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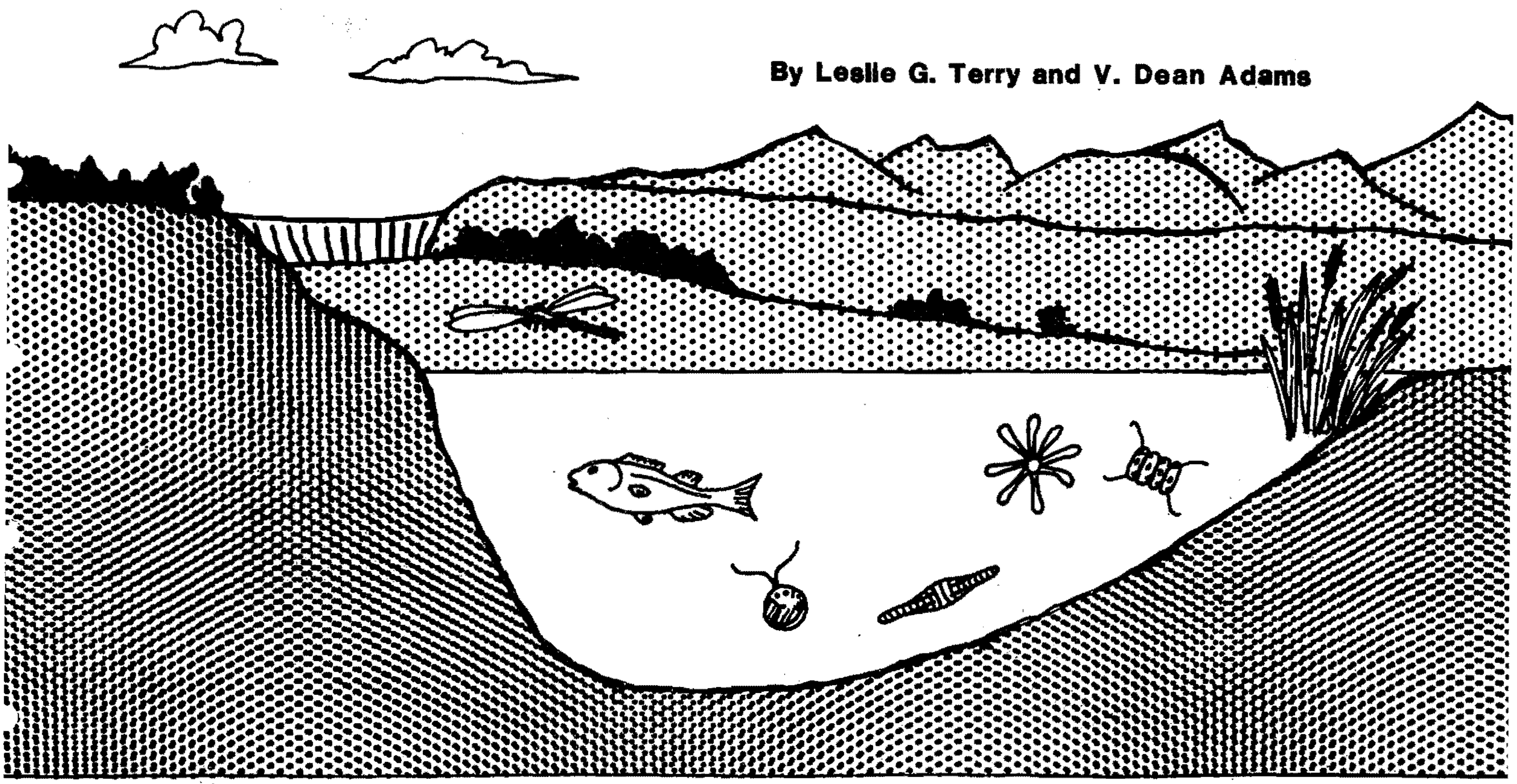
ALGAL BIOASSAY STUDY
for the
DOLORES PROJECT
DOMINGUEZ PROJECT
SAN MIGUEL PROJECT
WEST DIVIDE PROJECT

By Leslie G. Terry and V. Dean Adams



Utah Water Research Laboratory
College of Engineering
Utah State University
Logan, Utah 84321

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ALGAL BIOASSAY STUDY FOR THE DOLORES PROJECT, DOMINGUEZ PROJECT, SAN MIGUEL PROJECT, WEST DIVIDE PROJECT

by

Leslie G. Terry
V. Dean Adams

This report was completed for the United States Bureau of Reclamation as a part of Contract No. 7-07-40-S0329 (Chemical and Biological Analysis of Colorado Water Samples).

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I. Sample Pretreatment

Sample pretreatment was conducted in a similar manner for each of five sampling dates (September 8, 1977; November 29, 1977; January 9, 1978; March 8, 1978 and May 10, 1978) and for each of the samples from the four project sites. Immediately upon arrival three liters of each sample were filter sterilized using 0.45 μ millipore membrane filters. Filtering removes native algae and bacteria from the test water and enables the use of uni-algal test species in the bioassay. Following filtration, the samples were subjected to routine chemical analyses for the determination of indigenous levels of soluble total and ortho phosphorus and soluble inorganic nitrogen (Tables 1 - 4). Also listed are total inorganic nitrogen/ortho phosphorus ratios as determined by chemical analysis.

Chemical analysis is useful for identifying specific ions but cannot distinguish between biologically available ions and those which are not available. This is where the value of the bioassay lies. Bioassays use the measureable response of living organisms to environmental variables including determining whether or not nutrients are biologically available.

II. Experimental Set-up Procedure

The bioassays were conducted using 100 ml sample volumes in 500 ml Erlenmeyer flasks. Inverted beakers were chosen for flask closures in order to permit good CO_2-O_2 exchange and to prevent contamination.

Table 1.
Dolores Project
Results of Chemical Analyses

	Orthophosphate (PO_4-P) (µg/l)	Total Soluble Phosphorus (µg/l)	Ammonia (NH_3-N) (µg/l)	Nitrate+Nitrite (NO_3+NO_2)-N (µg/l)	Nitrogen/Phosphorus* ($NH_3+NO_3+NO_2$)-N/PO_4-P
9/8/1977					
Dolores River at Dolores	3.	13.	60.	35.	32.
Dolores River below Rico Tailings	1.	8.	64.	52.	116.
Dolores River above Rico Tailings	1.	7.	40.	112.	152.
Dolores River below West Dolores River	4.	7.	46.	41.	22.
11/29/1977					
Dolores River at Dolores	2.	6.	20.	110.	65.
1/9/1978					
Dolores River at Dolores	1.	6.	21.	170.	191.
3/8/1978					
Dolores River at Dolores	<1.	12.	24.	302.	>326.
5/10/1978					
Dolores River at Dolores	<1.	4.	17.	80.	> 97.

*A nitrogen/phosphorus ratio of <15 indicates nitrogen limitation while an N/P ratio of >15 indicates phosphorus limitation.

Table 2.
Dominquez Project
Results of Chemical Analyses

	Orthophosphate (PO_4-P) (µg/l)	Total Soluble Phosphorus (µg/l)	Ammonia (NH_3-N) (µg/l)	Nitrate+Nitrite (NO_3+NO_2)-N (µg/l)	Nitrogen/Phosphorus* ($NH_3+NO_3+NO_2$)-N/PO_4-P
11/29/1977					
Gunnison River near Grand Junction	2.	90.	6.	318.	162.
1/9/1978					
Gunnison River near Grand Junction	3.	25.	100.	1600.	567.
3/8/1978					
Gunnison River near Grand Junction	3.	186.	51.	1035.	362.
5/10/1978					
Gunnison River near Grand Junction	17.	32.	54.	900.	56.

*A nitrogen/phosphorus ratio of <15 indicates nitrogen limitation while an N/P ratio of >15 indicates phosphorus limitation.

Table 3.
San Miguel Project
Results of Chemical Analyses

	Orthophosphate (PO_4-P) (µg/l)	Total Soluble Phosphorus (µg/l)	Ammonia (NH_3-N) (µg/l)	Nitrate+Nitrite (NO_3+NO_2)-N (µg/l)	Nitrogen/Phosphorus* (NH_3+NO_3+NO_2)-N/PO_4-P
9/8/1977					
San Miguel River near Placerville	6.	11.	42.	164.	34.
San Miguel River near Sawpit	13.	23.	61.	245.	24.
Leopard Creek	1.	7.	64.	31.	95.
11/29/1977					
San Miguel River near Placerville	6.	54.	10.	240.	42.
San Miguel River near Sawpit	12.	34.	54.	390.	37.
Leopard Creek	1.	10.	2.	80.	82.
1/9/1978					
San Miguel River near Placerville	34.	71.	116.	840.	28.
San Miguel River near Sawpit	12.	23.	90.	320.	34.
Leopard Creek	3.	14.	66.	100.	55.
3/8/1978					
San Miguel River near Placerville	7.	32.	29.	101.	19.
San Miguel River near Sawpit	22.	41.	21.	339.	16.
Leopard Creek	2.	9.	27.	73.	50.
5/10/1978					
San Miguel River near Placerville	4.	6.	24.	40.	16.
San Miguel River near Sawpit	2.	3.	98.	150.	124.
Leopard Creek	11.	14.	32.	210.	22.

*A nitrogen/phosphorus ratio of <15 indicates nitrogen limitation while an N/P ratio of >15 indicates phosphorus limitation.

Table 4.
West Divide Project
Results of Chemical Analyses

	Orthophosphate (PO_4-P) (μg/l)	Total Soluble Phosphorus (μg/l)	Ammonia (NH_3-N) (μg/l)	Nitrate+Nitrite (NO_3+NO_2)-N (μg/l)	Nitrogen/Phosphorus* ($NH_3+NO_3+NO_2$)-N/PO_4-P
<u>11/29/1977</u>					
Colorado River at Newcastle (upstream)	2.	28.	5.	3.	4.
Colorado River at Newcastle (downstream)	2.	40.	4.	8.	6.
<u>1/9/1978</u>					
Colorado River at Newcastle (upstream)	17.	28.	70.	310.	22.
Colorado River at Newcastle (downstream)	17.	37.	49.	310.	21.
<u>3/8/1978</u>					
Colorado River at Newcastle (upstream)	17.	96.	59.	164.	13.
Colorado River at Newcastle (downstream)	17.	96.	43.	175.	13.
<u>5/10/1978</u>					
Colorado River at Newcastle (upstream)	11.	16.	97.	270.	33.
Colorado River at Newcastle (downstream)	12.	15.	55.	240.	25.

*A nitrogen/phosphorus ratio of <15 indicates nitrogen limitation while an N/P ratio of >15 indicates phosphorus limitation.

Prior to use in the bioassays all glass and labware contacting the samples were treated in the following manner: sodium bicarbonate wash, tap water rinses, 1:2 hydrochloric acid rinses, deionized water rinses and finally ultra pure deionized water rinses. Following washing, all glassware was autoclaved using aluminum foil closures at 121^{o}C for 15 minutes.

Samples from each of the projects received the treatments listed on Tables 5 - 8 for each of the five sampling dates. Each treatment was set up in triplicate. The sample blanks (treatments A and H) were included to provide the basis for comparison of the other treatments and to provide a measure of general fertility of the sample. The control treatments were included to provide an estimate of theoretical maximum cell growth and an index for comparing growth levels of the test waters.

Table 9 lists the constituents of Algal Assay Medium (AAM). AAM is a precisely prepared growth medium containing known concentrations of all compounds essential to algal growth. The samples and controls (with the exception of 9/8/77 controls which contained full strength AAM for all constituents) contained one half AAM levels of nitrogen and phosphorus whereas all other constituents were added at full strength levels. Disodium EDTA (Ethylene dinitrilo tetraacetic acid), a commonly used organic chelator, was added to Treatments A-G at a level of 1 mg/l in order to render excess toxic metal ions biologically inactive. Metal toxicity was detected in earlier bioassays from the heavily mined western Colorado area, therefore as a precautionary measure for the detection of metal toxicity the EDTA addition was made. Treatments H and I (with EDTA) were included to confirm any metal toxicity. Increased growth in EDTA spiked flasks in

Table 5.
Dolores Project
Treatment Constituents

9/8/77

Dolores River below Rico Tailings
Dolores River above Rico Tailings
Dolores River at Dolores
Dolores River below West Dolores River

A. Sample + 1 mg/l EDTA
B. Sample + 1 mg/l EDTA + 2.1 mg/l Nitrogen (N)
C. Sample + 1 mg/l EDTA + 0.093 mg/l Phosphorus (P)
D. Sample + 1 mg/l EDTA + 2.1 mg/l N + 0.093 mg/l P
E. Sample + 1 mg/l EDTA + trace element (AAM levels)
F. Sample + 1 mg/l EDTA + 15.0 mg/l $NaHCO_3$
G. Sample + 1 mg/l EDTA + 2.1 mg/l N + 0.093 mg/l P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$ and $MgSO_4$
H. Sample
I. Sample + 2.1 mg/l N + 0.093 mg/l P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$ and $MgSO_4$

Control: Distilled water + 4.2 mg/l N + 0.186 mg/l P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$ and $MgSO_4$
Control + EDTA: Distilled water + 1 mg/l EDTA + same as control above.

11/29/77

Dolores River at Dolores
Sample treatments same as 9/8/77
Control: Distilled water + 2.1 mg/l N + 0.093 mg/l P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$ and $MgSO_4$
Control + EDTA: Distilled water + 1 mg/l EDTA + same as control above.

1/9/78

Dolores River at Dolores
Sample treatments same as 11/29/77 except treatments E and F eliminated due to lack of sample
Controls same as 11/29/77

3/8/78

Dolores River at Dolores
Sample treatments and controls same as 11/29/77

5/10/78

Dolores River at Dolores

A. Sample
B. Sample + 2.1 mg/l N
C. Sample + 0.093 mg/l P
D. Sample + 2.1 mg/l N + 0.093 mg/l P
E. Sample + trace elements (AAM level)
F. Sample + 15.0 mg/l $NaHCO_3$
G. Sample + 2.1 mg/l N + 0.093 mg/l P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$ and $MgSO_4$

Control: Same as 11/29/77

Table 6.
Dominquez Project
Treatment Constituents

11/29/77

Gunnison River at Grand Junction

A. Sample + 1 mg/l EDTA
B. Sample + 1 mg/l EDTA + 2.1 mg/l Nitrogen (N)
C. Sample + 1 mg/l EDTA + 0.093 mg/l Phosphorus (P)
D. Sample + 1 mg/l EDTA + 2.1 mg/l N + 0.093 mg/l P
E. Sample + 1 mg/l EDTA + trace elements (AAM level)
F. Sample + 1 mg/l EDTA + 15.0 mg/l $NaHCO_3$
G. Sample + 1 mg/l EDTA + 2.1 mg/l N + 0.093 mg/l P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$ and $MgSO_4$
H. Sample
I. Sample + 2.1 mg/l N + 0.093 mg/l P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$ and $MgSO_4$

Control: Distilled water + 2.1 mg/l N + 0.093 mg/l P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$, and $MgSO_4$

Control + EDTA: Distilled water + 1 mg/l EDTA + same as control above.

1/9/78

Gunnison River at Grand Junction

Sample treatments same as 11/29/77 except treatments E and F eliminated due to lack of sample.

Controls same as 11/29/77.

3/8/78

Gunnison River at Grand Junction

Sample treatments and controls same as 11/29/77

5/10/79

Gunnison River at Grand Junction

A. Sample
B. Sample + 2.1 mg/l N
C. Sample + 0.093 mg/l P
D. Sample + 2.1 mg/l N + 0.093 mg/l P
E. Sample + trace elements
F. Sample + 15.0 mg/l $NaHCO_3$
G. Sample + 2.1 mg/l N + 0.093 mg/l P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$ and $MgSO_4$

Control: same as 11/29/77

Table 7.
San Miguel Project
Treatment Constituents

9/8/77

San Miguel River near Placerville
San Miguel River near Sawpit
Leopard Creek

A. Sample + 1 mg/1 EDTA
B. Sample + 1 mg/1 EDTA + 2.1 mg/1 Nitrogen (N)
C. Sample + 1 mg/1 EDTA + 0.093 mg/1 Phosphorus (P)
D. Sample + 1 mg/1 EDTA + 2.1 mg/1 N + 0.093 mg/1 P
E. Sample + 1 mg/1 EDTA + trace elements (AAM levels)
F. Sample + 1 mg/1 EDTA + 15.0 mg/1 $NaHCO_3$
G. Sample + 1 mg/1 EDTA + 2.1 mg/1 N + 0.093 mg/1 P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$, and $MgSO_4$
H. Sample
I. Sample + 2.1 mg/1 N + 0.093 mg/1 P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$ and $MgSO_4$

Control: Distilled water + 4.2 mg/1 N + 0.186 mg/1 P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$, and $MgSO_4$
Control + EDTA: Same as control above + 1 mg/1 EDTA

11/29/77

San Miguel River near Placerville
San Miguel River near Sawpit
Leopard Creek

Sample treatments same as 9/8/77
Control: Distilled water + 2.1 mg/1 + 0.093 mg/1 P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$ and $MgSO_4$
Control + EDTA: Same as above + 1 mg/1 EDTA

1/9/78

San Miguel River near Placerville
San Miguel River near Sawpit
Leopard Creek

Sample treatments same as 11/29/77 except treatments E and F were eliminated due to lack of sample
Controls same as 11/29/77

3/8/78

San Miguel River near Placerville
San Miguel River near Sawpit
Leopard Creek

Sample treatments and controls same as 11/29/77

5/10/78

San Miguel River near Placerville
San Miguel River at Sawpit
Leopard Creek

Table 7. Continued.
San Miguel Project
Treatment Constituents

- A. Sample
- B. Sample + 2.1 mg/l N
- C. Sample + 0.093 mg/l P
- D. Sample + 2.1 mg/l N + 0.093 mg/l P
- E. Sample + trace elements (AAM levels)
- F. Sample + 15.0 mg/l $NaHCO_3$
- G. Sample + 2.1 mg/l N + 0.093 mg/l P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$ and $MgSO_4$

Control same as 11/29/77

San Miguel River Sawpit

After several days of incubation very little growth resulted. Metal toxicity was suspected therefore the following treatments were added.

- G. Sample + 2.1 mg/l N + 0.093 mg/l P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$ and $MgSO_4$ (this treatment was repeated as a check on the fertility of the sample).
- H. Sample + 1 mg/l EDTA + 2.1 mg/l N + 0.093 mg/l P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$ and $MgSO_4$

Table 8.
West Divide Project
Treatment Constituents

11/29/79

Colorado River at Newcastle (upstream)
Colorado River at Newcastle (downstream)

A. Sample + 1 mg/l EDTA
B. Sample + 1 mg/l EDTA + 2.1 mg/l Nitrogen (N)
C. Sample + 1 mg/l EDTA + 0.093 mg/l Phosphorus (P)
D. Sample + 1 mg/l EDTA + 2.1 mg/l N + 0.093 mg/l P
E. Sample + 1 mg/l EDTA + trace elements
F. Sample + 1 mg/l EDTA + 15.0 mg/l $NaHCO_3$
G. Sample + 1 mg/l EDTA + 2.1 mg/l N + 0.093 mg/l P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$, and $MgSO_4$
H. Sample
I. Sample + 2.1 mg/l N + 0.093 mg/l P + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$ and $MgSO_4$.

Control: Distilled water + 2.1 mg/l N + 0.093 mg/l P -- AAM levels of trace elements, $NaHCO_3$, $CaCl_2$ and $MgSO_4$.
Control + EDTA: Same as control above + 1 mg/l EDTA.

1/9/78

Colorado River at Newcastle (upstream)
Colorado River at Newcastle (downstream)

Sample treatments same as 11/29/77 except treatments E and F eliminated due to lack of sample.
Controls same as 11/29/77

3/8/78

Colorado River at Newcastle (upstream)
Colorado River at Newcastle (downstream)
Sample treatments and controls same as 11/29/77

5/10/78

Colorado River at Newcastle (upstream)
Colorado River at Newcastle (downstream)

A. Sample
B. Sample + 2.1 mg/l N
C. Sample + 0.093 mg/l P
D. Sample + 2.1 mg/l N + 0.093 mg/l P
E. Sample + trace elements
F. Sample + 15.0 mg/l $NaHCO_3$
G. Sample + 2.1 mg/l + 0.093 mg/l + AAM levels of: trace elements, $NaHCO_3$, $CaCl_2$, and $MgSO_4$

Control: Same as 11/29/77

Table 9. Algal Assay medium (AAM)

	Compound	Concentration in NAAM: Compound mg/l	Concentration in NAAM: Element	Element mg/l
A_1	$NaNO_3$	25.500	N	4.2
A_2	$MgCl_2$ $6H_2O$	12.171	Mg	2.9
	$MgSO_4$ $7H_2O$	14.700		
A_3	$CaCl_2$ $2H_2O$	4.410	Ca	1.2
A_4	$NaHCO_3$	15.000		
B	K_2HPO_4	1.044	P	0.186
		μg/l		μg/l
C	H_3BO_3	185.64	B	32.45
	$MnCl_2$ $4H_2O$	417.18	Mn	115.80
	$ZnCl_2$	32.70	Zn	15.68
	Na_3MoO_4 $2H_2O$	7.26	Mo	2.88
	$CoCl_2$ $6H_2O$	1.43	Co	0.35
	$CuCl_2$ $2H_2O$	0.01	Cu	0.004
D	$FeCl_3$ $6H_2O$	160	Fe	33.05
	Na_2EDTA $2H_2O$	300		mg/l
Protocol for Nutrient Spiking			S	1.91
A_1	Nitrogen		Na	11.04
B	Phosphorus		K	0.47
A_1 + B	N + P		C	2.14
C + D	Trace Elements (T. E.)			
ALL	NAAM			

Reference: Environmental Protection Agency, "Algal Assay Procedures: Bottle Test". Corvallis, Oregon. (1971) 82 pages.

comparison to yields in untreated flasks can be directly attributed to organic chelation and consequently metal toxicity.

Algal bioassays were performed according to EPA (1971) using the green alga, Selenastrum capricornutum PRINTZ. The test flasks were placed in a constant temperature room ($24^{o} \pm 2^{o}C$) with "cool white" fluorescent lighting providing illumination of 400 ft-C (4304 lux) $\pm$ 10 percent.

The algal bioassays were monitored by determining the optical density (OD Bausch and Lomb Spectrophotometer 70 at 750 nm, 1 cm path length) and relative fluorescence (RF x 30, Turner fluorometer, Model 110). Optical density was measured over a 14 day period while relative fluorescence was measured to monitor the progress of the cultures for the first six to seven days when optical density does not provide a great deal of sensitivity. Fluorescence is a physiological response measuring chlorophyll a and optical density is a measurement of biomass. Although they are different measurements, the two can be correlated. Normally when chlorophyll a is increasing so is biomass and vice versa. Maximum values for optical density are listed on Tables 10 - 13.

Optical density (OD) is an indirect means of measuring algal cell biomass. As a consequence OD is linearly related to biomass as dry weight (Porcella et al., 1973). Due to this linearity, biomass, as volatile suspended solids (VSS), can be calculated directly from OD. The relationship used to convert OD to VSS in Tables 14-17 is:

VSS, mg/1 = 350 (OD) + 3.5

Because of the difficulty of measuring biomass in low density cultures, relative fluorescence of in vivo chlorophyll a was used to estimate biomass

Table 10.
Dolores Project
Maximum Amount of Growth Observed As Optical Density; 750 mm., 1 cm.

Sample	Treatment								
	A	B	C	D	E	F	G	H	I
9/8/77									
Dolores River at Dolores	.005	.004	.037	.272	.004	.007	.270	.005	.222
Dolores River Below Rico Tailings	.002	.003	.042	.250	.002	.002	.245	.002	.245
Dolores River Above Rico Tailings	.003	.006	.057	.236	.003	.002	.124	.004	.004
Dolores River Below West Dolores River	.005	.006	.045	.256	.003	.002	.240	.003	.254
Control							.416		
Control + EDTA									.420
11/29/77									
Dolores River at Dolores	.002	.002	.046	.274	.003	.003	.272	.003	.257
Control							.331		
Control + EDTA									.331
1/9/78									
Dolores River at Dolores	.007	.008	.037	.197			.301	.010	.296
Control							.266		
Control + EDTA									.283
3/8/78									
Dolores River at Dolores	.010	.003	.050	.277	.004	.005	.262	.007	.262
Control							.270		
Control + EDTA									.265
5/10/78									
Dolores River at Dolores	.010	.006	.018	.287	.008	.006	.303		
Control							.267		

Table 11.
Dominquez Project
Maximum Amount of Growth Observed as Optical Density; 750 mm., 1 cm.

	Treatment								
Sample	A	B	C	D	E	F	G	H	I
11/29/77									
Gunnison River near Grand Junction	.011	.020	.133	.175	.014	.003	.170	.003	.218
Control							.331		
Control + EDTA									.331
1/9/78									
Gunnison River near Grand Junction	.040	.009	.174	.224			.239	.016	.192
Control							.266		
Control + EDTA									.283
3/8/78									
Gunnison River near Grand Junction	.002	.003	.206	.229	.010	.005	.228	.010	.287
Control							.270		
Control + EDTA									.265
5/10/78									
Gunnison River near Grand Junction	.006	.015	.070	.084	.037	.037	.273		
Control							.267		

Table 12.
San Miguel Project
Maximum Amount of Growth Observed as Optical Density; 750 mm., 1 cm.

Sample	Treatment A	B	C	D	E	F	G	H	I
9/8/77									
San Miguel River near Placerville	.003	.004	.060	.282	.001	.002	.256	.003	.182
San Miguel River near Sawpit	.003	.004	.076	.256	.005	.003	.231	.003	.181
Leopard Creek	.003	.063	.045	.186	.007	.007	.197	.002	.176
Control							.416		
Control + EDTA									.420
11/29/77									
San Miguel River near Placerville	.008	.008	.063	.304	.008	.008	.273	.003	.251
San Miguel River near Sawpit	.027	.026	.083	.321	.023	.024	.278	.009	.159
Leopard Creek	.003	.003	.013	.257	.004	.010	.271	.002	.245
Control							.331		
Control + EDTA									.331
1/9/78									
San Miguel River near Placerville	.082	.071	.212	.120			.349	.021	.307
San Miguel River near Sawpit	.014	.051	.069	.277			.341	.010	.343
Leopard Creek	.009	.009	.035	.259			.282	.009	.231
Control							.266		
Control + EDTA									.283

Table 12. Continued.

San Miguel Project

Maximum Amount of Growth Observed as Optical Density; 750 mm., 1 cm.

Sample	Treatment								
	A	B	C	D	E	F	G	H	I
3/8/78									
San Miguel River near Placerville	.018	.015	.048	.264	.028	.017	.293	.017	.285
San Miguel River near Sawpit	.063	.070	.075	.284	.062	.058	.282	.045	.308
Leopard Creek	.005	.003	.033	.274	.003	.004	.278	.008	.285
Control							.270		
Control + EDTA									.265
5/10/78									
San Miguel River near Placerville	.006	.006	.037	.040	.008	.005	.298		
San Miguel River near Sawpit	.004	.002	.012	.013	.003	.002	.023		.295
Leopard Creek	.021	.020	.025	.333	.021	.014	.295		
Control							.267		
Control + EDTA									.264

Table 13.
West Divide Project
Maximum Amount Of Growth Observed As Optical Density; 750 mm., 1 cm.

	Treatment								
Sample	A	B	C	D	E	F	G	H	I
<u>11/29/77</u>									
Colorado River at Newcastle (Upstream)	.017	.021	.038	.287	.029	.018	.270	.008	.278
Colorado River at Newcastle (Downstream)	.007	.007	.026	.290	.006	.005	.267	.006	.262
Control							.331		
Control + EDTA									.331
<u>1/9/78</u>									
Colorado River at Newcastle (Upstream)	.050	.042	.089	.305			.328	.045	.336
Colorado River at Newcastle (Downstream)	.020	.028	.098	.282			.330	.039	.331
Control							.266		
Control +EDTA									.283
<u>3/8/79</u>									
Colorado River at Newcastle (Upstream)	.040	.036	.067	.302	.052	.044	.345	.008	.308
Colorado River at Newcastle (Downstream)	.046	.040	.057	.312	.043	.044	.295	.050	.333
Control							.270		
Control + EDTA									.265
<u>5/10/78</u>									
Colorado River at Newcastle (Upstream)	.024	.020	.100	.329	.031	.016	.310		
Colorado River at Newcastle (Downstream)	.023	.020	.062	.291	.039	.018	.318		
Control							.267		

Table 14.
Dolores Project
Maximum Amount of Growth Observed as mg/l VSS.[a]

Sample	Treatment								
	A	B	C	D	E	F	G	H	I
9/8/77									
Dolores River at Dolores	5.3	4.9	16.5	98.7	4.9	6.0	98.0	5.3	81.2
Dolores River Below Rico Tailings	4.2	4.6	18.2	91.0	4.2	4.2	89.3	4.2	89.3
Dolores River Above Rico Tailings	4.6	5.6	23.5	86.1	4.6	4.2	46.9	4.9	4.9
Dolores River Below West Dolores River	5.3	5.6	19.3	93.1	4.6	4.2	87.5	4.6	92.4
Control							149.1		
Control + EDTA									150.5
11/29/77									
Dolores River at Dolores	4.2	4.2	19.6	99.4	4.6	4.6	98.7	4.6	93.5
Control							119.4		
Control + EDTA									119.4
1/9/78									
Dolores River at Dolores	6.0	6.3	16.5	72.5			108.4	7.0	107.1
Control							96.6		
Control + EDTA									102.6
3/8/78									
Dolores River at Dolores	7.0	4.6	21.0	100.5	4.9	5.3	95.2	6.0	95.2
Control							98.0		
Control + EDTA									96.3
5/10/78									
Dolores River at Dolores	7.0	5.6	9.8	107.0	6.3	5.6	109.6		
Control							96.0		

[a]VSS = Volatile Suspended Solids
VSS, mg/l = 350 (Optical Density) + 3.5 (Porcella, et al., 1973)

Table 15.
Dominquez Project
Maximum Amount of Growth Observed as mg/l VSS.[a]

Sample	A	B	C	D	E	F	G	H	I
				Treatment					
11/29/77									
Gunnison River near Grand Junction	7.4	10.5	50.1	64.8	8.4	4.6	63.0	4.6	79.8
Control							119.4		
Control + EDTA									119.4
1/9/78									
Gunnison River near Grand Junction	17.5	6.7	64.4	81.9			87.2	9.1	70.7
Control							96.6		
Control + EDTA									102.6
3/8/78									
Gunnison River near Grand Junction	4.2	4.6	75.6	83.7	7.0	5.3	83.3	7.0	104.0
Control							98.0		
Control + EDTA									96.3
5/10/78									
Gunnison River near Grand Junction	5.6	8.8	28.0	32.9	16.5	16.5	99.1		
Control							96.0		

[a]VSS = Volatile Suspended Solids
VSS, mg/l = 350 (Optical Density) + 3.5 (Porcella, et al., 1973)

Table 16.
San Miguel Project
Maximum Amount of Growth Observed as mg/l VSS.[a]

Sample	Treatment A	B	C	D	E	F	G	H	I
9/8/77									
San Miguel River near Placerville	4.6	4.9	24.5	102.2	3.9	4.2	93.1	4.6	67.2
San Miguel River near Sawpit	4.6	4.9	30.1	93.1	5.3	4.6	84.4	4.6	66.9
Leopard Creek	4.6	25.6	19.3	68.6	6.0	6.0	72.5	4.2	65.1
Control							149.1		
Control + EDTA									150.5
11/29/77									
San Miguel River near Placerville	6.3	6.3	25.6	109.9	6.3	6.3	99.1	4.6	91.4
San Miguel River near Sawpit	13.0	12.6	32.6	115.9	11.6	11.9	100.8	6.7	59.2
Leopard Creek	4.6	4.6	8.1	93.5	4.9	7.0	98.4	4.2	89.3
Control							119.4		
Control + EDTA									119.4
1/9/78									
San Miguel River near Placerville	32.2	28.4	77.7	45.5			125.7	10.9	111.0
San Miguel River near Sawpit	8.4	21.4	27.7	100.5			122.9	7.0	123.6
Leopard Creek	6.7	6.7	15.8	94.2			102.2	6.7	84.4
Control							96.6		
Control + EDTA									102.6
3/8/78									
San Miguel River near Placerville	9.8	8.8	20.3	95.9	13.3	9.5	106.1	9.5	103.3
San Miguel River near Sawpit	25.6	28.0	29.8	102.9	25.2	23.8	102.2	19.3	111.3
Leopard Creek	5.3	4.6	15.1	99.4	4.6	4.9	100.8	6.3	103.3
Control							98.0		
Control + EDTA									96.3

Table 16. Continued.
San Miguel Project
Maximum Amount of Growth Observed as mg/l VSS.[a]

Sample	Treatment A	B	C	D	E	F	G	H	I
5/10/78									
San Miguel River near Placerville	5.6	5.6	16.5	17.5	6.3	5.3	107.8		
San Miguel River near Sawpit	4.9	4.2	7.7	8.1	4.6	4.2	11.6		106.8
Leopard Creek	10.9	10.5	12.3	120.1	10.9	8.4	106.8		
Control							96.0		
Control + EDTA									95.9

[a]VSS = Volatile Suspended Solids
VSS, mg/l = 350 (Optical Density) + 3.5 (Porcella, et al., 1973)

Table 17.
West Divide Project
Maximum Amount of Growth Observed as mg/l VSS.[a]

Sample	Treatment								
	A	B	C	D	E	F	G	H	I
<u>11/29/77</u>									
Colorado River at Newcastle (Upstream)	9.5	10.9	16.8	104.0	13.7	9.8	98.0	6.3	100.8
Colorado River at Newcastle (Downstream)	6.0	6.0	12.6	105.0	5.6	5.3	97.0	5.6	95.2
Control							119.4		
Control + EDTA									119.4
<u>1/9/78</u>									
Colorado River at Newcastle (Upstream)	21.0	18.2	34.7	110.3			118.3	19.3	121.1
Colorado River at Newcastle (Downstream)	10.5	13.3	37.8	102.2			119.0	17.2	119.4
Control							96.6		
Control + EDTA									102.6
<u>3/8/78</u>									
Colorado River at Newcastle (Upstream)	17.5	16.1	27.0	109.2	21.7	18.9	124.3	6.3	111.3
Colorado River at Newcastle (Downstream)	19.6	17.5	23.5	112.7	18.6	18.9	106.7	21.0	120.1
Control							98.0		
Control + EDTA									96.3
<u>5/10/78</u>									
Colorado River at Newcastle (Upstream)	11.9	10.5	38.5	118.7	14.4	9.1	112.0		
Colorado River at Newcastle (Downstream)	11.6	10.5	25.2	105.4	17.2	9.8	114.8		
Control							96.0		

[a]VSS = Volitile Suspended Solids
VSS,mg/l = 350 (Optical Density) + 3.5 (Porcella, et al., 1973)

in the early phases of the bioassay. Maximum values for relative fluorescence are listed on Tables 18 - 21. Calculations of average maximum specific growth rate batch ($\hat{\mu}_b$) were made using relative fluorescence. The maximum specific growth occurs during the logarithmic phase of growth, usually between day 0 and day 5 and is useful in determining a sample response to each treatment. Maximum specific growth rates are calculated in Tables 22 - 25.

III. Results and Interpretation

Tables 26 - 29 outline the nutrient limitation as a result of chemical analysis and as a result of algal bioassay for all sites on all projects. While nitrogen and phosphorus are most often the algal growth limiting nutrient, it should be recognized that other nutrients may be growth limiting as well. Theoretical productivity potential must be verified by actual algal assay analyses to determine: 1) the presence of growth limiting nutrients; 2) the presence of toxicants such as heavy metals and 3) if the chemical analyses for N and P are realistic.

A. Dolores Project

1. Dolores River at Dolores (Figures 1 - 18)

Each bioassay at this sampling site showed similar net results. Indigenous nutrient levels remained consistently low with the amount of total inorganic nitrogen progressively increasing during the winter months reaching a maximum concentration of 326 μg/l just before spring runoff then rapidly declining to 97 μg/l when runoff occurred. However, at no time during the year did the nitrogen or phosphorus concentrations in the sample reach a level that resulted in a productive untreated sample. Increased biomass was observed only when both nitrogen and phosphorus were added to

Table 18.
Dolores Project
Maximum Amount of Growth Observed as Relative Fluorescence, RF x 30

	Treatments								
Sample	A	B	C	D	E	F	G	H	I
9/8/77									
Dolores River at Dolores	14.	16.	77.	923.	13.	18.	800.	22.	765.
Dolores River Below Rico Tailings	11.	11.	67.	880.	10.	10.	753.	26.	800.
Dolores River Above Rico Tailings	15.	14.	91.	925.	11.	14.	563.	19.	46.
Dolores River Below West Dolores River	14.	16.	75.	827.	18.	12.	687.	26.	772.
Control							1640.		
Control + EDTA									2055.
11/29/77									
Dolores River at Dolores	11.	13.	40.	945.	16.	10.	860.	9.	700.
Control							1360.		
Control + EDTA									1170.
1/9/78									
Dolores River at Dolores	16.	21.	56.	820.			1260.	25.	1065.
Control							1280		
Control + EDTA									1390
3/8/78									
Dolores River at Dolores	27.	9.	59.	1290.	13.	12.	1030.	11.	1000.
Control							1870.		
Control + EDTA									1777.
5/10/78									
Dolores River at Dolores	36.	32.	35.	1680.	25.	25.	1230.		
Control							1400.		

Table 19.
Dominquez Project
Maximum Amount of Growth Observed as Relative Fluorescence, RF x 30

Sample	Treatments								
	A	B	C	D	E	F	G	H	I
<u>11/29/77</u>									
Gunnison River near Grand Junction	43.	64.	307.	510.	87.	12.	420.	11.	627.
Control							1360.		
Control + EDTA									1170.
<u>1/9/78</u>									
Gunnison River near Grand Junction	24.	21.	545.	855.			675.	17.	440.
Control							1280.		
Control + EDTA									1390.
<u>3/8/78</u>									
Gunnison River near Grand Junction	22.	17.	723.	1070.	33.	31.	920.	22.	1180.
Control							1870.		
Control + EDTA									1777.
<u>5/10/78</u>									
Gunnison River near Grand Junction	29.	58.	291.	580.	114.	132.	1310.		
Control							1400.		

Table 20.
San Miguel Project
Maximum Amount of Growth Observed As Relative Fluorescence, RF x 30

Sample	Treatments A	B	C	D	E	F	G	H	I
9/8/77									
San Miguel River near Placerville	12.	242.	156.	1410.	14.	15.	1133.	14.	762.
San Miguel River near Sawpit	12	14.	170.	983.	17.	15.	863.	10.	920.
Leopard Creek	19.	65.	83.	543.	13.	11.	930.	7.	470.
Control							1640.		
Control + EDTA									2055.
11/29/77									
San Miguel River near Placerville	32.	29.	122.	1150.	33.	28.	990.	11.	830.
San Miguel River near Sawpit	86.	87.	227.	1280.	87.	85.	1110.	35.	980.
Leopard Creek	16.	10.	24.	810.	9.	8.	800.	9.	650.
Control							1360.		
Control + EDTA									1170.
1/9/78									
San Miguel River near Placerville	135.	147.	620.	460.			1455.	176.	1215.
San Miguel River near Sawpit	25.	129.	140.	795.			1425.	61.	1400.
Leopard Creek	22.	19.	47.	1050.			960.	25.	700.
Control							1280.		
Control + EDTA									1390.

Table 20. Continued.
San Miguel Project
Maximum Amount of Growth Observed As Relative Fluorescence, RF x 30

Sample	Treatment A	B	C	D	E	F	G	H	I
3/8/78									
San Miguel River near Placerville	64.	37.	70.	1300.	72.	43.	1310.	77.	1280.
San Miguel River near Sawpit	215.	335.	177.	1850.	223.	255.	1660.	230.	2020.
Leopard Creek	15.	10.	40.	1220.	16.	12.	1160.	17.	1120.
Control							1870.		
Control + EDTA									1777.
5/10/78									
San Miguel River near Placerville	24.	24.	89.	473.	40.	26.	1350.		
San Miguel River near Sawpit	20.	18.	52.	54.	28.	22.	253.		1440.
Leopard Creek	88.	83.	63.	1830.	100.	94.	1290.		
Control							1400.		

Table 21.
West Divide Project
Maximum Amount of Growth Observed As Relative Fluorescence, RF x 30

Sample	Treatments								
	A	B	C	D	E	F	G	H	I
11/29/77									
Colorado River at Newcastle (Upstream)	24.	25.	61.	843.	26.	42.	797.	21.	820.
Colorado River at Newcastle (Downstream)	22.	28.	47.	817.	21.	20.	797.	16.	793.
Control							1360.		
Control + EDTA									1170.
1/9/78									
Colorado River at Newcastle (Upstream)	105.	103.	119.	1200.			1170.	92.	1200.
Colorado River at Newcastle (Downstream)	63.	58.	200.	1055.			1110.	81.	1005.
Control							1280.		
Control + EDTA									1390.
3/8/78									
Colorado River at Newcastle (Upstream)	129.	107.	130.	1820.	154.	155.	1650.	37.	1523.
Colorado River at Newcastle (Downstream)	128.	126.	109.	1400.	148.	147.	1180.	111.	1620.
Control							1870.		
Control + EDTA									1777.
5/10/78									
Colorado River at Newcastle (Upstream)	103.	84.	337.	1370.	119.	90.	1280.		
Colorado River at Newcastle (Downstream)	115.	102.	198.	1200.	110.	88.	1280.		
Control							1400.		

