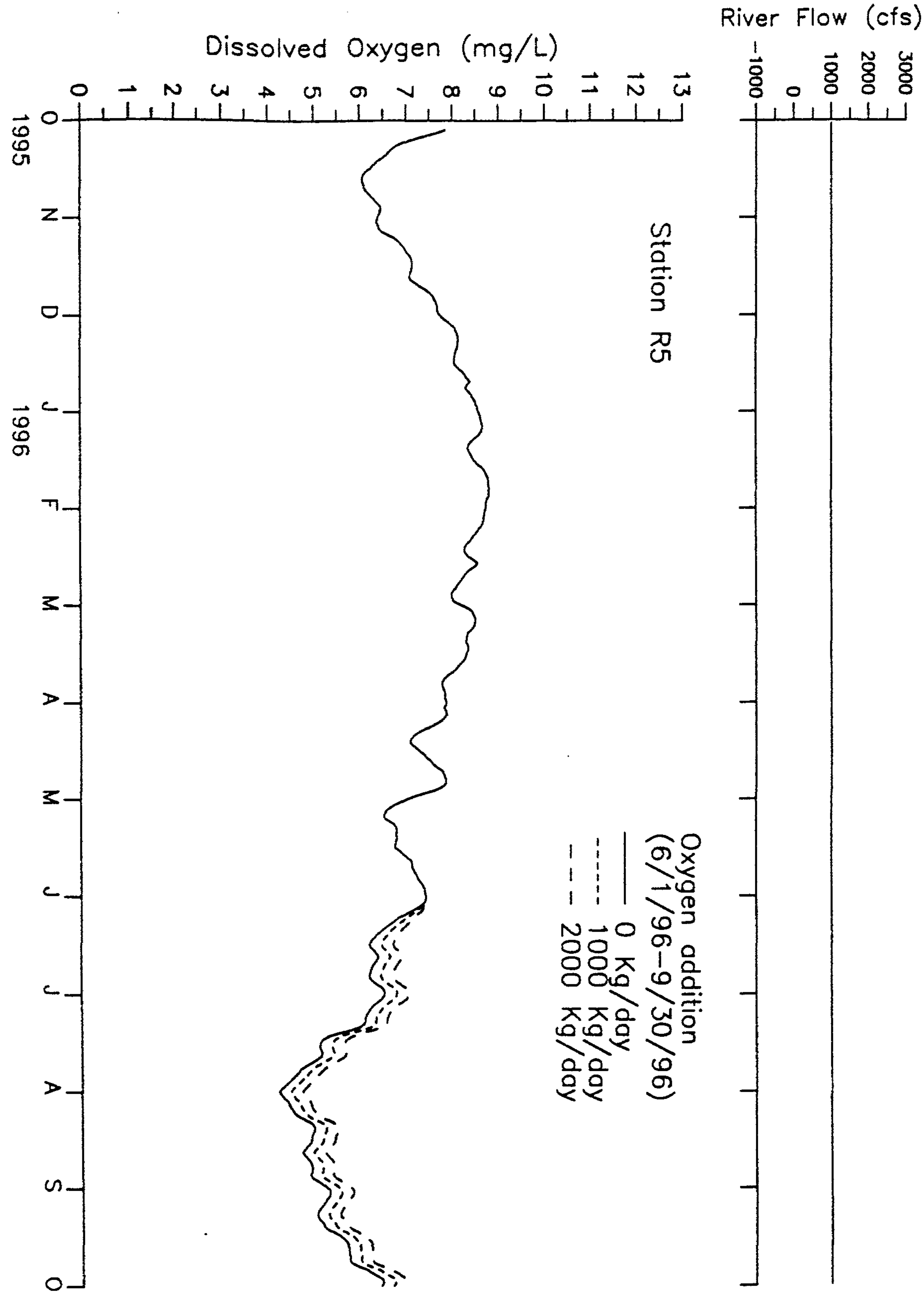

River Flow (cfs)
3000
2000
1000
0
-1000
Station R3
Oxygen addition
(6/1/96-9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D-041789



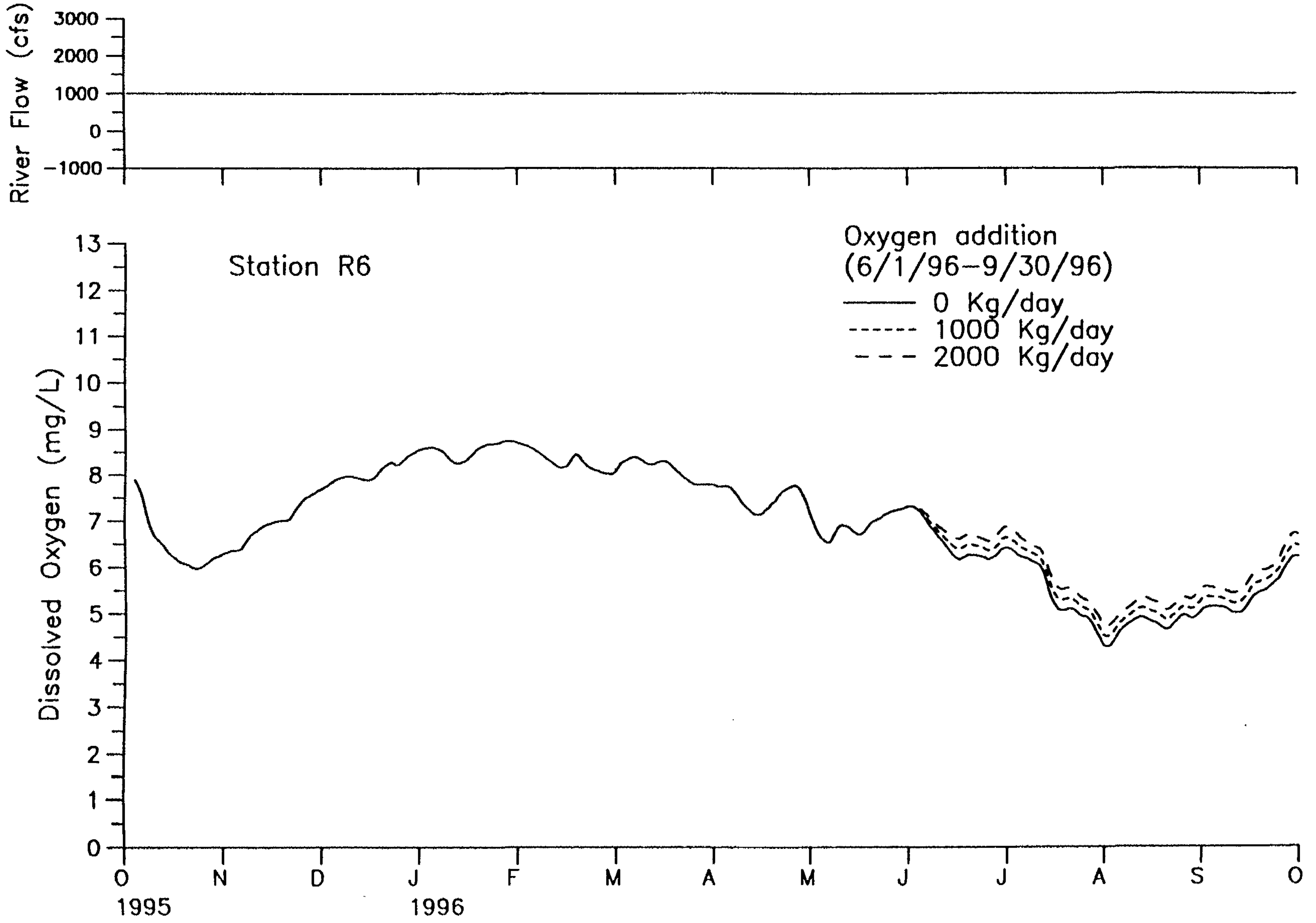
River Flow (cfs)
3000
2000
1000
0
-1000
Station R4
Oxygen addition
(6/1/96-9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D-041790



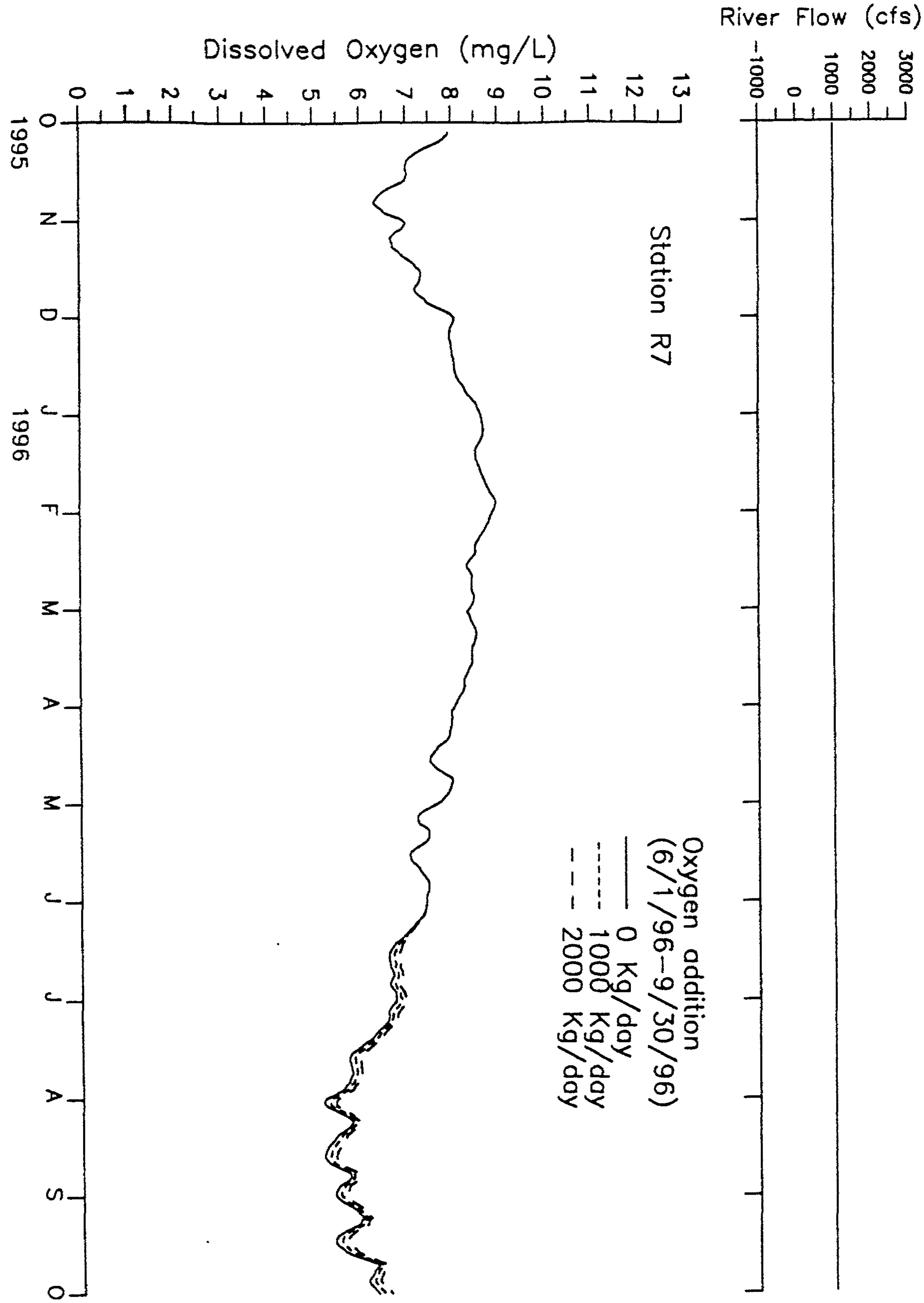
D-041791

D-041791



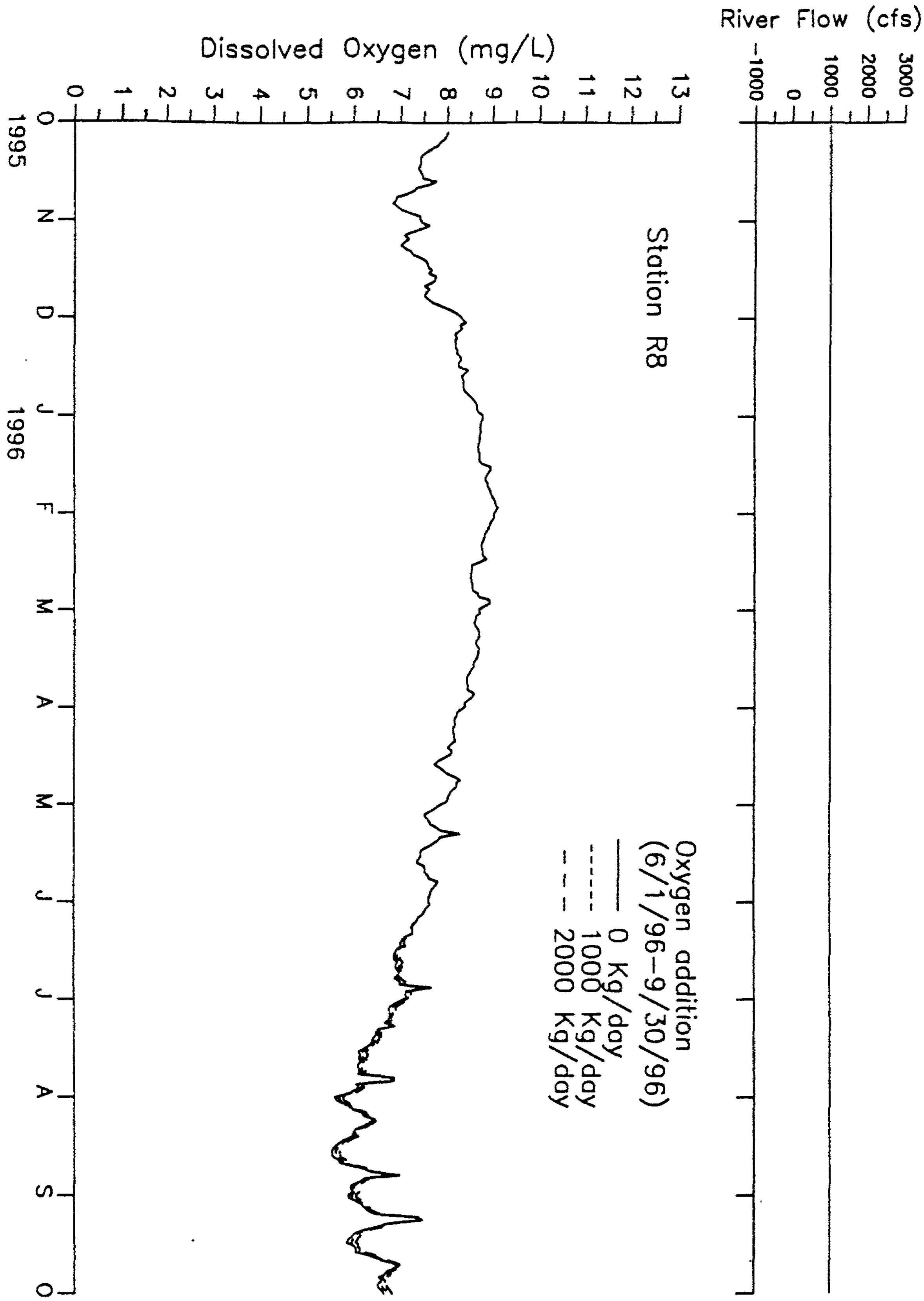
River Flow (cfs)
3000
2000
1000
0
−1000
Station R6
Oxygen addition
(6/1/96–9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1995
1996