Table 22.
Dolores Project
Maximum Specific Growth Rates; $\hat{\mu}_b$, days^{-1}[a]

Sample	Treatment								
	A	B	C	D	E	F	G	H	I
<u>9/8/77</u>									
Dolores River below Rico Tailings	0.00	0.22	1.26	1.72	0.11	0.12	1.81	0.00	1.60
Dolores River above Rico Tailings	0.41	0.07	1.48	1.62	0.11	0.10	1.82	0.59	0.17
Dolores River at Dolores	0.07	0.06	1.57	1.81	0.05	0.12	1.69	0.00	1.75
Dolores River below West Dolores River	0.48	0.55	1.61	1.90	0.13	0.09	1.75	0.09	1.72
<u>11/29/77</u>									
Dolores River at Dolores	0.20	0.20	0.39	2.93	0.19	0.06	2.44	0.13	2.61
<u>1/9/78</u>									
Dolores River at Dolores	0.41	0.42	0.62	1.34			1.60	0.41	2.13
<u>3/8/78</u>									
Dolores River at Dolores	0.41	0.41	0.50	1.25	0.20	0.29	1.55	0.25	1.49
<u>5/10/78</u>									
Dolores River at Dolores	0.20	0.12	0.18	1.51	0.06	0.09	1.66		

[a]The maximum specific growth rate ($\hat{\mu}_b$) for an individual treatment is the largest specific growth rate (μ_b) occurring at any time during incubation. The specific growth rate, μ_b, is defined by:

$$\mu_b = \frac{\ln(X_2/X_1)}{t_2 - t_1} \text{ days}^{-1}$$

where

X_2 = biomass concentration at end of selected time interval
X_1 = biomass concentration at beginning of selected time interval
$t_2 - t_1$ = elapsed time (in days) between selected determinations of biomass

Table 23.
Dominquez Project
Maximum Specific Growth Rate, $\hat{\mu}_b$, days^{-1}[a]

Sample	Treatment A	B	C	D	E	F	G	H	I
11/29/77									
Gunnison River at Grand Junction	0.18	0.18	0.94	1.81	0.26	0.14	1.79	0.11	2.19
1/9/78									
Gunnison River at Grand Junction	0.49	0.37	0.83	1.04			1.29	0.15	1.53
3/8/78									
Gunnison River at Grand Junction	0.45	0.27	1.03	1.22	0.45	0.26	1.32	0.20	1.56
5/10/78									
Gunnison River at Grand Junction	0.12	0.37	1.02	1.01	0.76	0.80	1.65		

[a]The maximum specific growth rate ($\hat{\mu}_b$) for an individual treatment is the largest specific growth rate (μ_b) occurring at any time during incubation. The specific growth rate, μ_b, is defined by:

$$\mu_b = \frac{\ln(X_2/X_1)}{t_2 - t_1} \text{ days}^{-1}$$

where
X_2 = biomass concentration at end of selected time interval
X_1 = biomass concentration at beginning of selected time interval
$t_2 - t_1$ = elapsed time (in days) between selected determinations of biomass

Table 24.
San Miguel Project
Maximum Specific Growth Rate; $\hat{\mu}_b$, $days^{-1}$[a]

Sample	Treatment								
	A	B	C	D	E	F	G	H	I
9/8/77									
San Miguel River near Placerville	0.12	0.73	1.68	1.67	0.10	0.80	1.77	0.74	1.73
San Miguel River near Sawpit	0.13	0.18	1.62	1.78	0.29	0.32	2.19	0.69	1.82
Leopard Creek	0.18	0.82	1.50	1.64	0.18	0.18	1.60	0.34	1.64
11/29/77									
San Miguel River near Placerville	0.25	0.32	1.22	2.94	0.24	0.20	2.56	0.06	2.48
San Miguel River near Sawpit	0.65	0.74	1.44	2.97	1.09	1.18	2.29	0.57	2.70
Leopard Creek	0.29	0.36	0.31	2.55	0.24	0.35	2.19	0.28	2.06
1/9/78									
San Miguel River near Placerville	1.25	0.86	1.95	1.45			2.24	0.70	2.41
San Miguel River near Sawpit	0.43	0.88	1.30	1.27			2.37	0.29	1.94
Leopard Creek	0.15	0.31	0.42	1.50			1.79	0.22	1.94
3/8/78									
San Miguel River near Placerville	0.29	0.21	0.41	1.47	0.30	0.38	1.75	0.46	1.71
San Miguel River near Sawpit	0.91	1.05	1.24	1.57	0.99	1.02	1.79	0.94	1.70
Leopard Creek	0.34	0.59	0.69	1.41	0.59	0.20	1.64	0.31	1.63
5/10/78									
San Miguel River near Placerville	0.07	0.12	0.64	0.74	0.35	0.13	1.66		
San Miguel River near Sawpit	0.18	0.13	0.31	0.46	0.25	0.12	0.81	1.27	
Leopard Creek	0.50	0.56	0.44	1.52	0.49	0.60	1.61		

[a]The maximum specific growth rate ($\hat{\mu}_b$) for an individual treatment is the largest specific growth rate (μ_b) occurring at any time during incubation. The specific growth rate, μ_b, is defined by:

$$\mu_b = \frac{\ln(X_2/X_1)}{t_2 - t_1} \ day^{-1}$$

where

X_2 = biomass concentration at end of selected time interval
X_1 = biomass concentration at beginning of selected time interval
$t_2 - t_1$ = elapsed time (in days) between selected determinations of biomass

Table 25.
West Divide Project
Maximum Specific Growth Rate; $\hat{\mu}_b$, days^{-1}[a]

Sample	Treatment								
	A	B	C	D	E	F	G	H	I
<u>11/29/77</u>									
Colorado River at Newcastle (Upstream)	0.25	0.34	0.33	2.52	0.17	0.31	2.08	0.17	2.54
Colorado River at Newcastle (Downstream)	0.32	0.34	0.14	2.64	0.13	0.17	1.90	0.10	2.40
<u>1/9/78</u>									
Colorado River at Newcastle (Upstream)	0.31	0.55	1.40	1.54			1.87	0.61	1.96
Colorado River at Newcastle (Downstream)	0.88	0.63	0.64	1.29			2.24	0.34	1.91
<u>3/8/78</u>									
Colorado River at Newcastle (Upstream)	0.62	0.63	0.84	1.74	0.80	0.78	1.68	0.26	1.58
Colorado River at Newcastle (Downstream)	0.69	0.29	0.77	1.60	0.72	0.80	1.61	0.80	1.68
<u>5/10/78</u>									
Colorado River at Newcastle (Upstream)	0.80	0.67	1.24	1.58	0.78	0.61	1.66		
Colorado River at Newcastle (Downstream)	0.73	0.71	1.07	1.65	0.61	0.57	1.61		

[a]The maximum specific growth rate ($\hat{\mu}_b$) for an individual treatment is the largest specific growth rate (μ_b) occurring at any time during incubation. The specific growth rate, μ_b, is defined by:

$$\mu_b = \frac{\ln(X_2/X_1)}{t_2 - t_1} \text{ days}^{-1}$$

where

X_2 = biomass concentration at end of selected time interval
X_1 = biomass concentration at beginning of selected time interval
$t_2 - t_1$ = elapsed time (in days) between selected determinations of biomass

Table 26.
Dolores Project
Limiting Nutrients

Sample	Limiting Nutrient(s)	
	Chemical Analysis	Bioassay
9/8/77		
Dolores River Below Rico Tailings	Phosphorus	Phosphorus & Nitrogen[a]
Dolores River Above Rico Tailings	Phosphorus	Phosphorus & Nitrogen[a]
Dolores River at Dolores	Phosphorus	Phosphorus & Nitrogen[a]
Dolores River Below West Dolores River	Phosphorus	Phosphorus & Nitrogen[a]
11/29/77		
Dolores River at Dolores	Phosphorus	Phosphorus & Nitrogen
1/9/78		
Dolores River at Dolores	Phosphorus	Phosphorus & Nitrogen
3/8/78		
Dolores River at Dolores	Phosphorus	Phosphorus & Nitrogen
5/10/78		
Dolores River at Dolores	Phosphorus	Phosphorus & Nitrogen

[a]Addition of phosphorus substantially increased the maximum specific growth rate, $\hat{\mu}_b$ indicating phosphorus limitation. However, due to the low level of both indigenous nitrogen and phosphorus growth was only minimal upon phosphorus addition as nitrogen became limiting as well.

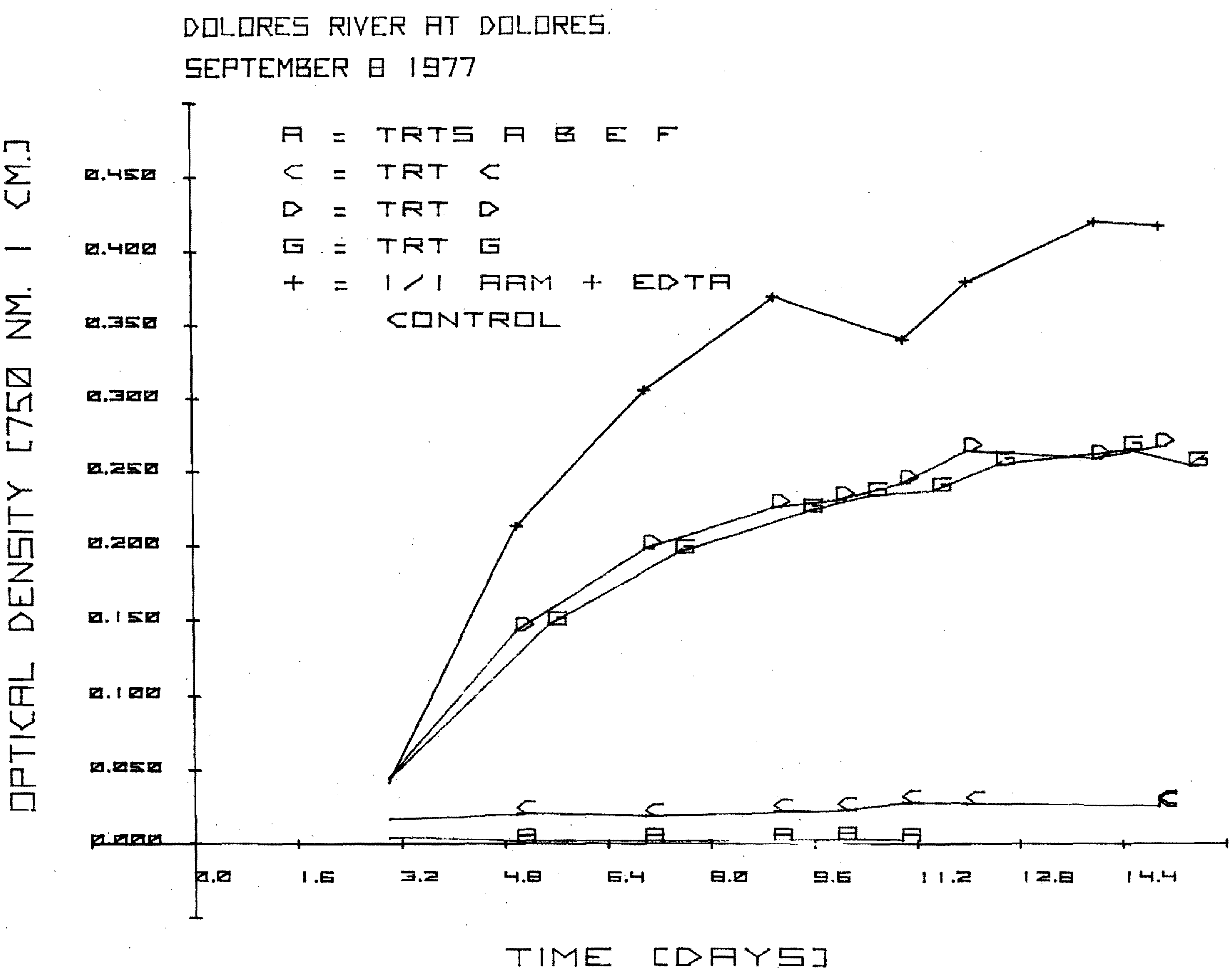

DOLORES RIVER AT DOLORES.
SEPTEMBER 8 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/1 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.6
3.2
4.8
6.4
8.0
9.6
11.2
12.8
14.4
TIME [DAYS]

Figure 1.

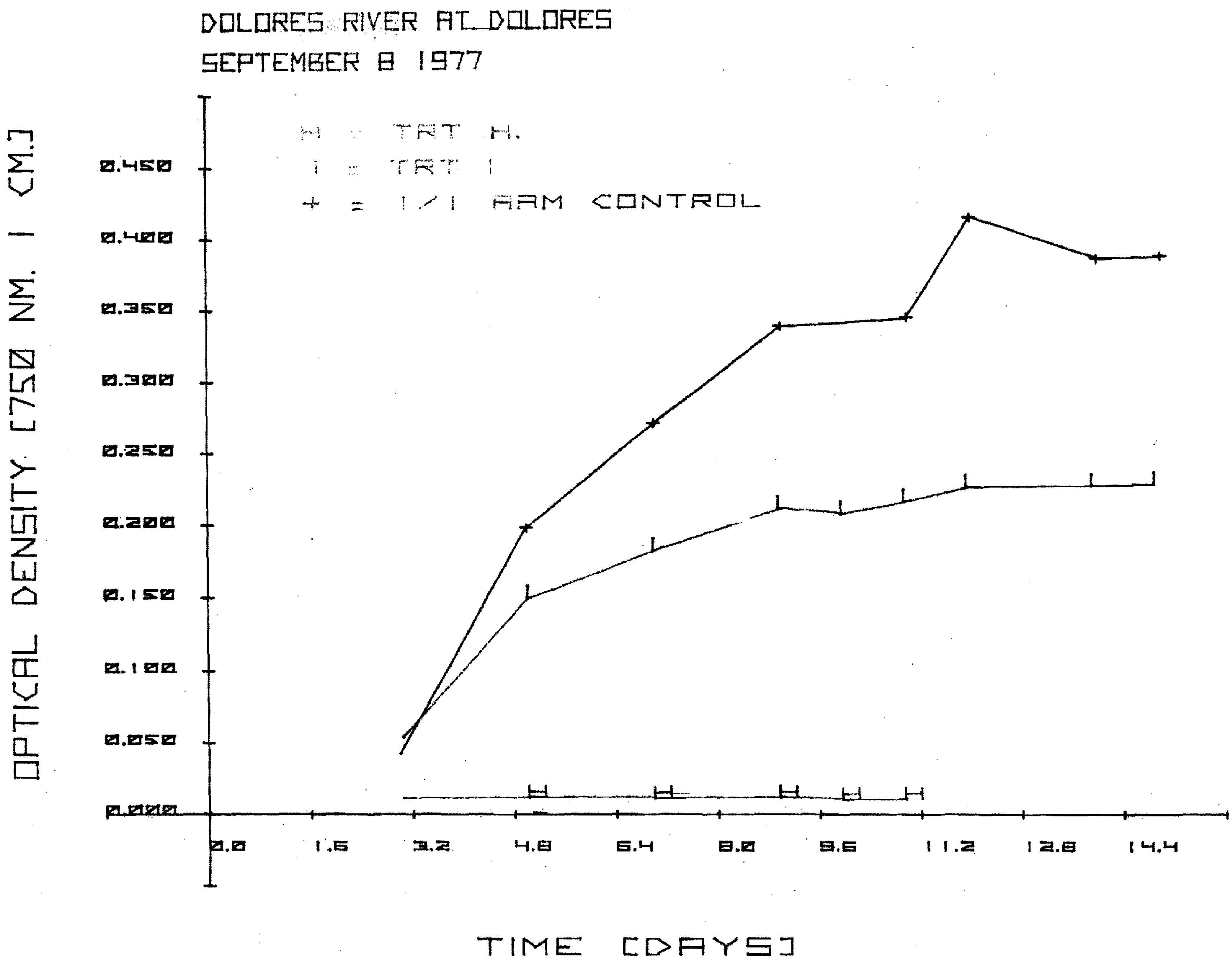
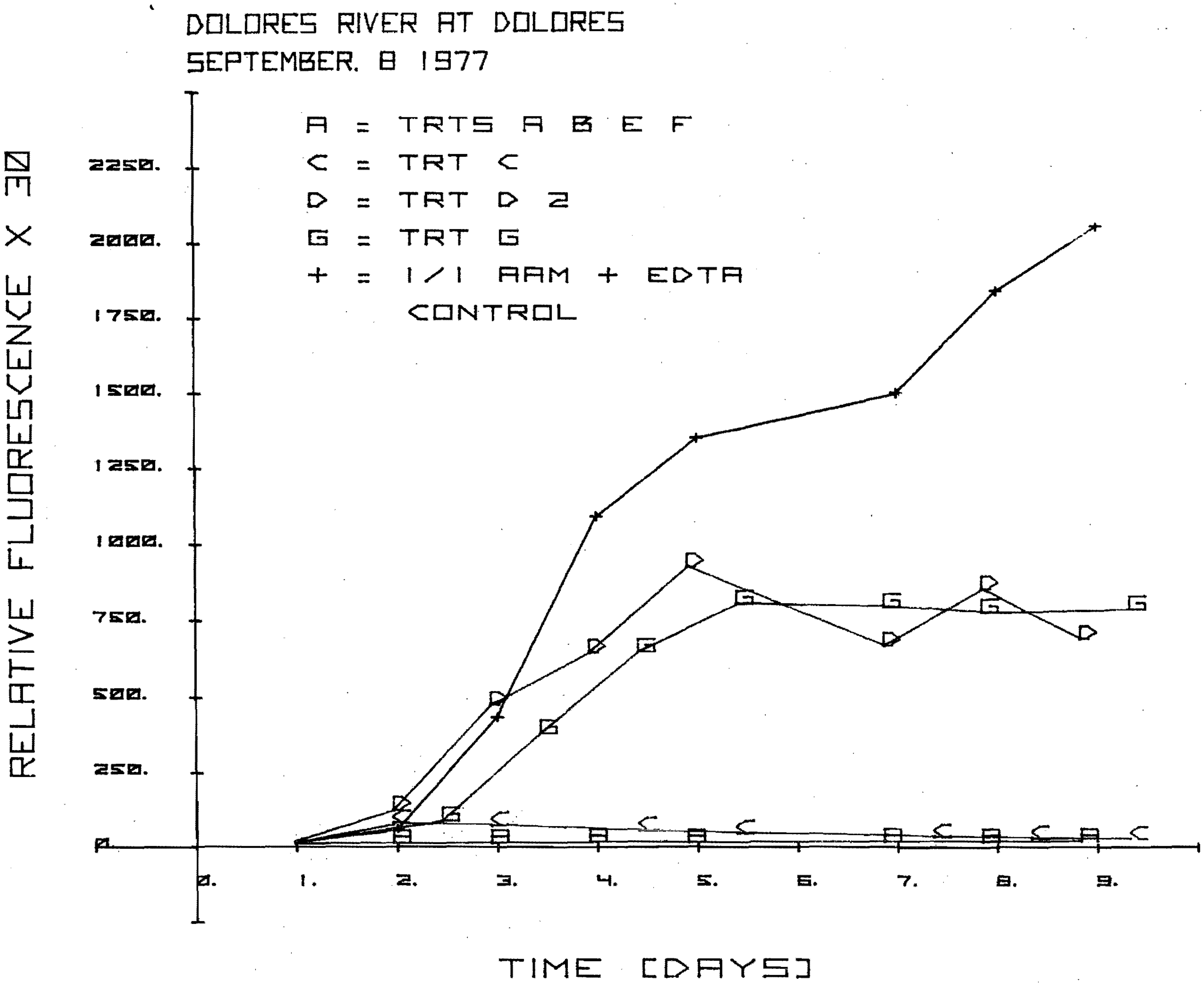

DOLORES RIVER AT DOLORES
SEPTEMBER 8 1977
H = TRT H.
I = TRT I
+ = 1/1 AAM CONTROL
OPTICAL DENSITY [750 NM. I CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.6
3.2
4.8
6.4
8.0
9.6
11.2
12.8
14.4
TIME [DAYS]

Figure 2.



DOLORES RIVER AT DOLORES
SEPTEMBER. 8 1977
A = TRTS A B E F
C = TRT C
D = TRT D 2
G = TRT G
+ = 1/1 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 3.

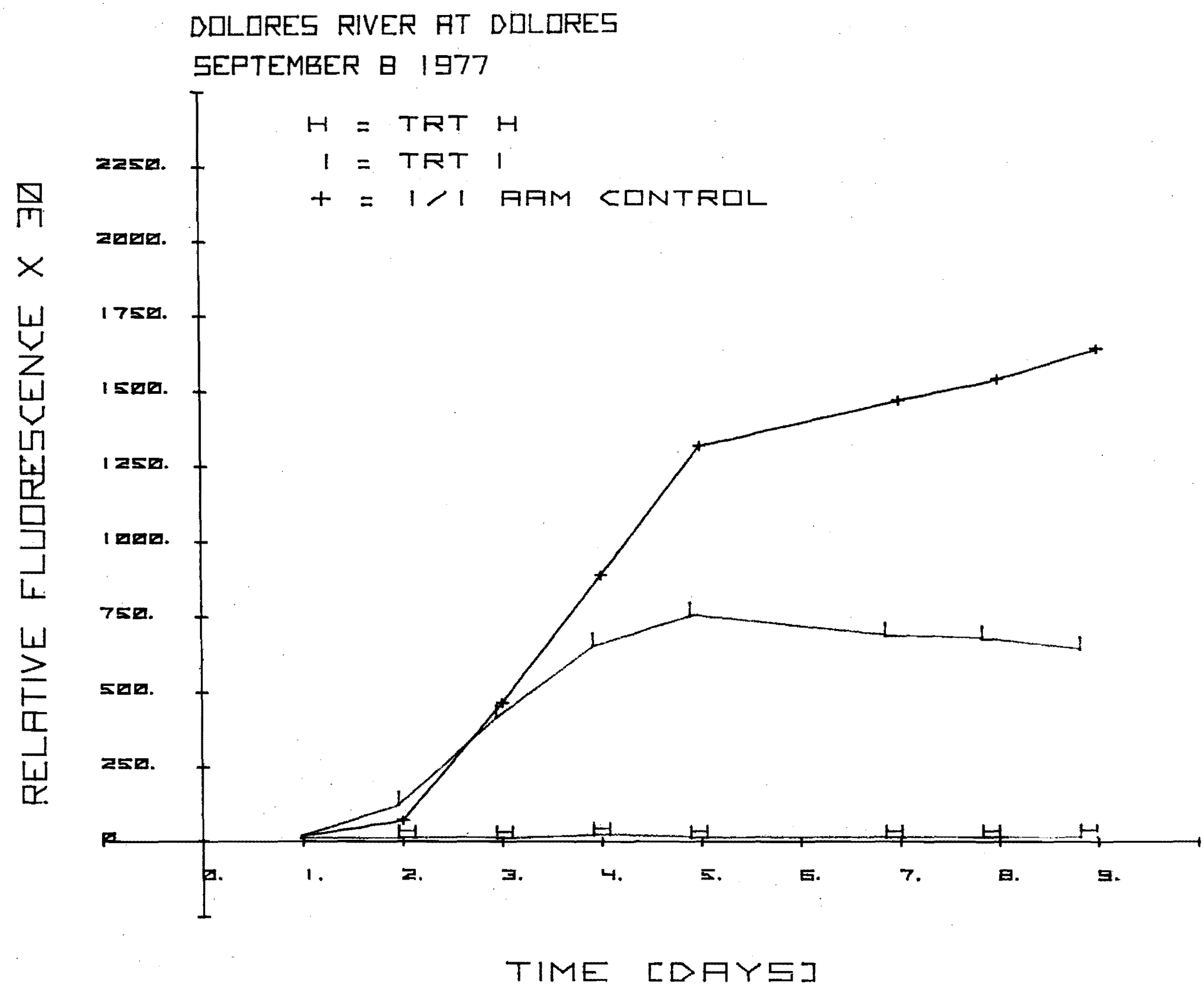

DOLORES RIVER AT DOLORES
SEPTEMBER 8 1977
H = TRT H
I = TRT I
+ = 1/1 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 4.

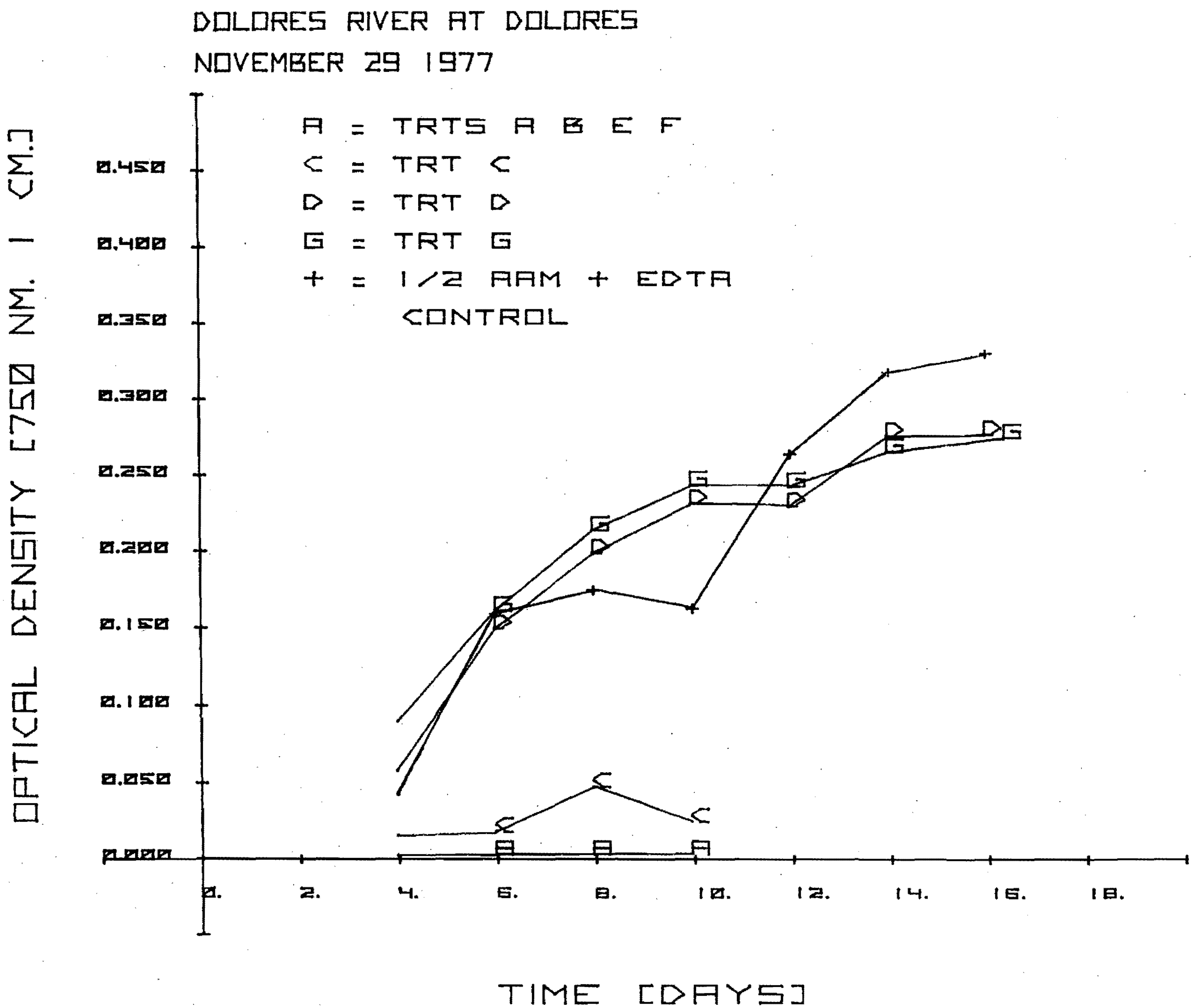

DOLORES RIVER AT DOLORES
NOVEMBER 29 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 5.

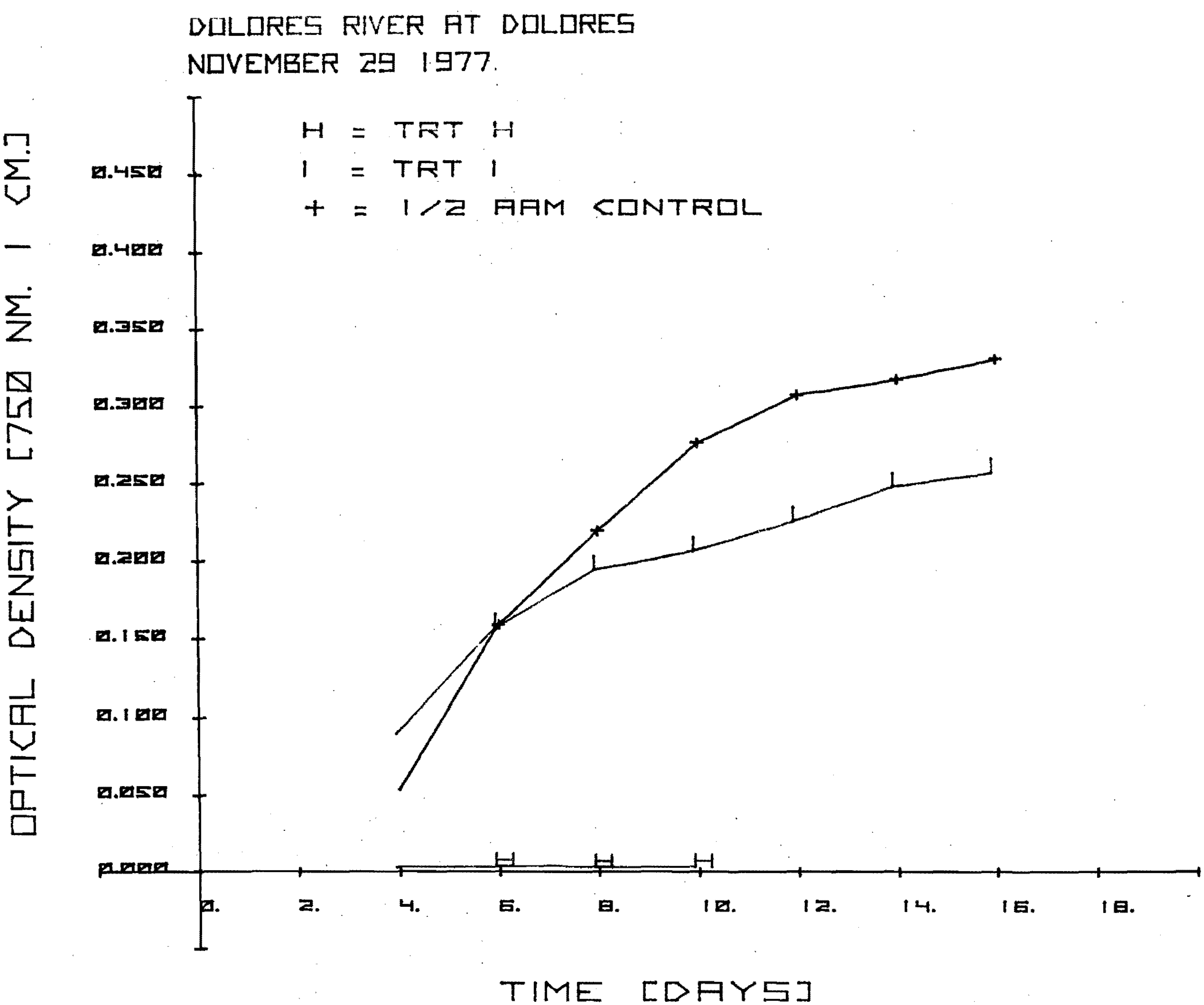
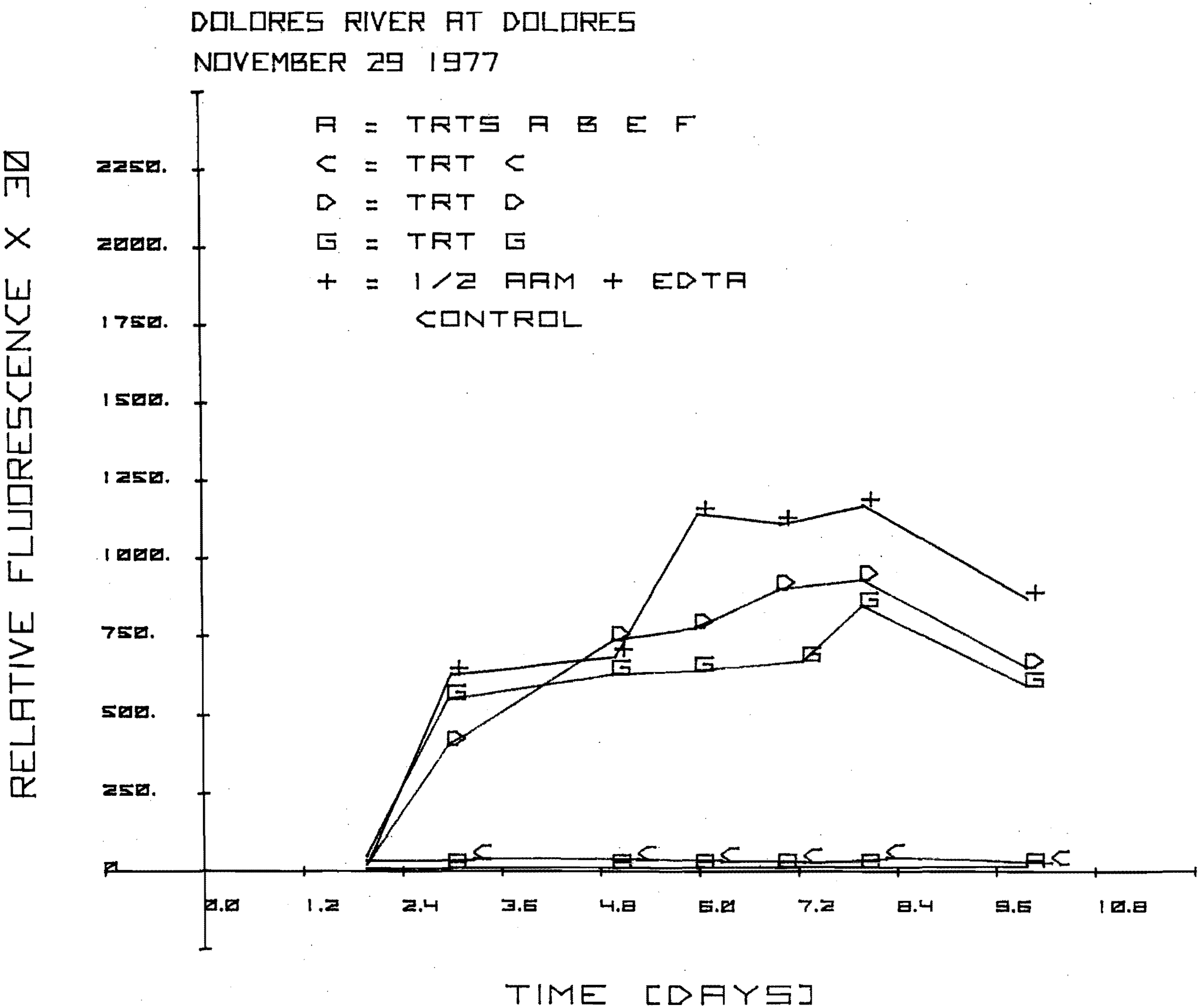

DOLORES RIVER AT DOLORES
NOVEMBER 29 1977
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 6.



DOLORES RIVER AT DOLORES
NOVEMBER 29 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.0
1.2
2.4
3.6
4.8
6.0
7.2
8.4
9.6
10.8
TIME [DAYS]

Figure 7.

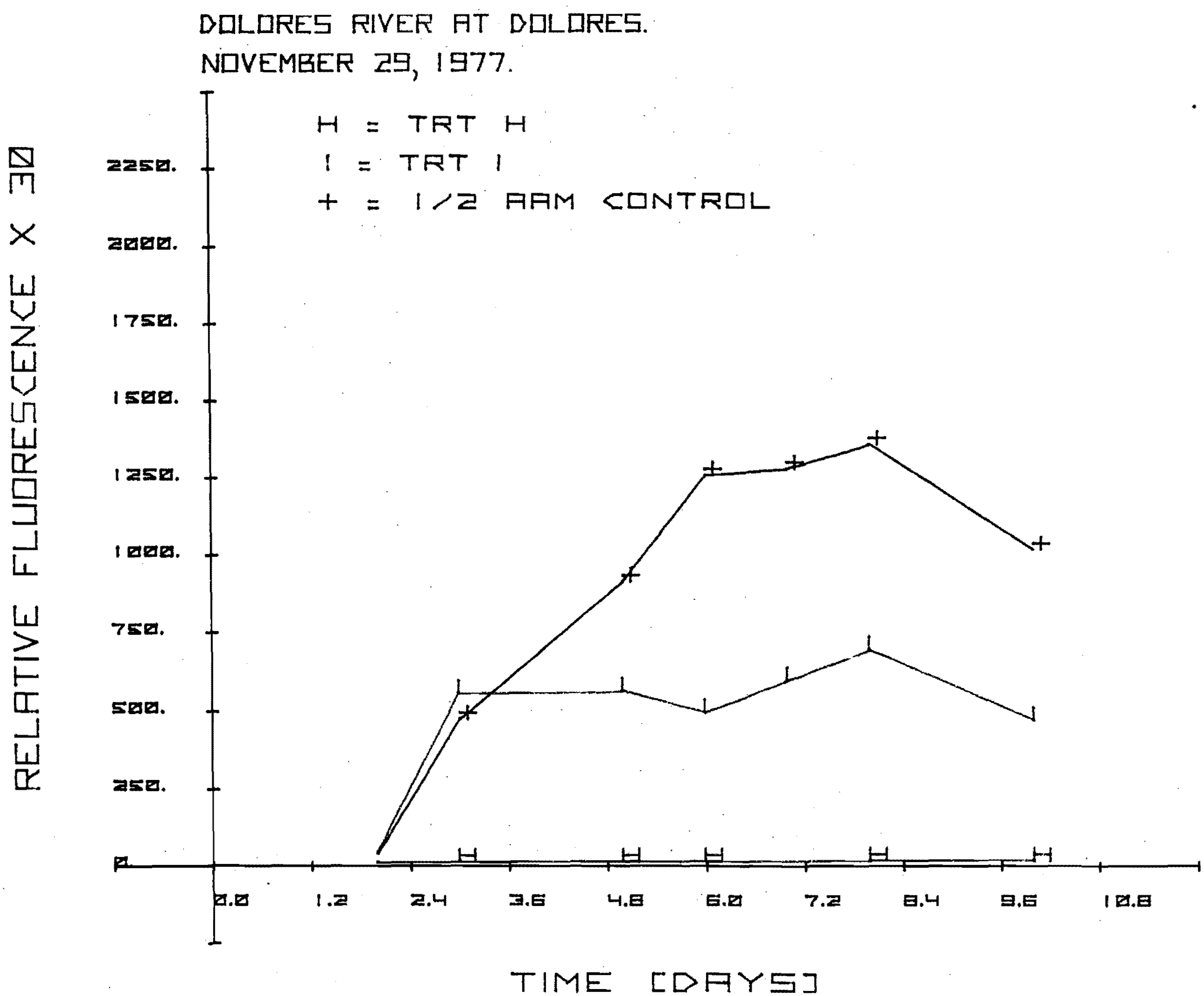

DOLORES RIVER AT DOLORES.
NOVEMBER 29, 1977.
H = TRT H
! = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.0
1.2
2.4
3.6
4.8
6.0
7.2
8.4
9.6
10.8
TIME [DAYS]

Figure 8.

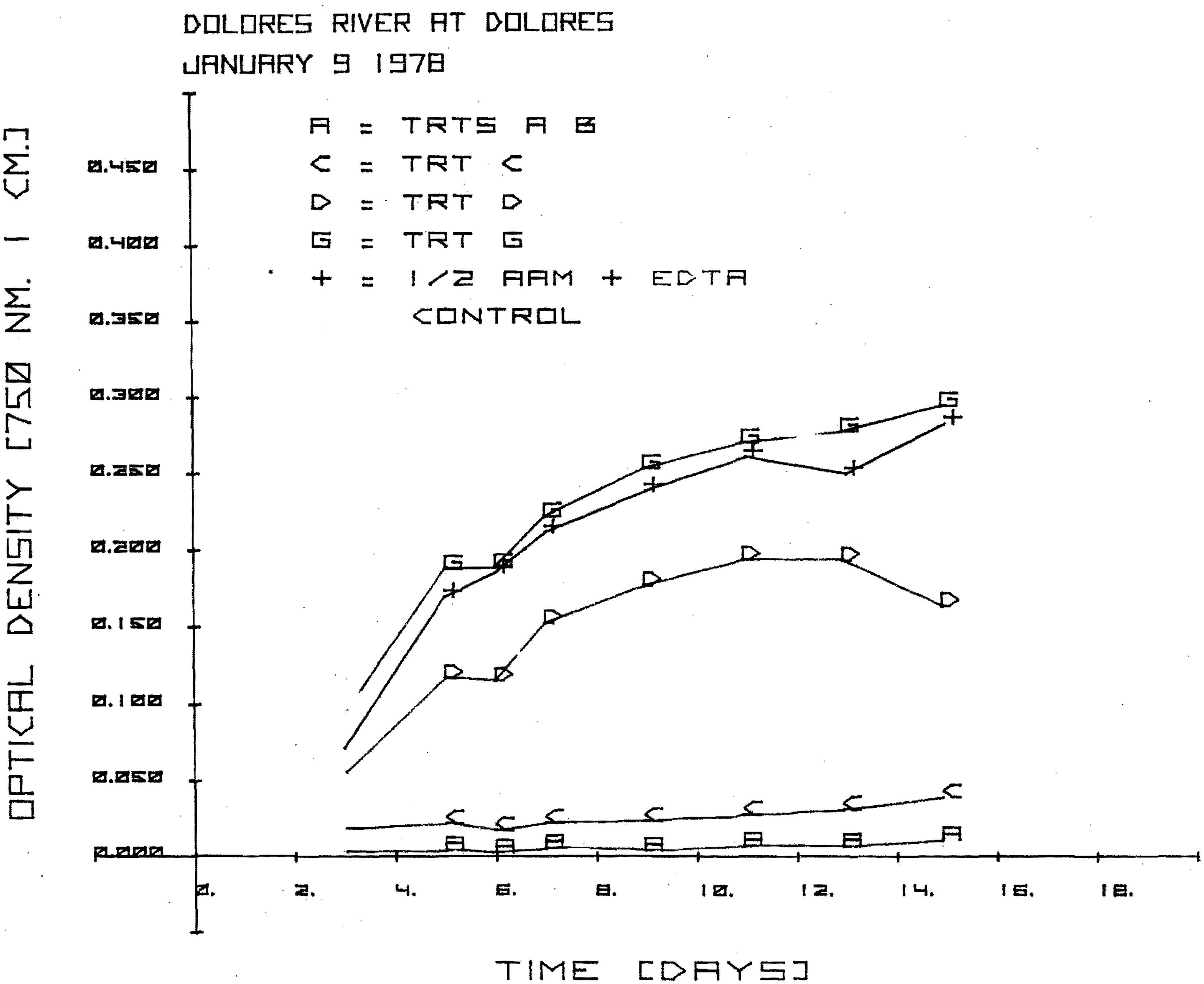

DOLORES RIVER AT DOLORES
JANUARY 9 1978
A = TRTS A B
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 9.