D —0 4 1 7 9 2



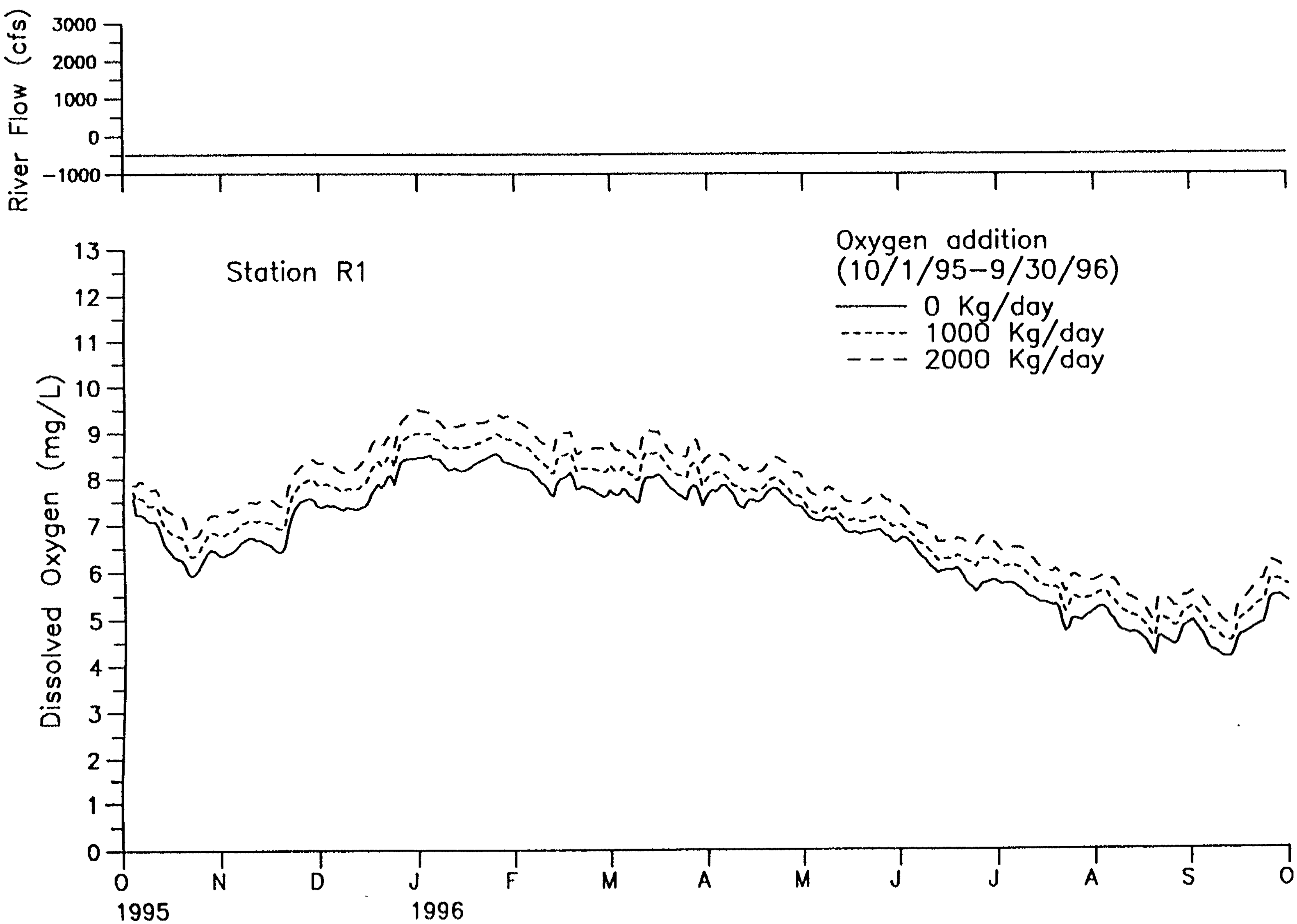
Station R7
Oxygen addition
(6/1/96–9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
Dissolved Oxygen (mg/L)
River Flow (cfs)
1995
1996
O
N
D
J
F
M
A
M
J
J
A
S
O

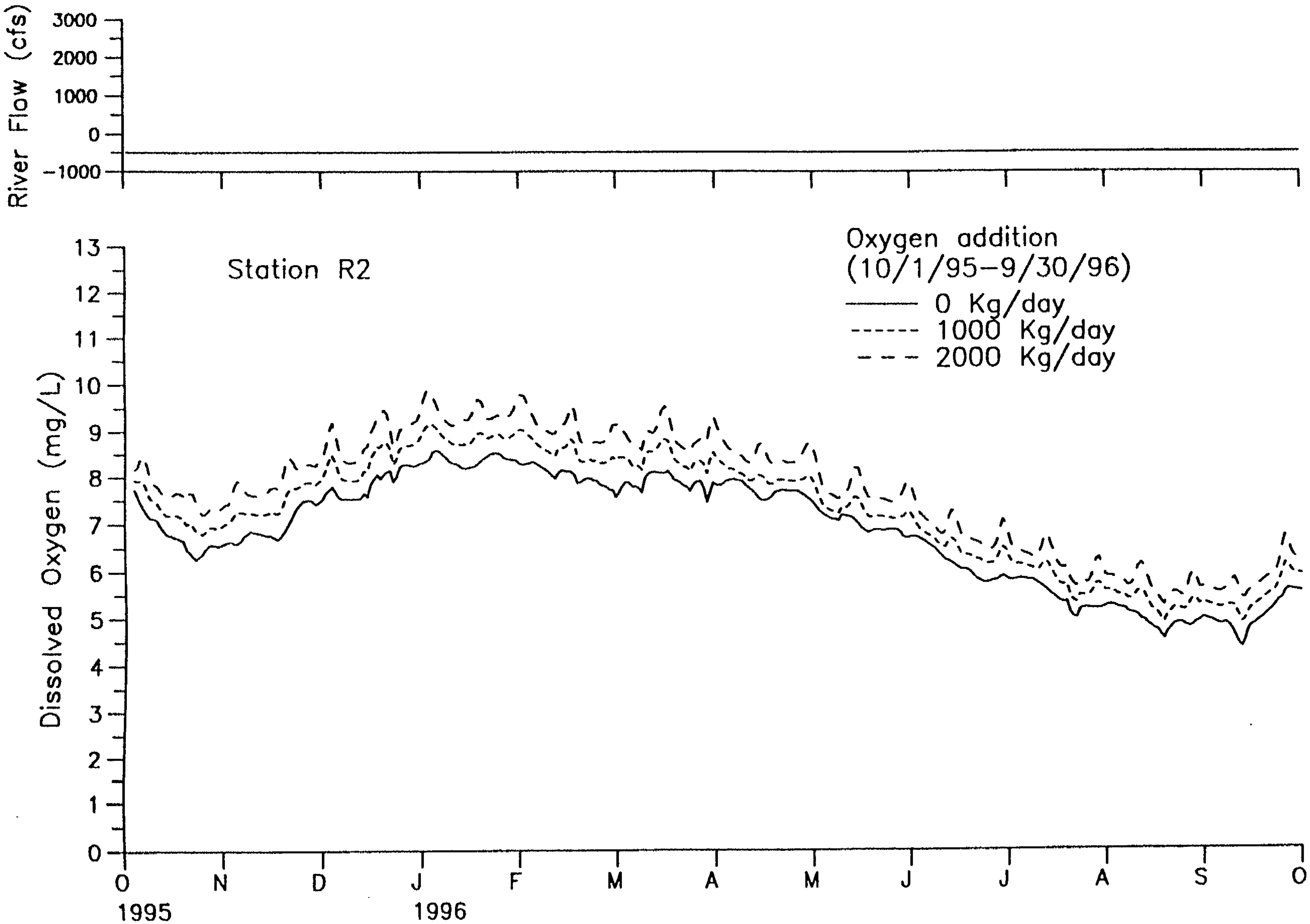
D-041793



River Flow (cfs)
-1000
0
1000
2000
3000
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Station R8
Oxygen addition
(6/1/96-9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

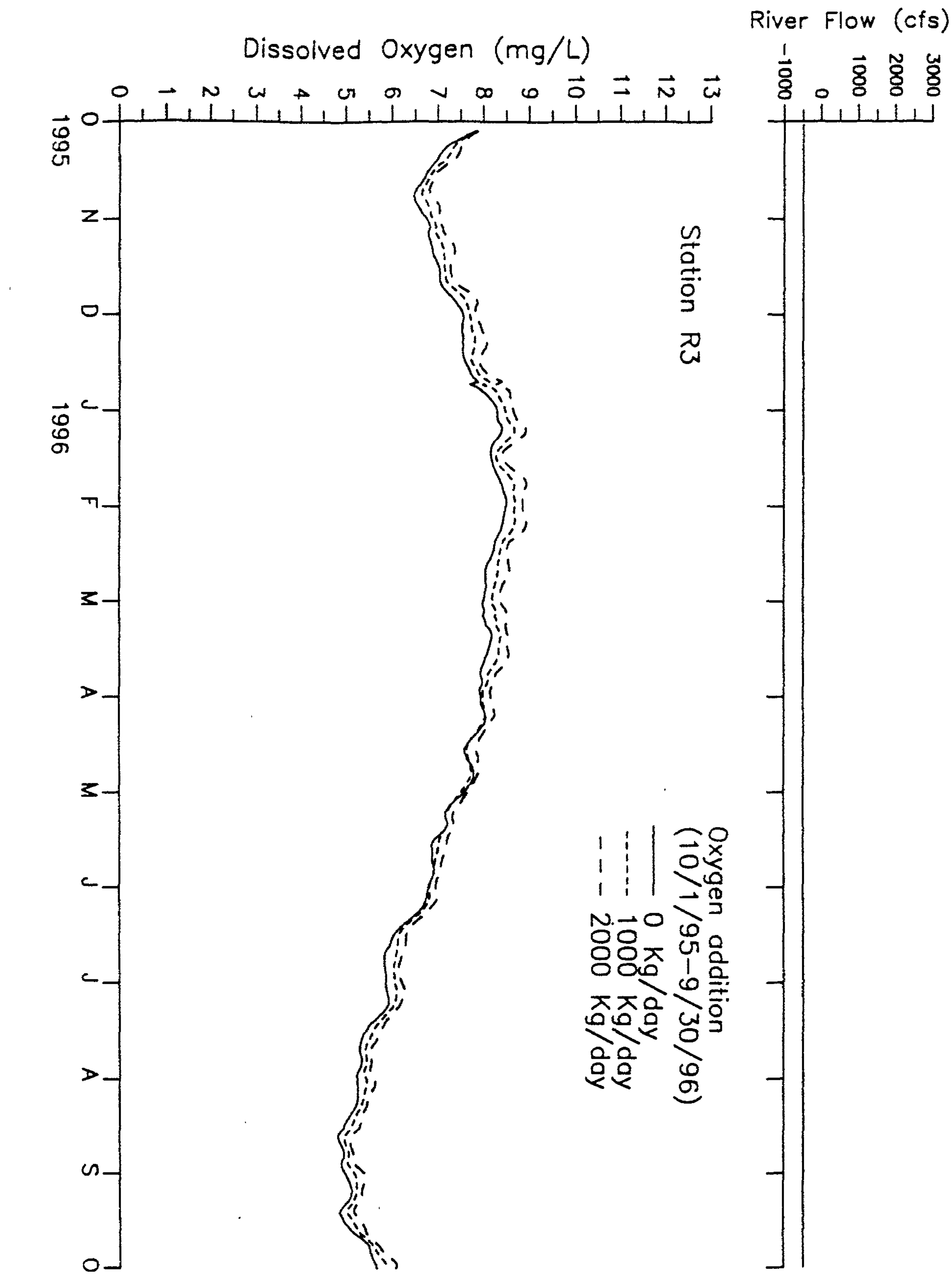
D-041794


River Flow (cfs)
3000
2000
1000
0
−1000
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Station R1
Oxygen addition
(10/1/95–9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

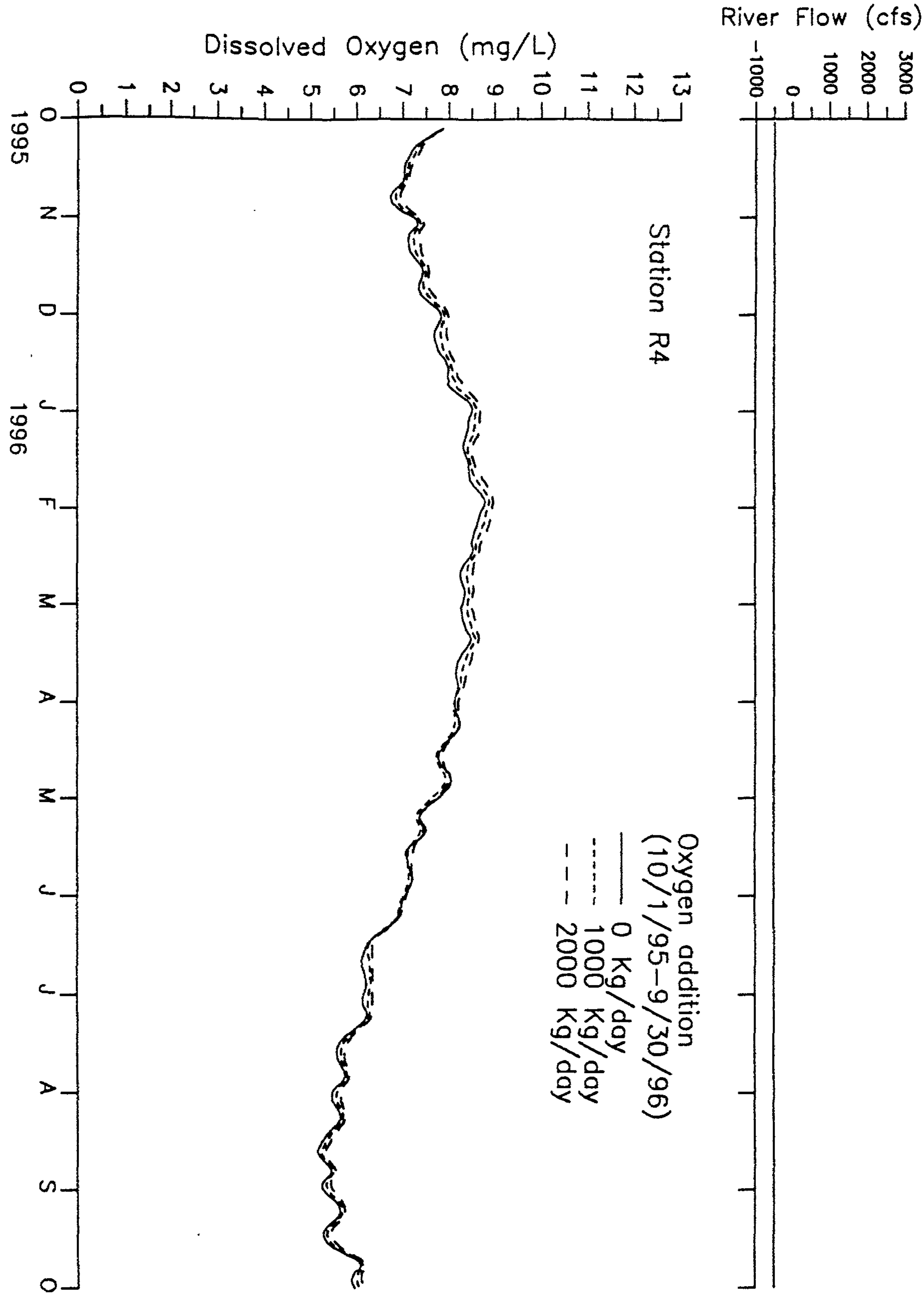


D-041796

D-041796

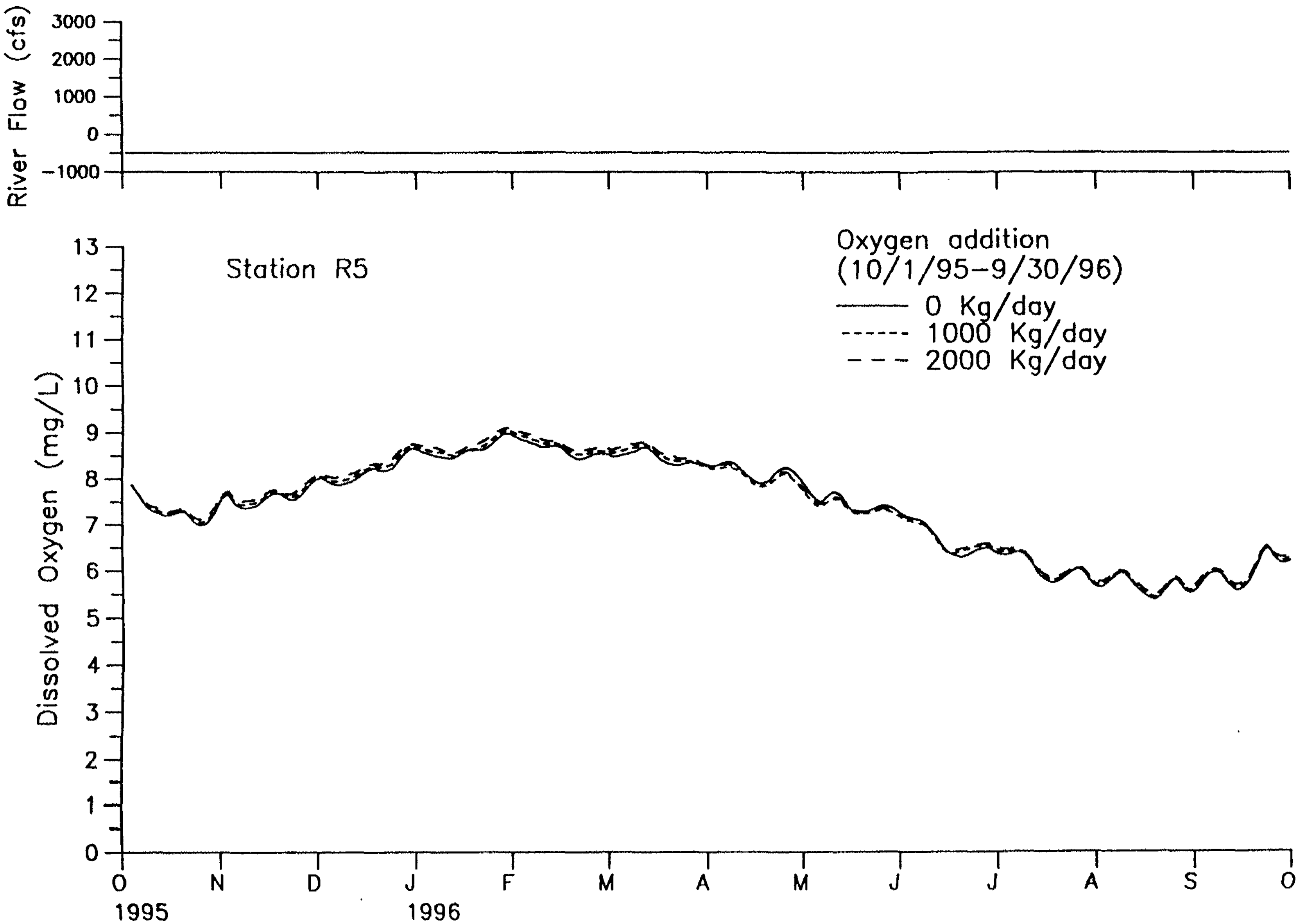

River Flow (cfs)
-1000
0
1000
2000
3000
Dissolved Oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Station R3
Oxygen addition
(10/1/95-9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D-041797



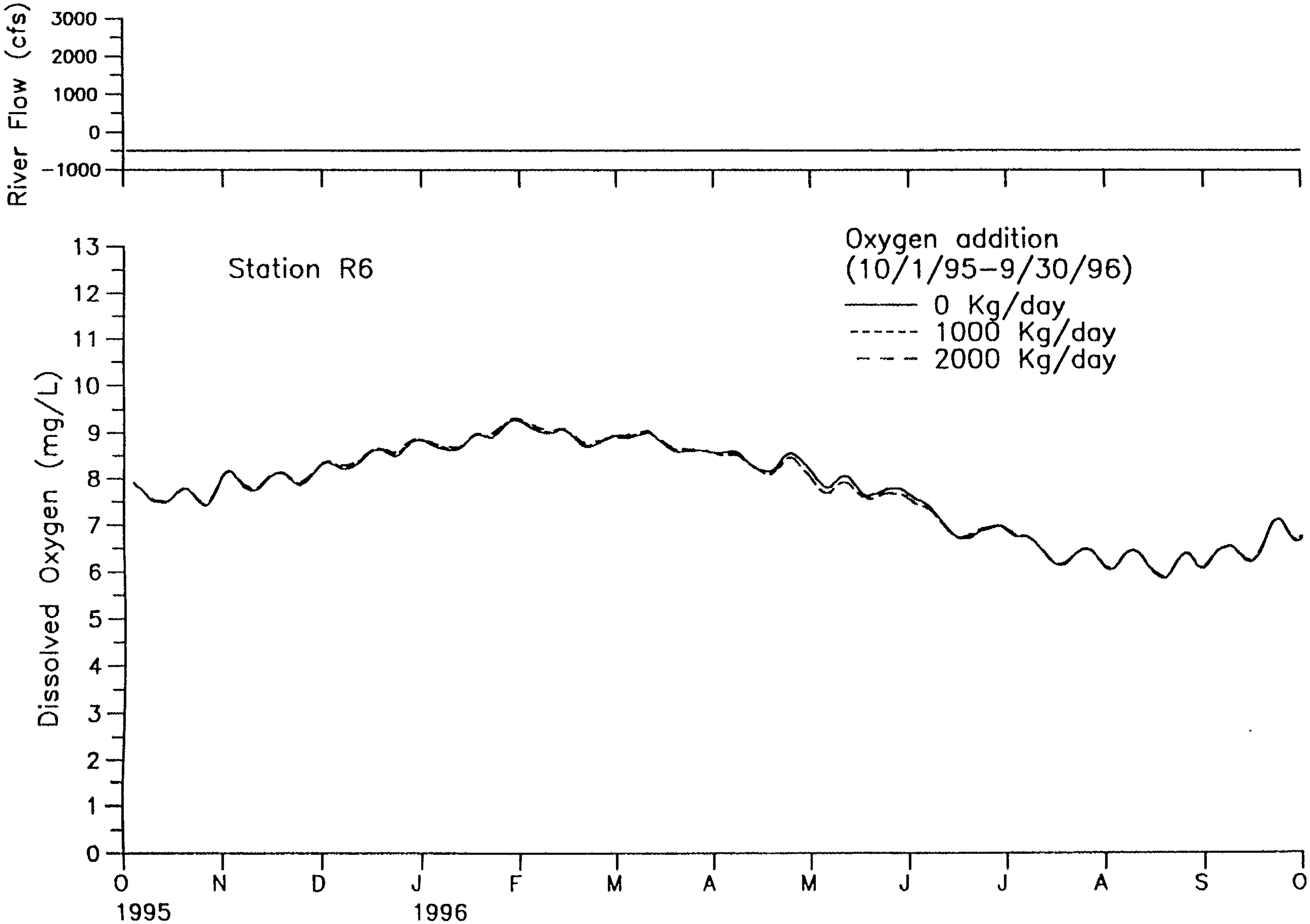
Dissolved Oxygen (mg/L)
River Flow (cfs)
Station R4
Oxygen addition
(10/1/95–9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
1995
1996
O N D J F M A M J J A S O
0 1 2 3 4 5 6 7 8 9 10 11 12 13
-1000 0 1000 2000 3000