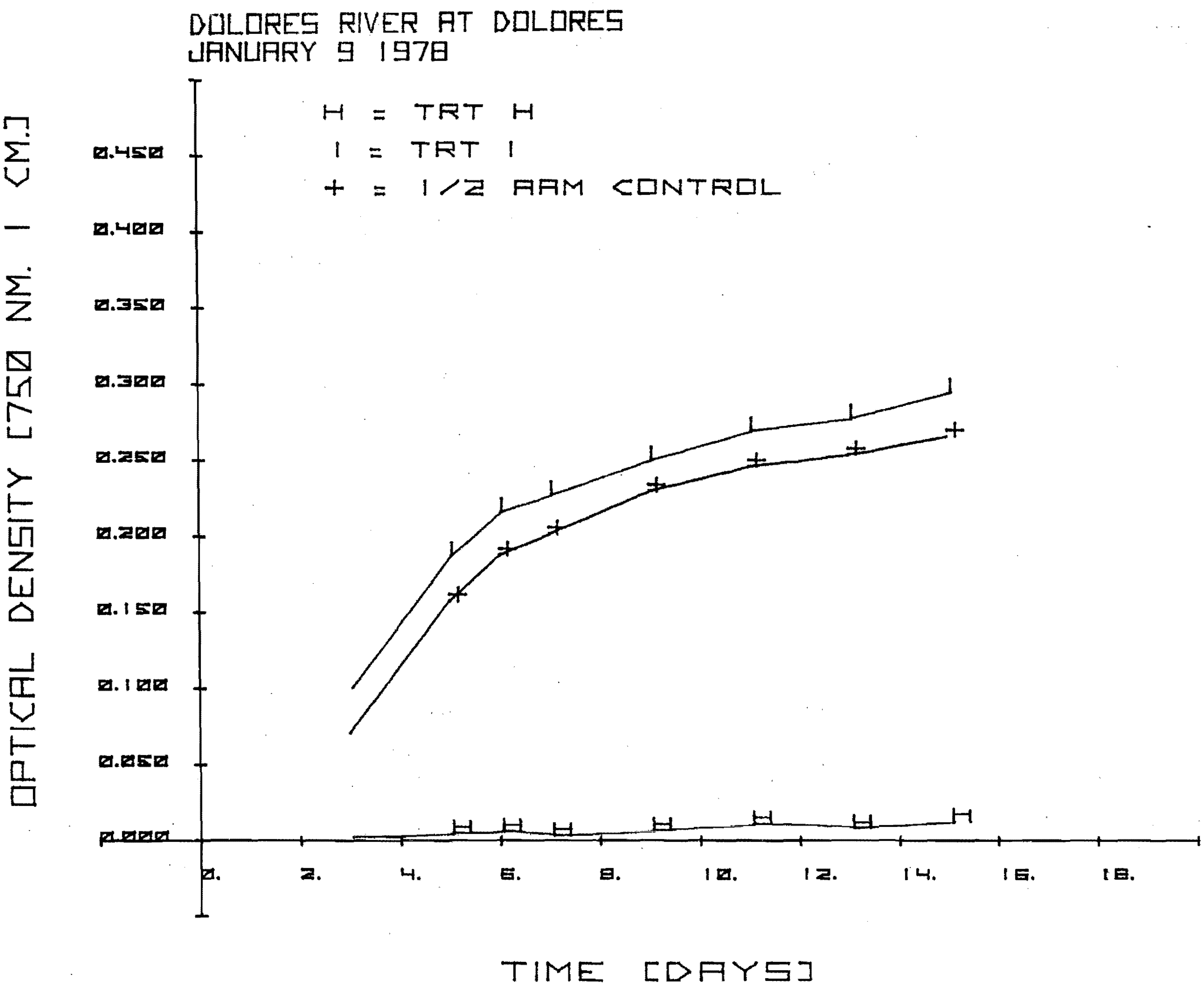

DOLORES RIVER AT DOLORES
JANUARY 9 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 10.

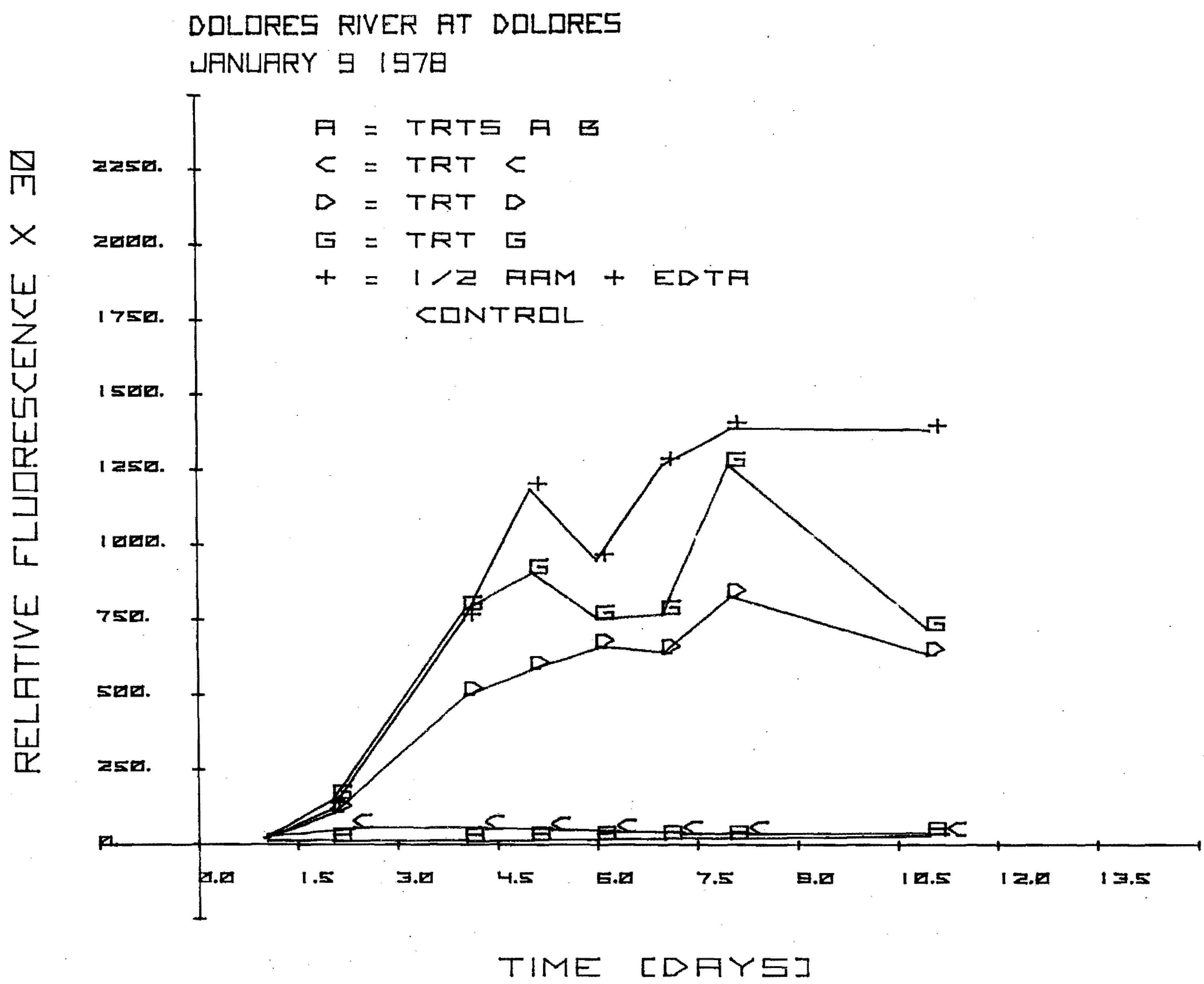

DOLORES RIVER AT DOLORES
JANUARY 9 1978
A = TRTS A B
< = TRT <
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 11.

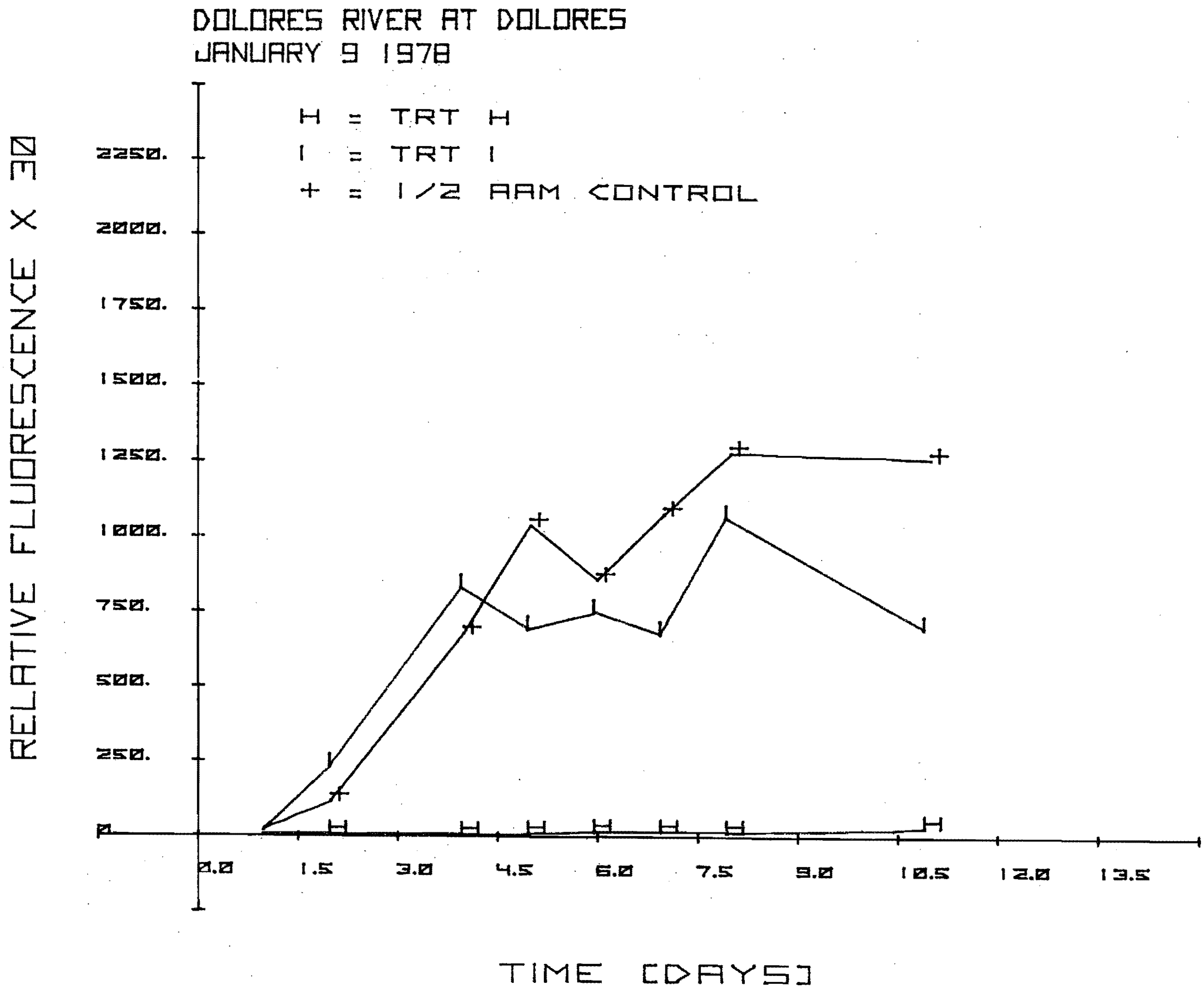

DOLORES RIVER AT DOLORES
JANUARY 9 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 12.

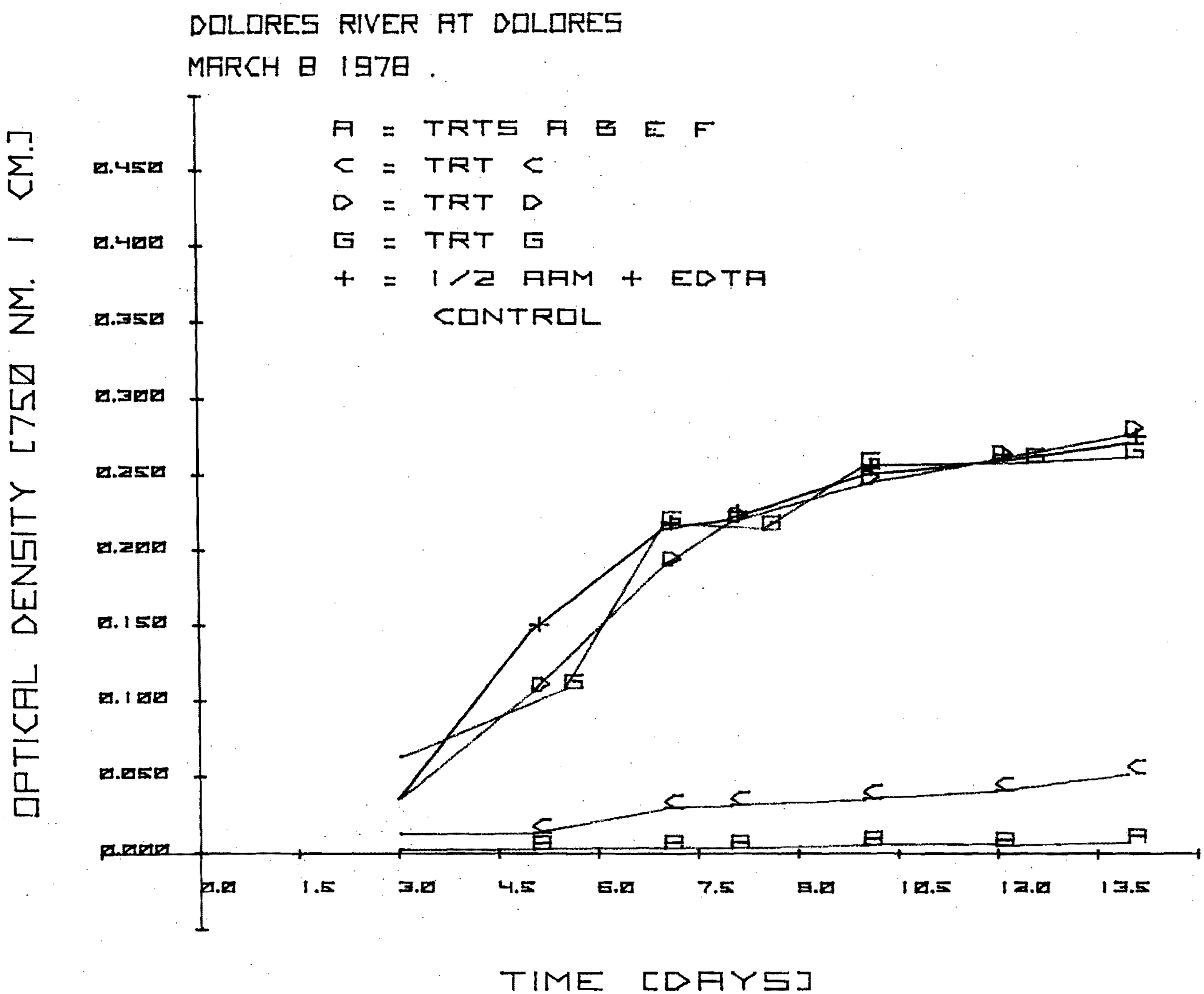

DOLORES RIVER AT DOLORES
MARCH 8 1978 .
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. | CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 13.

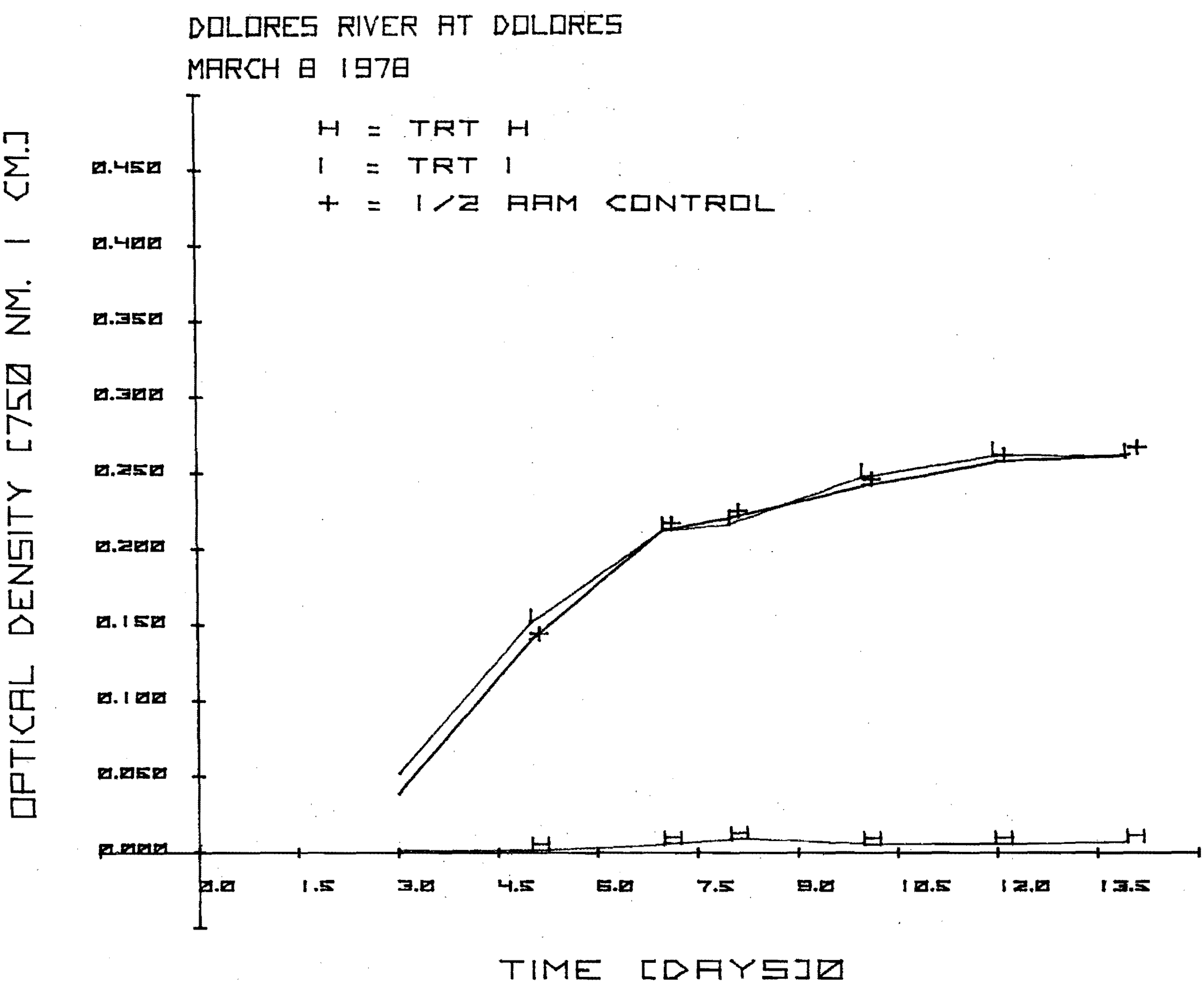
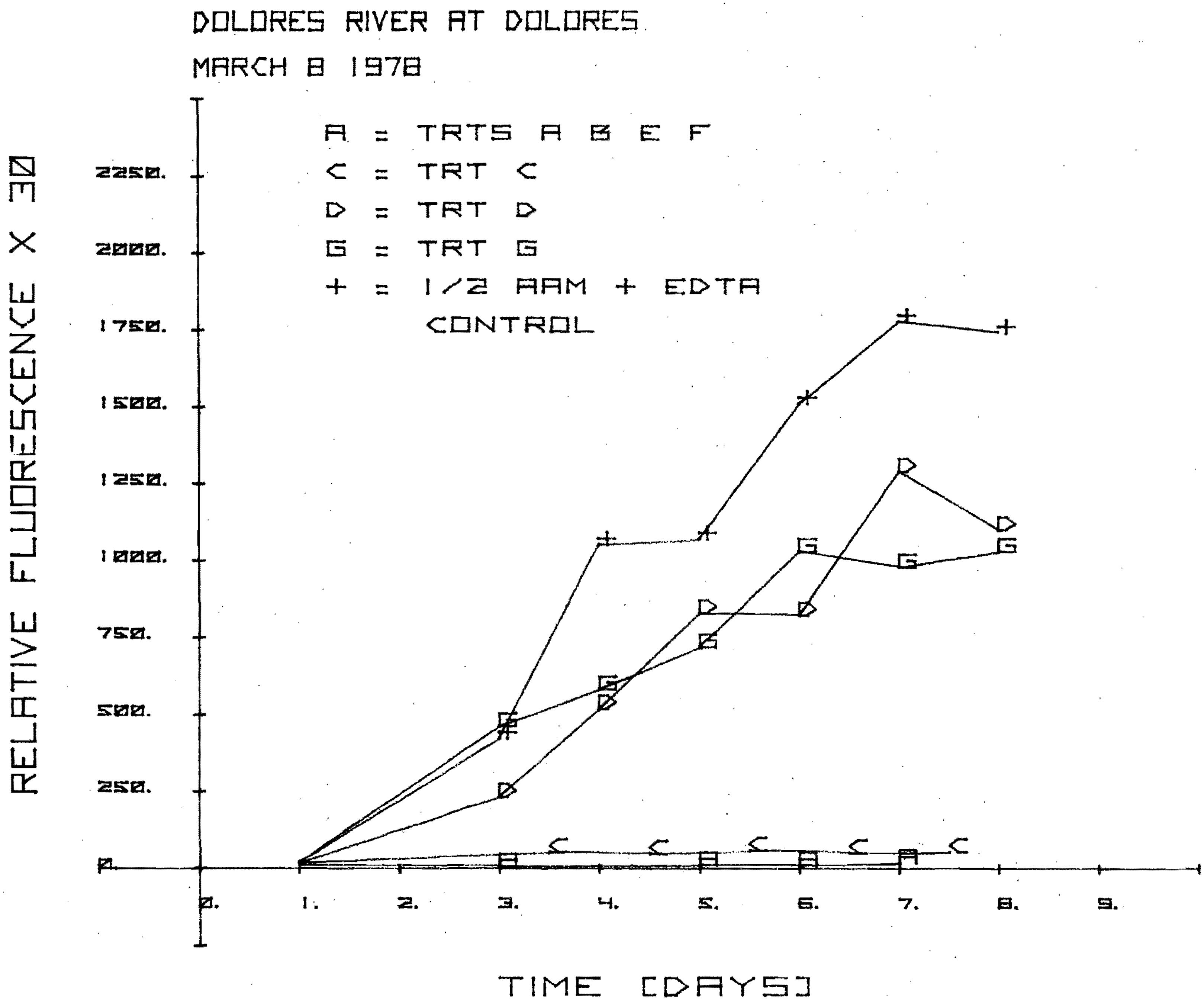

DOLORES RIVER AT DOLORES
MARCH 8 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 14.


DOLORES RIVER AT DOLORES
MARCH 8 1978
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]
Figure 15.

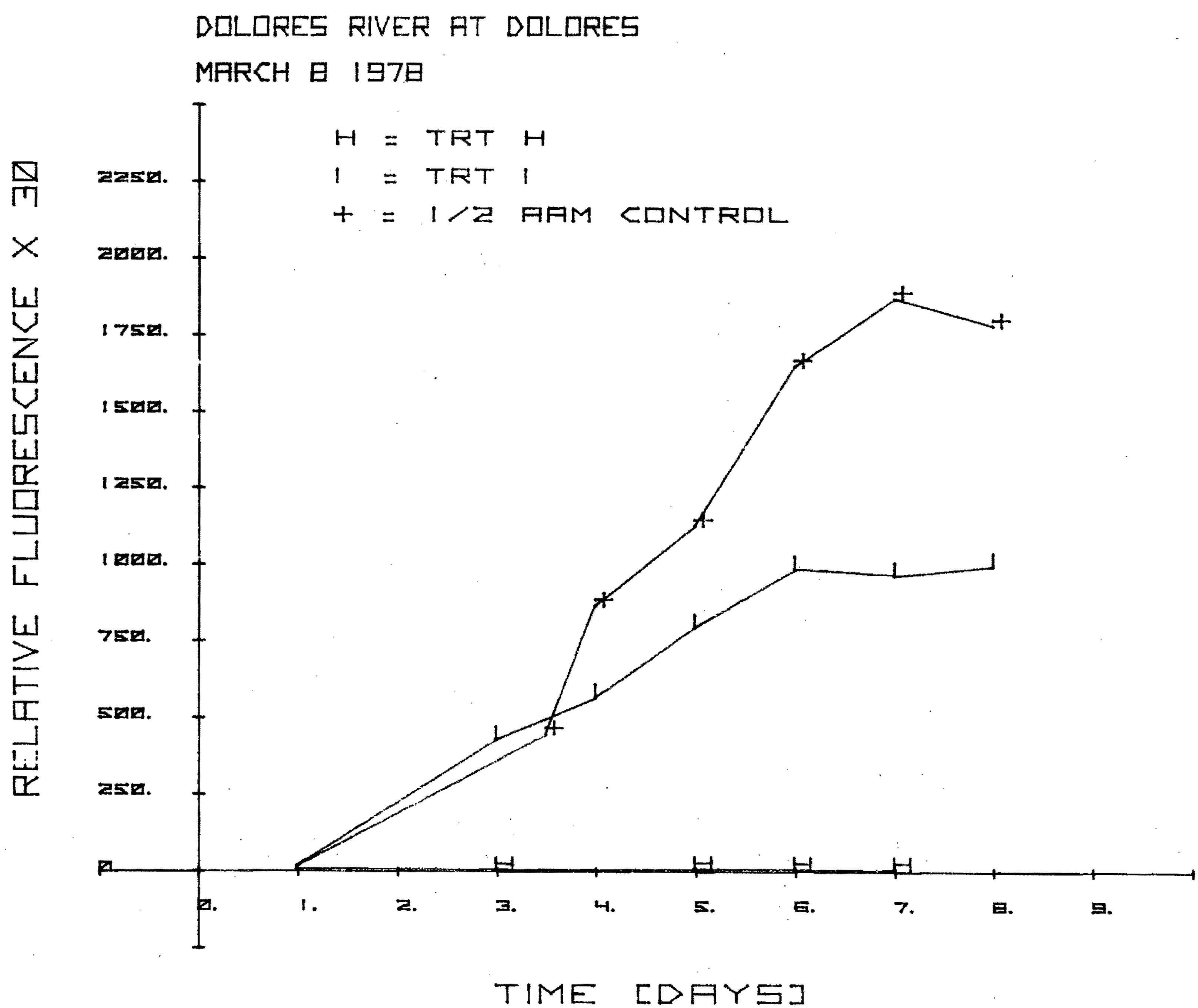

DOLORES RIVER AT DOLORES
MARCH 8 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME (DAYS)

Figure 16.

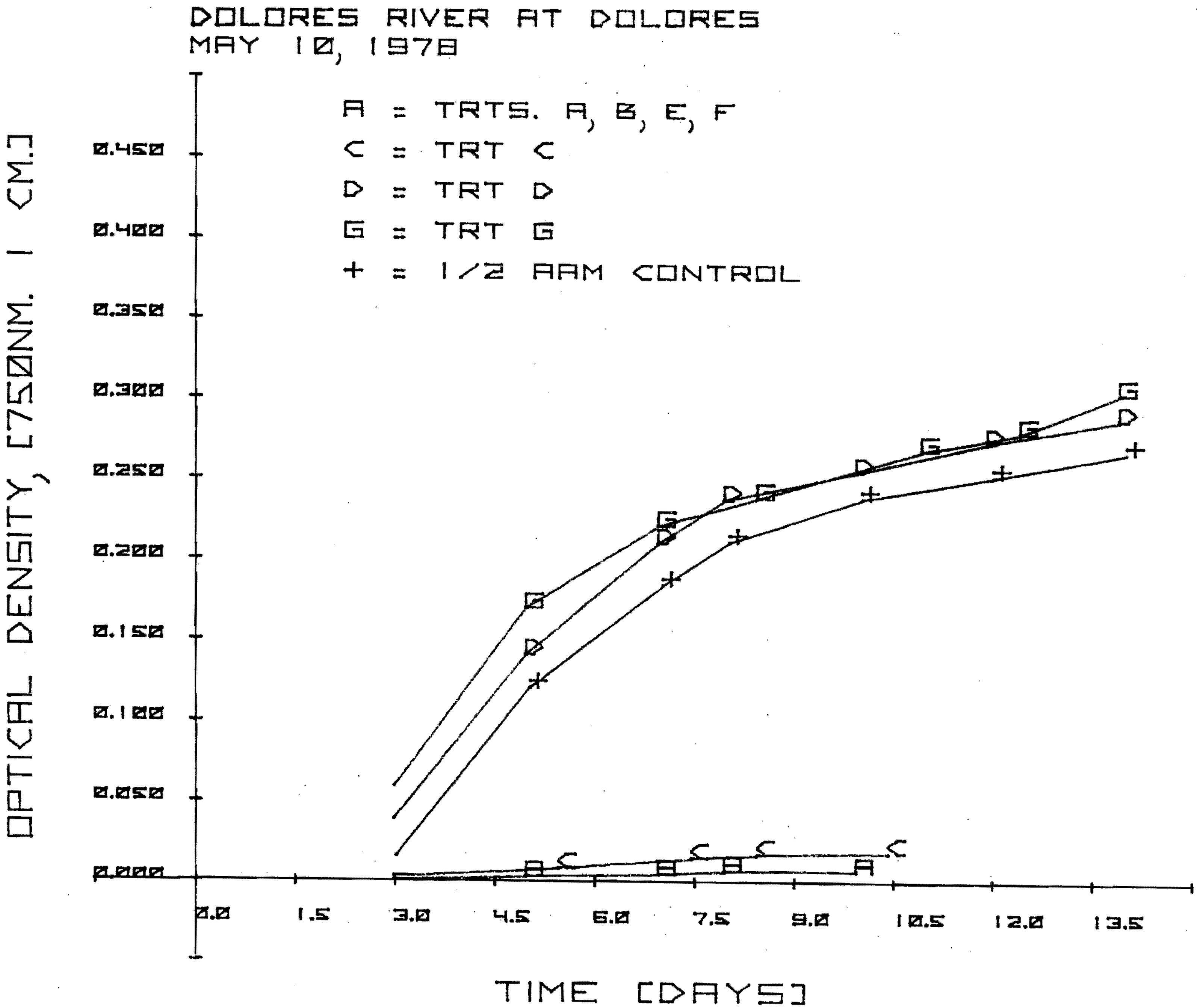

DOLORES RIVER AT DOLORES
MAY 10, 1978
A = TRTS. A, B, E, F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM CONTROL
OPTICAL DENSITY, [750NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 17.

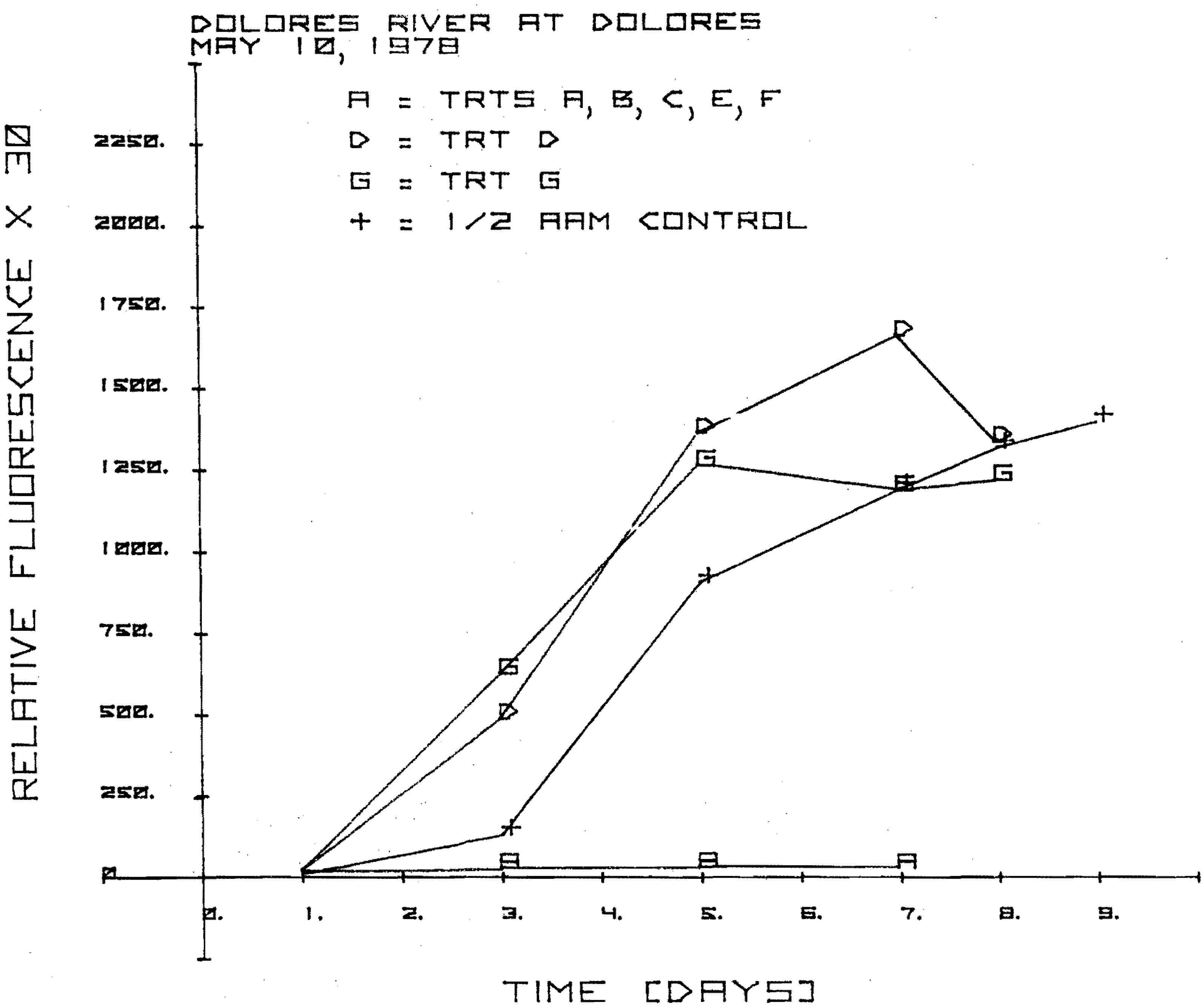

DOLORES RIVER AT DOLORES
MAY 10, 1978
A = TRTS A, B, C, E, F
D = TRT D
G = TRT G
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 18.

the system. Addition of phosphorus caused a slight growth increase averaging 16.7 mg/l VSS over an average of 5.9 mg/l VSS for the sample blank. Nitrogen and phosphorus addition increased the biomass to an average of 95.6 mg/l VSS substantiating the predicated nitrogen and phosphorus limitation.

The Dolores River sample at Dolores was found to be oligotrophic with respect to nutrients during the algal bioassay test period from September 1977 through May 1978. Both nitrogen and phosphorus must be increased by substantial amounts in order to change the degree of eutrophication.

Conclusions -

a. The sample was limited by both nitrogen and phosphorus.

b. There was a good correlation between chemical analysis and algal bioassay.

c. No metal toxicity was observed.

d. This sample represents an infertile body of water in terms of algae with oligotrophic to mesotrophic tendencies in the future.

2. Dolores River below Rico Tailings (Figures 19 - 22)
Dolores River above Rico Tailings (Figures 23 - 26)
Dolores River below West Dolores River (Figures 27 - 30)

These samples were subjected to algal bioassay only during September 1977. Consequently it was difficult to draw any conclusions beyond the limiting nutrient at that sampling date. Chemical analysis indicated a phosphorus limitation but as was true with the Dolores River at Dolores indigenous nutrient concentrations were extremely low. This fact made it appear likely that these sampling sites would be nitrogen limited as well.

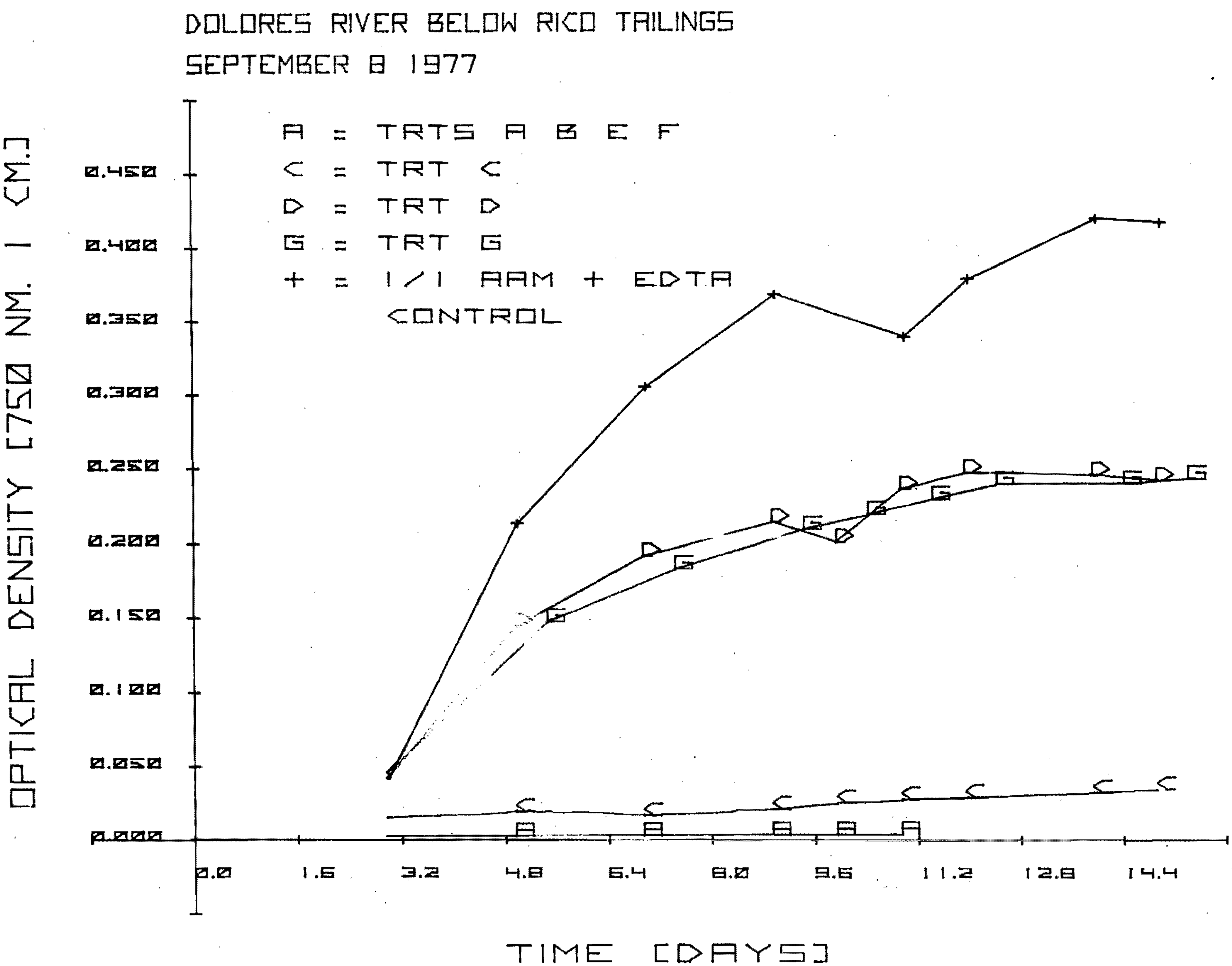

DOLORES RIVER BELOW RICO TAILINGS
SEPTEMBER 8 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/1 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. I CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.6
3.2
4.8
6.4
8.0
9.6
11.2
12.8
14.4
TIME [DAYS]

Figure 19.

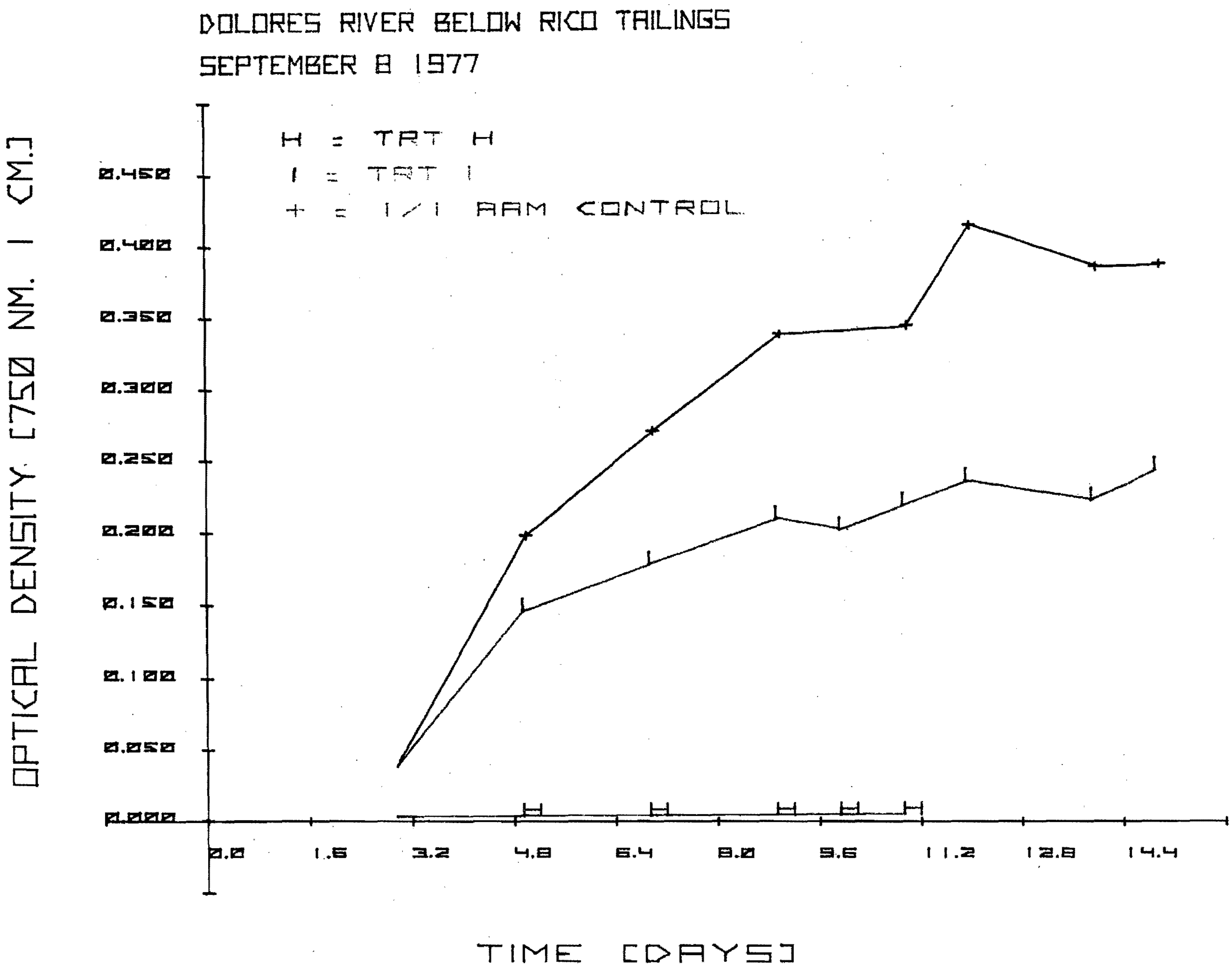

DOLORES RIVER BELOW RICO TAILINGS
SEPTEMBER 8 1977
H = TRT H
I = TRT I
+ = 1/1 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.6
3.2
4.8
6.4
8.0
9.6
11.2
12.8
14.4
TIME [DAYS]

Figure 20.