D-041798



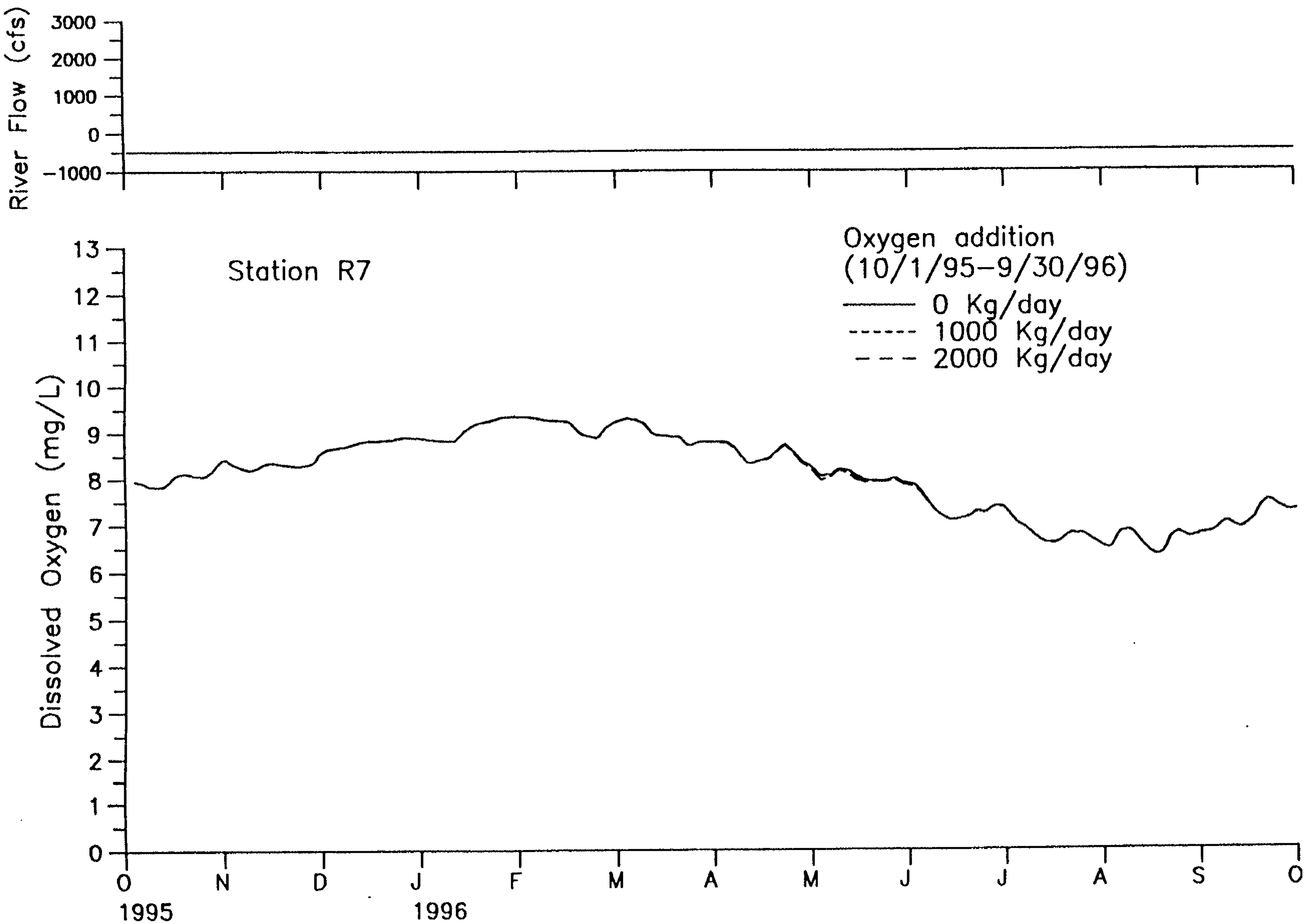
D-041799

D-041799



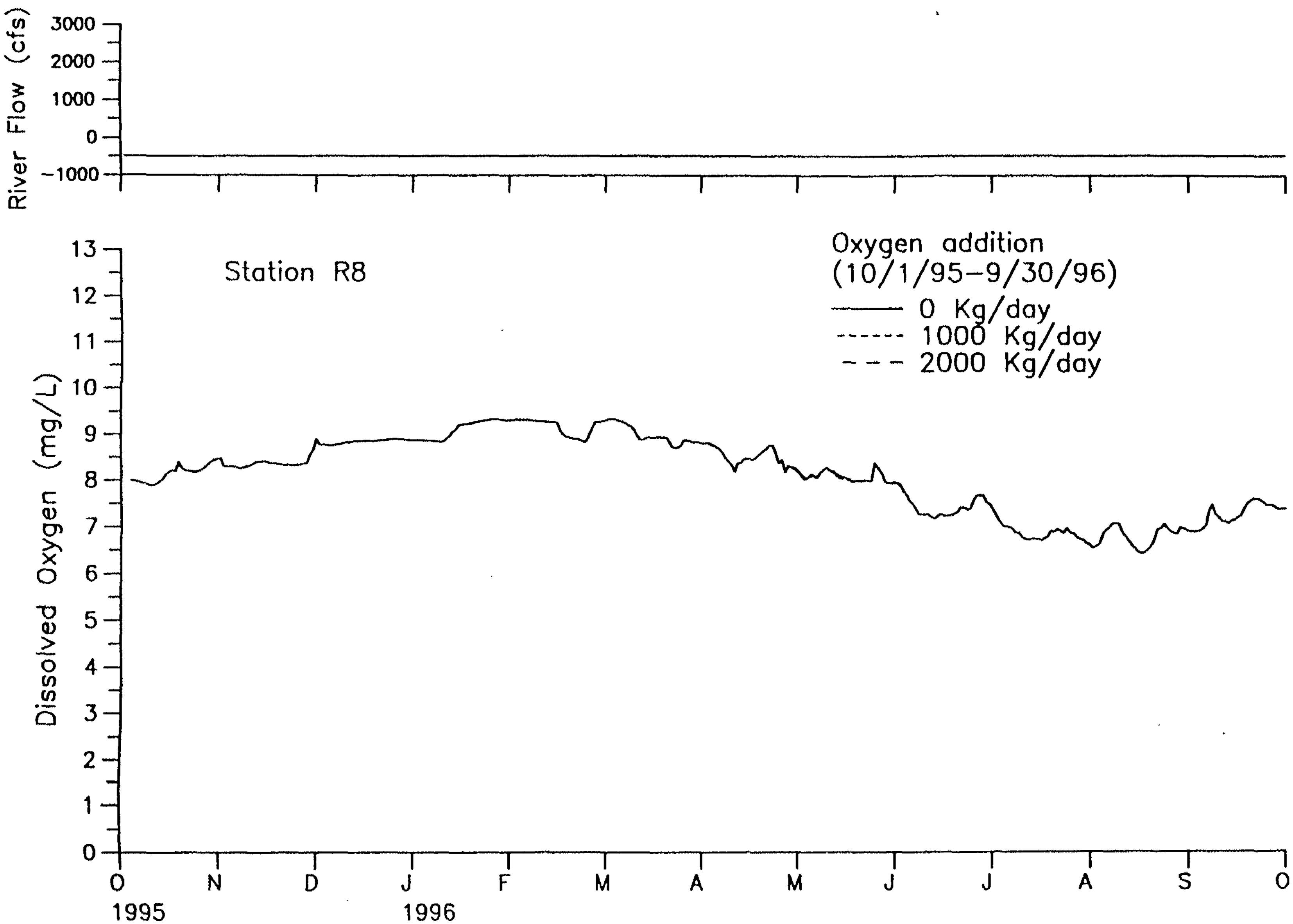
D-041800

D-041800

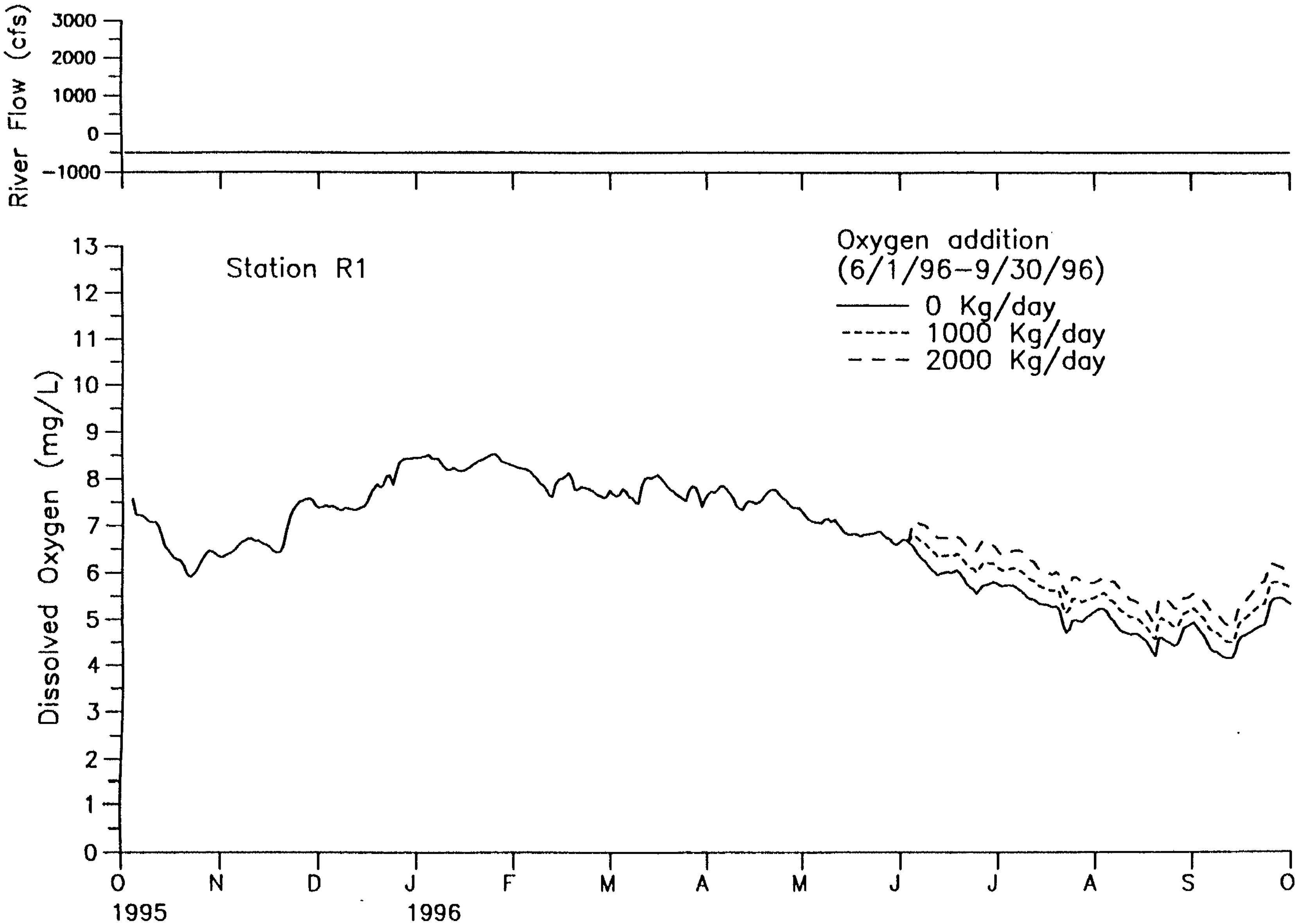


D-041801

D-041801

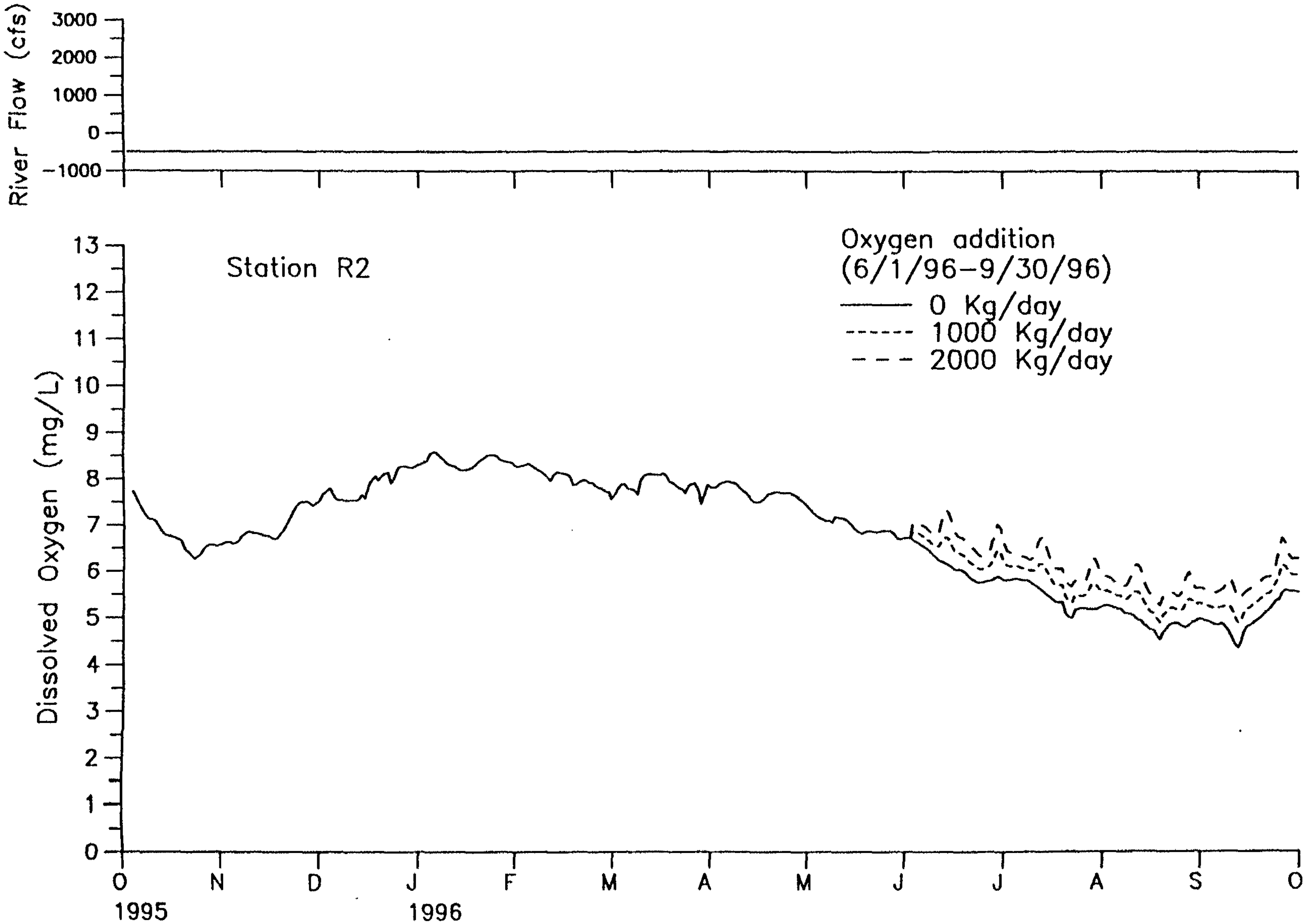

River Flow (cfs)
3000
2000
1000
0
−1000
Station R8
Oxygen addition
(10/1/95–9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1995
1996