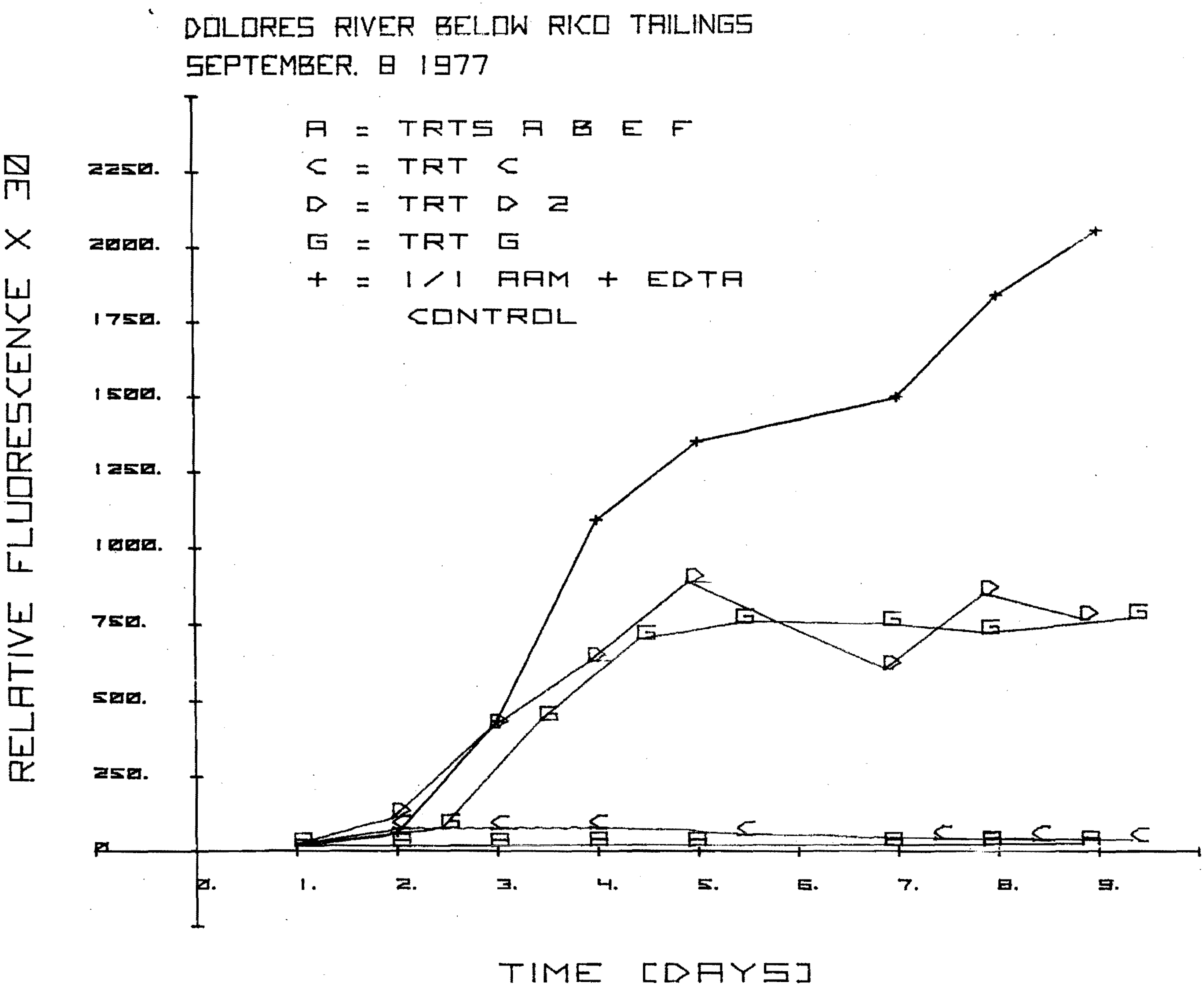
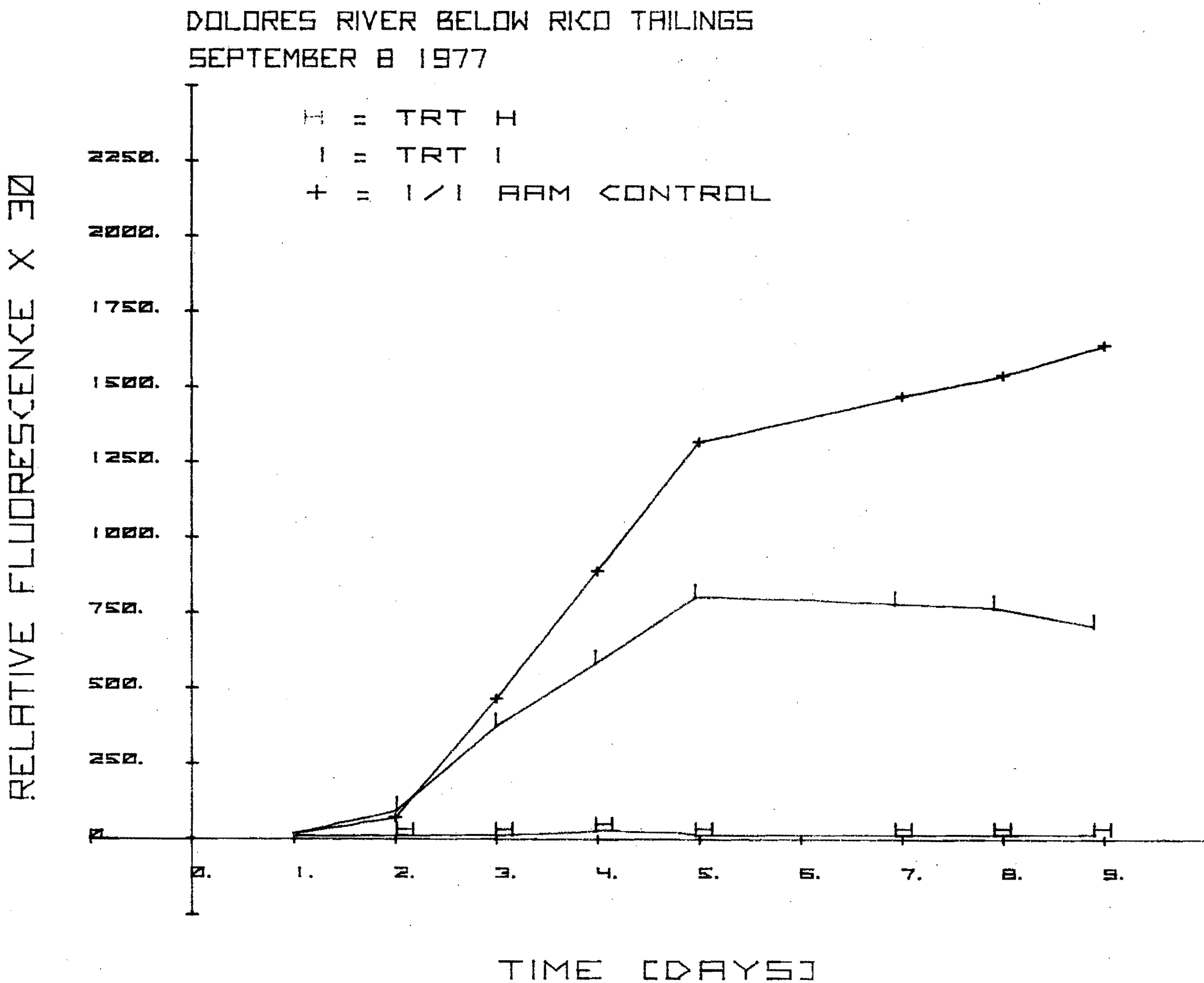

DOLORES RIVER BELOW RICO TRAILINGS
SEPTEMBER. 8 1977
A = TRTS A B E F
C = TRT C
D = TRT D 2
G = TRT G
+ = 1/1 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME (DAYS)

Figure 21.



DOLORES RIVER BELOW RICO TAILINGS
SEPTEMBER 8 1977
H = TRT H
I = TRT I
+ = 1/1 AAM <CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 22.

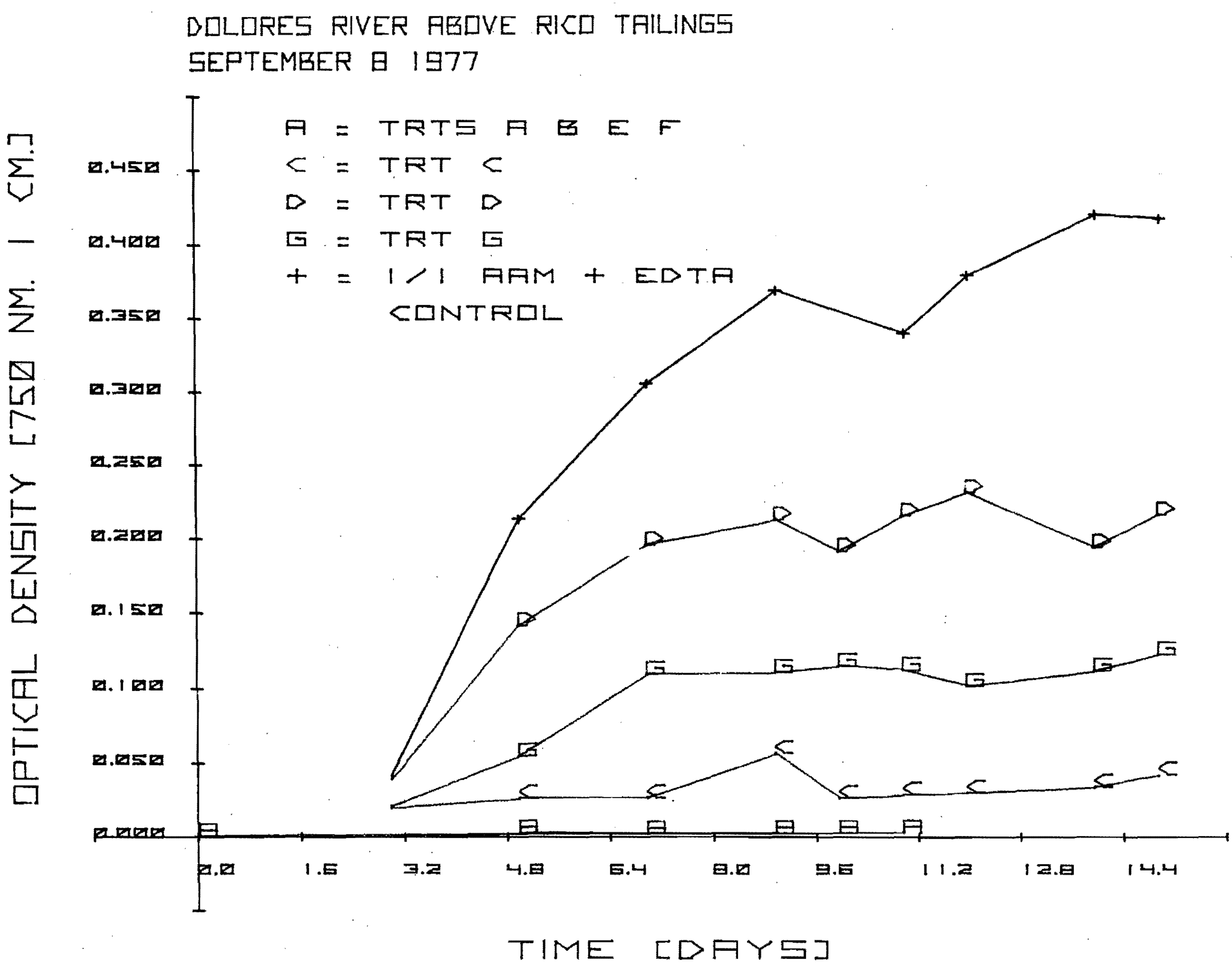

DOLORES RIVER ABOVE RICO TAILINGS
SEPTEMBER 8 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/1 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.6
3.2
4.8
6.4
8.0
9.6
11.2
12.8
14.4
TIME [DAYS]

Figure 23.

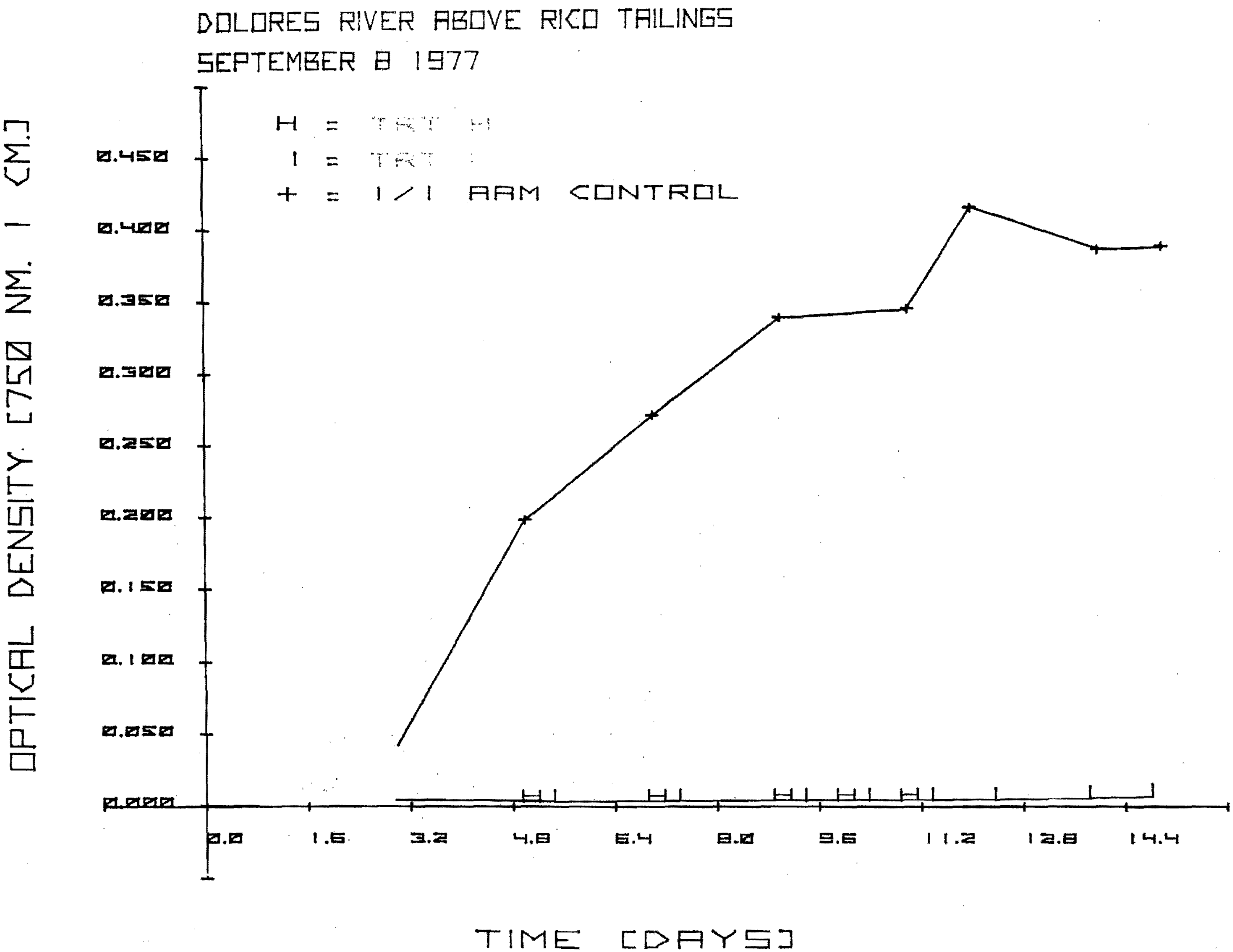

DOLORES RIVER ABOVE RICO TAILINGS
SEPTEMBER 8 1977
H =
I =
+ = 1/1 ARM <CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.6
3.2
4.8
6.4
8.0
9.6
11.2
12.8
14.4
TIME [DAYS]

Figure 24.

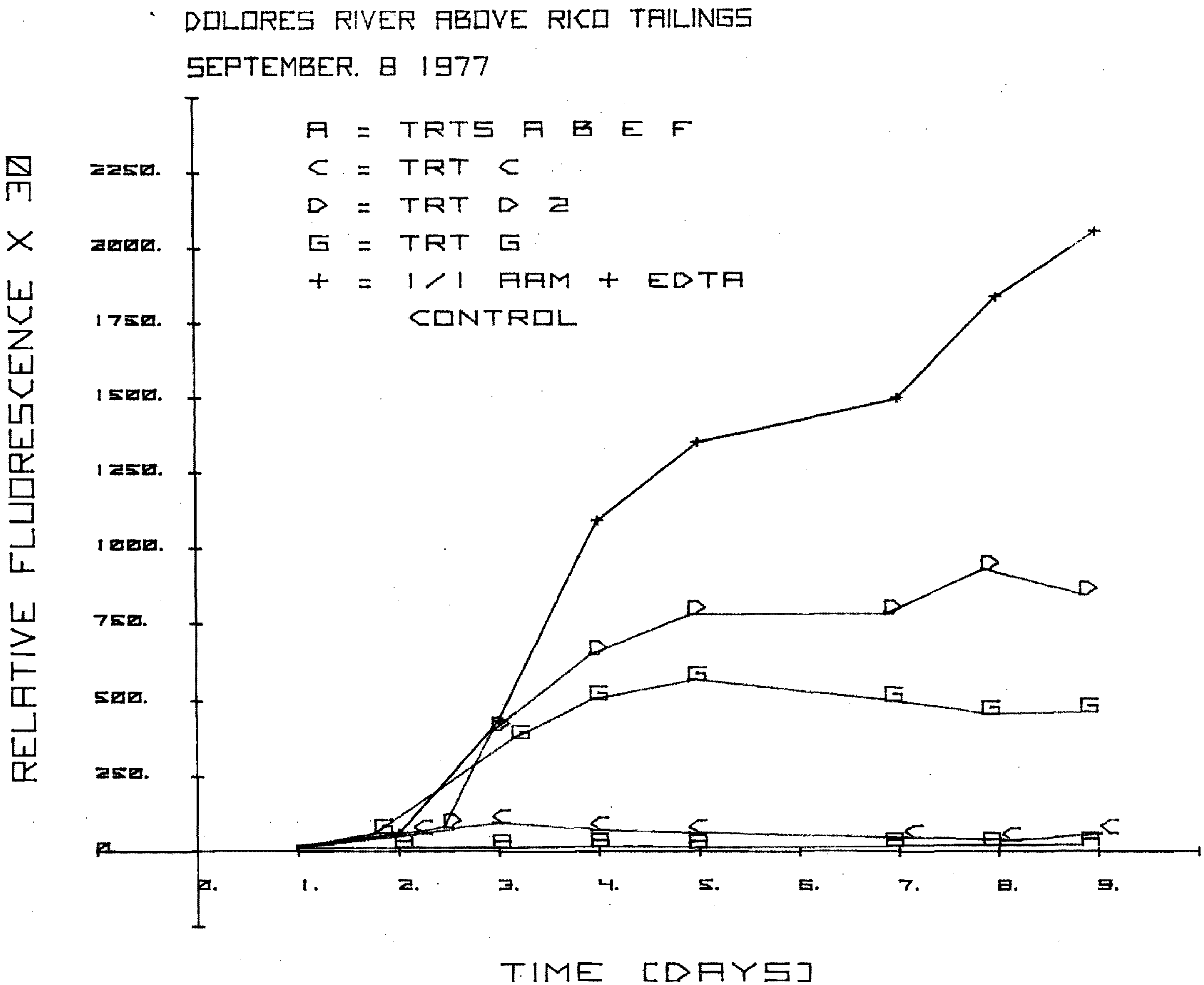

DOLORES RIVER ABOVE RICO TRAILINGS
SEPTEMBER. 8 1977
A = TRTS A B E F
C = TRT C
D = TRT D 2
G = TRT G
+ = 1/1 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME (DAYS)

Figure 25.

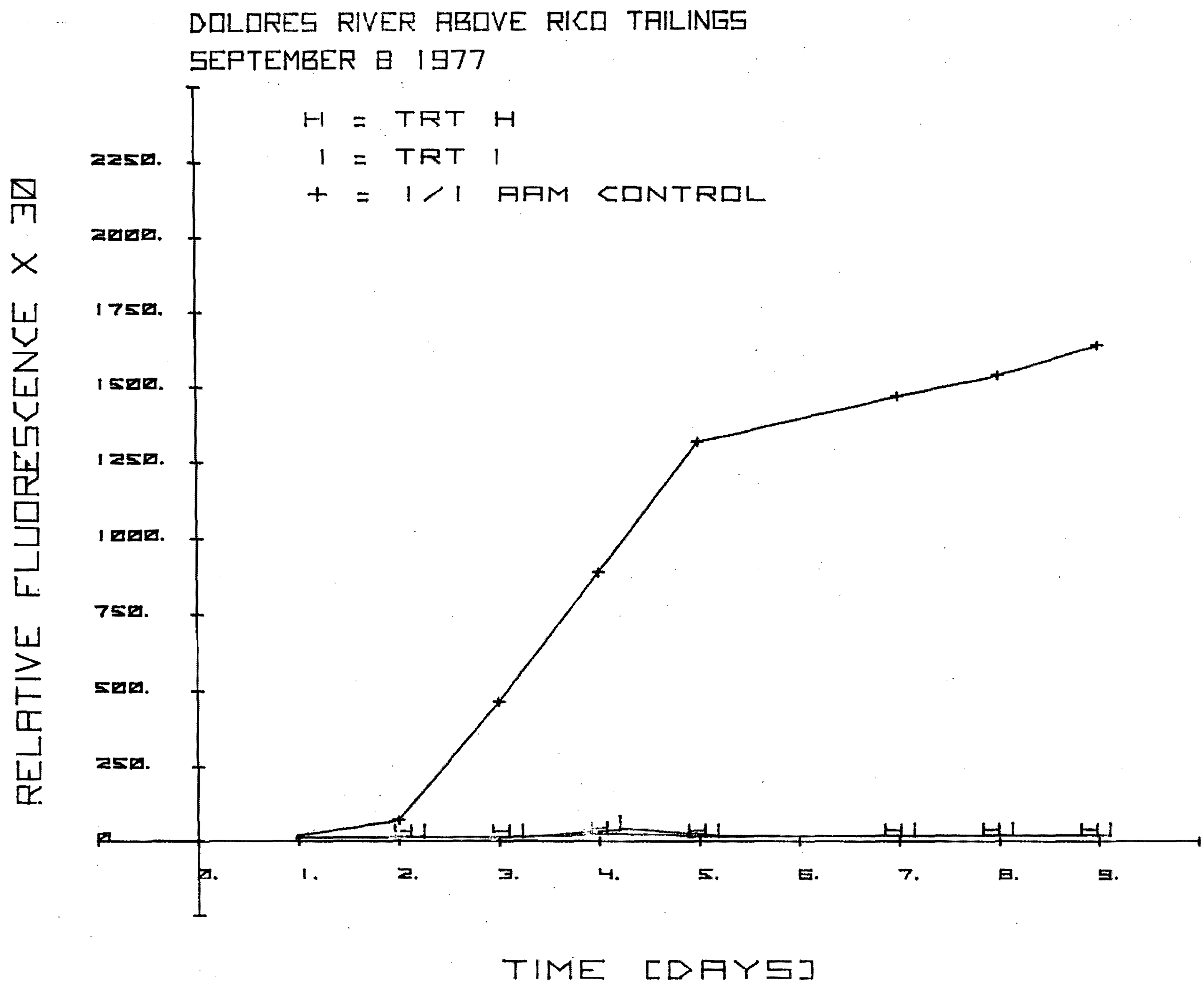
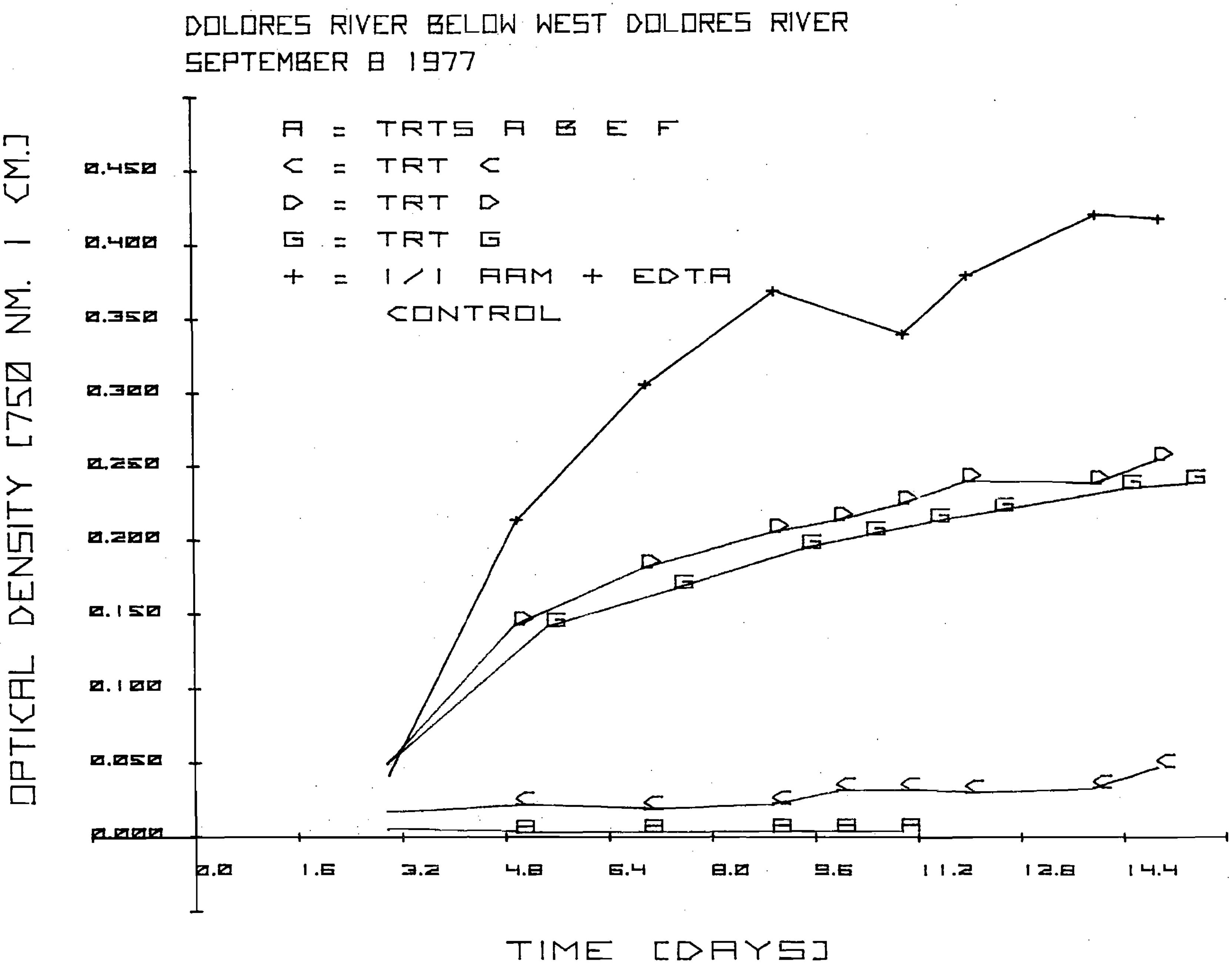

DOLORES RIVER ABOVE RICO TAILINGS
SEPTEMBER 8 1977
H = TRT H
I = TRT I
+ = 1/1 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME (DAYS)

Figure 26.



DOLORES RIVER BELOW WEST DOLORES RIVER
SEPTEMBER 8 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/1 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.6
3.2
4.8
6.4
8.0
9.6
11.2
12.8
14.4
TIME [DAYS]

Figure 27.

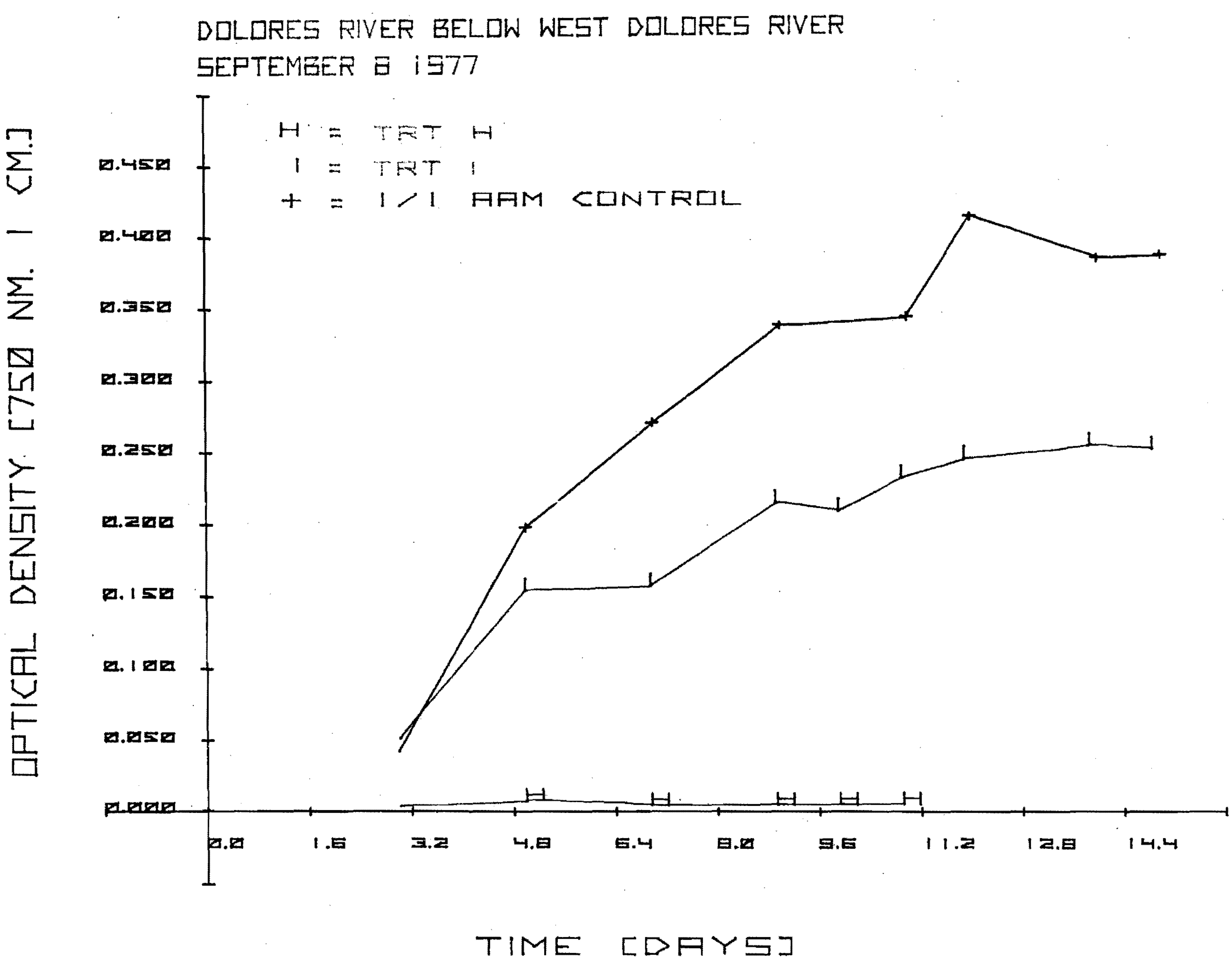

DOLORES RIVER BELOW WEST DOLORES RIVER
SEPTEMBER 8 1977
H = TRT H
I = TRT I
+ = 1/1 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.6
3.2
4.8
6.4
8.0
9.6
11.2
12.8
14.4
TIME [DAYS]

Figure 28.

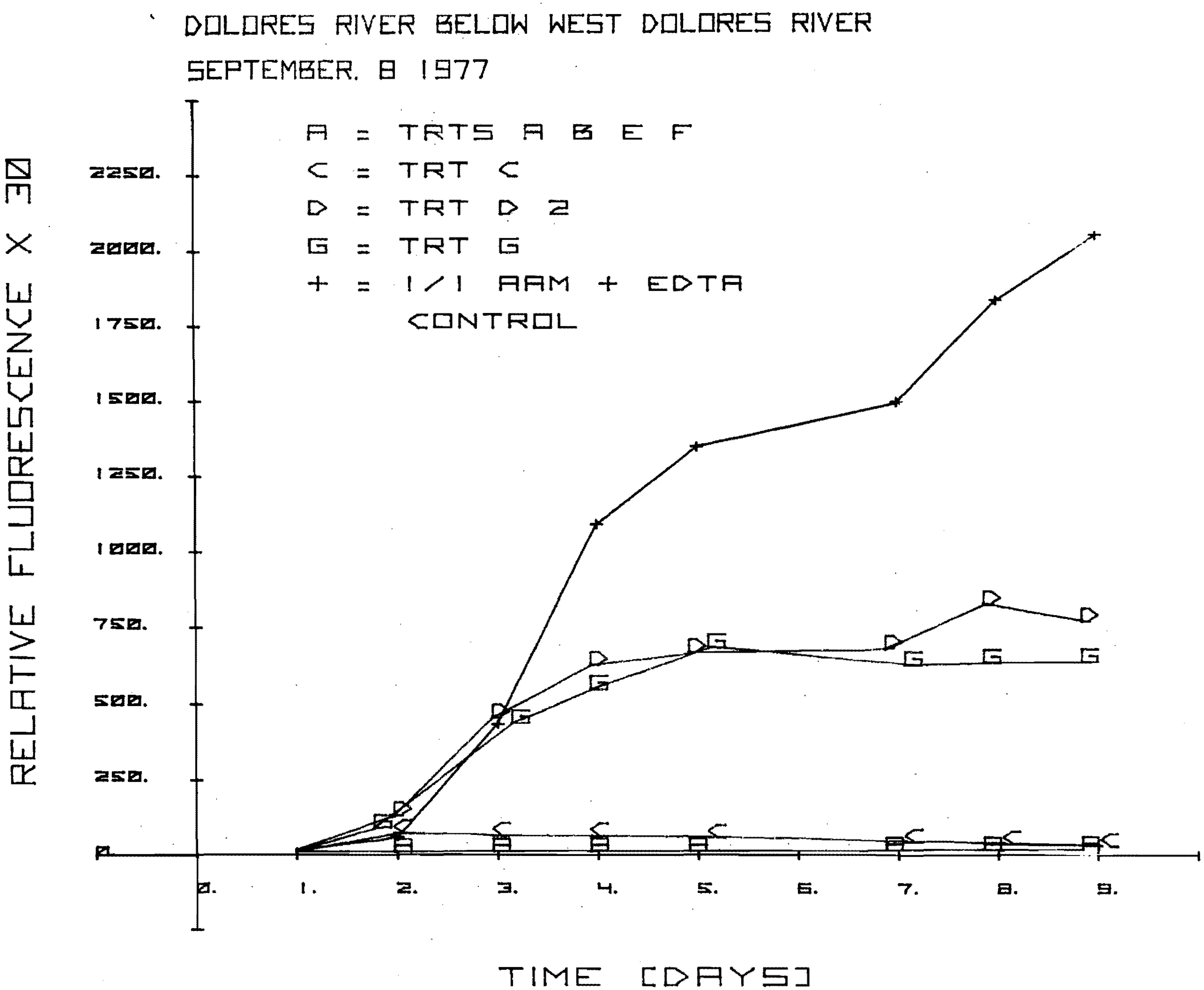
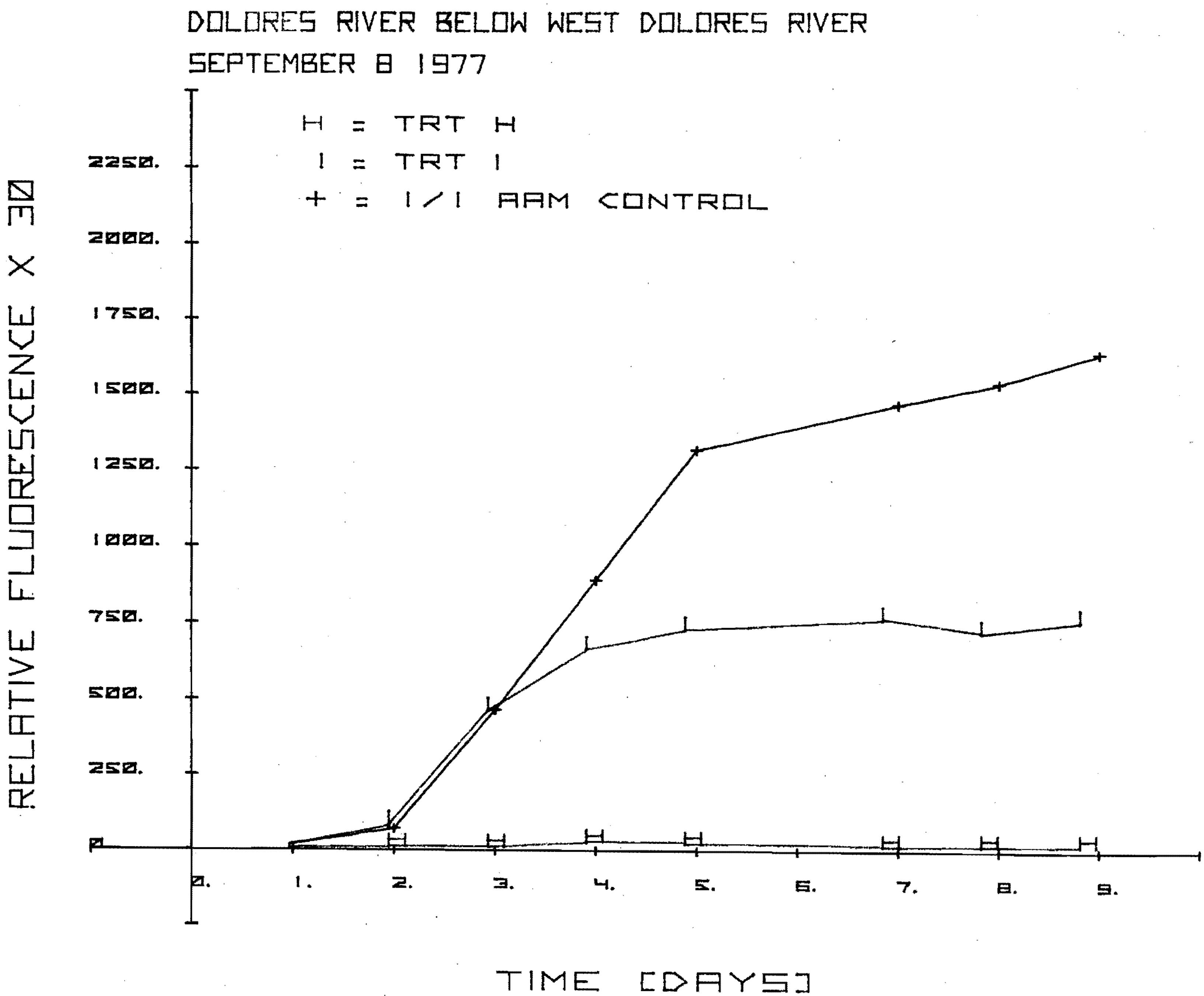

DOLORES RIVER BELOW WEST DOLORES RIVER
SEPTEMBER. 8 1977
A = TRTS A B E F
C = TRT C
D = TRT D 2
G = TRT G
+ = 1/1 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 29.



DOLORES RIVER BELOW WEST DOLORES RIVER
SEPTEMBER 8 1977
H = TRT H
I = TRT I
+ = 1/1 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 30.

The results of the bioassay clearly indicated limitation by phosphorus and nitrogen with phosphorus being the most limiting. The maximum specific growth rates (Table 22) were much higher when phosphorus was added but due to the low nitrogen concentration growth was minimal when nitrogen also became limiting.

One interesting fact resulted from the bioassay. A metal toxicity problem was detected on the Dolores River above Rico Tailings. Growth did not occur when EDTA was removed fron the system but biomass increased in the presence of EDTA.

Conclusions:

a. The samples were limited by both nitrogen and phosphorus.
b. There was a good correlation between chemical analysis and algal bioassay.
c. Metal toxicity was observed in the Dolores River above Rico Tailings but not at the other two sites.
d. During September 1977 these samples represented an infertile body of water.

B. Dominquez Project

Gunnison River near Grand Junction (Figures 31 - 44)

Chemical analysis was very accurate in predicating phosphorus limitation during November, 1977; January, 1978; and March, 1978. Bioassay verified that indigenous nitrogen was at a high enough concentration to support a large increase in biomass upon addition of phosphorus (Treatment C). Table 15 shows that the resulting biomass after addition of phosphorus alone nearly equaled the biomass increase when the sample was spiked with both nitrogen and phosphorus.

Table 27.
Dominquez Project
Limiting Nutrients

Sample	Limiting Nutrient(s)	
	Chemical Analysis	Bioassay
11/29/77		
Gunnison River Near Grand Junction	Phosphorus	Phosphorus[a]
1/9/78		
Gunnison River Near Grand Junction	Phosphorus	Phosphorus[a]
3/8/78		
Gunnison River Near Grand Junction	Phosphorus	Phosphorus
5/10/78		
Gunnison River Near Grand Junction	Phosphorus	Phosphorus[b]

[a]Nitrogen also became limiting but only after significant growth occurs upon addition of phosphorus.

[b]No increase in growth occurred upon addition of both nitrogen and phosphorus over phosphorus addition alone. However, growth increased when total AAM was added indicating a possible trace metal limitation as well as phosphorus limitation.

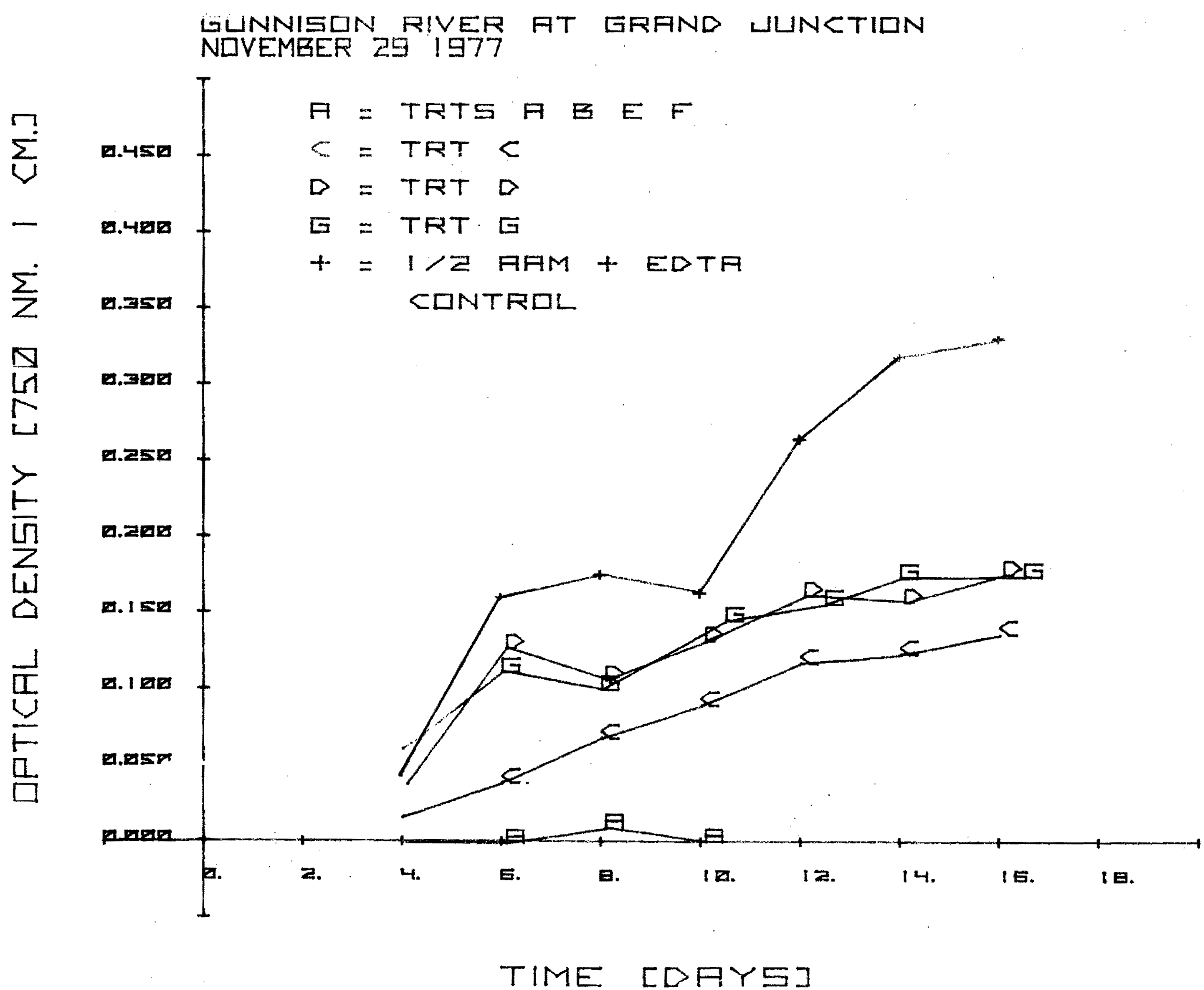

GUNNISON RIVER AT GRAND JUNCTION
NOVEMBER 29 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 31.

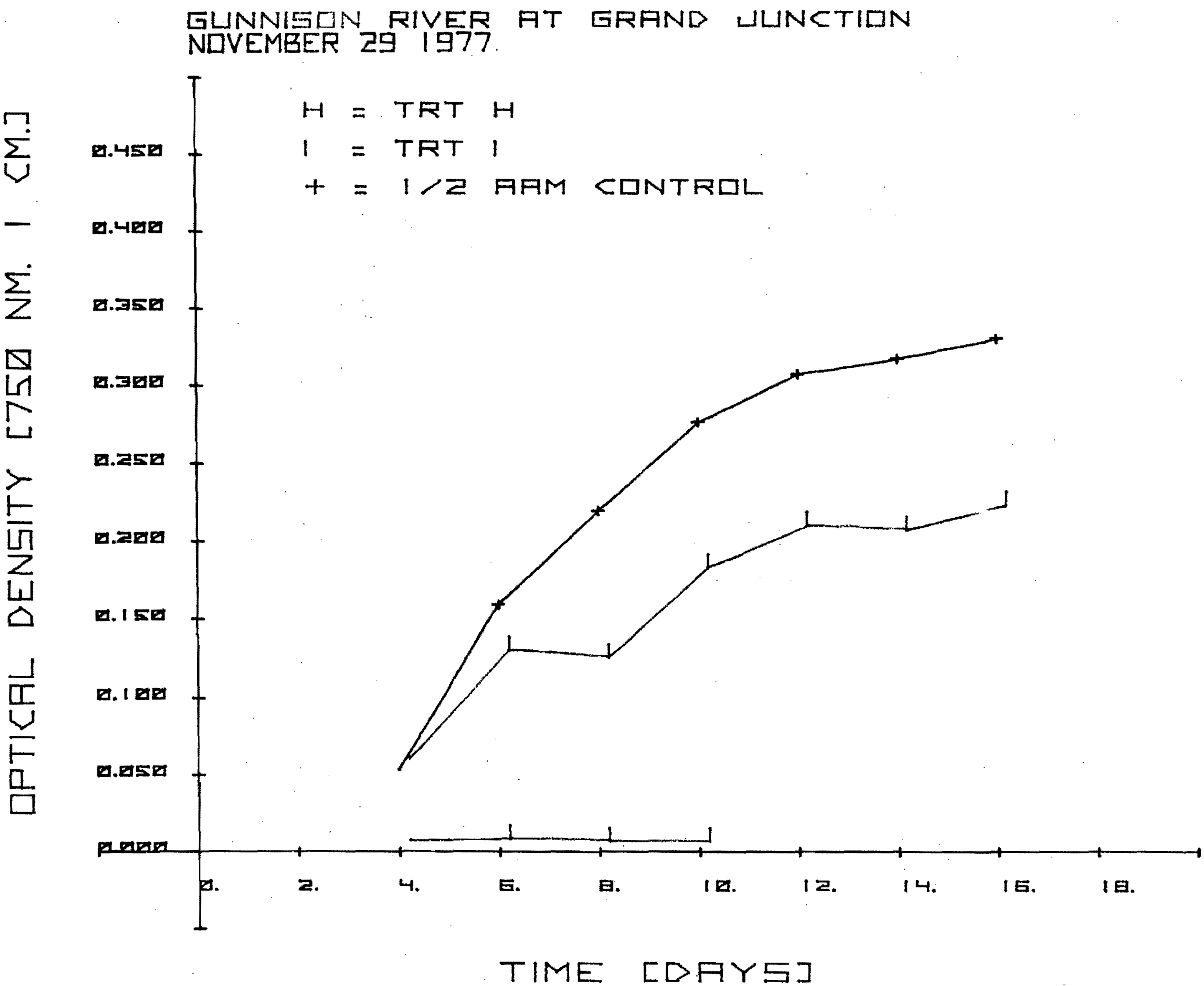

GUNNISON RIVER AT GRAND JUNCTION
NOVEMBER 29 1977
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 32.

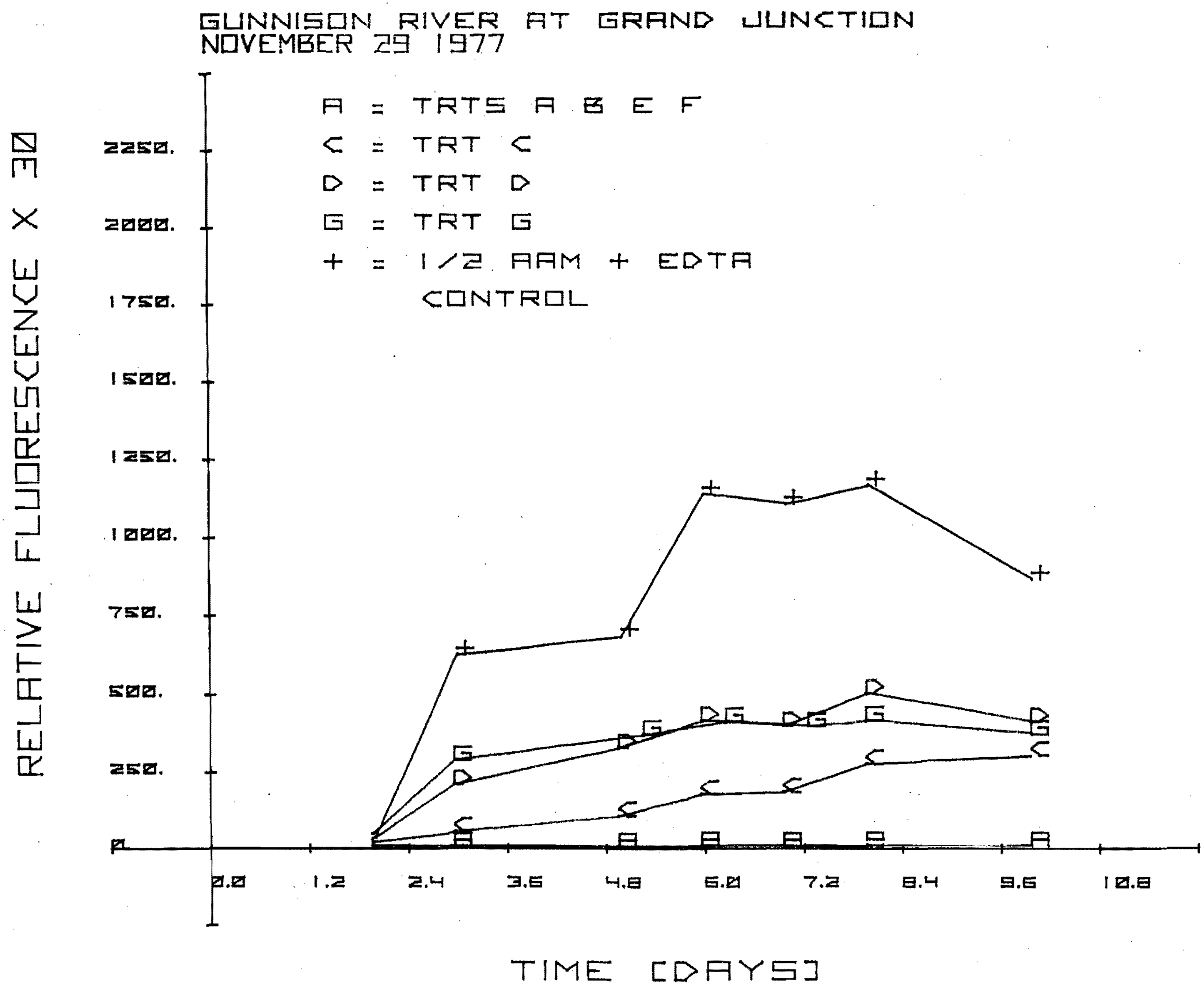

GUNNISON RIVER AT GRAND JUNCTION
NOVEMBER 29 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.0
1.2
2.4
3.6
4.8
6.0
7.2
8.4
9.6
10.8
TIME [DAYS]

Figure 33.

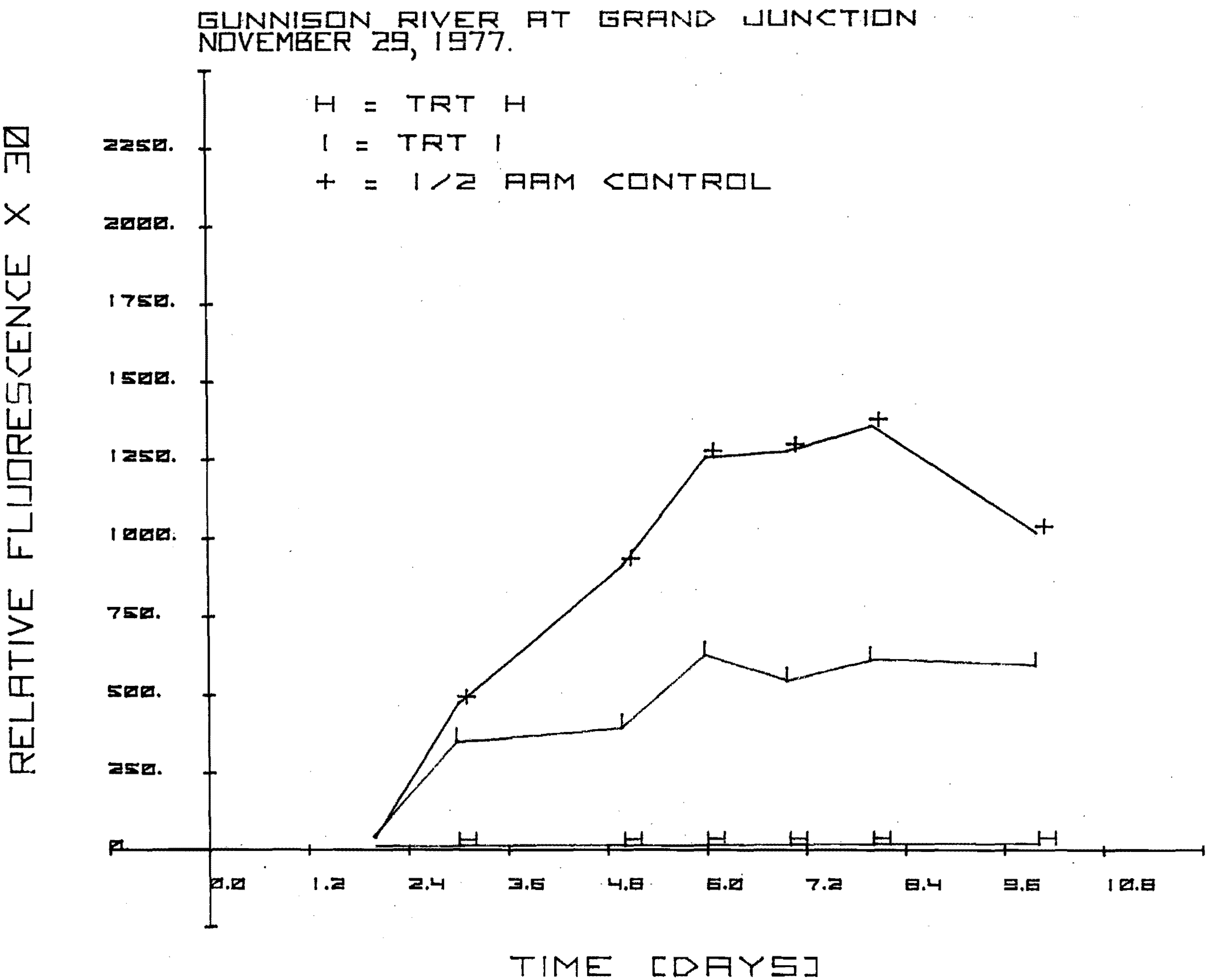

GUNNISON RIVER AT GRAND JUNCTION
NOVEMBER 29, 1977.
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
0
250.
500.
750.
1000.
1250.
1500.
1750.
2000.
2250.
0.0
1.2
2.4
3.6
4.8
6.0
7.2
8.4
9.6
10.8
TIME [DAYS]

Figure 34.

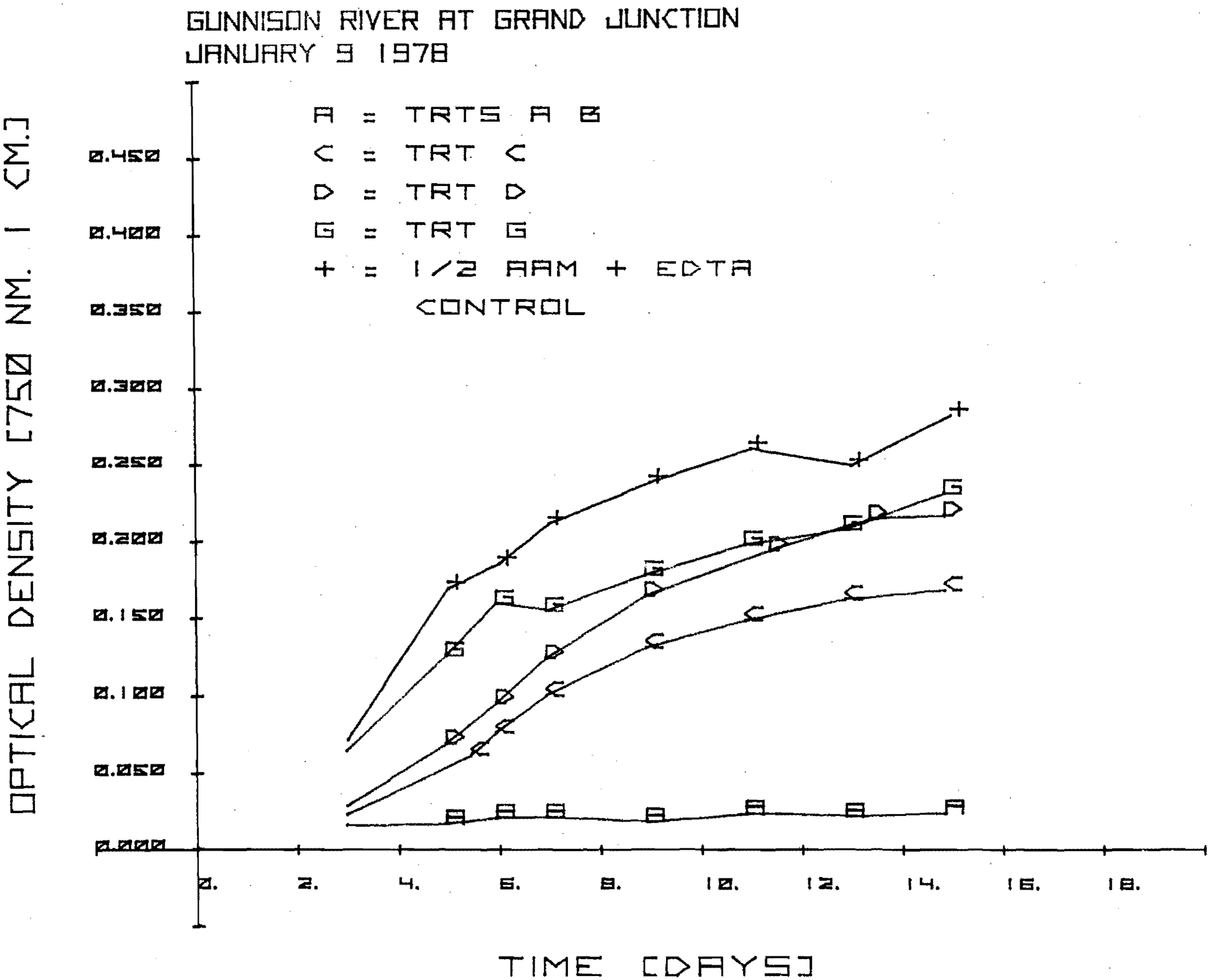

GUNNISON RIVER AT GRAND JUNCTION
JANUARY 9 1978
A = TRTS A B
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 35.

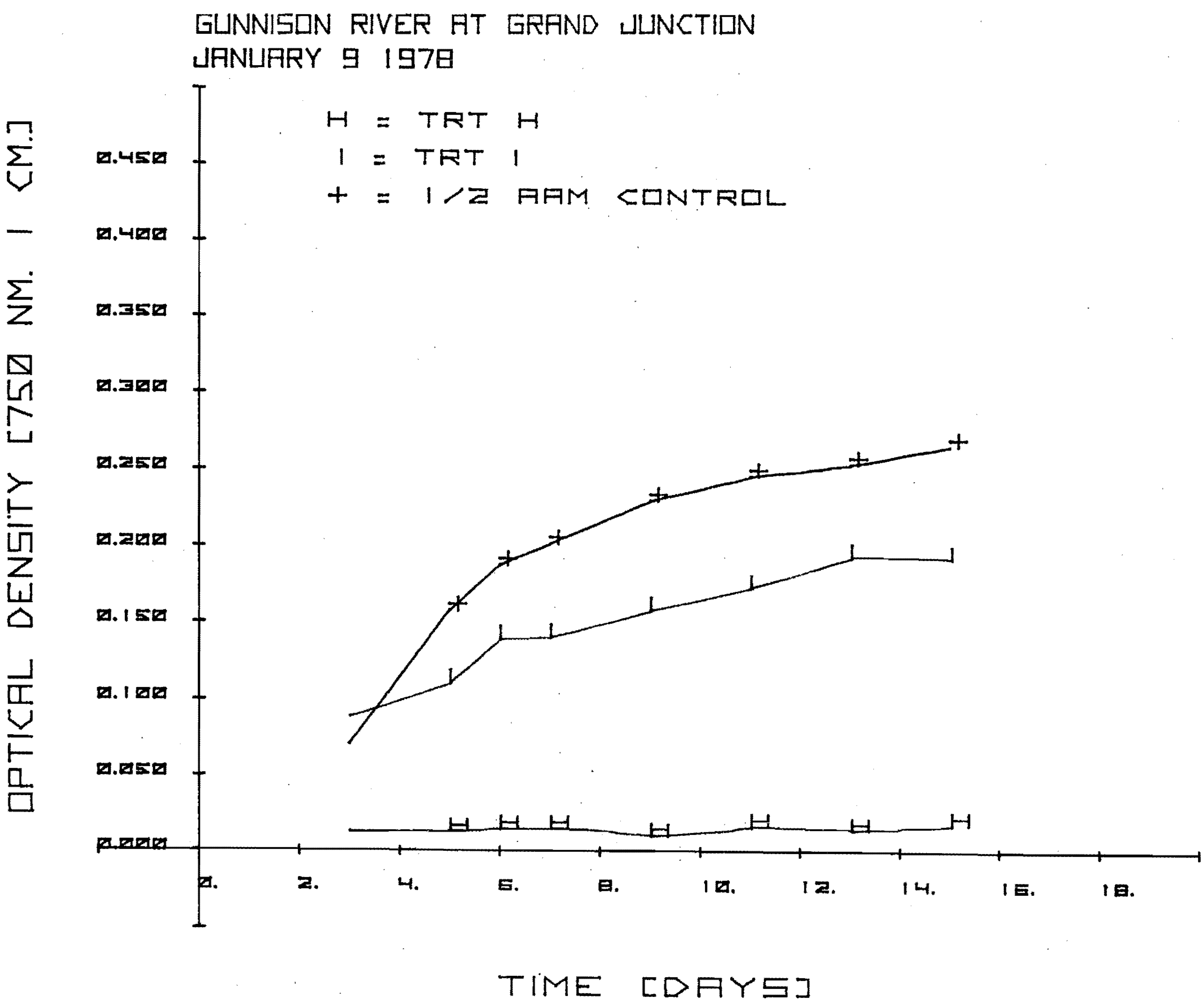
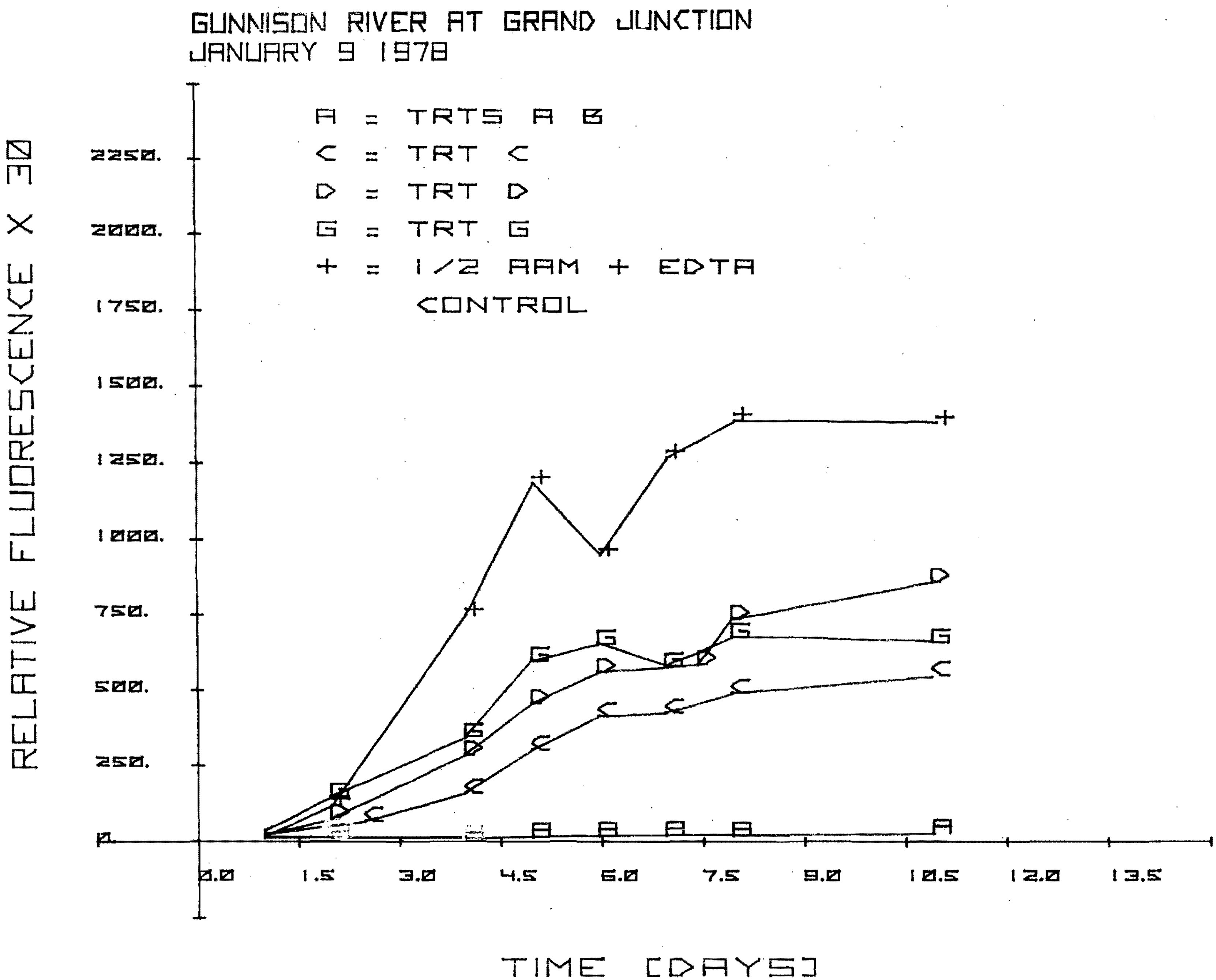

GUNNISON RIVER AT GRAND JUNCTION
JANUARY 9 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. I CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 36.



GUNNISON RIVER AT GRAND JUNCTION
JANUARY 9 1978
A = TRTS A B
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 37.

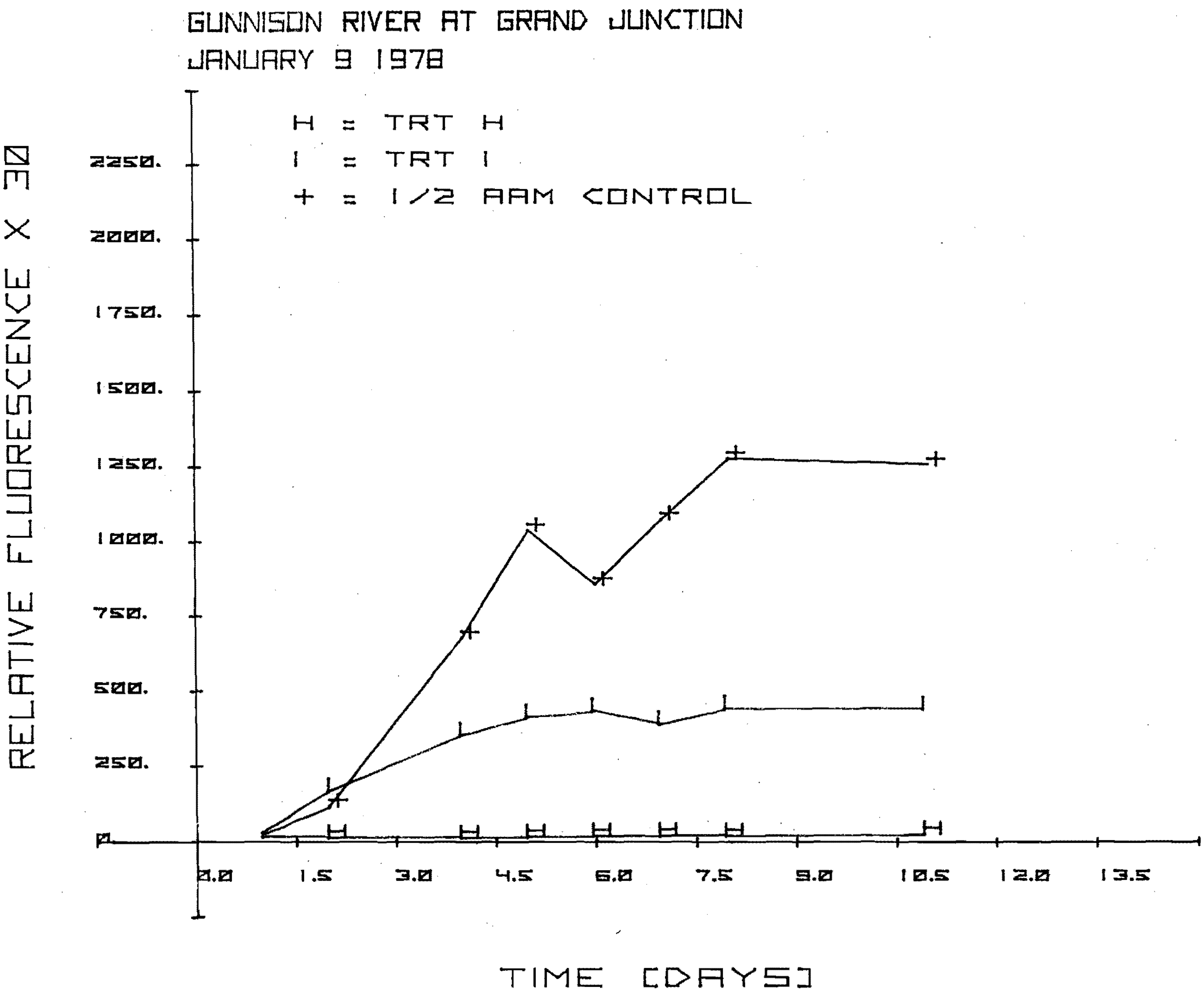

GUNNISON RIVER AT GRAND JUNCTION
JANUARY 9 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME (DAYS)

Figure 38.

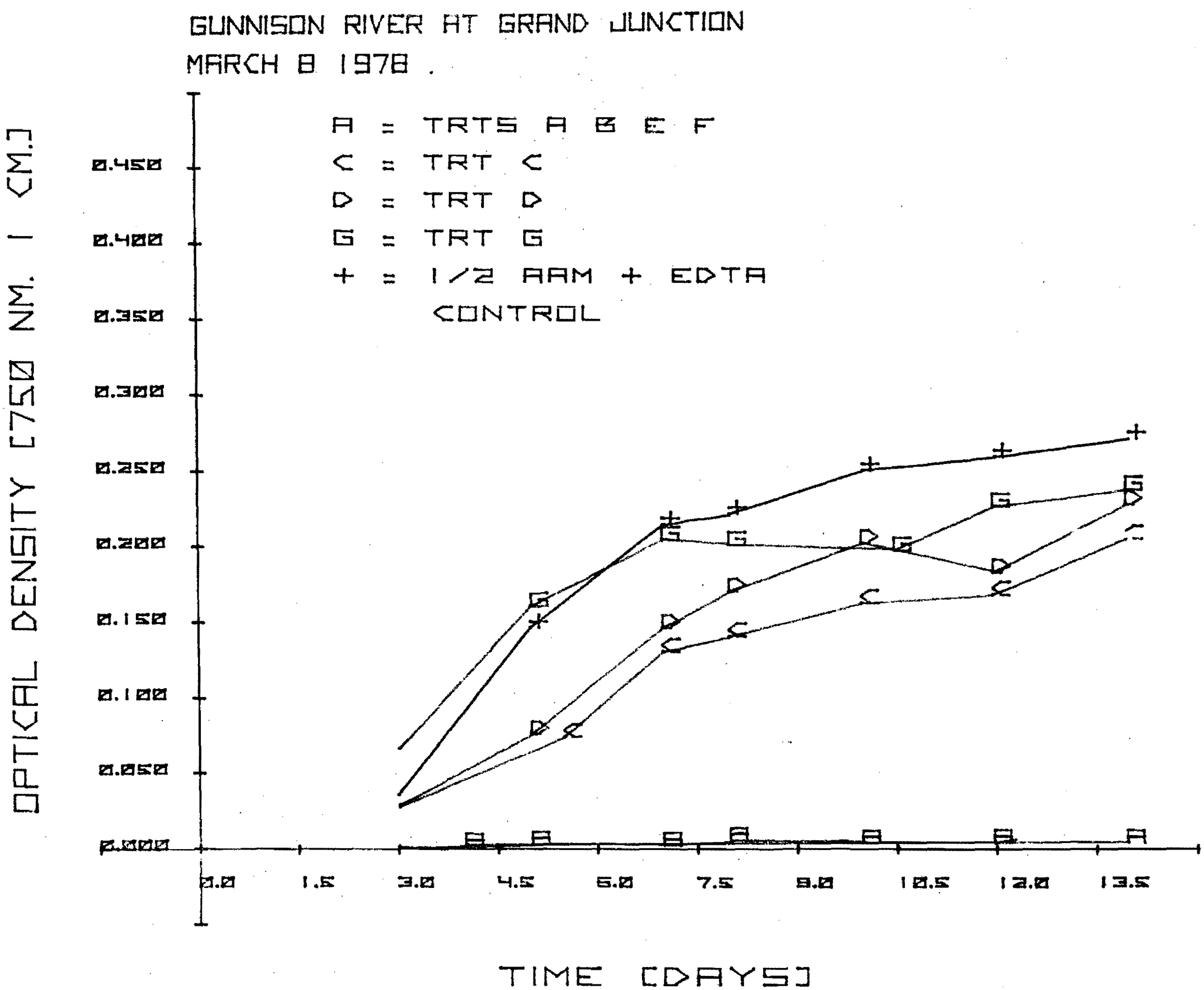

GUNNISON RIVER AT GRAND JUNCTION
MARCH 8 1978 .
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 39.

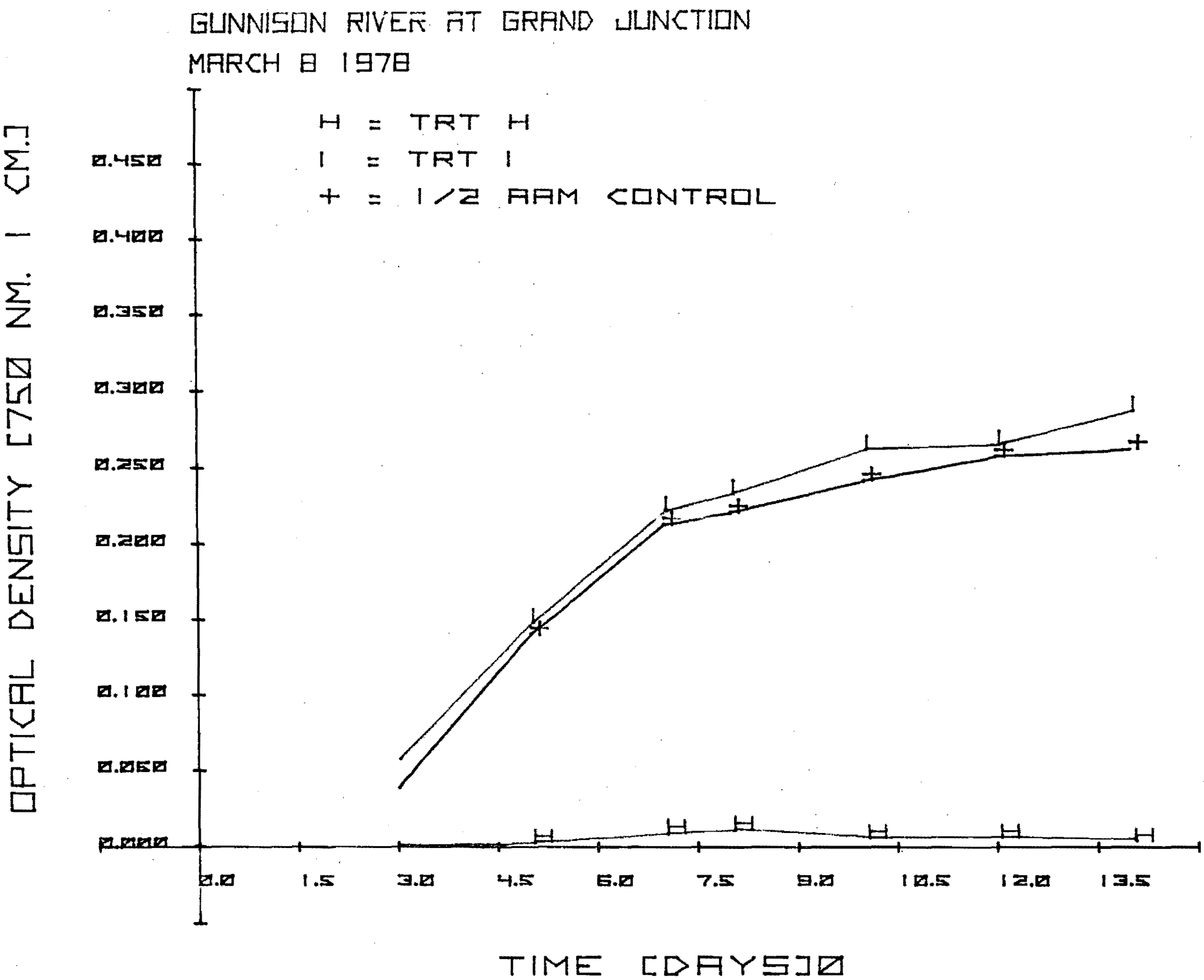

GUNNISON RIVER AT GRAND JUNCTION
MARCH 8 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 40.

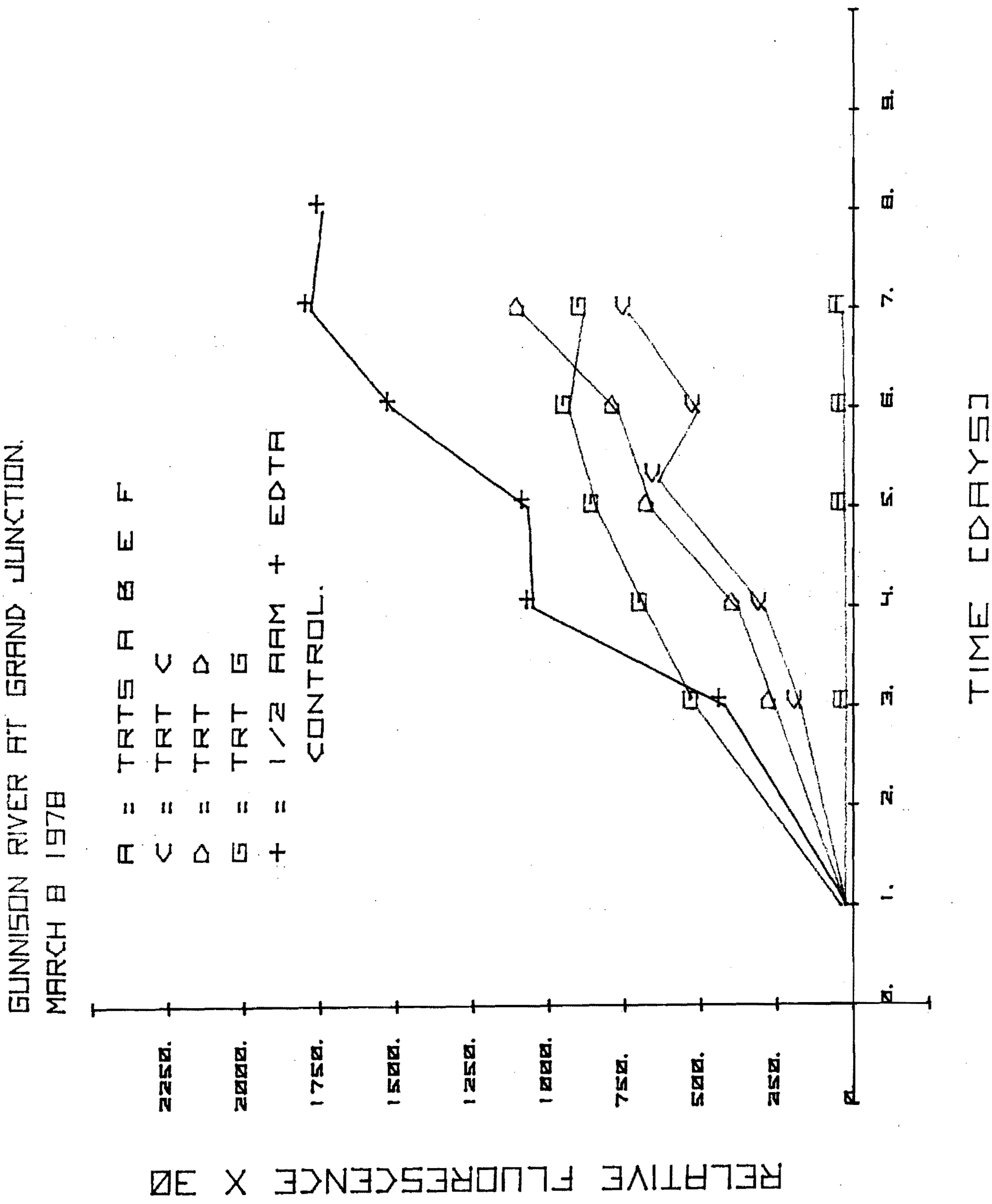

GUNNISON RIVER AT GRAND JUNCTION.
MARCH 8 1978
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL.
RELATIVE FLUORESCENCE X 30
0.
250.
500.
750.
1000.
1250.
1500.
1750.
2000.
2250.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME (DAYS)

Figure 41.

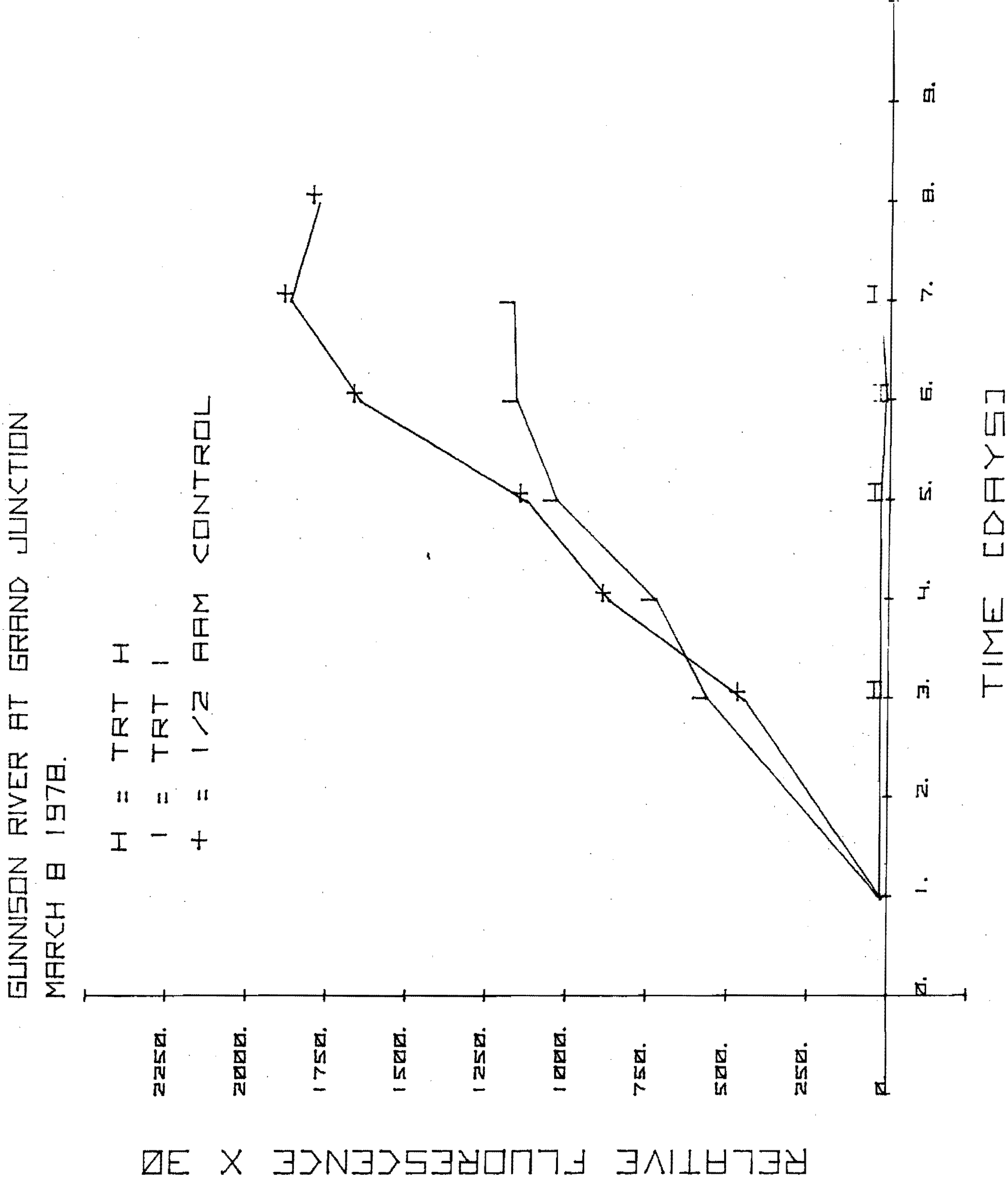

GUNNISON RIVER AT GRAND JUNCTION
MARCH 8 1978.
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
TIME [DAYS]
0.
250.
500.
750.
1000.
1250.
1500.
1750.
2000.
2250.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.

Figure 42.