D-041802



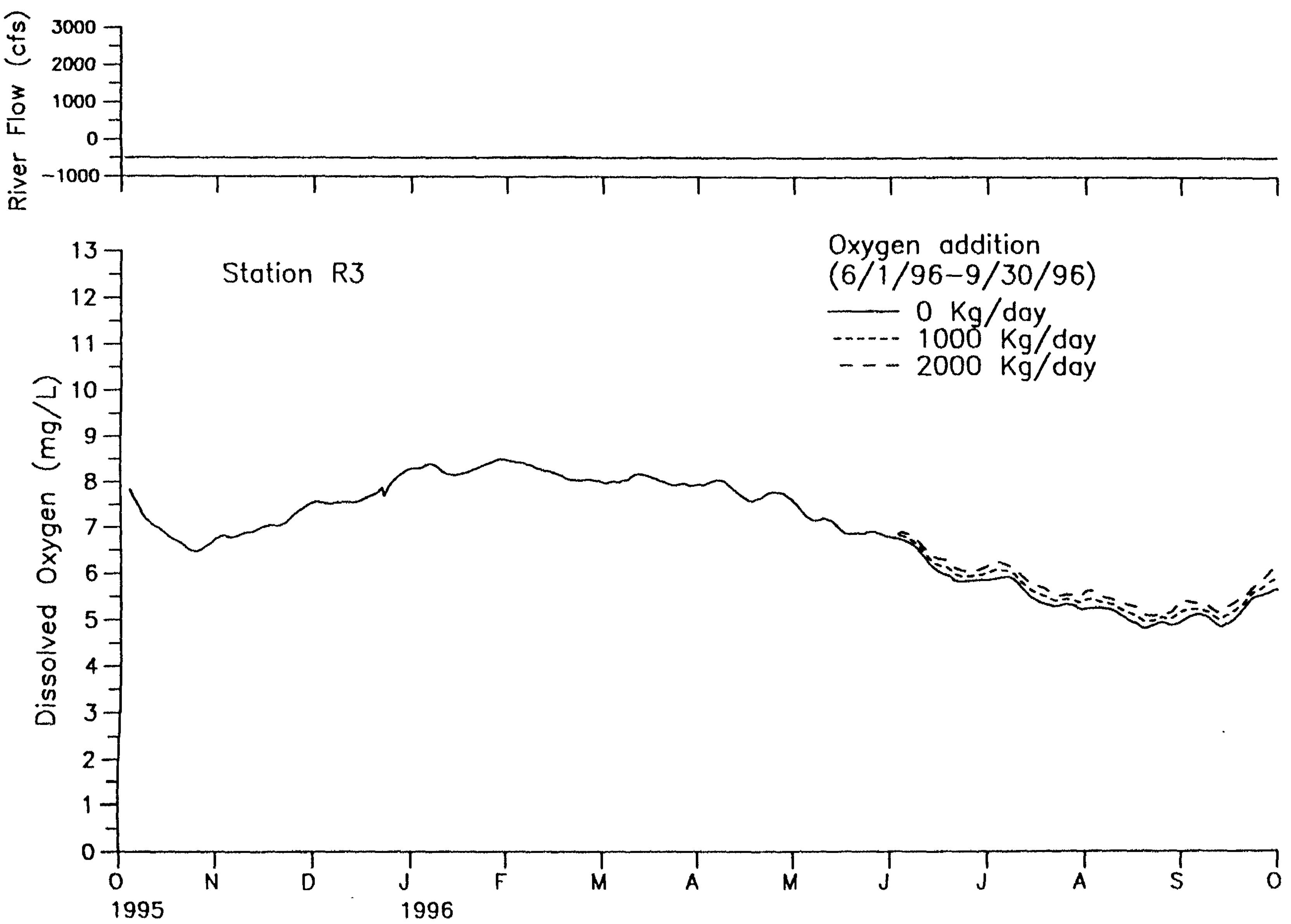
D-041803

D-041803



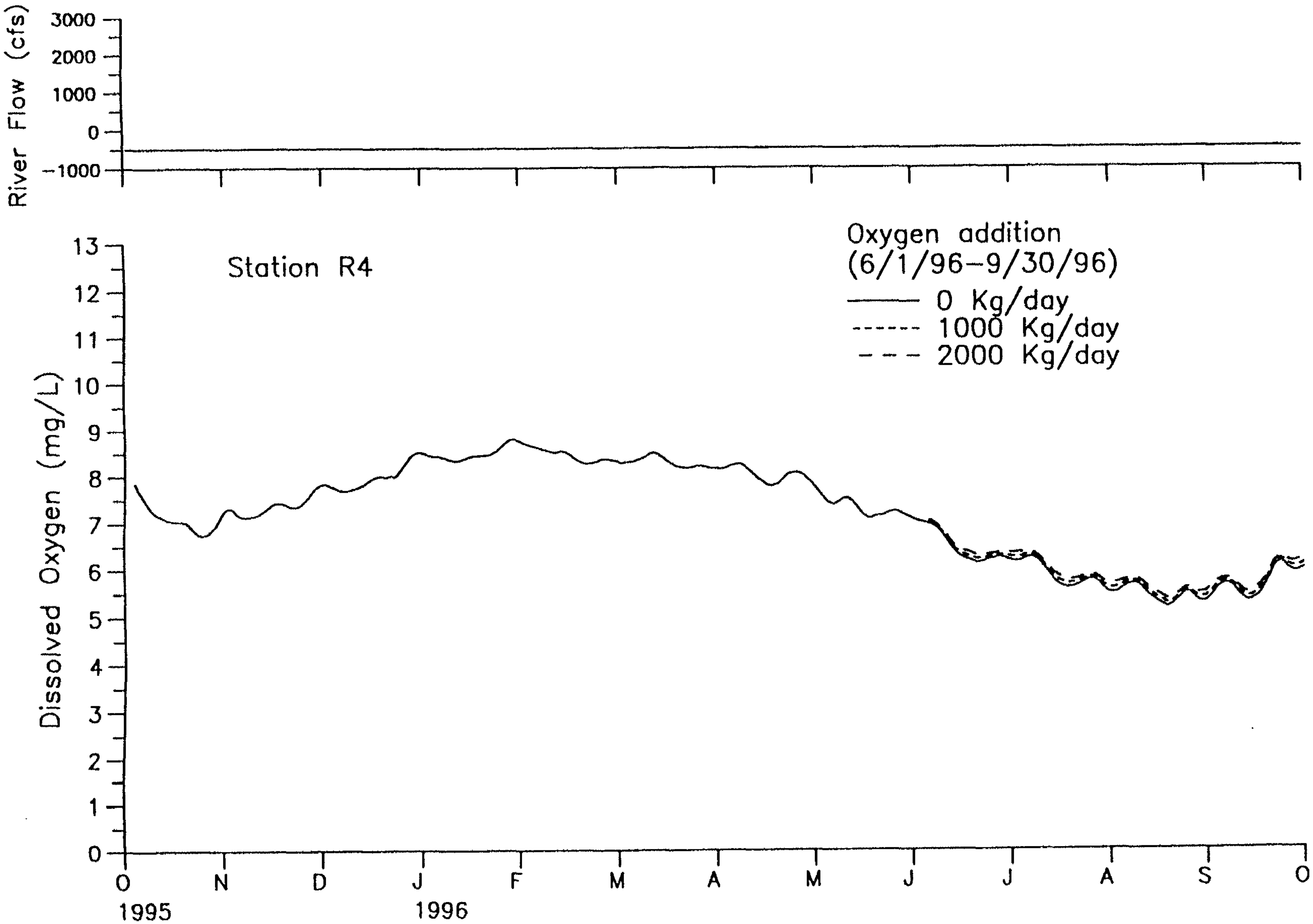
D-041804

D-041804



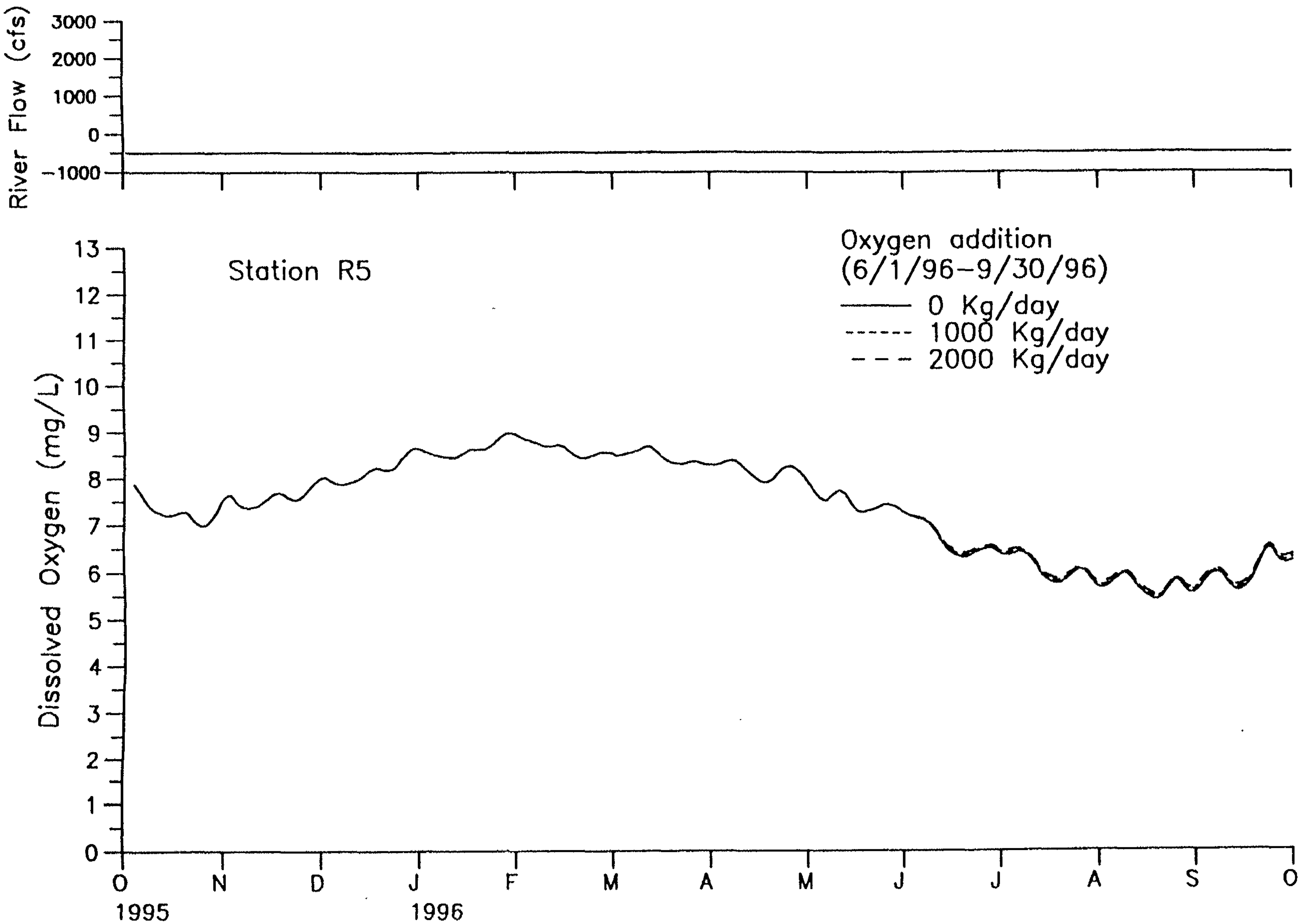
D —0 4 1 8 0 5

D-041805



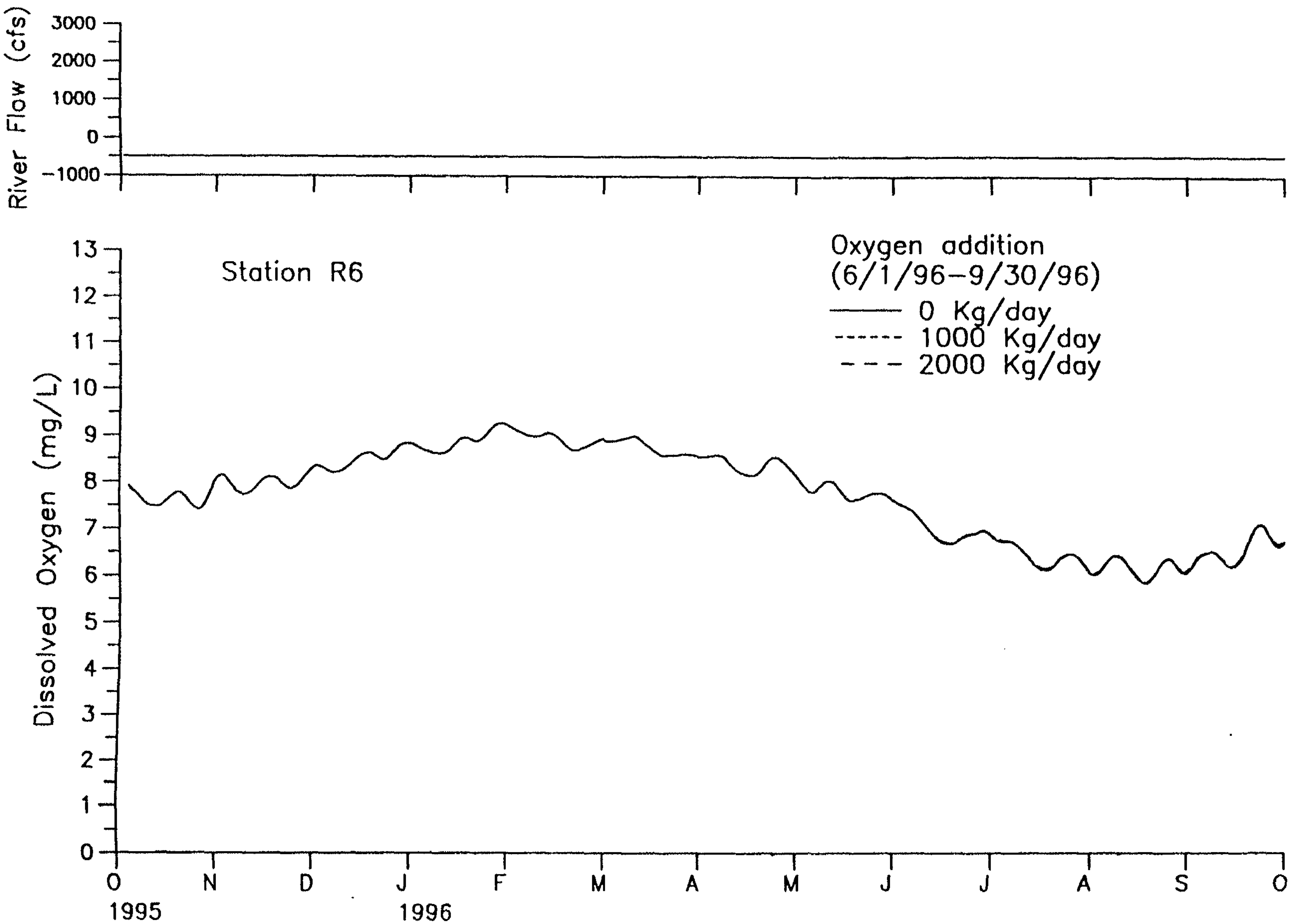
D-041806

D-041806



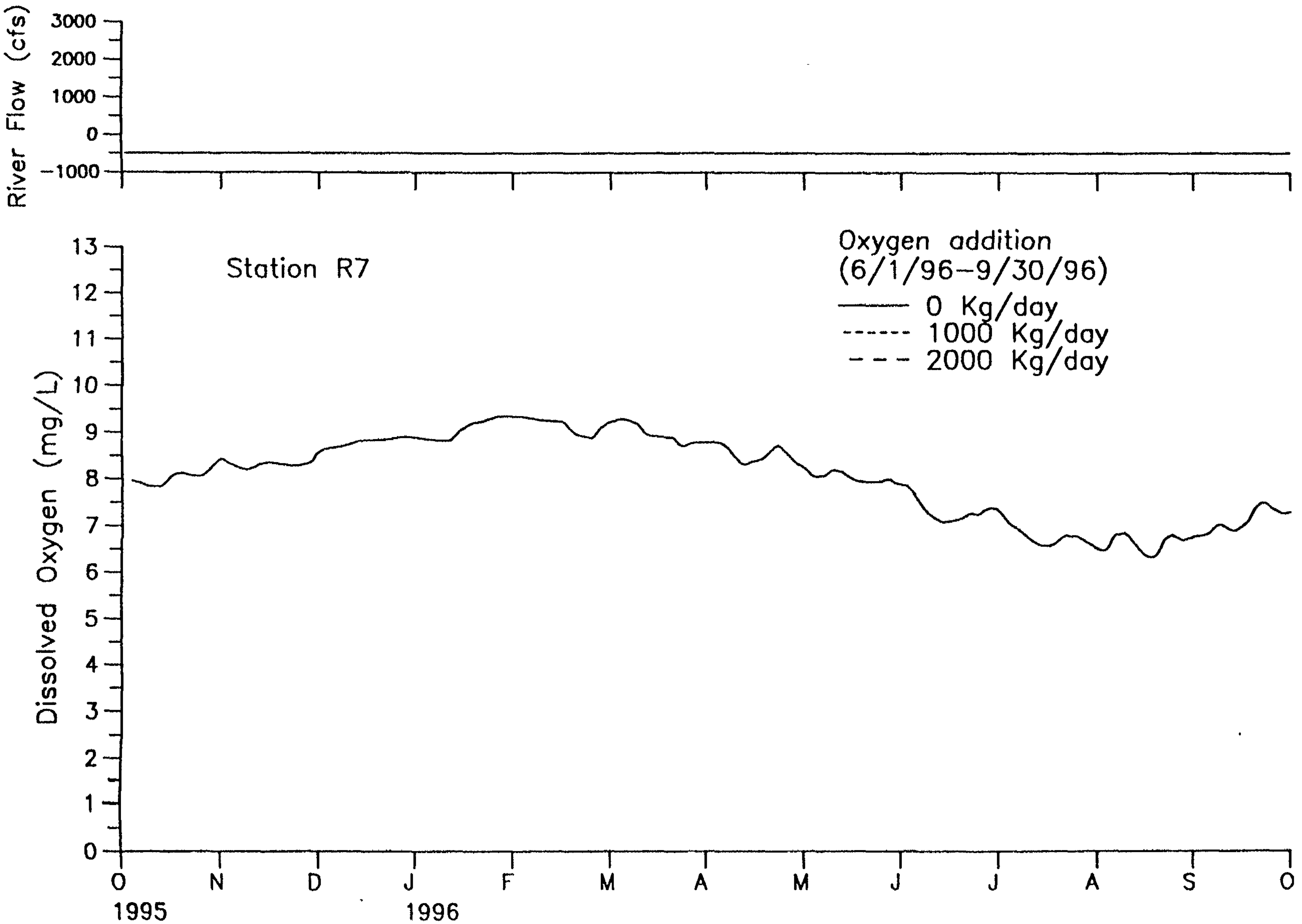
River Flow (cfs)
3000
2000
1000
0
-1000
Station R5
Oxygen addition
(6/1/96-9/30/96)
0 Kg/day
1000 Kg/day
2000 Kg/day
Dissolved Oxygen (mg/L)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1995
1996

D-041807



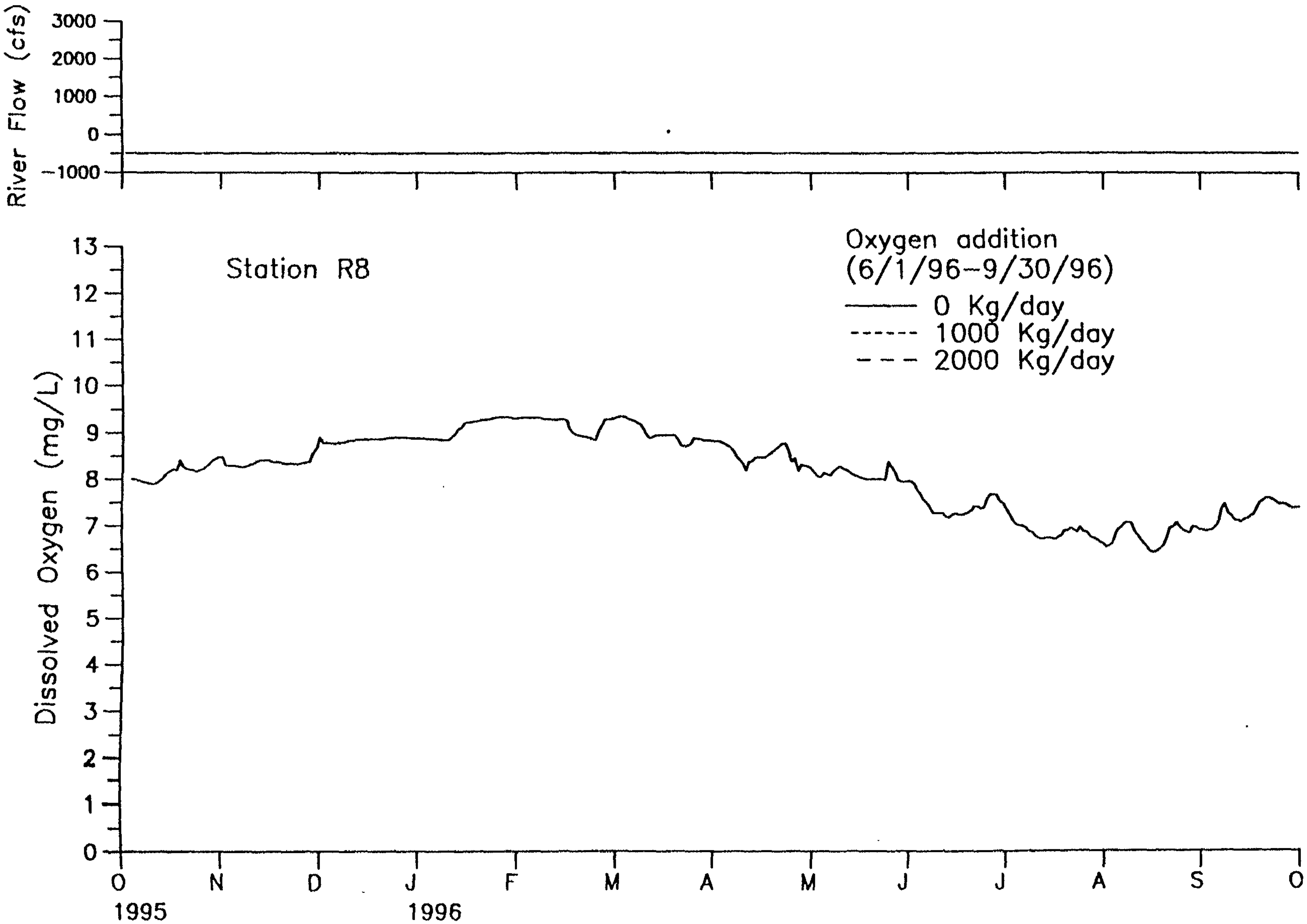
D—041808

D-041808



D-041809

D-041809

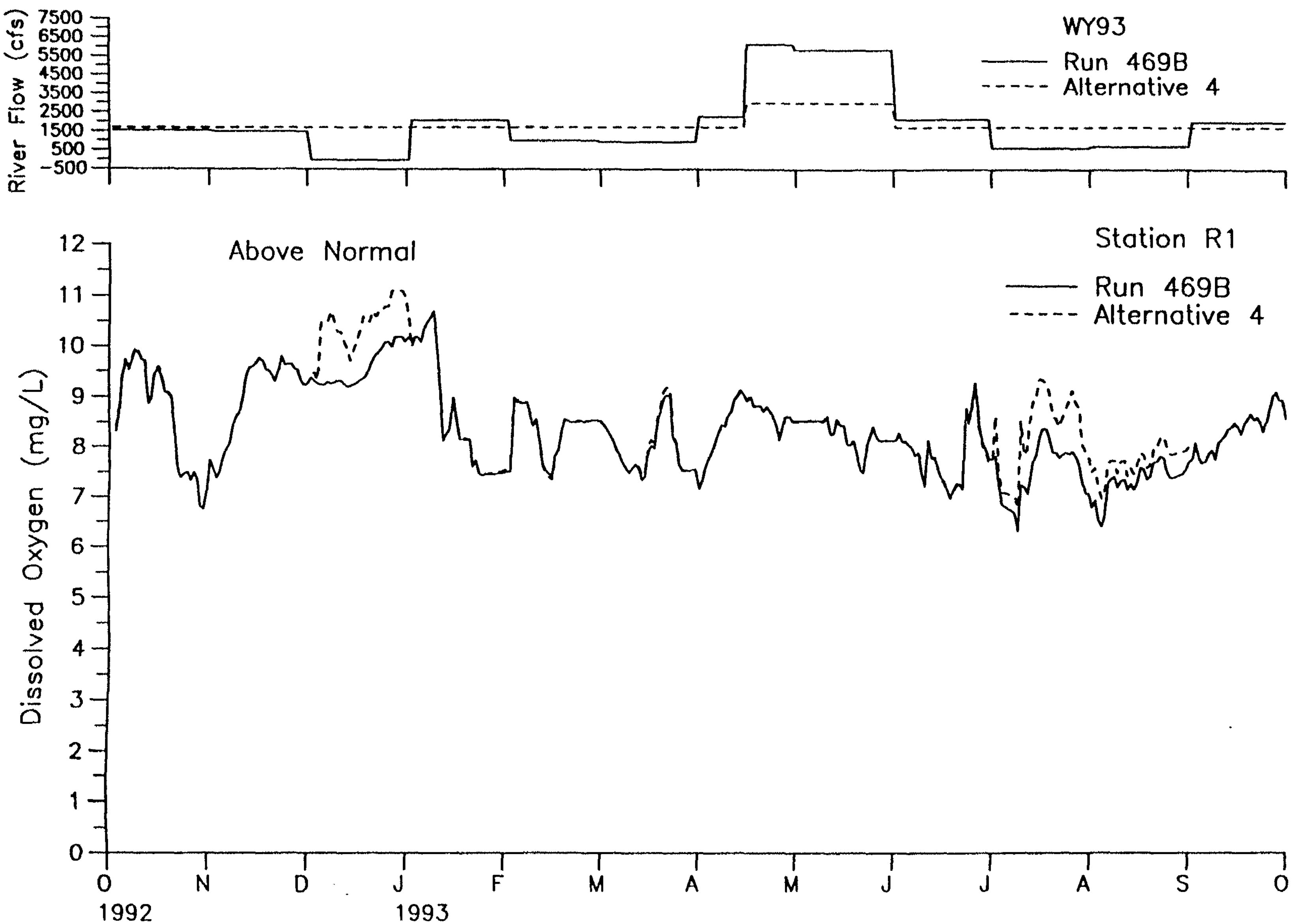


D—041810

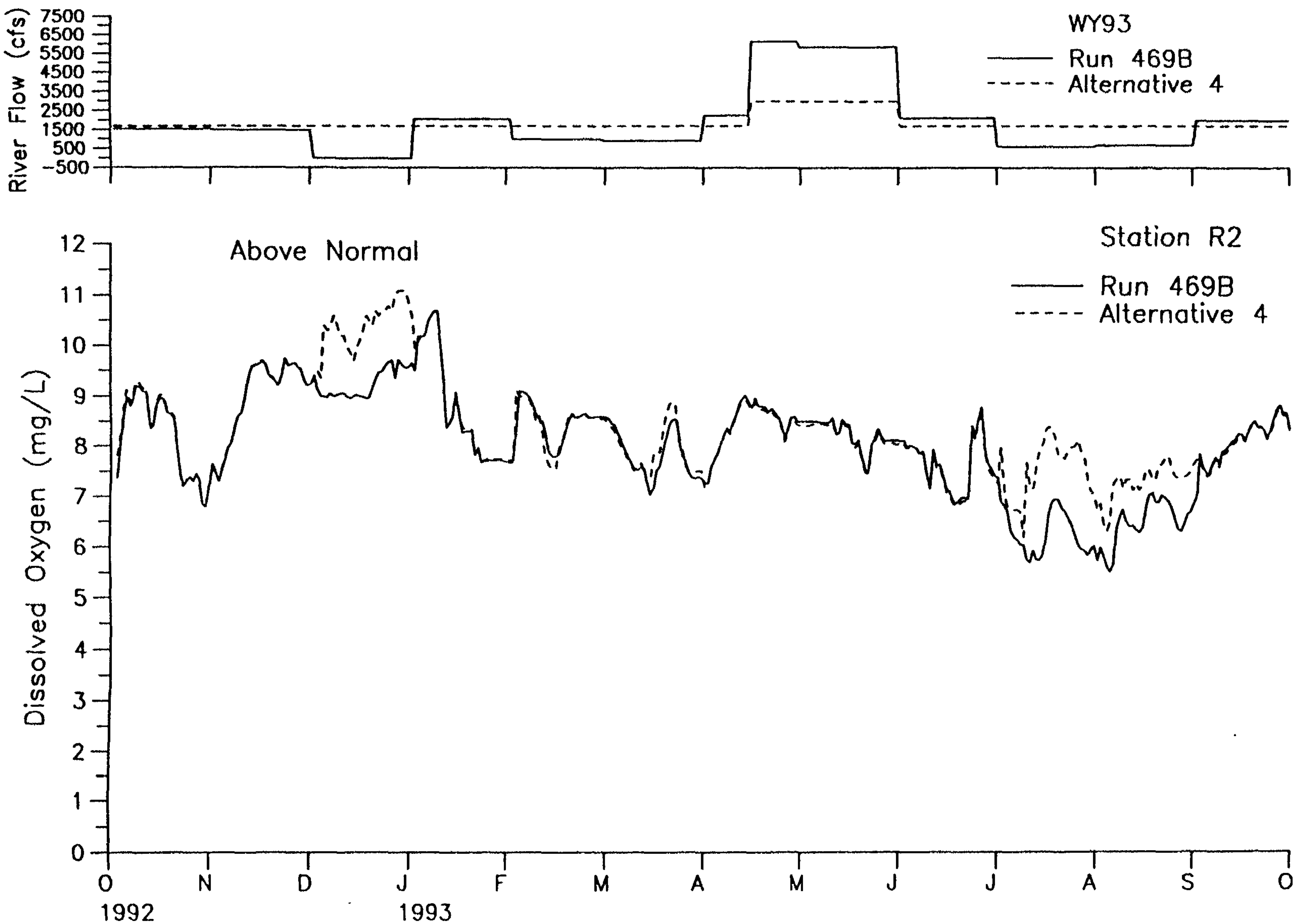
D-041810

Appendix Q.

DO With Flow Redistribution

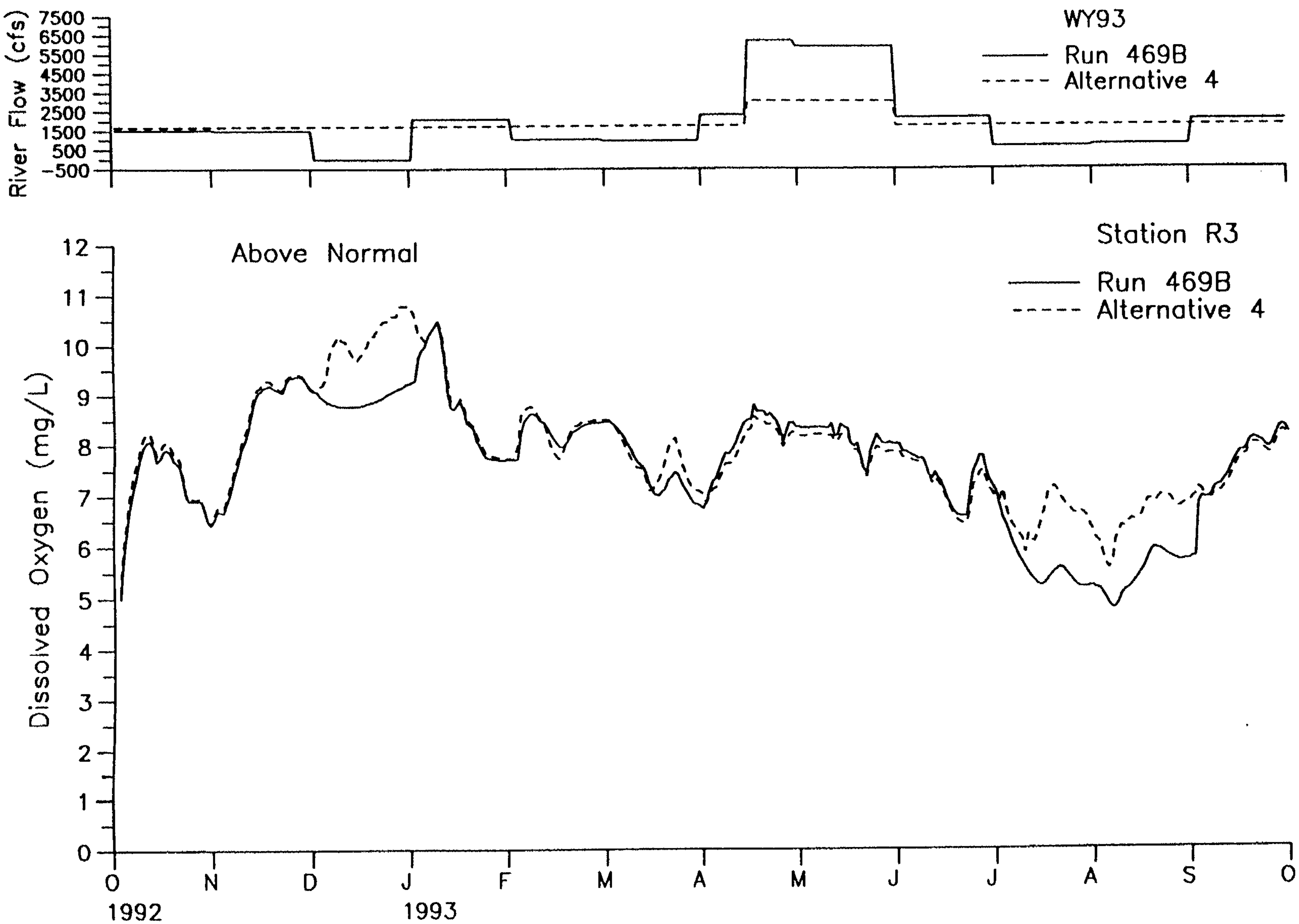

WY93
Run 469B
Alternative 4
River Flow (cfs)
7500
6500
5500
4500
3500
2500
1500
500
-500
Station R1
Above Normal