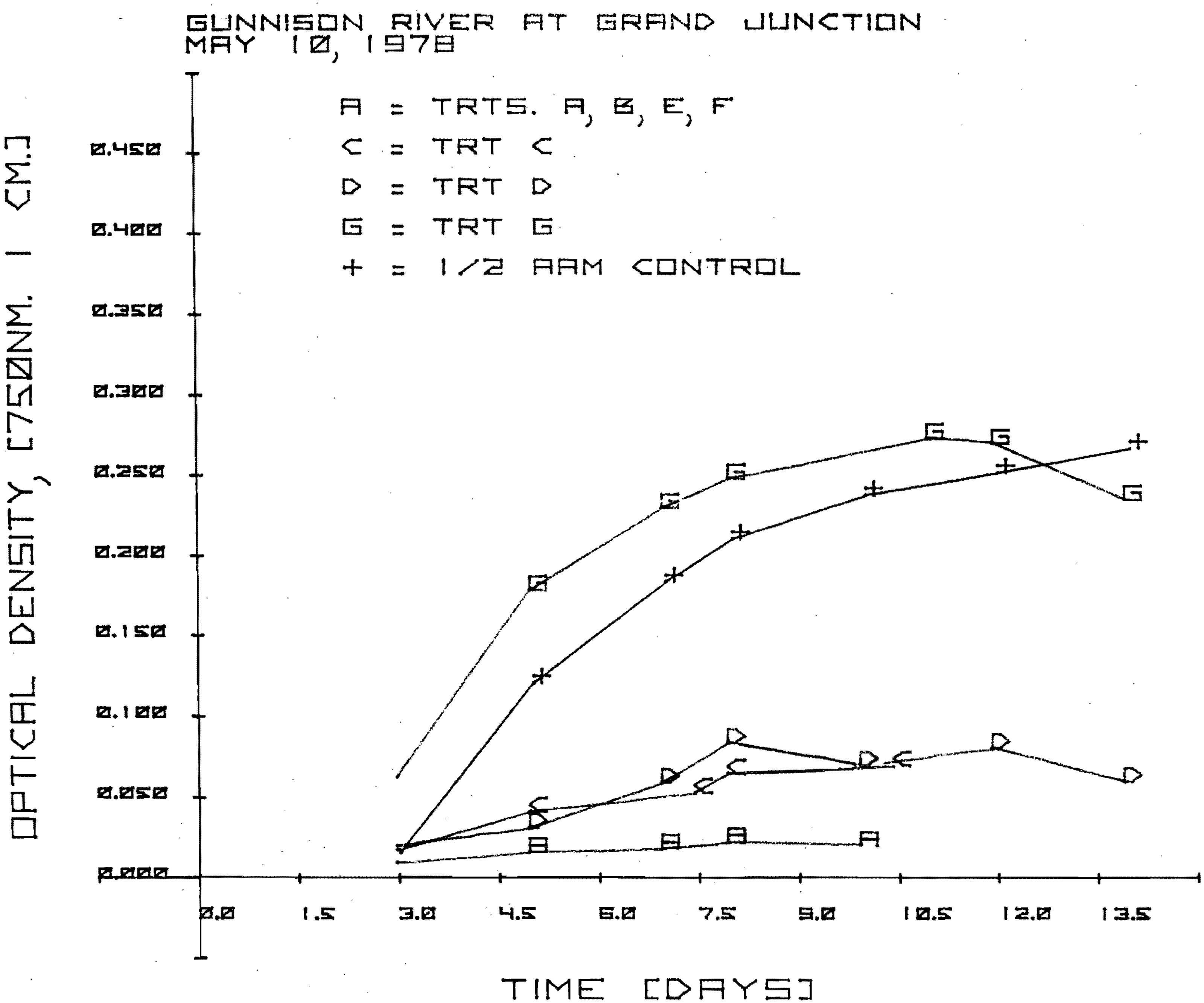

GUNNISON RIVER AT GRAND JUNCTION
MAY 10, 1978
A = TRTS. A, B, E, F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM CONTROL
OPTICAL DENSITY, [750NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 43.

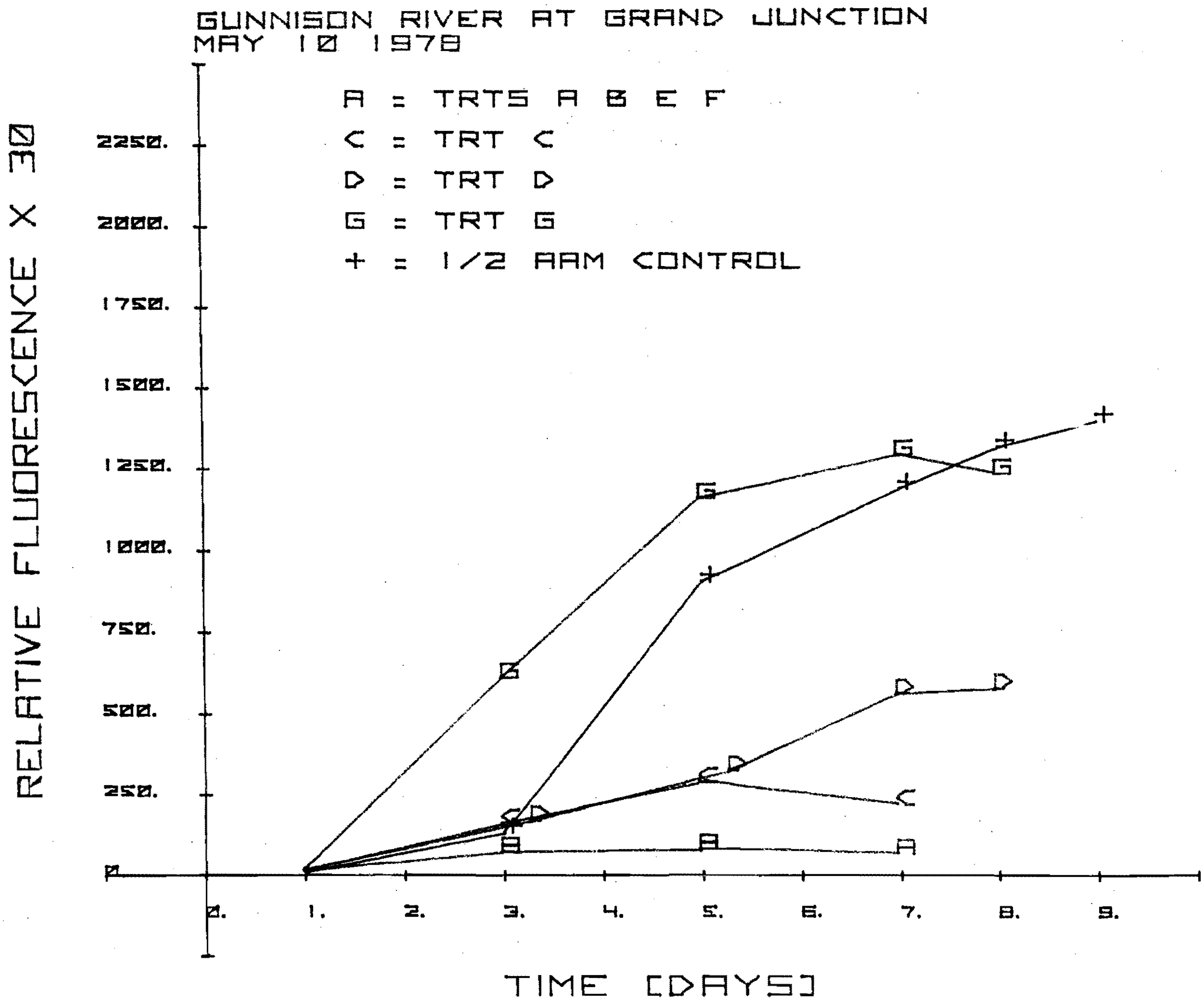

GUNNISON RIVER AT GRAND JUNCTION
MAY 10 1978
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 44.

A slightly different situation arose in May, 1978. The sample was still phosphorus limited with treatments C and D nearly identical as far as biomass increase. However growth was retarded when compared to previous months and to treatment G (all AAM constituents added). This fact represents growth limitation by an element other than nitrogen or phosphorus. Further study of this water must be undertaken in order to ascertain the true cause of growth inhibition during May, 1978.

Conclusions:

1. Phosphorus was the limiting nutrient in all bioassays.
2. Chemical analysis and algal bioassay correlated well.
3. During the spring period another element in addition to phosphorus contributed to growth limitation.
4. This sample was classified as mesotrophic in its present state but a slight increase in the phosphorus concentration will result in a greater degree of eutrophication unless another element becomes limiting as was true in May, 1978.
5. No metal toxicity was observed.

C. San Miguel Project

1. San Miguel River near Placerville (Figures 45 - 62)

September, 1977 and November, 1977 chemical analysis indicated a tendency toward phosphorus limitation but due to the extremely low concentrations of phosphorus and nitrogen the bioassay verified, as expected, limitation by both elements. During this fall period the sample proved to be highly infertile but as the water level decreased by mid winter, the January, 1978 chemical analysis showed an increase in the nutrient concentration (Table 3). The bioassay reflected this higher nutrient

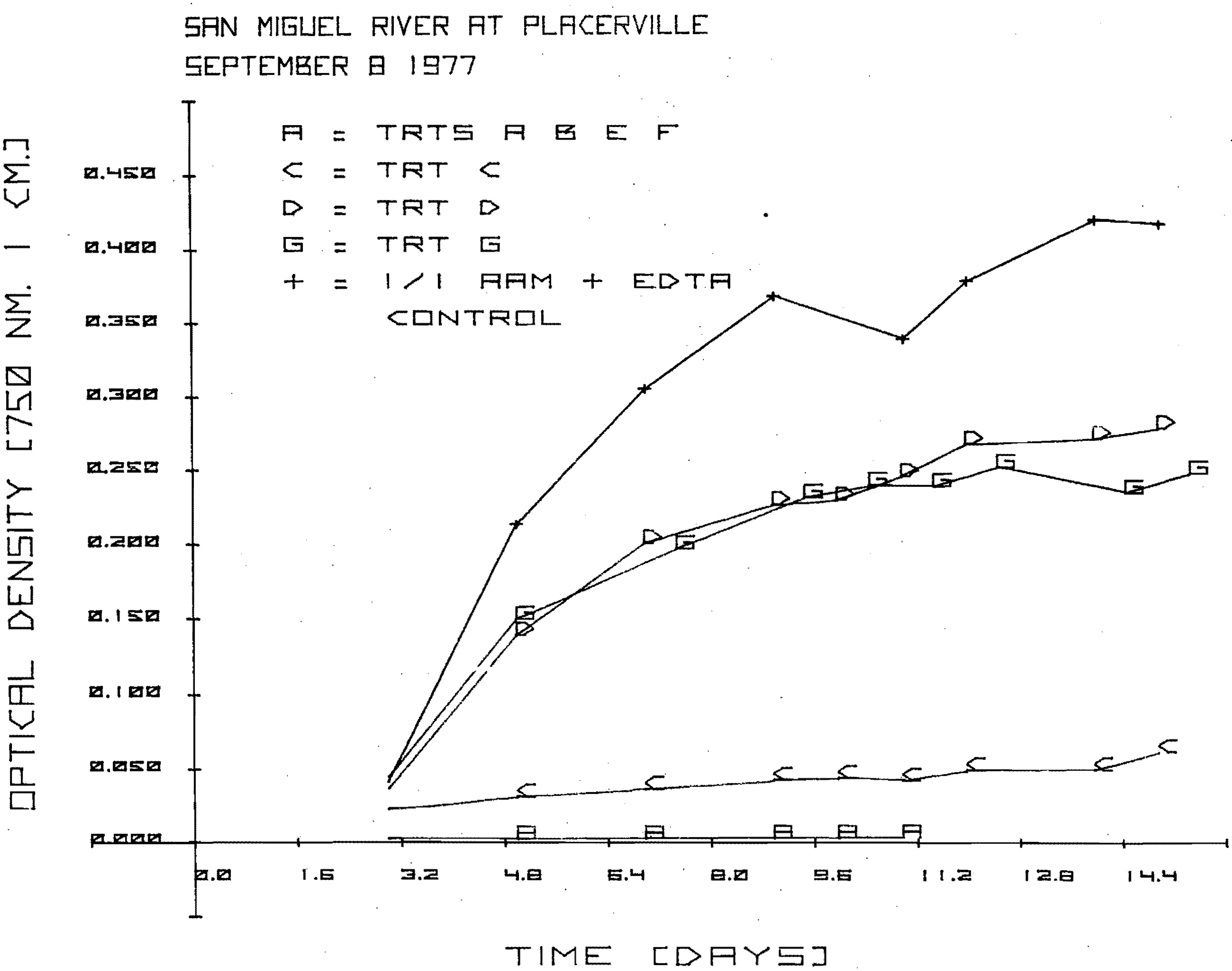

SAN MIGUEL RIVER AT PLACERVILLE
SEPTEMBER 8 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/1 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.000
0.050
0.100
0.150
0.200
0.250
0.300
0.350
0.400
0.450
0.0
1.6
3.2
4.8
6.4
8.0
9.6
11.2
12.8
14.4
TIME [DAYS]

Figure 45.

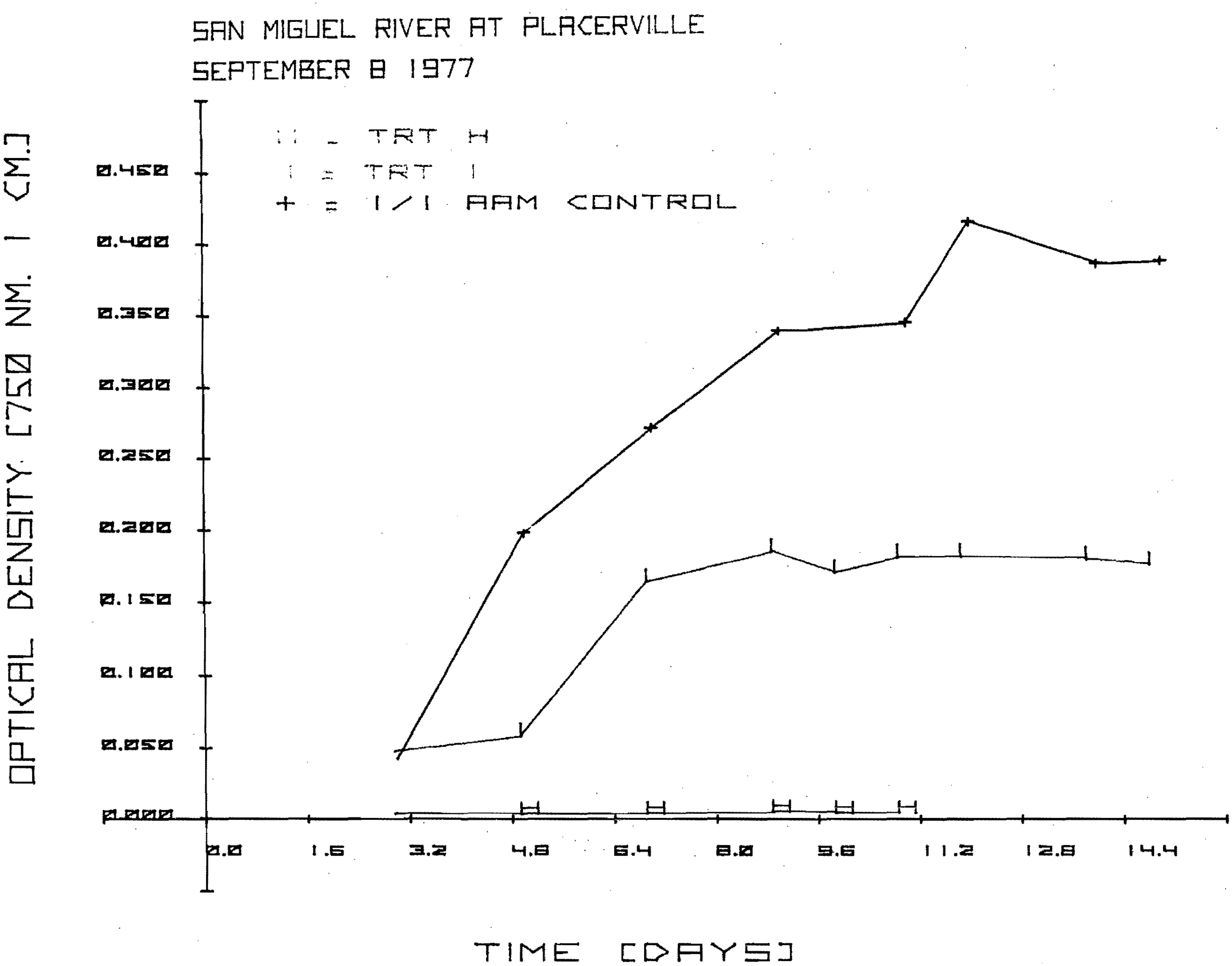

SAN MIGUEL RIVER AT PLACERVILLE
SEPTEMBER 8 1977
H = TRT H
I = TRT I
+ = 1/1 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.6
3.2
4.8
6.4
8.0
9.6
11.2
12.8
14.4
TIME [DAYS]

Figure 46.

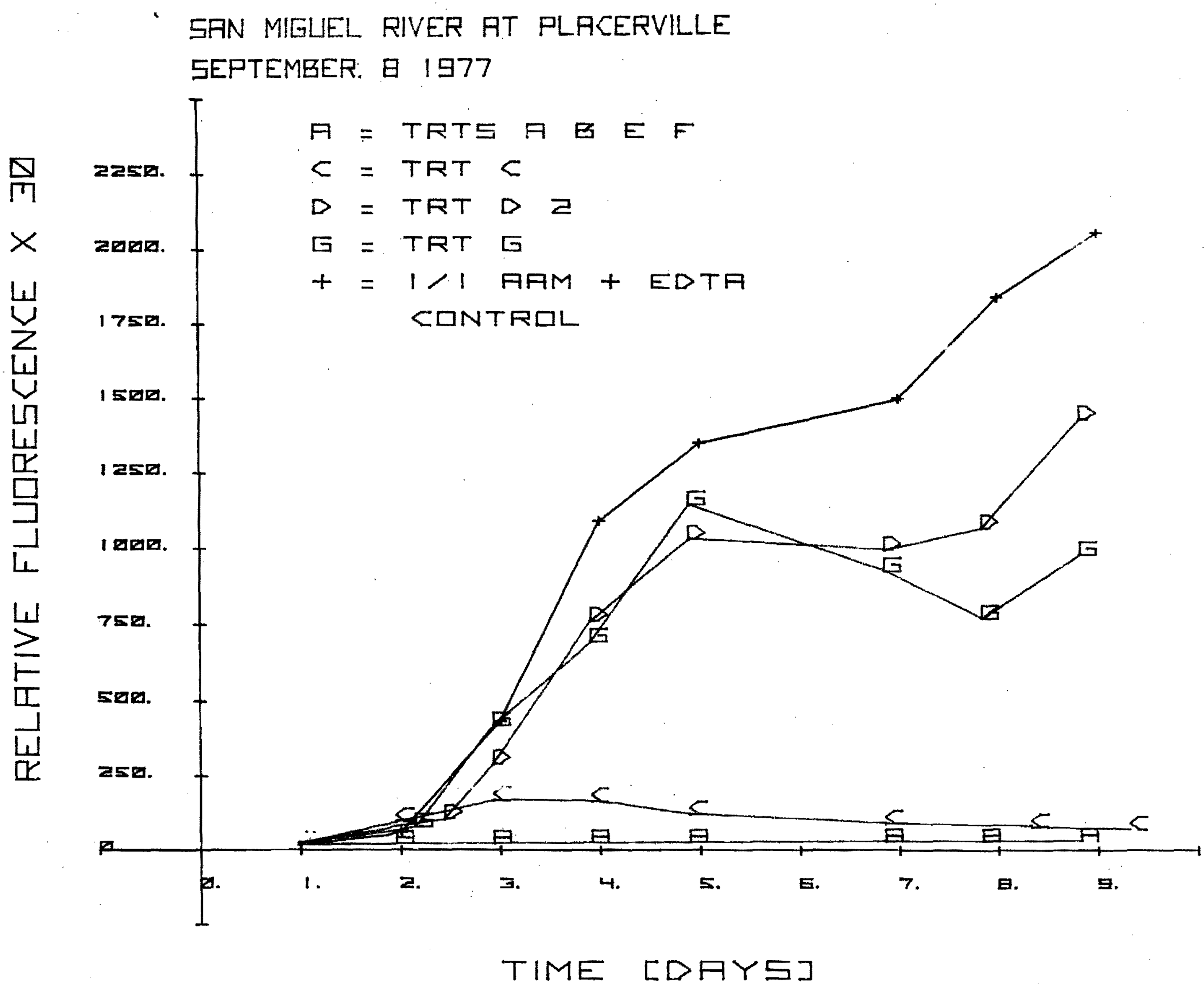

SAN MIGUEL RIVER AT PLACERVILLE
SEPTEMBER 8 1977
A = TRTS A B E F
C = TRT C
D = TRT D 2
G = TRT G
+ = 1/1 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 47.

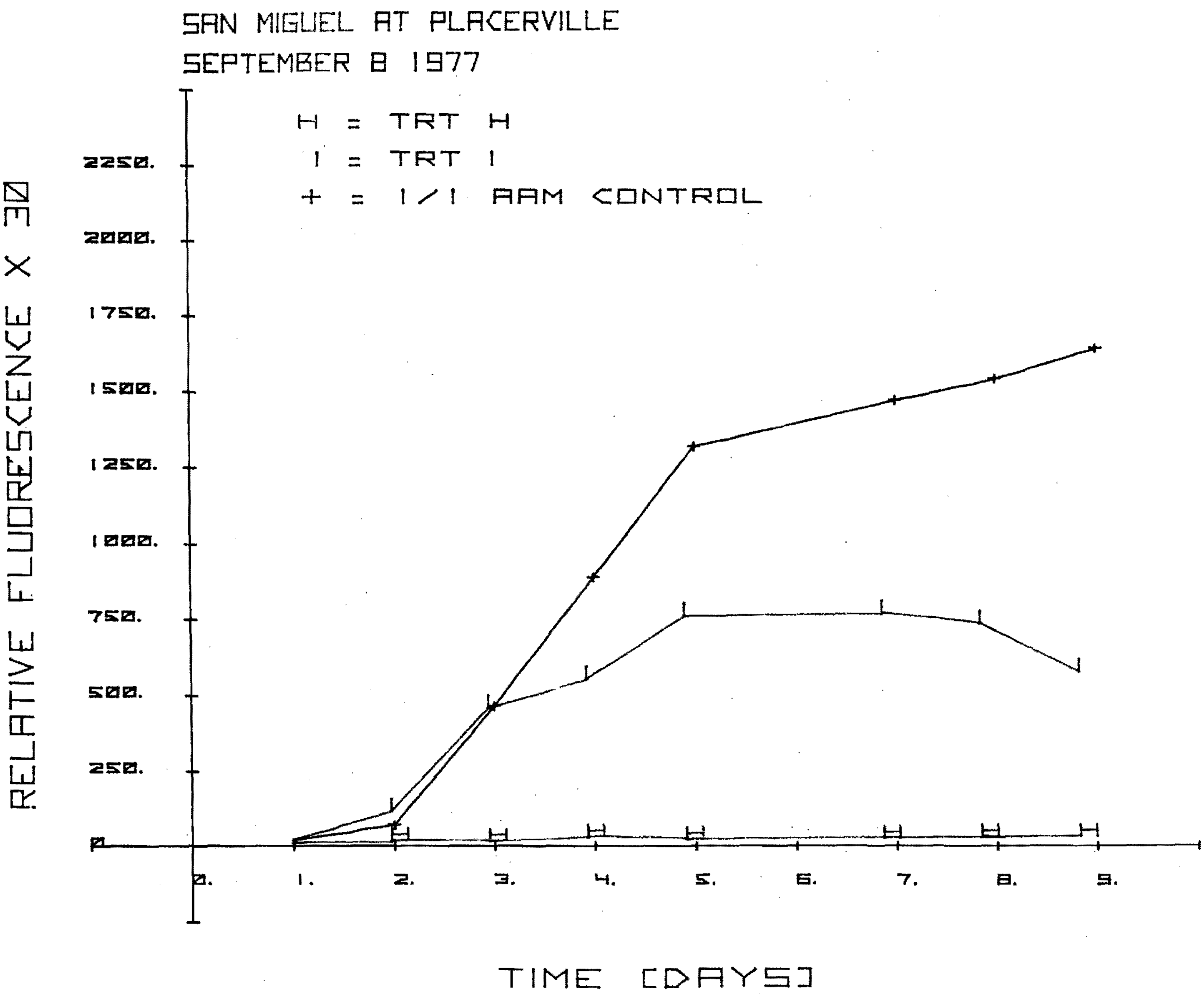

SAN MIGUEL AT PLACERVILLE
SEPTEMBER 8 1977
H = TRT H
I = TRT I
+ = 1/1 AAM CONTROL
RELATIVE FLUORESCENCE X 30
0
250.
500.
750.
1000.
1250.
1500.
1750.
2000.
2250.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME (DAYS)

Figure 48.

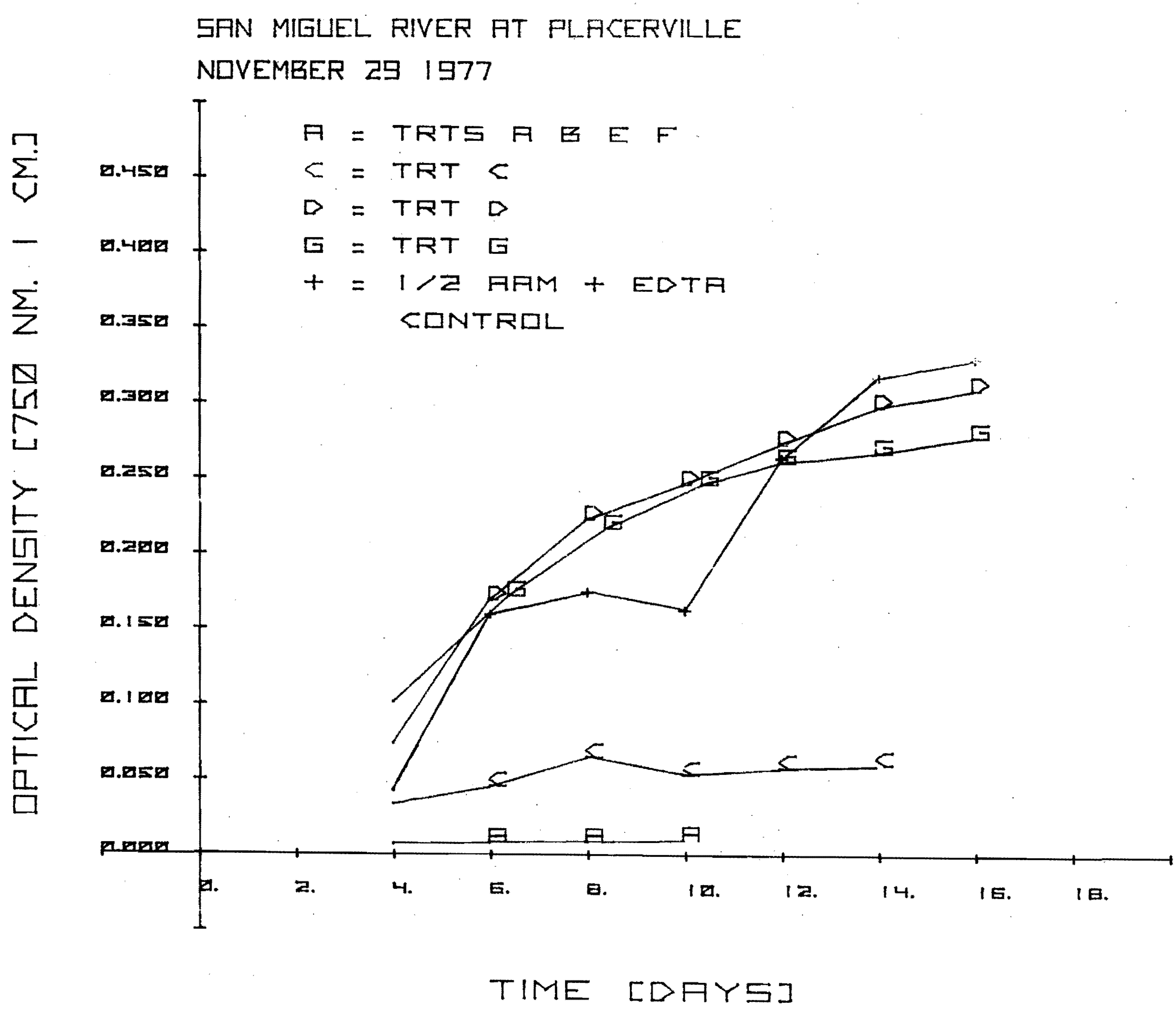

SAN MIGUEL RIVER AT PLACERVILLE
NOVEMBER 29 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY (750 NM. 1 CM.)
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME (DAYS)

Figure 49.

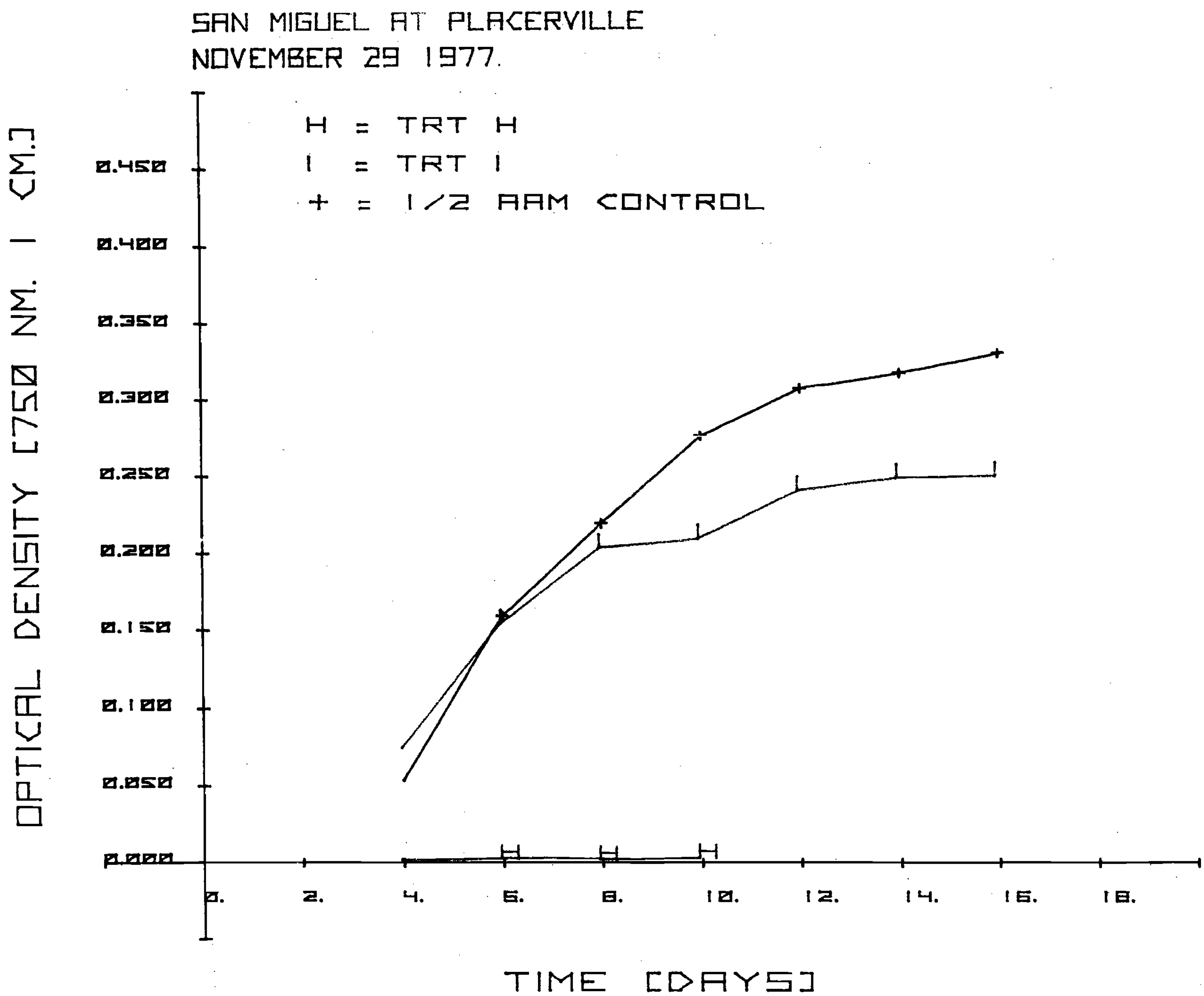

SAN MIGUEL AT PLACERVILLE
NOVEMBER 29 1977.
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. I CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 50.

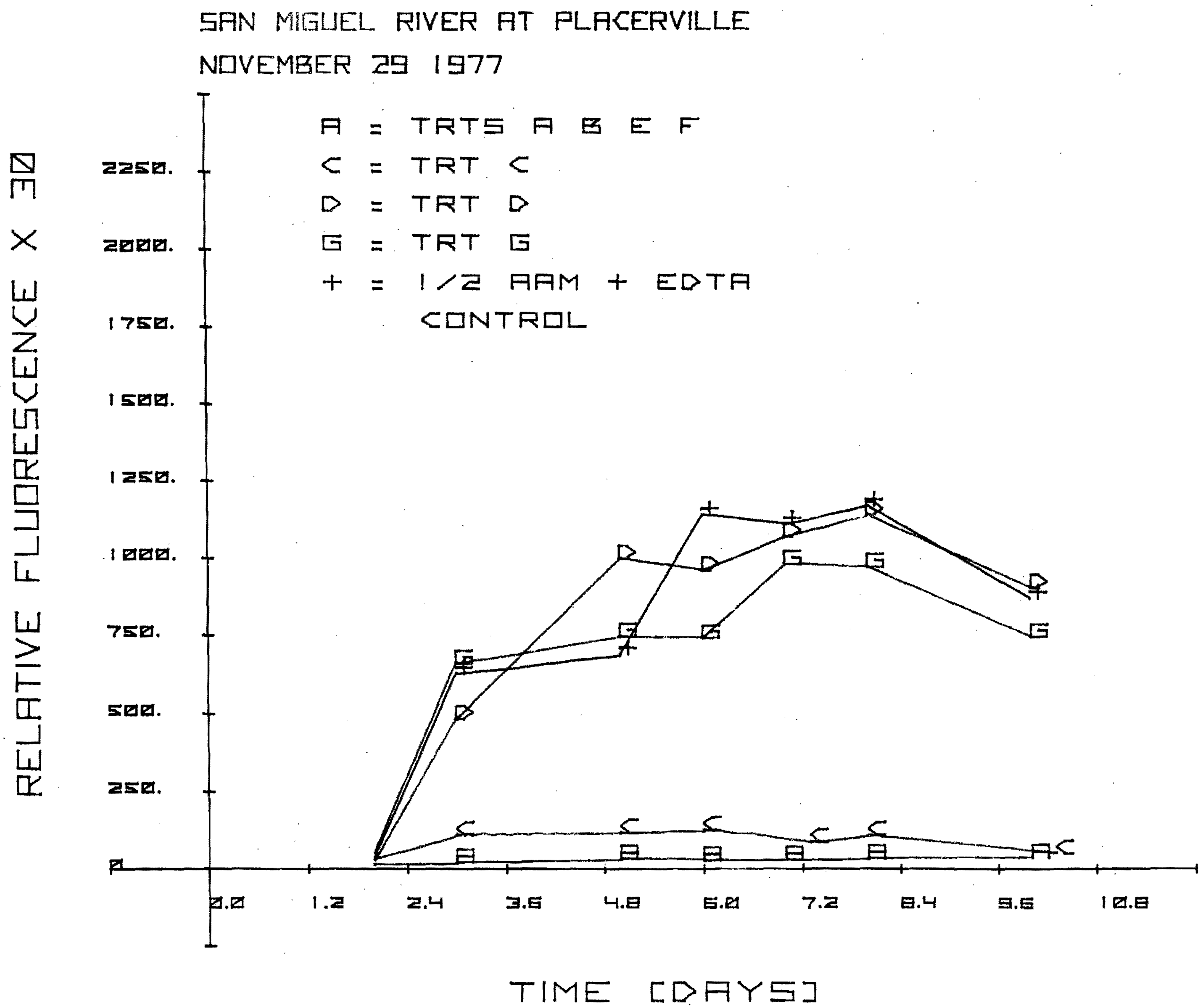

SAN MIGUEL RIVER AT PLACERVILLE
NOVEMBER 29 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.0
1.2
2.4
3.6
4.8
6.0
7.2
8.4
9.6
10.8
TIME [DAYS]

Figure 51.

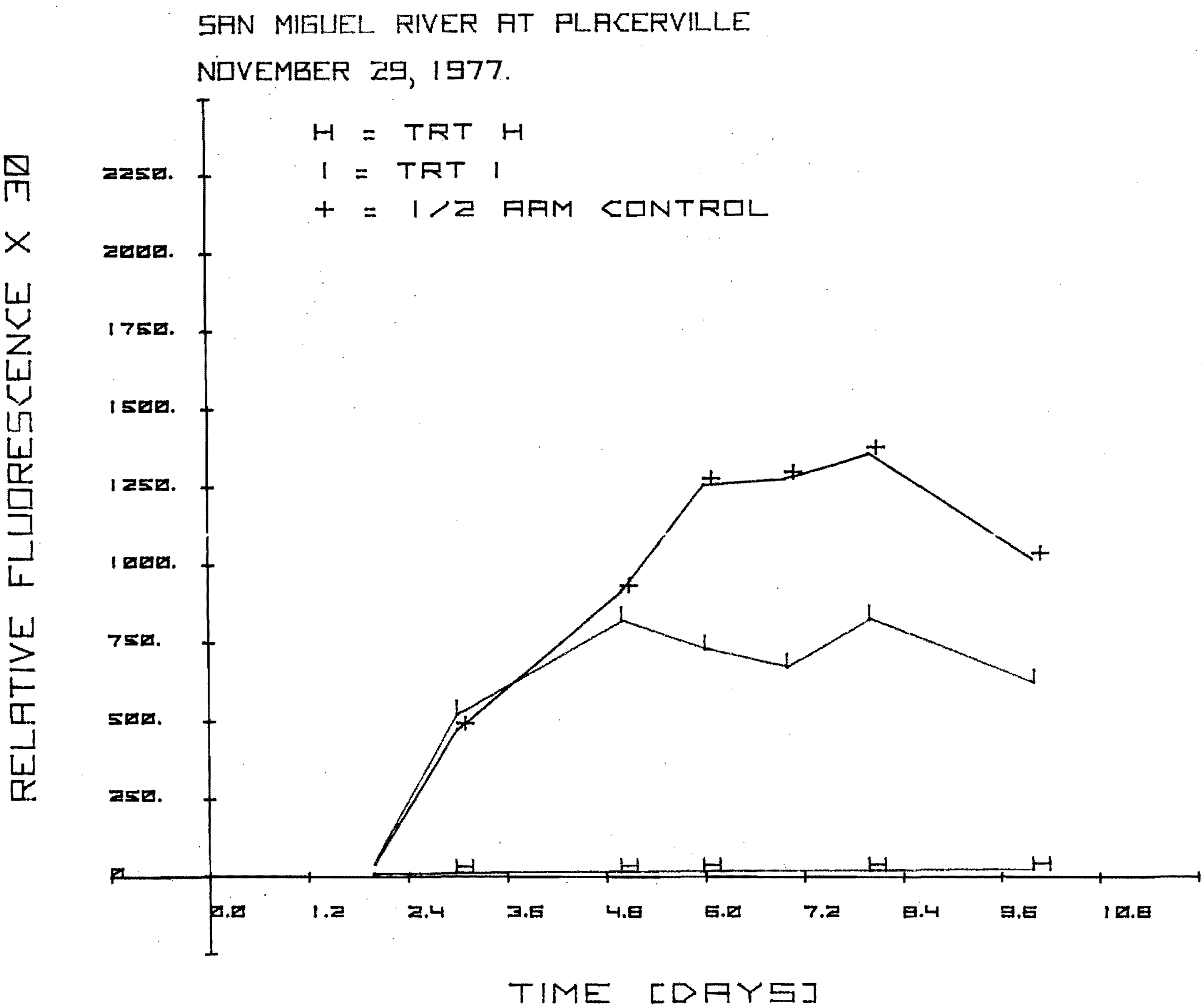

SAN MIGUEL RIVER AT PLACERVILLE
NOVEMBER 29, 1977.
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.0
1.2
2.4
3.6
4.8
6.0
7.2
8.4
9.6
10.8
TIME [DAYS]

Figure 52.

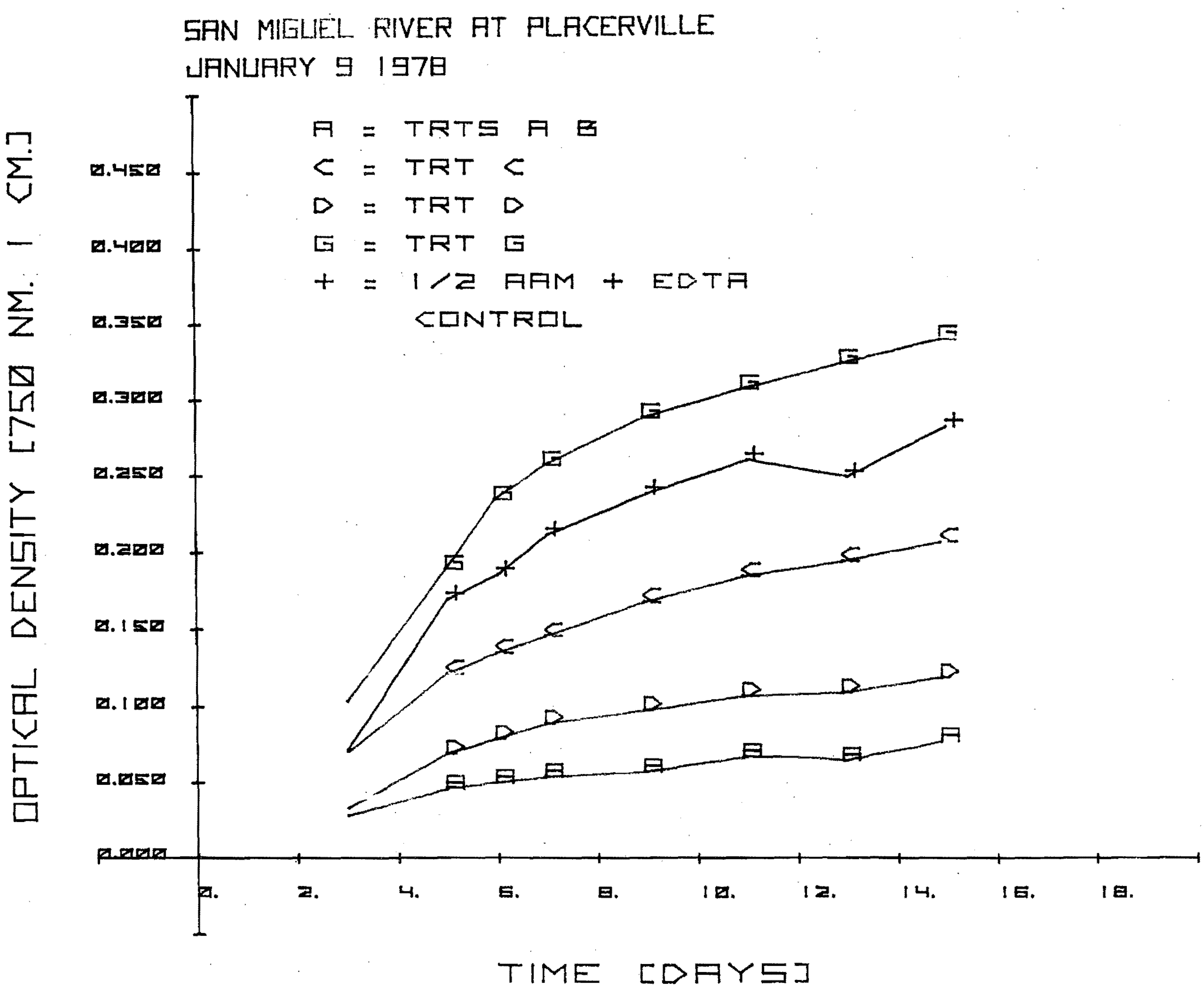

SAN MIGUEL RIVER AT PLACERVILLE
JANUARY 9 1978
A = TRTS A B
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 53.