Run 469B
Alternative 4
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1992
1993

D-041812

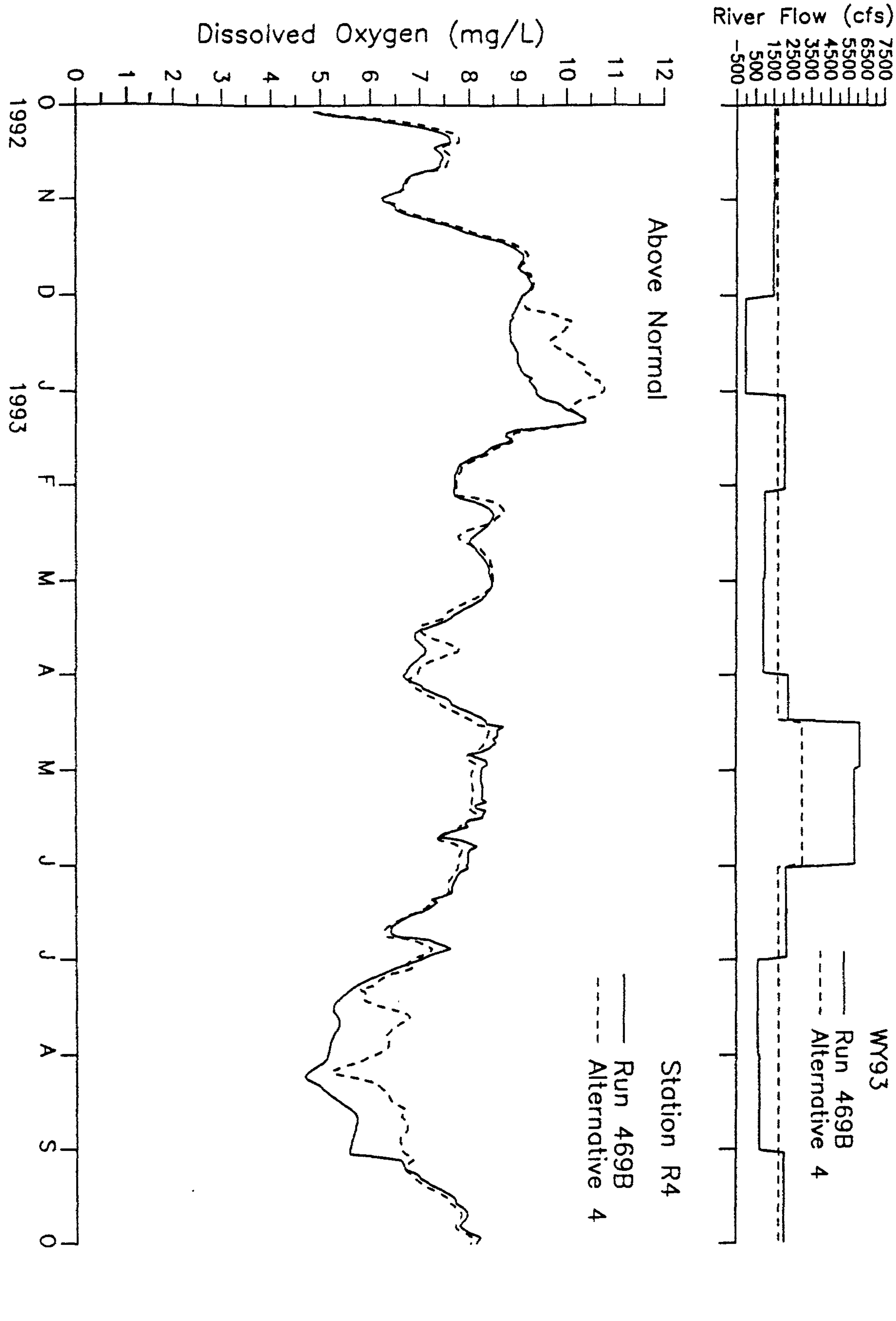


D-041813

D—041813

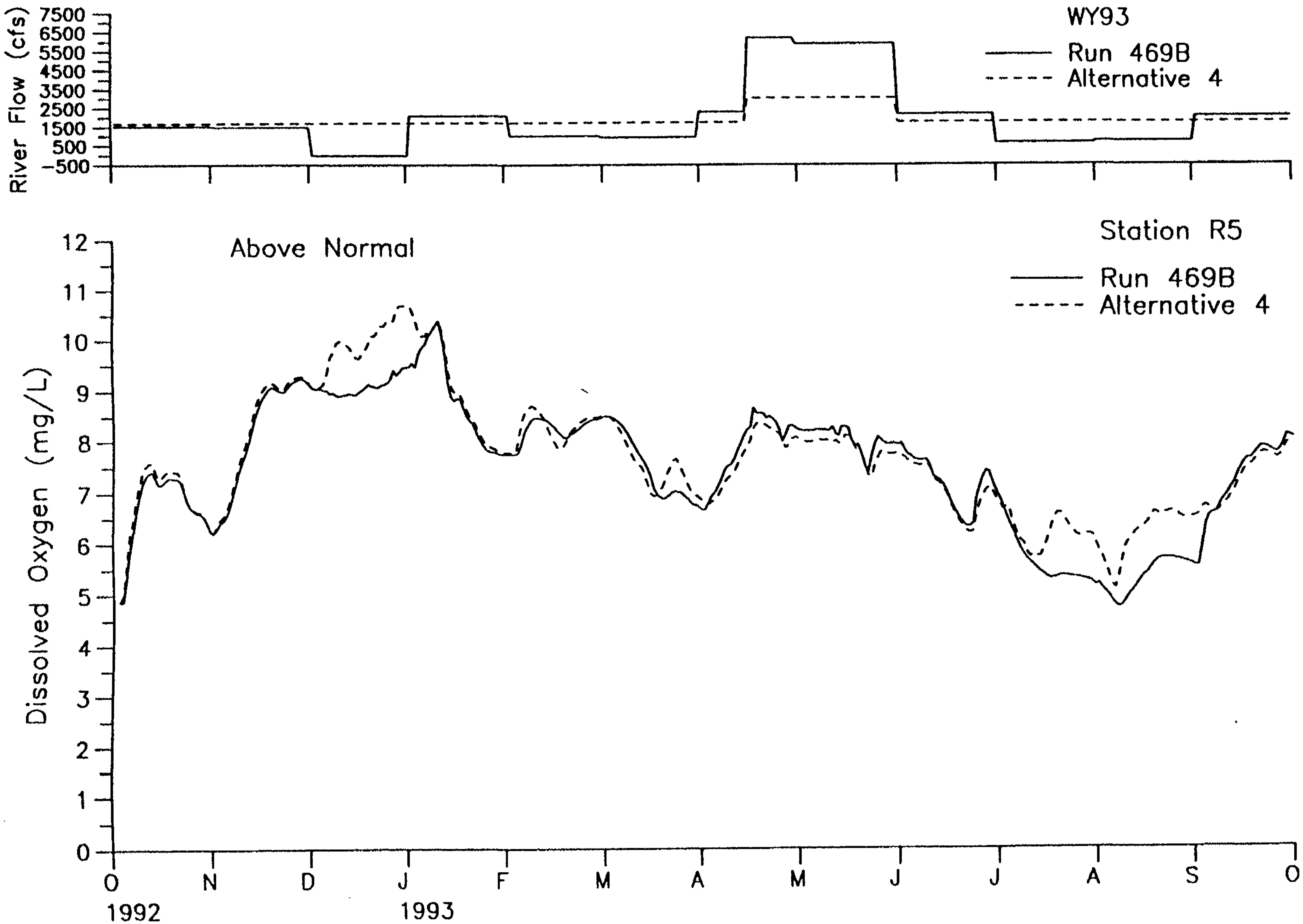

WY93
Run 469B
Alternative 4
River Flow (cfs)
7500
6500
5500
4500
3500
2500
1500
500
-500
Station R3
Above Normal
Run 469B
Alternative 4
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1992
1993