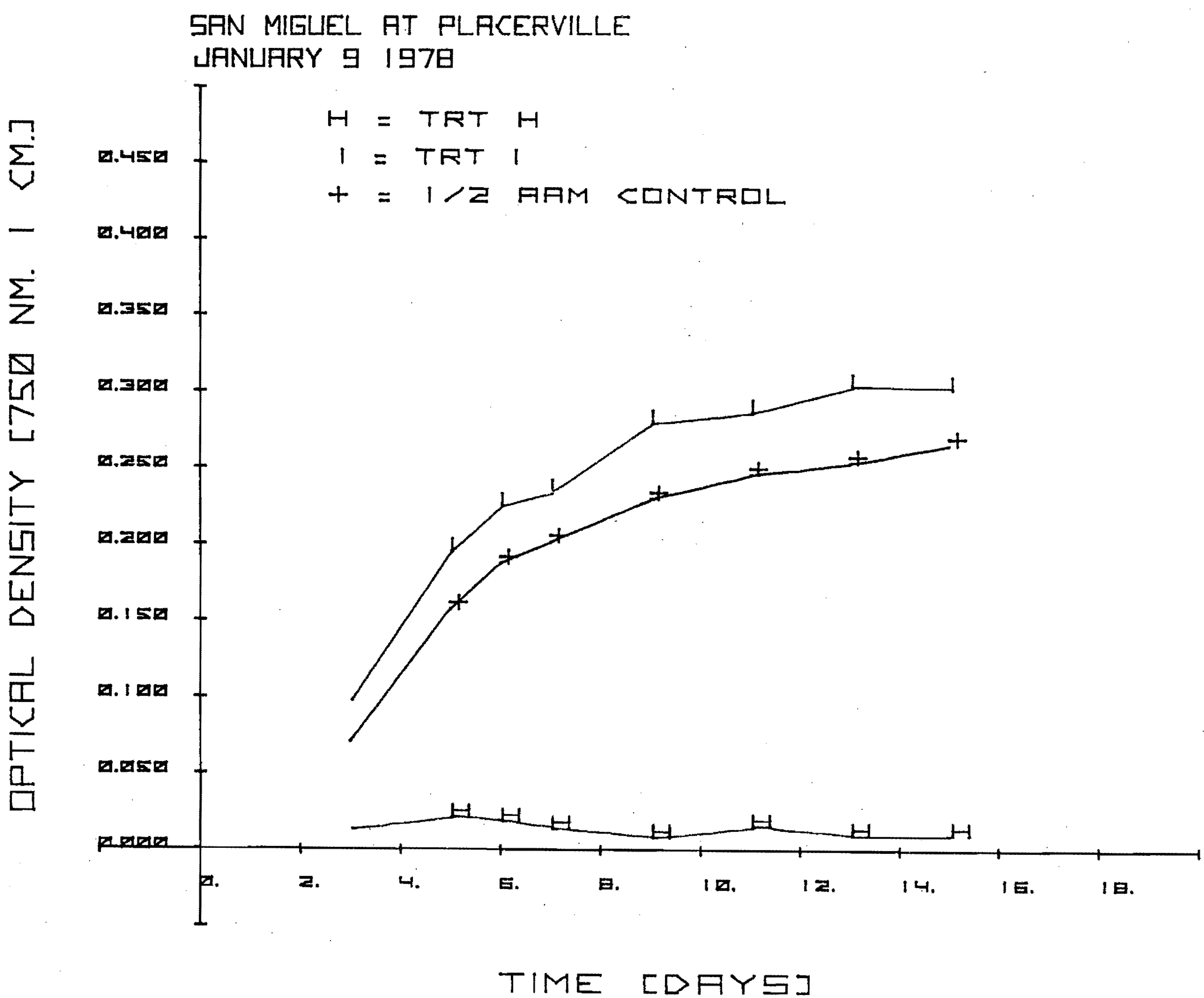

SAN MIGUEL AT PLACERVILLE
JANUARY 9 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 54.

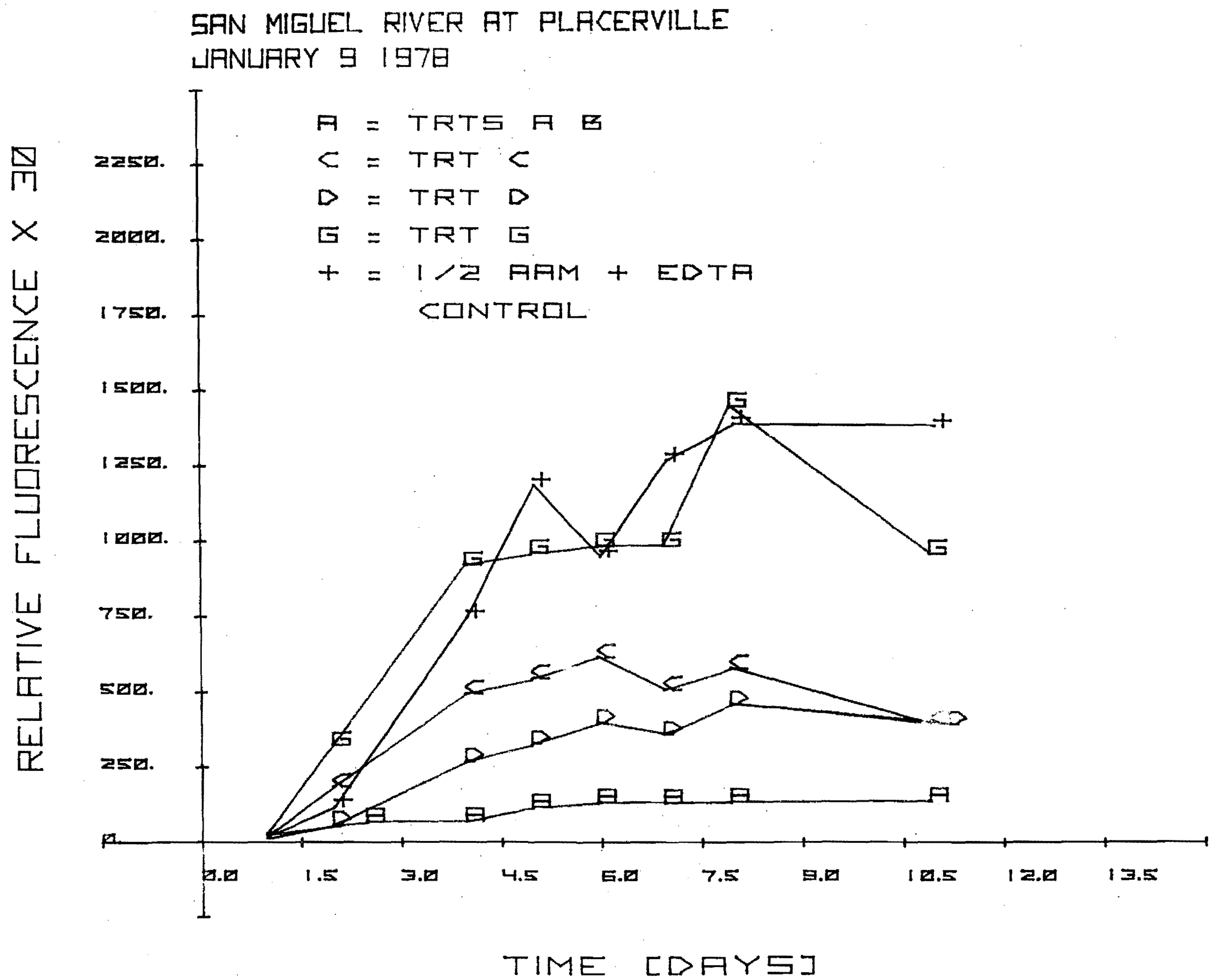

SAN MIGUEL RIVER AT PLACERVILLE
JANUARY 9 1978
A = TRTS A B
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME (DAYS)

Figure 55.

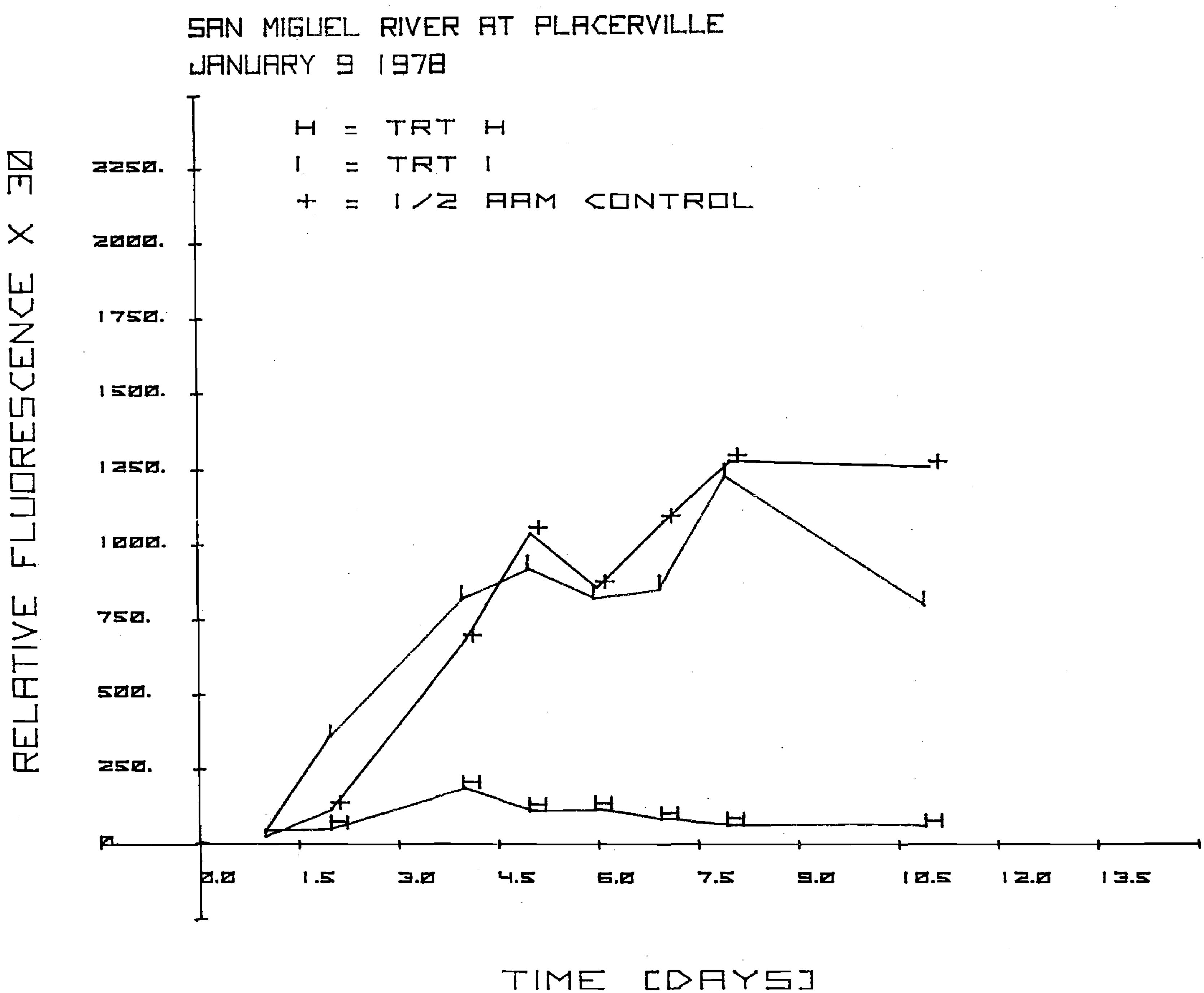

SAN MIGUEL RIVER AT PLACERVILLE
JANUARY 9 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME (DAYS)

Figure 56.

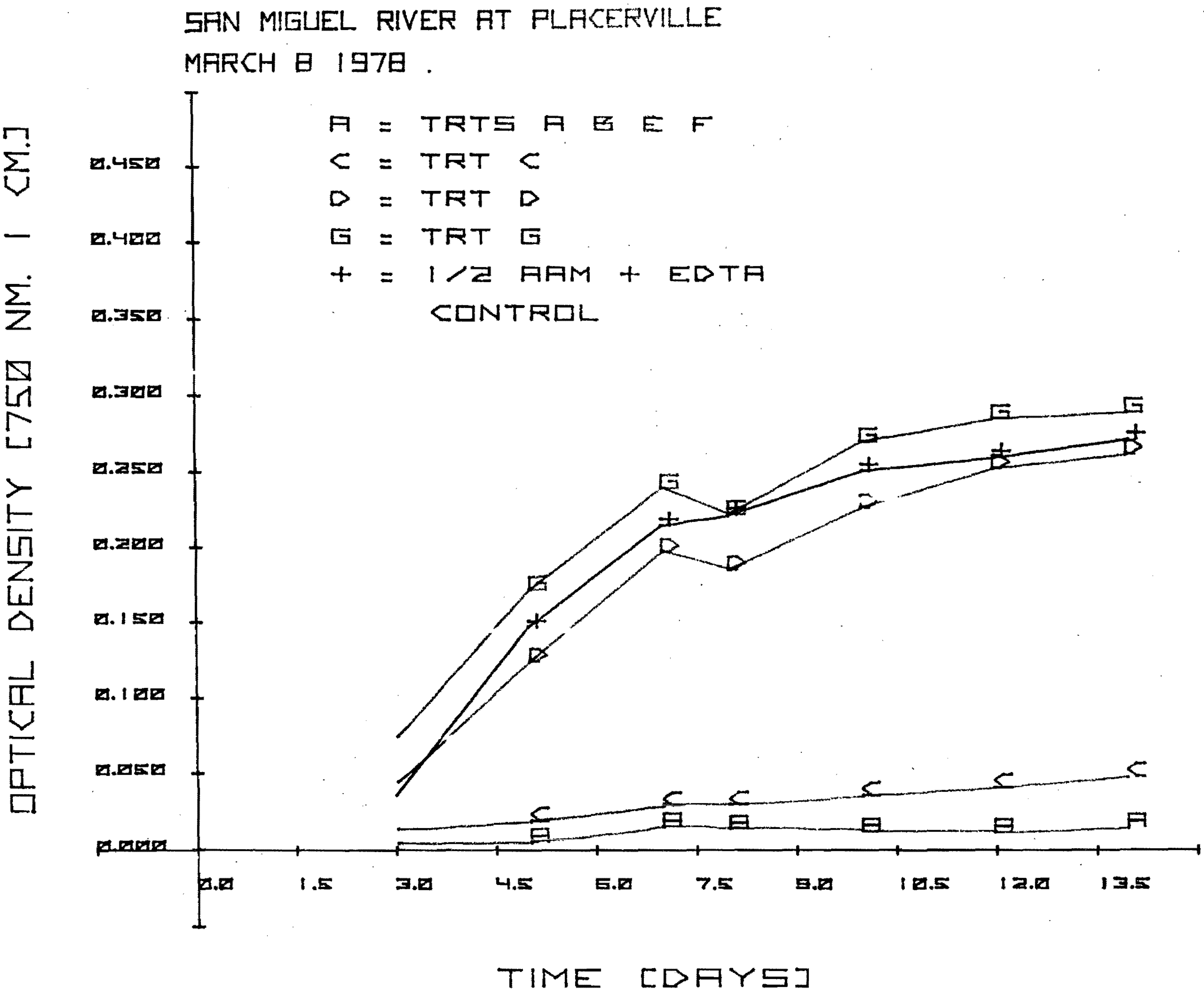

SAN MIGUEL RIVER AT PLACERVILLE
MARCH 8 1978 .
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 57.

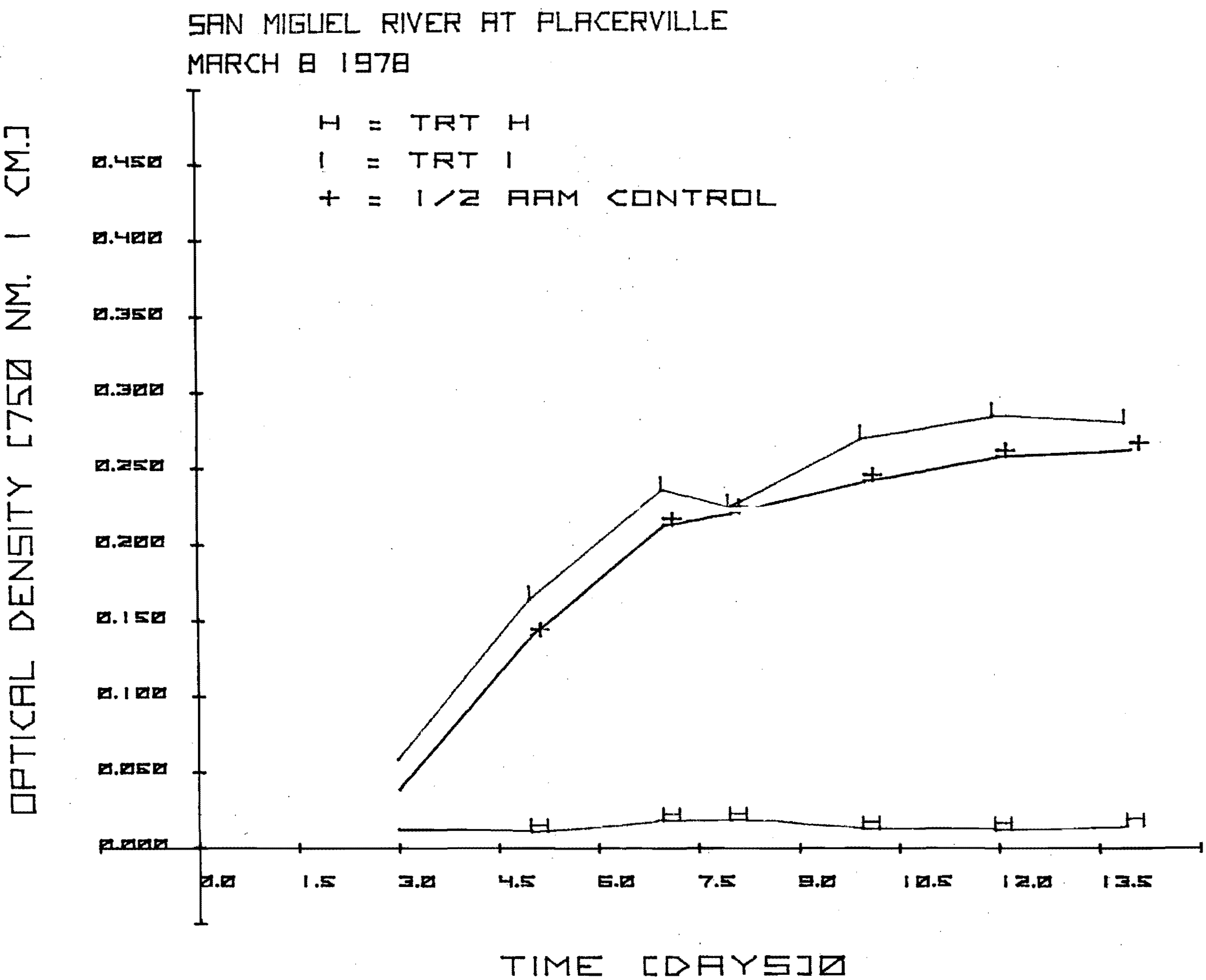
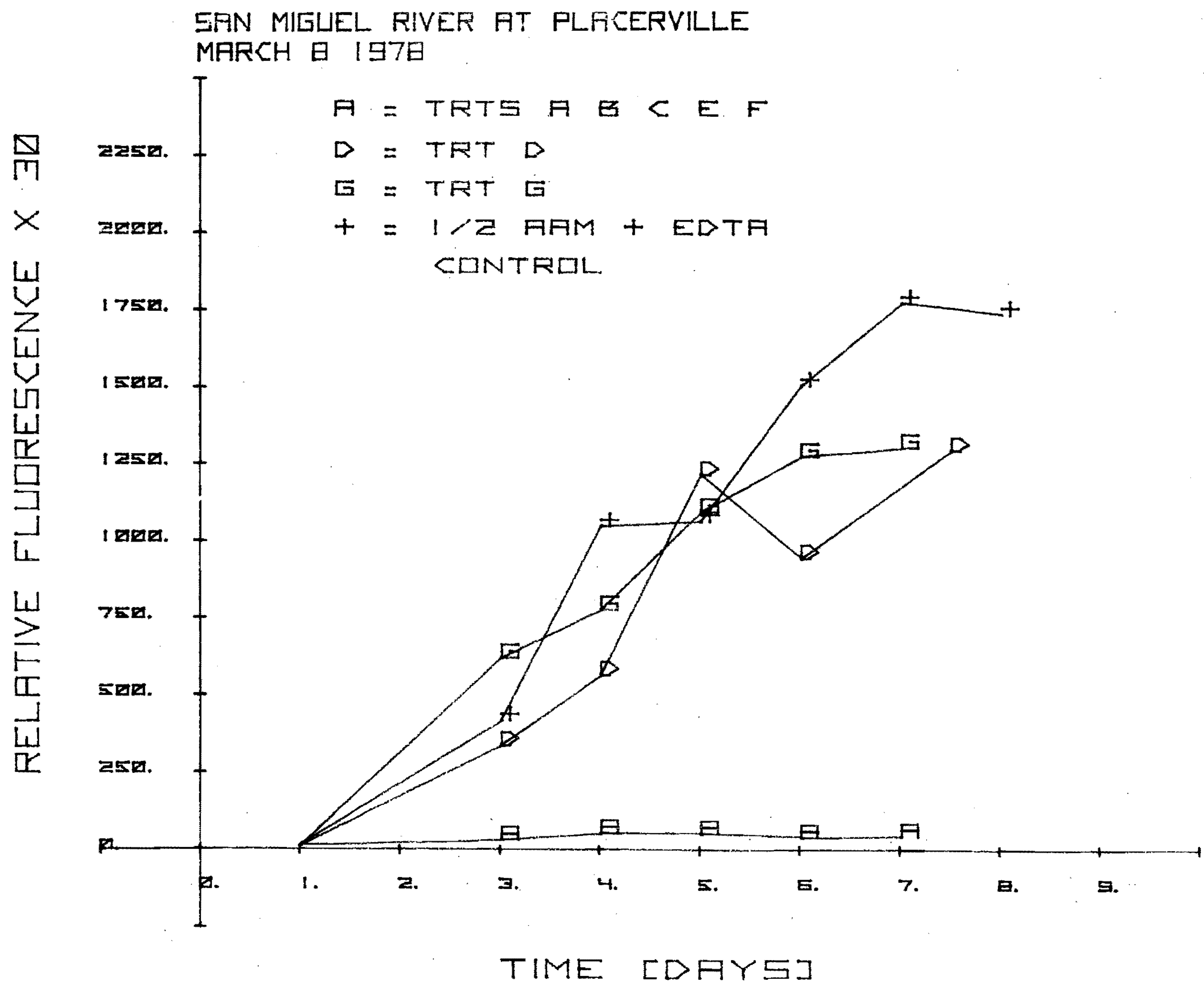
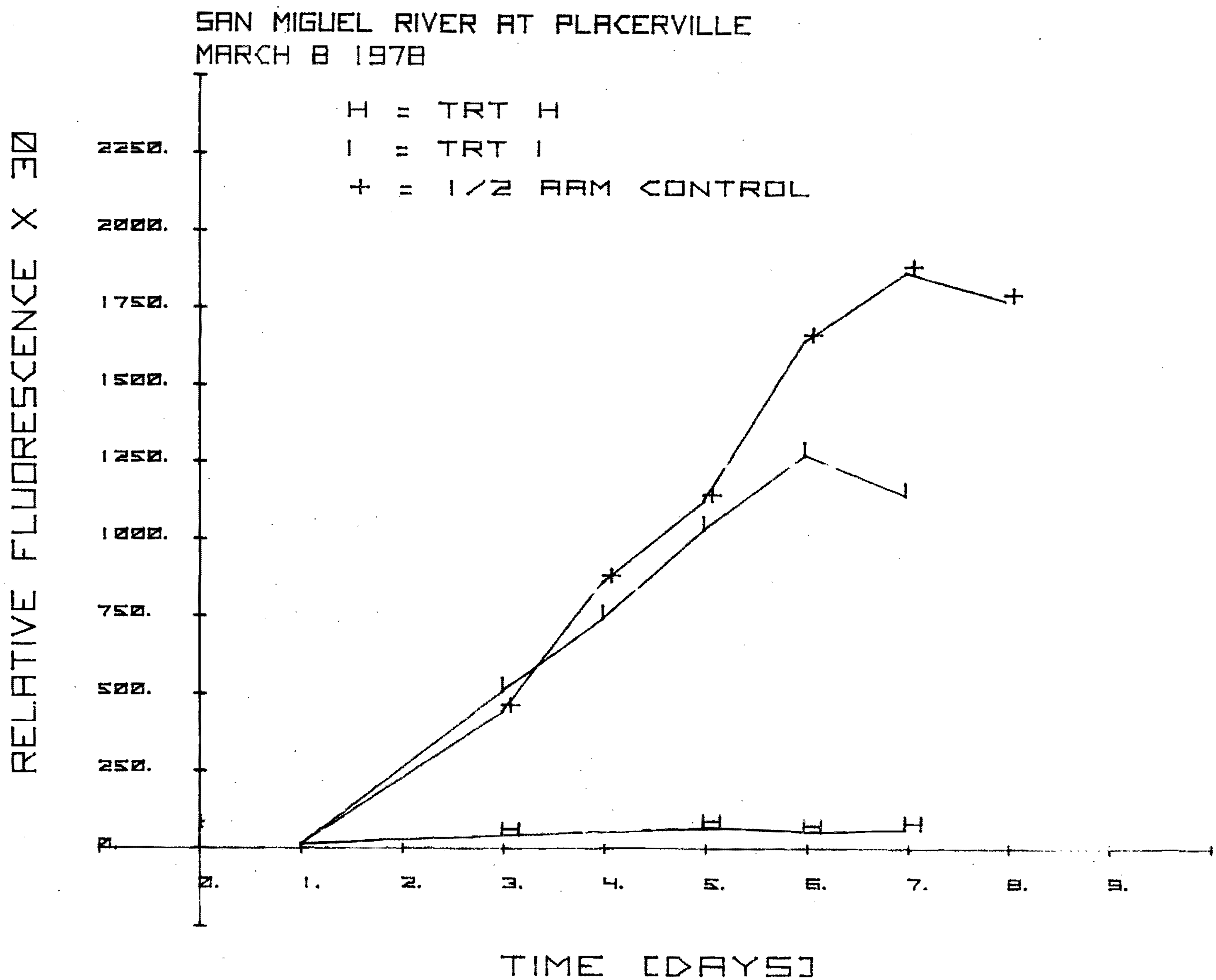

SAN MIGUEL RIVER AT PLACERVILLE
MARCH 8 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]0

Figure 58.



SAN MIGUEL RIVER AT PLACERVILLE
MARCH 8 1978
A = TRTS A B C E F
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 59.



SAN MIGUEL RIVER AT PLACERVILLE
MARCH 8 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 60.

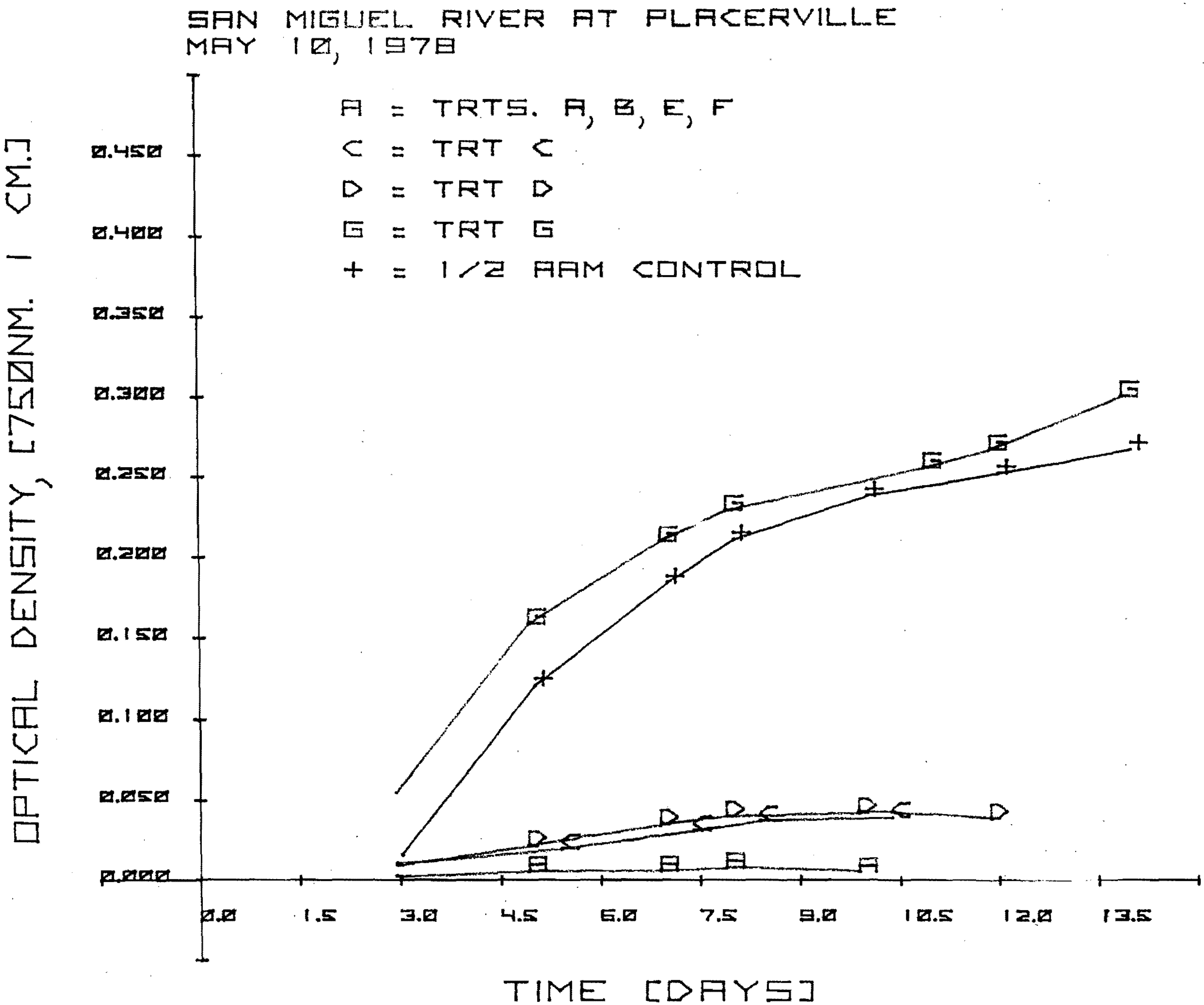

SAN MIGUEL RIVER AT PLACERVILLE
MAY 10, 1978
A = TRTS. A, B, E, F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM CONTROL
OPTICAL DENSITY, [750NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 61.

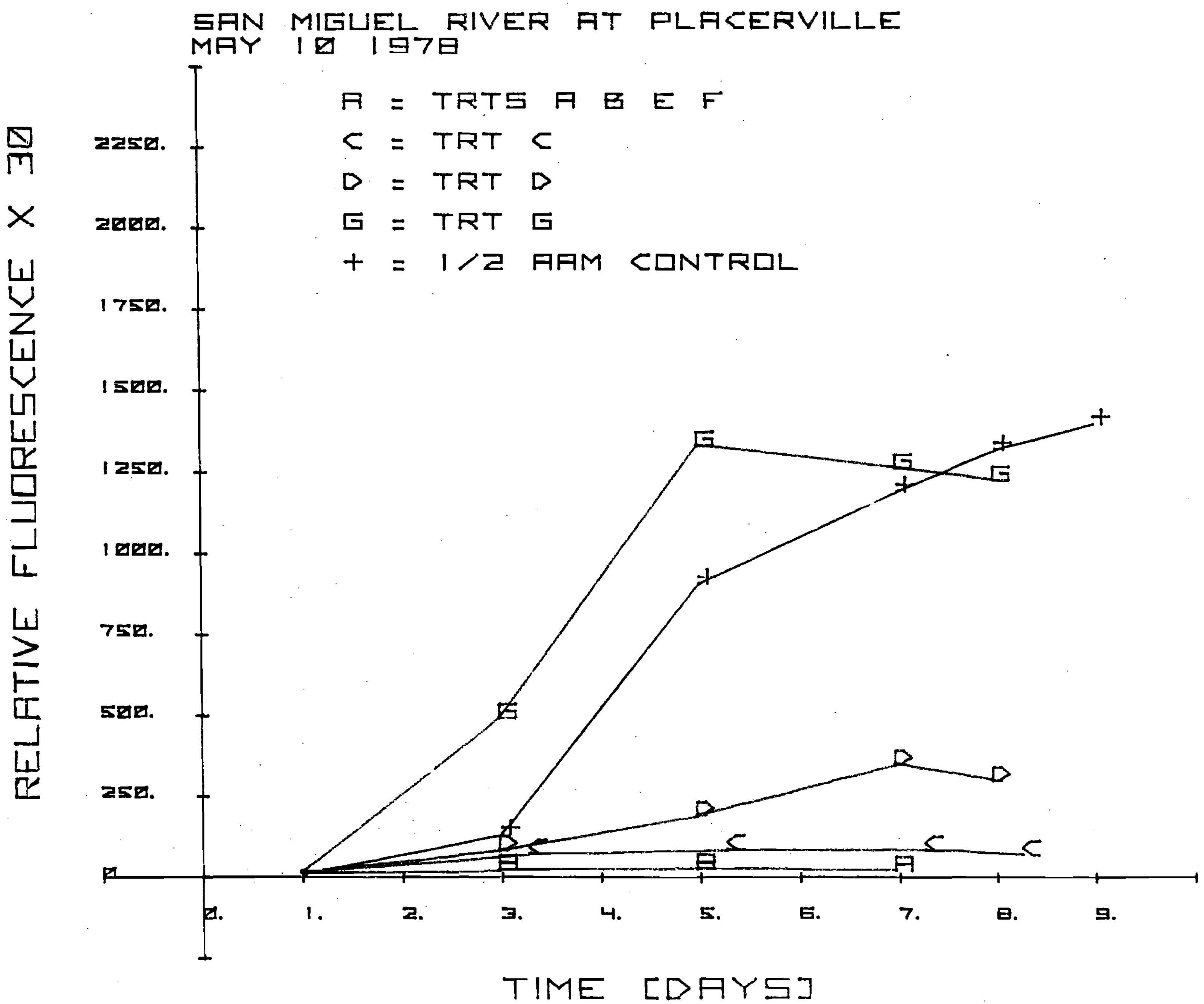

SAN MIGUEL RIVER AT PLACERVILLE
MAY 10 1978
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 62.

Table 28
San Miguel Project
Limiting Nutrients

Sample	Limiting Nutrients	
	Chemical Analysis	Bioassay
9/8/77		
San Miguel River near Placerville	Phosphorus	Phosphorus[a]
San Miguel River near Sawpit	Phosphorus	Phosphorus[a]
Leopard Creek	Phosphorus	Phosphorus[a]
11/29/77		
San Miguel River near Placerville	Phosphorus	Phosphorus[a]
San Miguel River near Sawpit	Phosphorus	Phosphorus[a]
Leopard Creek	Phosphorus	Phosphorus & Nitrogen
1/9/78		
San Miguel River near Placerville	Phosphorus	Phosphorus
San Miguel River near Sawpit	Phosphorus	Phosphorus[a]
Leopard Creek	Phosphorus	Phosphorus & Nitrogen
3/8/78		
San Miguel River near Placerville	Phosphorus & Nitrogen	Phosphorus & Nitrogen
San Miguel River near Sawpit	Phosphorus & Nitrogen	Phosphorus & Nitrogen
Leopard Creek	Phosphorus	Phosphorus & Nitrogen
5/10/78		
San Miguel River near Placerville	Phosphorus & Nitrogen	Phosphorus & Nitrogen[b]
San Miguel River near Sawpit	Phosphorus	Phosphorus & Nitrogen[c]
Leopard Creek	Phosphorus	Phosphorus & Nitrogen

[a]Addition of phosphorus substantially increased the maximum specific growth rate, $\hat{\mu}_b$ indicating phosphorus limitation. However, due to the low level of both indigenous nitrogen and phosphorus growth was only minimal upon phosphorus addition as nitrogen became limiting as well.

[b]A trace element in addition to N and P was limiting.

[c]Trace metal toxicity was present at this sampling date.

concentration in a more fertile sample (VSS, Treatment A was 32.2 in January as compared to an average of 5.5 in September and November). However the nutrient increase was not proportional as the nitrogen concentration increased to a far greater extent than the phosphorus. The net result was a profound phosphorus limitation.

The March, 1978 bioassay showed a return to the fall conditions probably as a result of increasing water levels as the spring turnover began. Indigenous nutrients dropped again to very low concentrations and the sample again became nitrogen and phosphorus limited. As the spring turnover continued into May, 1978 chemical analysis showed the nutrient levels continuing to drop to extremely low concentrations. The May, 1978 bioassay reflected low nutrient concentrations with only minimal response even upon nitrogen and phosphorus addition (Treatment D). Other elements, as well as N and P, appeared to have become limiting on the San Miguel River at Placerville during May, 1978.

Conclusions:

a. The sample was limited by nitrogen and phosphorus during the fall and spring months but became phosphorus limited alone when the water flow and level were lower during winter.

b. Chemical analysis and bioassay correlated well.

c. During the spring period another element or elements in addition to N and P contributed to limitation.

d. No metal toxicity was observed.

e. This sample was classified as oligotrophic to mesotrophic. The low nutrient concentrations indicate that both nitrogen and phosphorus will be required before a shift in eutrophication occurs (graph, OD, 3/8/79 is not labeled).

2. San Miguel River near Sawpit (Figures 63 - 82)

As was true with most other samples analyzed during the bioassays, this sample appeared to be limited by phosphorus based solely on chemical analysis but in truth was limited by both N and P in all cases. Indigenous nutrient levels were low resulting in a low productivity sample which became productive only when nitrogen and phosphorus were introduced into the system.

The final bioassay in May, 1978 indicated a toxicity problem not before observed at this site. Growth upon addition of N and P (Treatment D) or total AAM (Treatment G) was not markedly greater than the sample blank. When this poor response was observed an EDTA spiked total AAM treatment (Treatment I) was added to the bioassay for this particular sample. The resulting growth with EDTA added was normal. Normally, as indicated by earlier bioassays, metal toxicity did not occur. It can only be assumed that spring turnover or runoff brought a toxic metal into the San Miguel River at the Sawpit site.

Conclusions:

a. The sample was limited by both nitrogen and phosphorus during each sampling period with phosphorus being the most limiting.

b. Algal bioassay and chemical analysis correlate well.

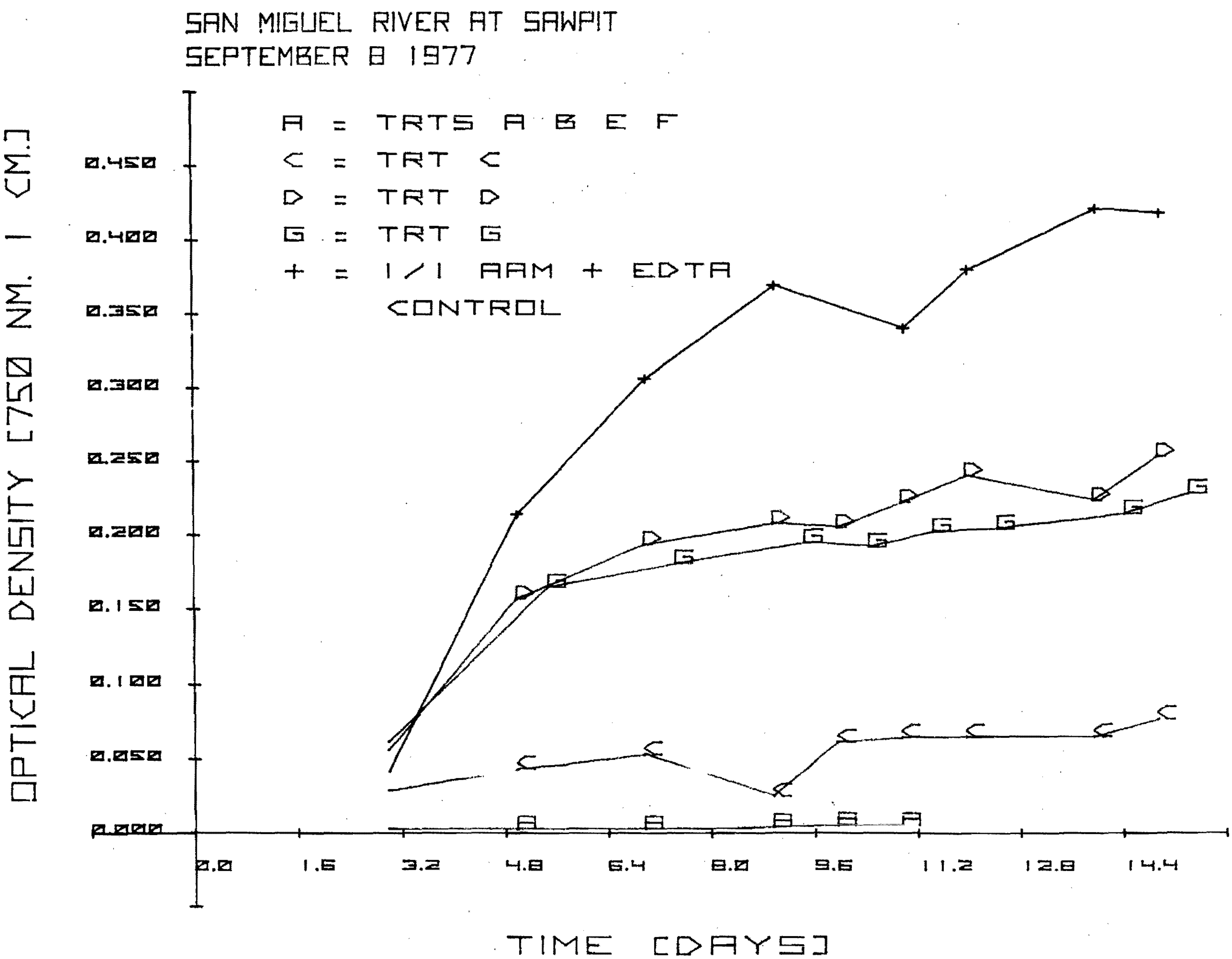

SAN MIGUEL RIVER AT SAWPIT
SEPTEMBER 8 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/1 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.6
3.2
4.8
6.4
8.0
9.6
11.2
12.8
14.4
TIME [DAYS]

Figure 63.