D-041814

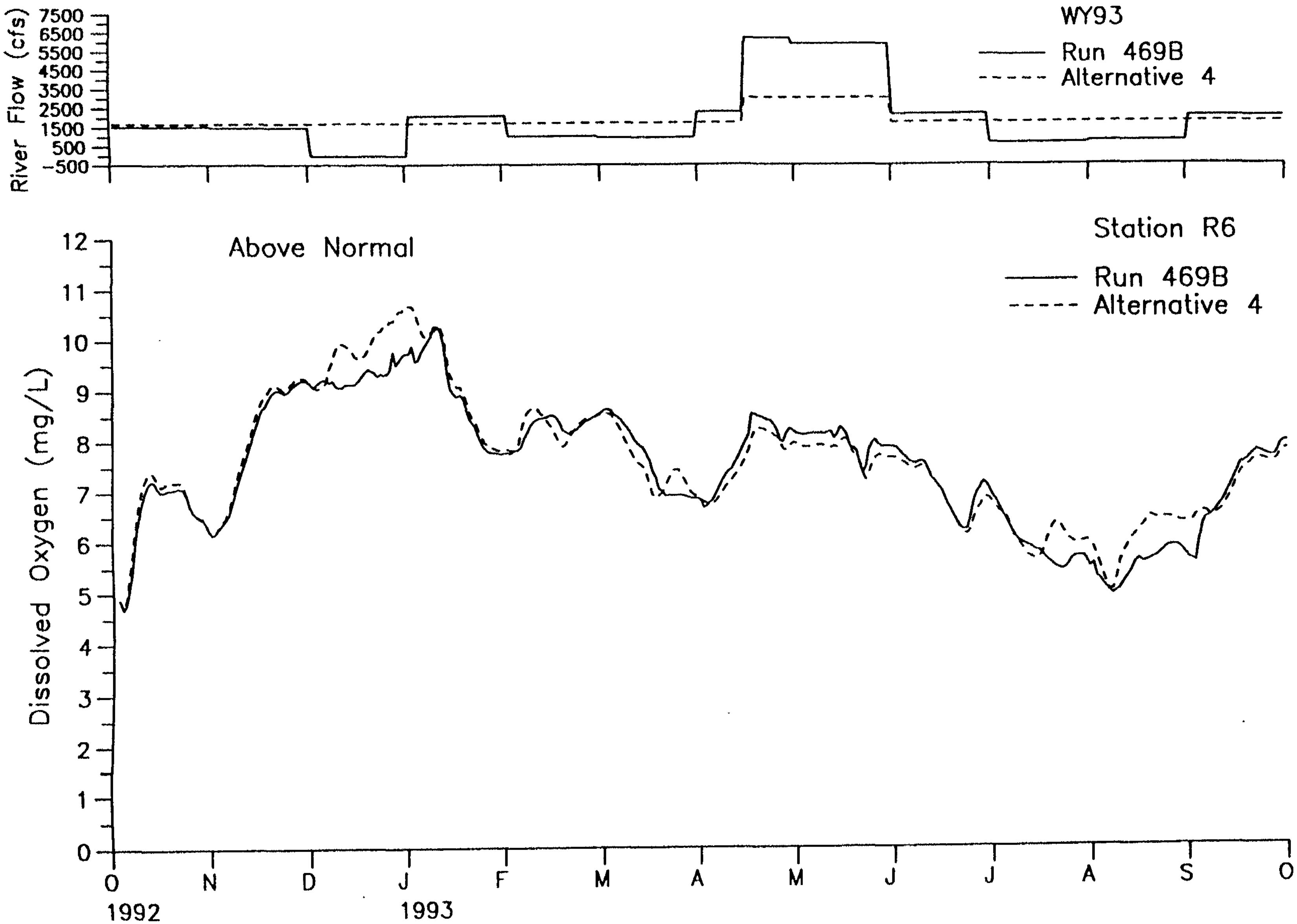


Dissolved Oxygen (mg/L)
River Flow (cfs)
-500
500
1500
2500
3500
4500
5500
6500
7500
0
1
2
3
4
5
6
7
8
9
10
11
12
O
N
D
J
F
M
A
M
J
J
A
S
O
1992
1993
Above Normal
Station R4
Run 469B
Alternative 4
WY93
Run 469B
Alternative 4

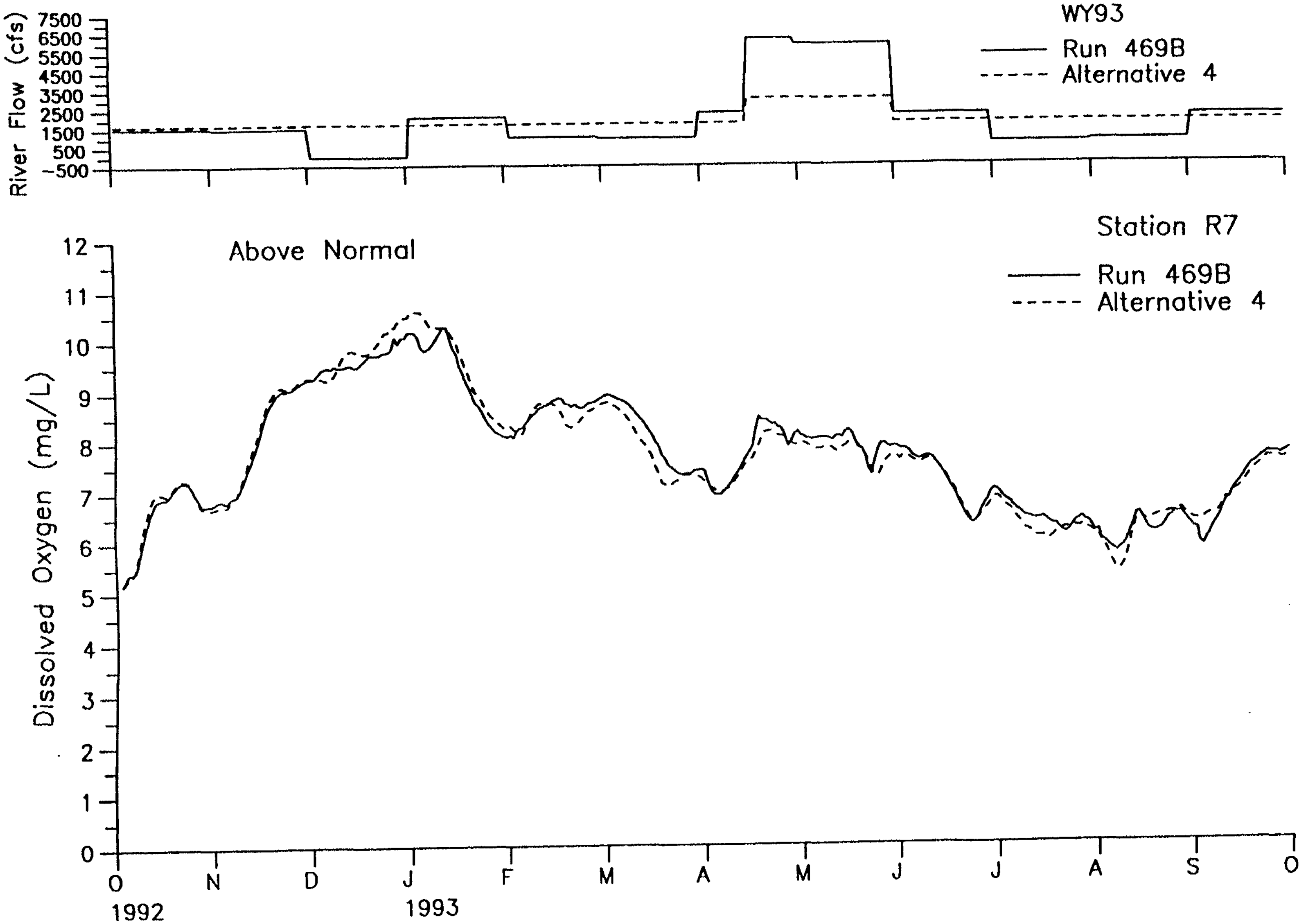
D —0 4 1 8 1 5


WY93
Run 469B
Alternative 4
River Flow (cfs)
7500
6500
5500
4500
3500
2500
1500
500
-500
Station R5
Above Normal
Run 469B
Alternative 4
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O N D J F M A M J J A S O
1992
1993

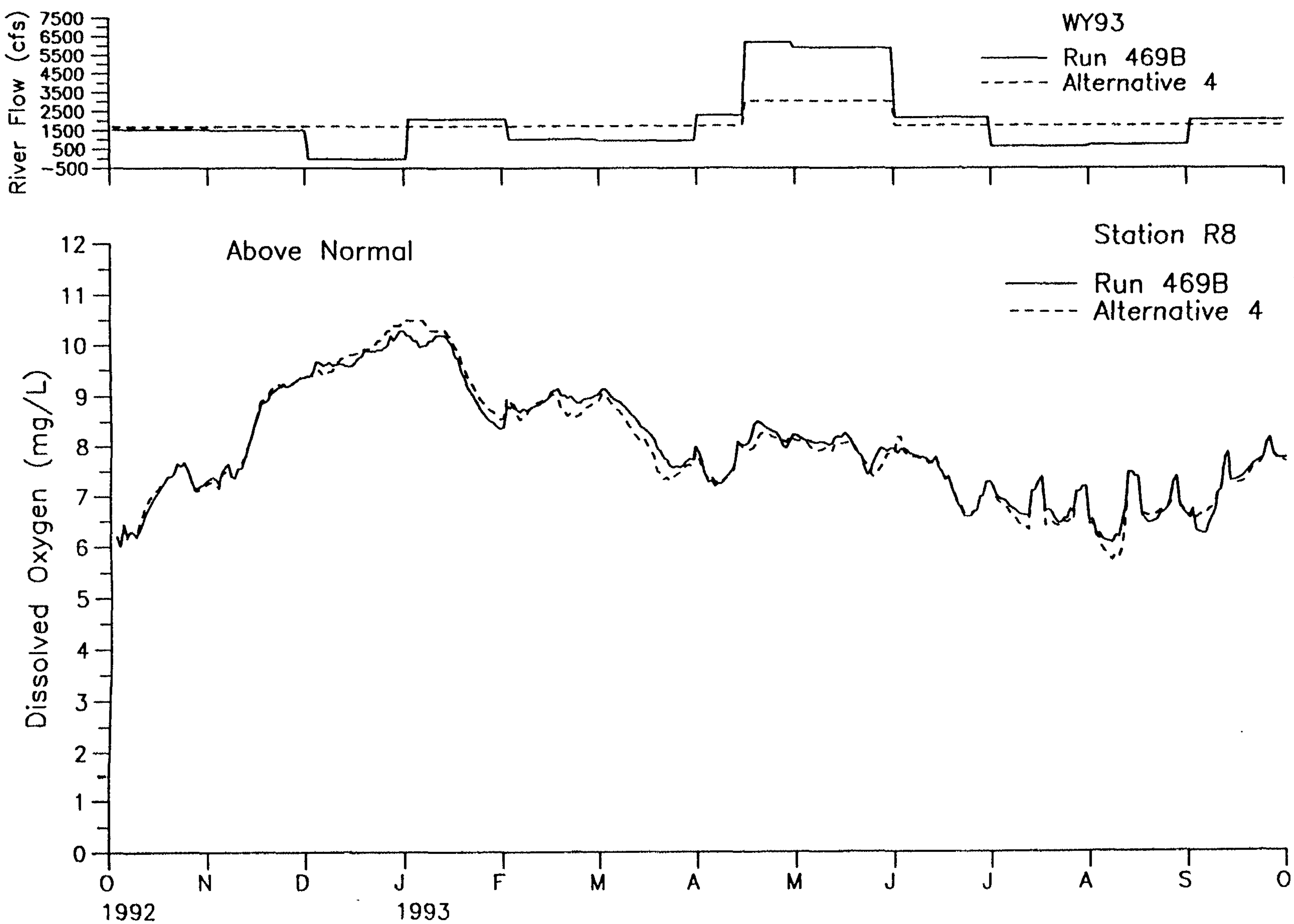
D—041816


WY93
Run 469B
Alternative 4
River Flow (cfs)
7500
6500
5500
4500
3500
2500
1500
500
-500
Station R6
Above Normal
Run 469B
Alternative 4
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1992
1993

D-041817


WY93
Run 469B
Alternative 4
River Flow (cfs)
7500
6500
5500
4500
3500
2500
1500
500
-500
Station R7
Above Normal
Run 469B
Alternative 4
Dissolved Oxygen (mg/L)
12
11
10
9
8
7
6
5
4
3
2
1
0
O
N
D
J
F
M
A
M
J
J
A
S
O
1992
1993

D-041818



D-041819

D-041819