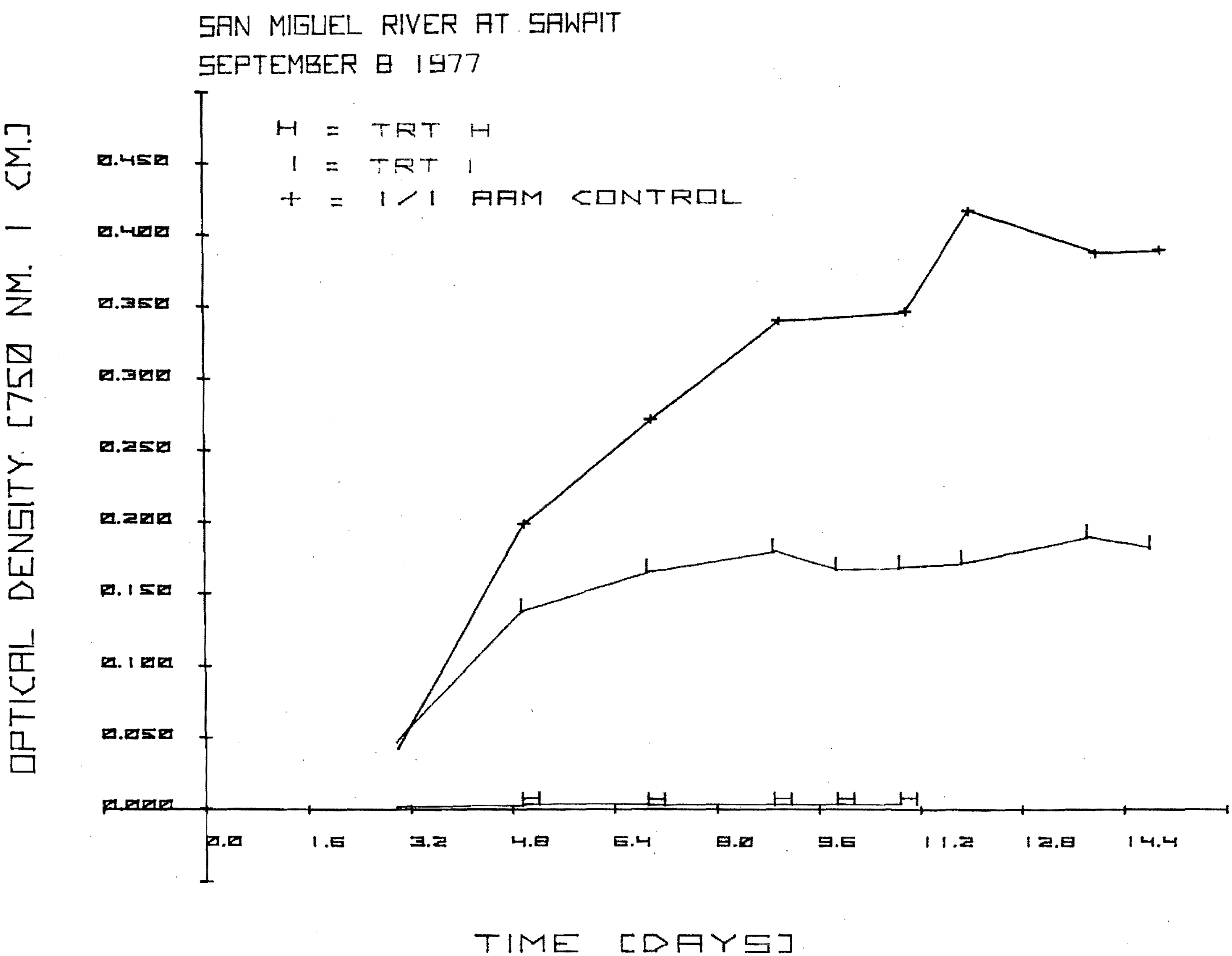

SAN MIGUEL RIVER AT SAWPIT
SEPTEMBER 8 1977
H = TRT H
I = TRT I
+ = 1/1 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.6
3.2
4.8
6.4
8.0
9.6
11.2
12.8
14.4
TIME [DAYS]

Figure 64.

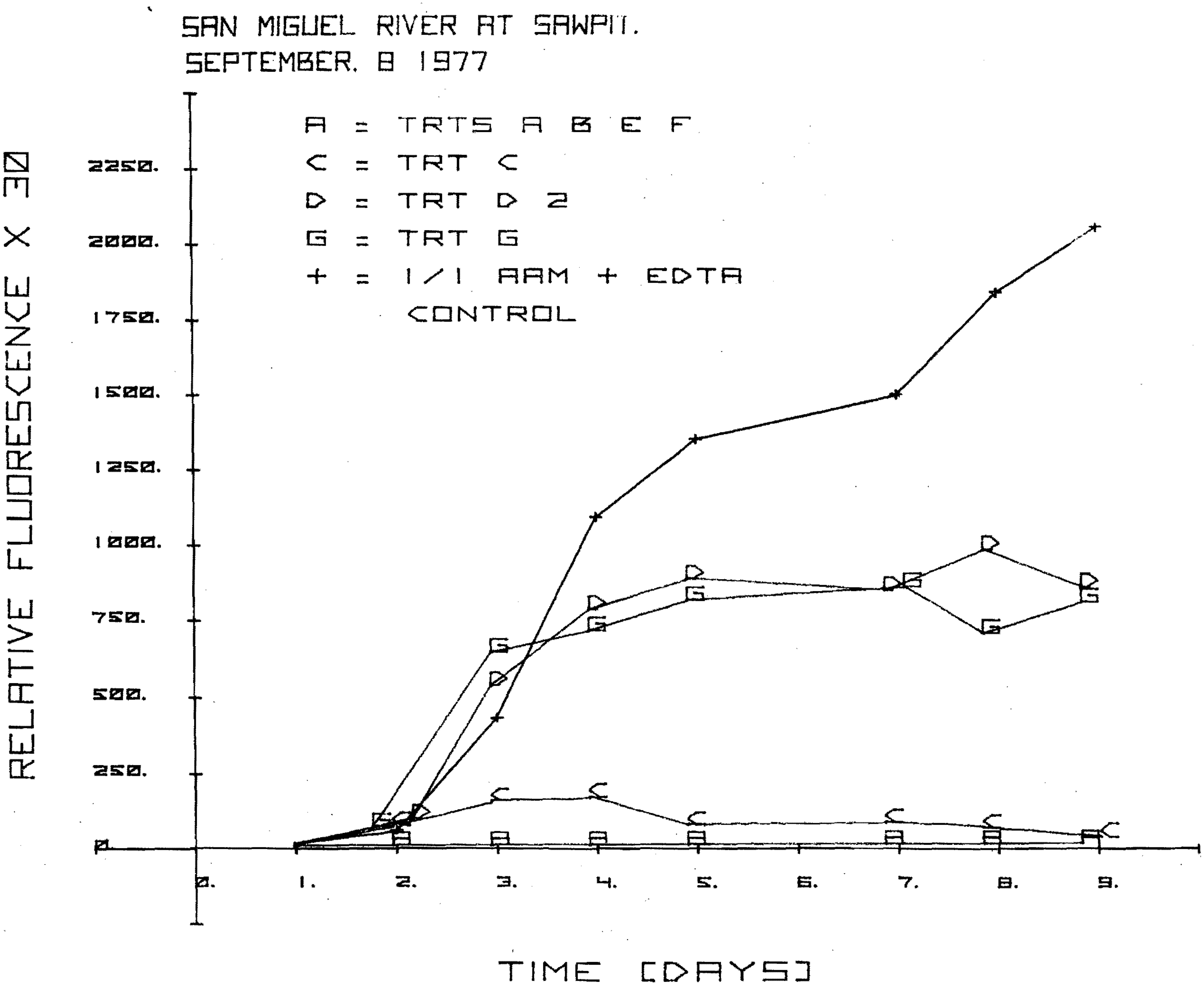

SAN MIGUEL RIVER AT SAWPIT.
SEPTEMBER. 8 1977
A = TRTS A B E F
C = TRT C
D = TRT D 2
G = TRT G
+ = 1/1 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 65.

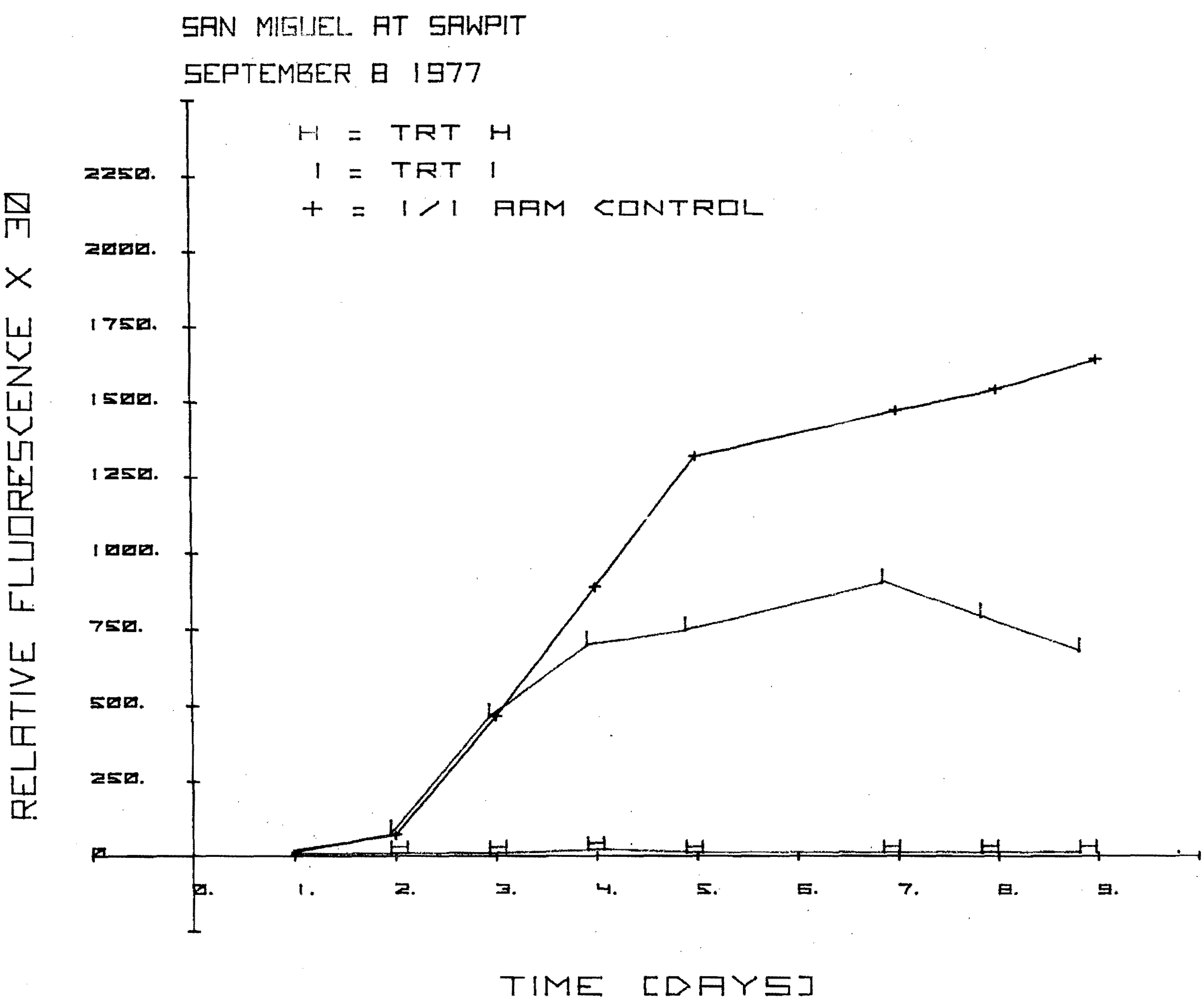

SAN MIGUEL AT SAWPIT
SEPTEMBER 8 1977
H = TRT H
I = TRT I
+ = 1/1 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME (DAYS)

Figure 66.

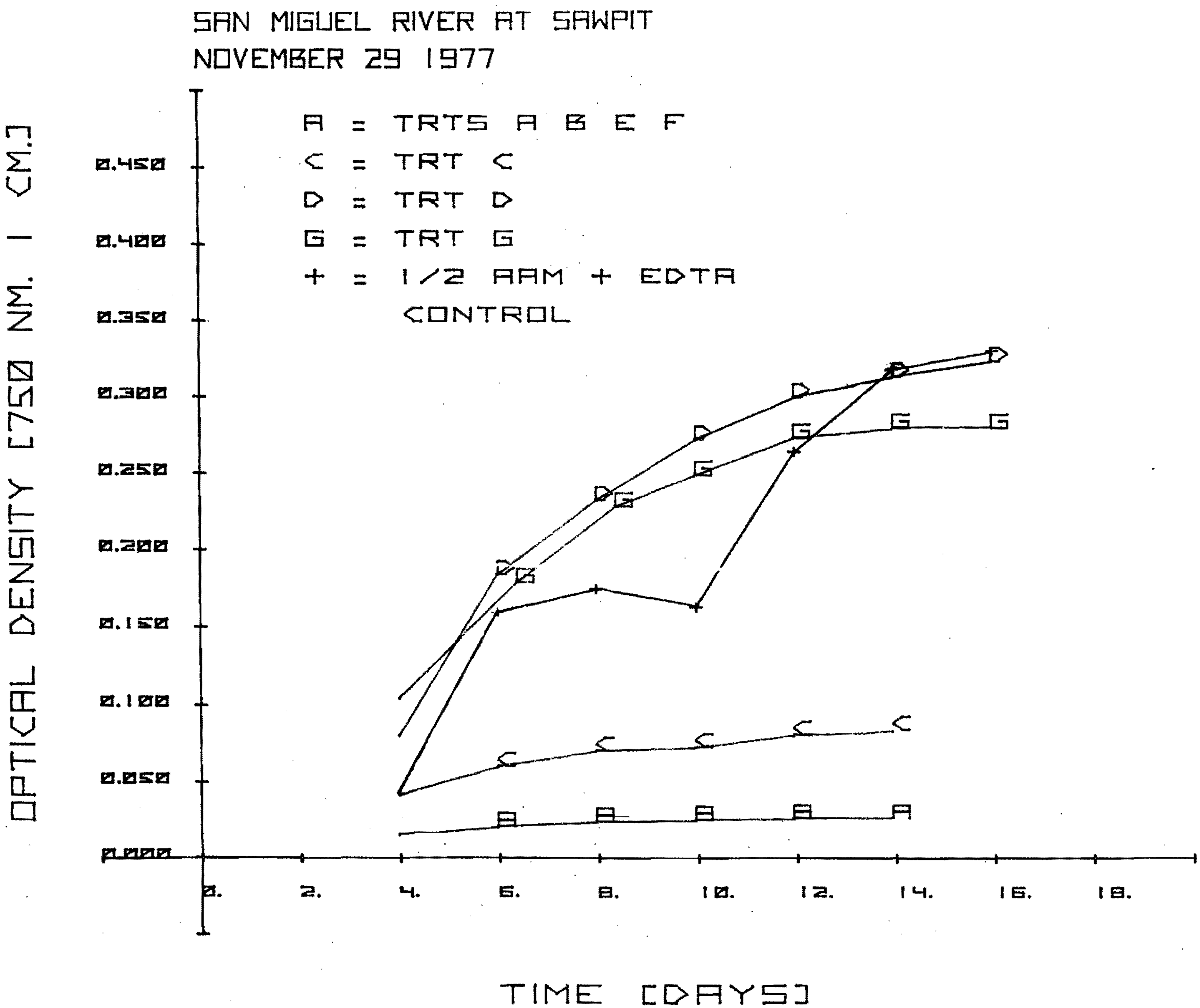

SAN MIGUEL RIVER AT SAWPIT
NOVEMBER 29 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
OPTICAL DENSITY [750 NM. 1 CM.]
TIME [DAYS]

Figure 67.

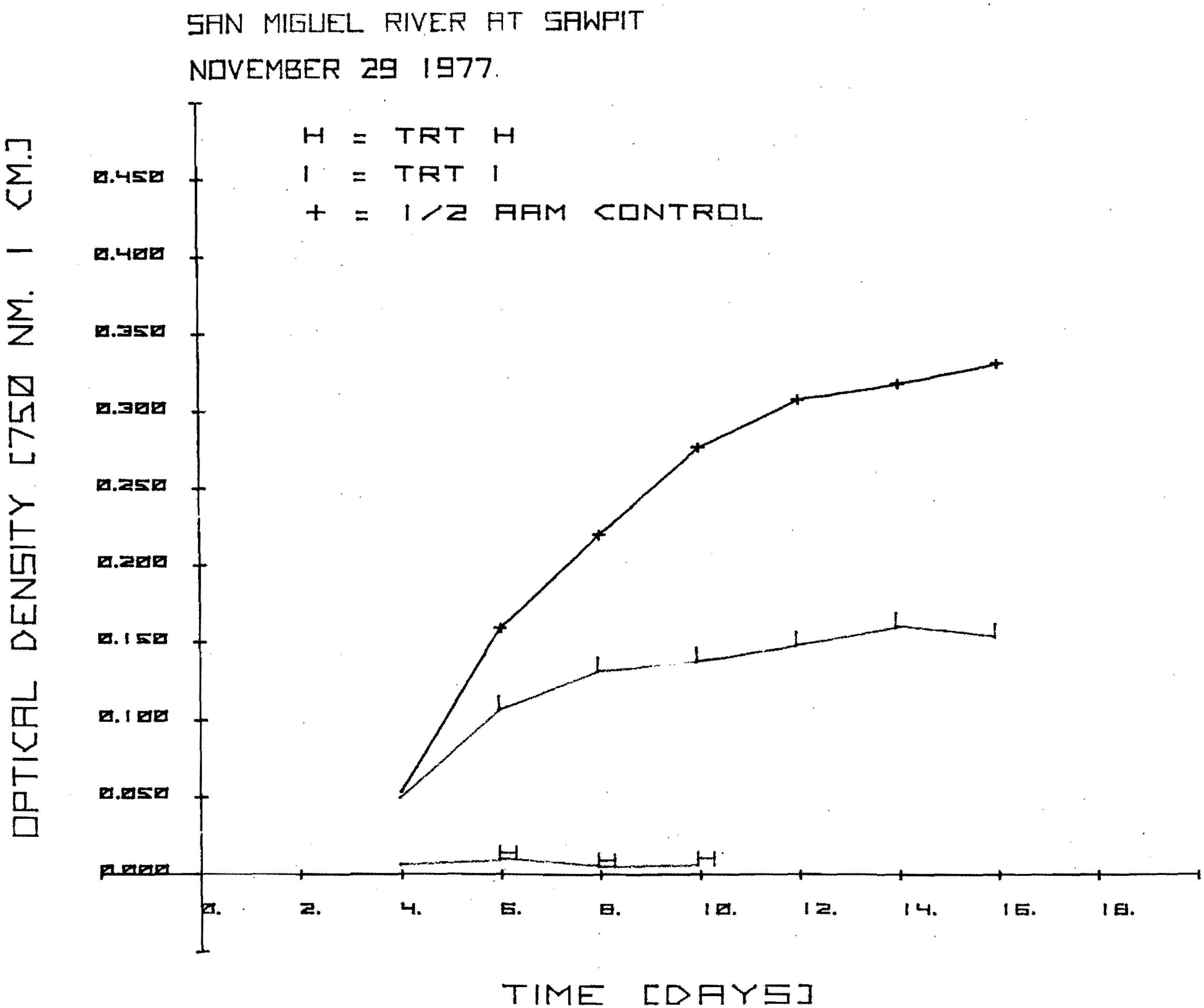

SAN MIGUEL RIVER AT SAWPIT
NOVEMBER 29 1977
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. I CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 68.

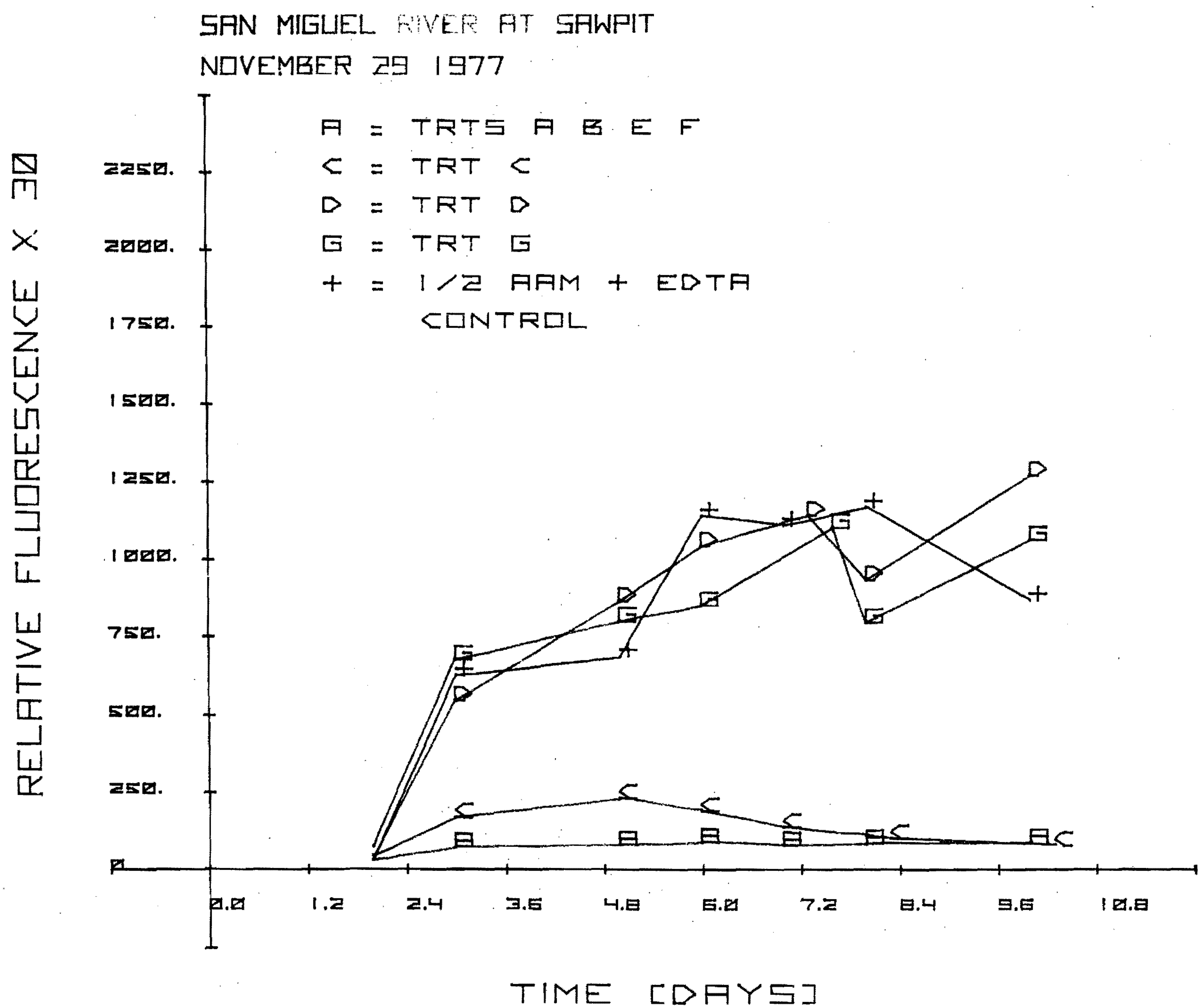
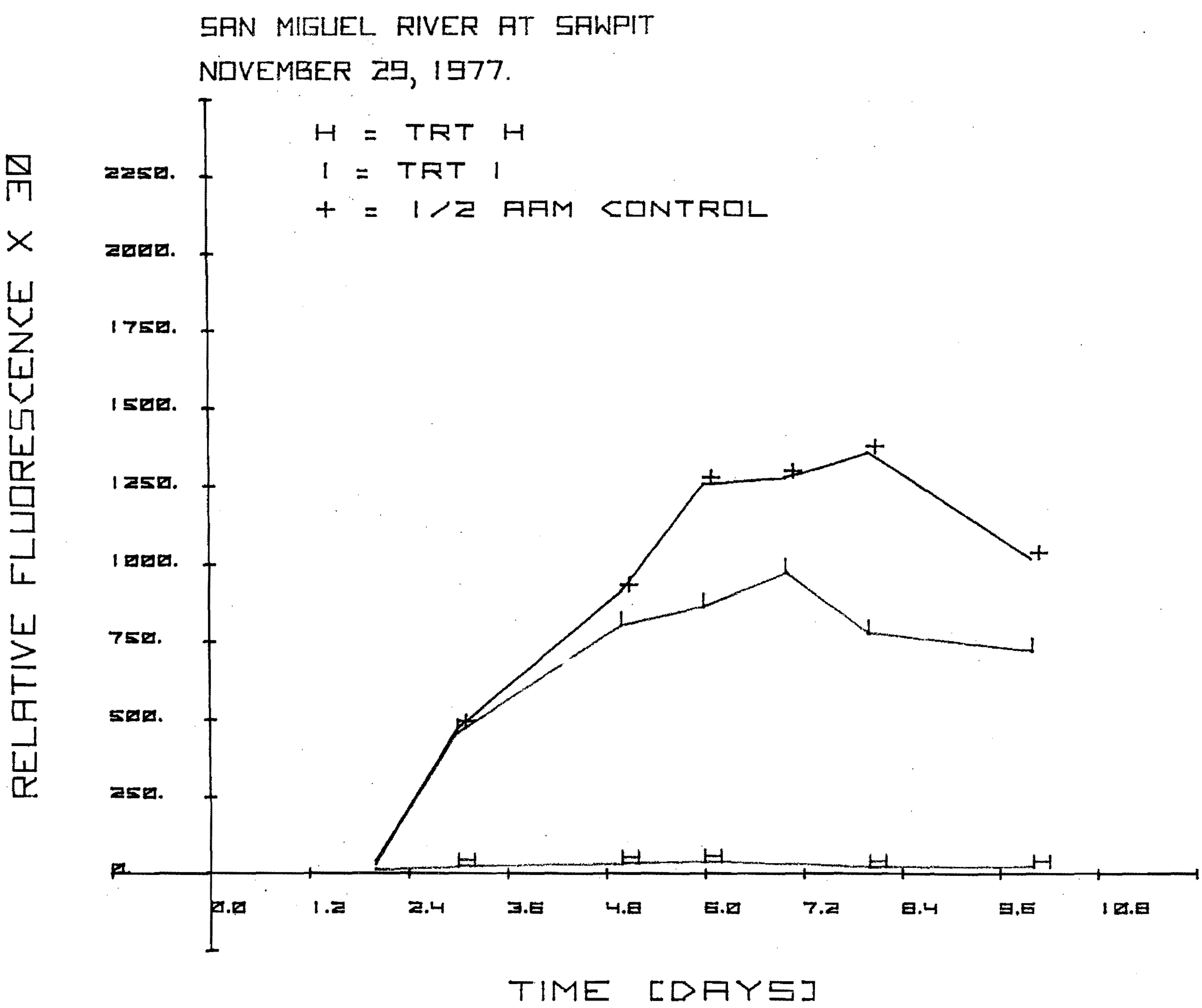

SAN MIGUEL RIVER AT SAWPIT
NOVEMBER 29 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.0
1.2
2.4
3.6
4.8
6.0
7.2
8.4
9.6
10.8
TIME [DAYS]

Figure 69.



SAN MIGUEL RIVER AT SAWPIT
NOVEMBER 29, 1977.
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.0
1.2
2.4
3.6
4.8
6.0
7.2
8.4
9.6
10.8
TIME [DAYS]

Figure 70.

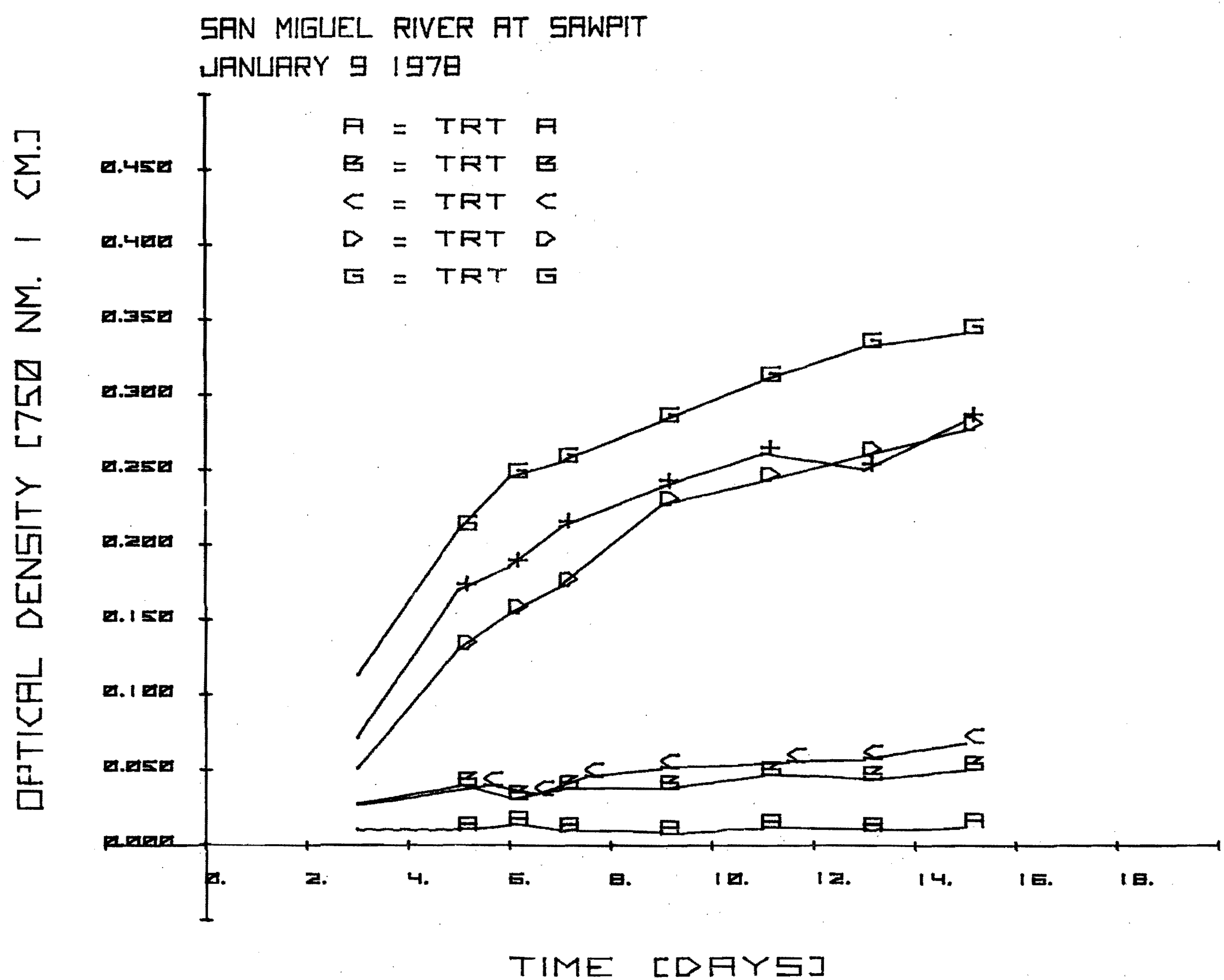

SAN MIGUEL RIVER AT SAWPIT
JANUARY 9 1978
A = TRT A
B = TRT B
C = TRT C
D = TRT D
G = TRT G
OPTICAL DENSITY [750 NM. I CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 71.

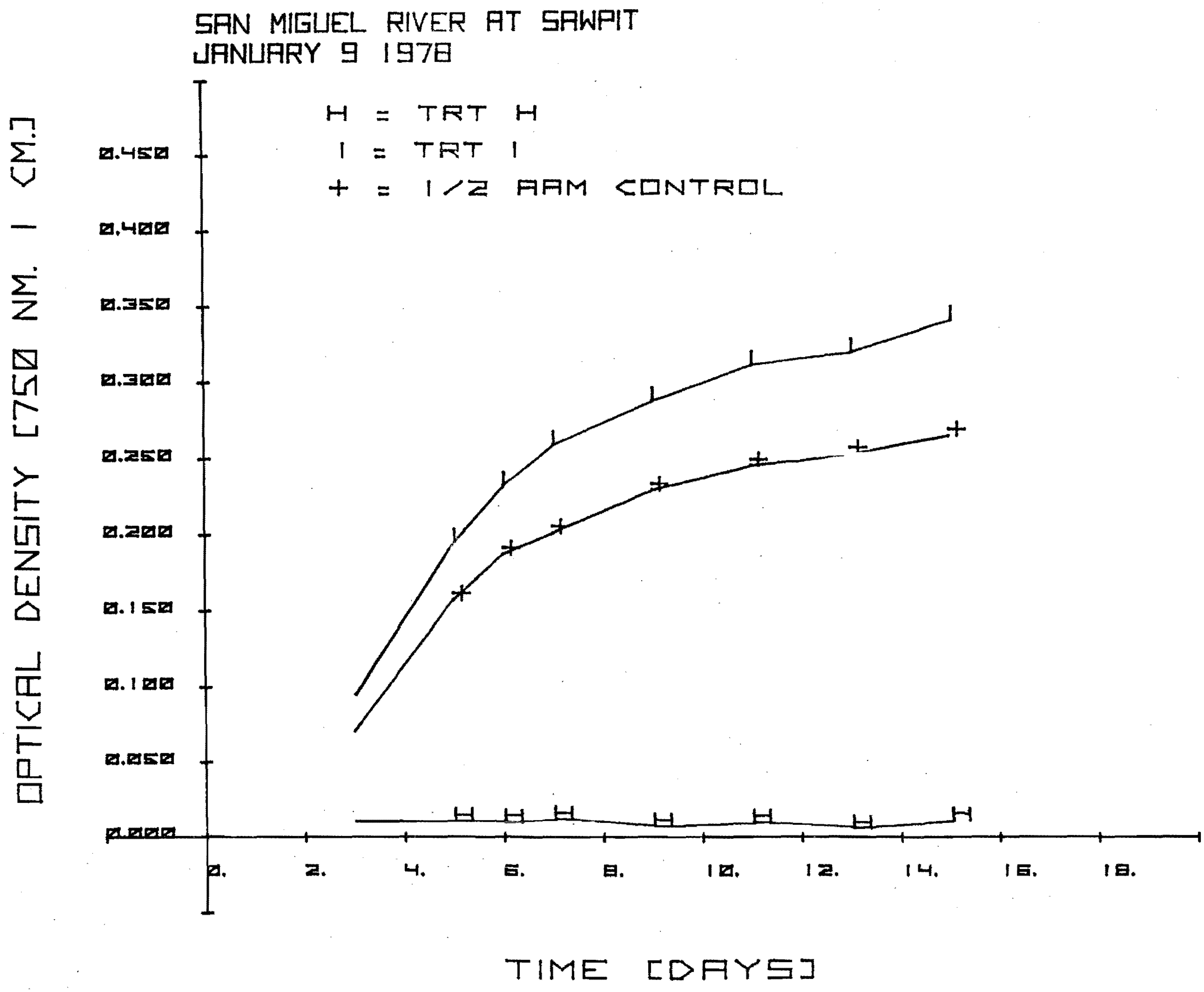

SAN MIGUEL RIVER AT SAWPIT
JANUARY 9 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 72.

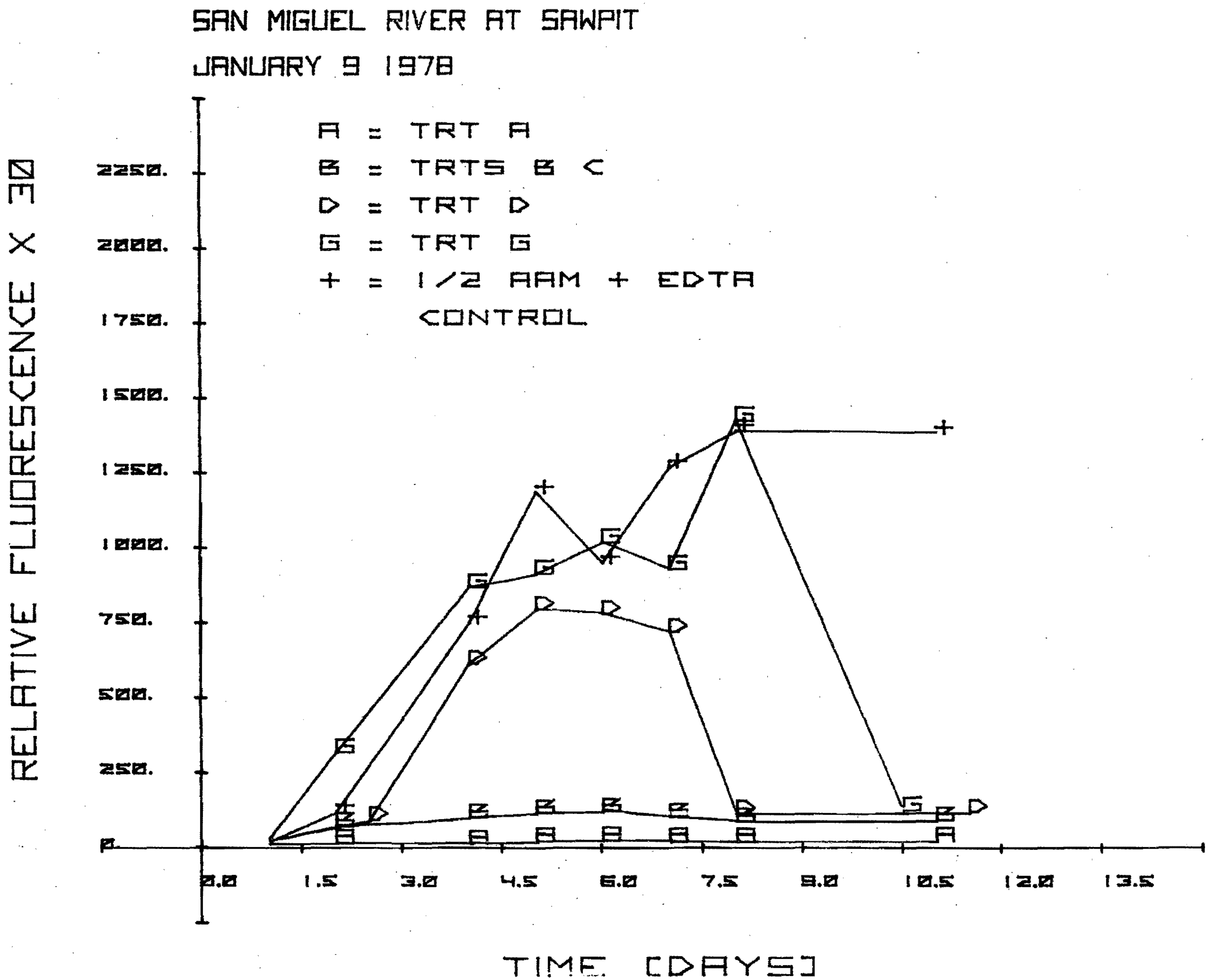

SAN MIGUEL RIVER AT SAWPIT
JANUARY 9 1978
A = TRT A
B = TRTS B C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 73.

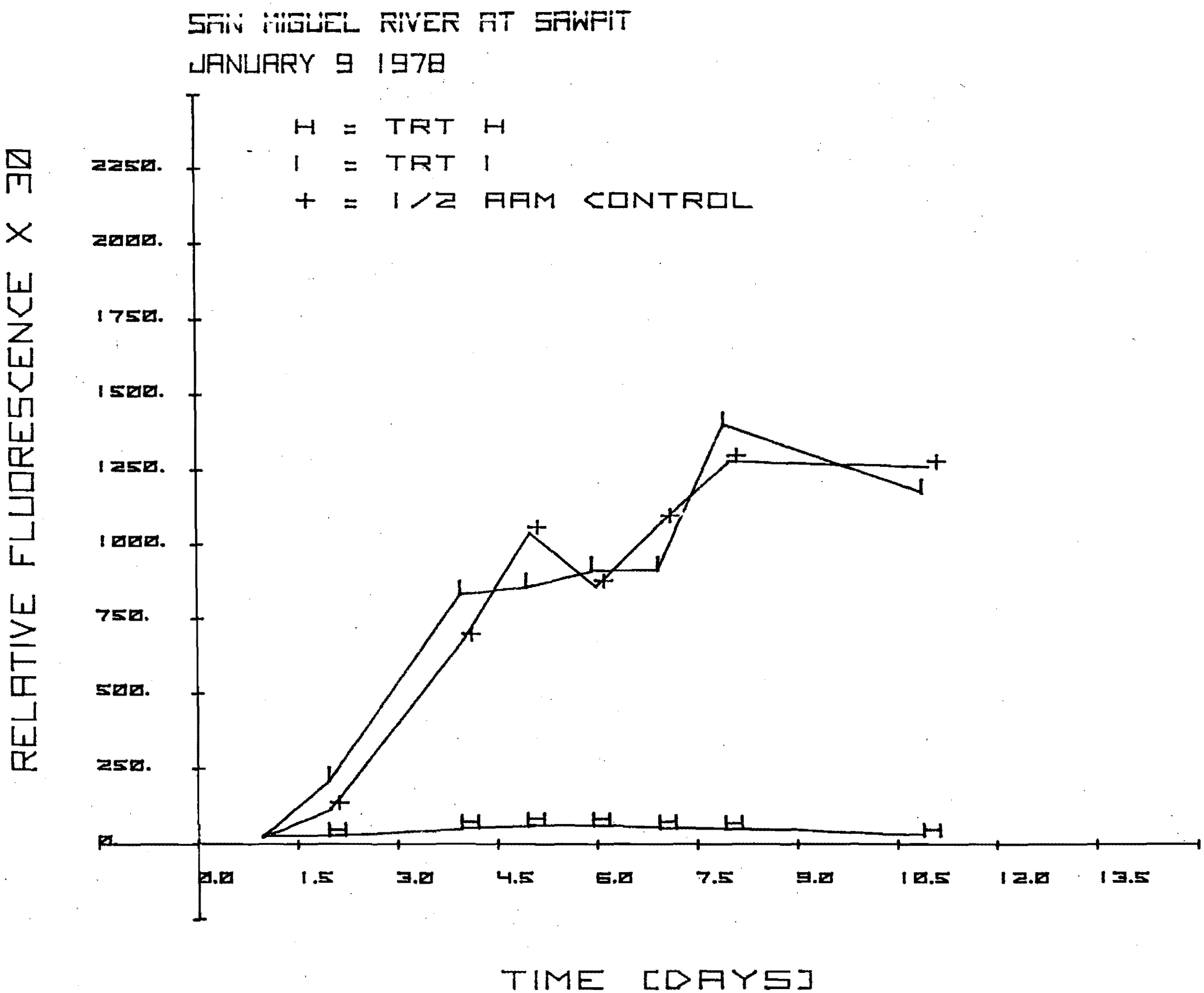

SAN MIGUEL RIVER AT SAWPIT
JANUARY 9 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 74.

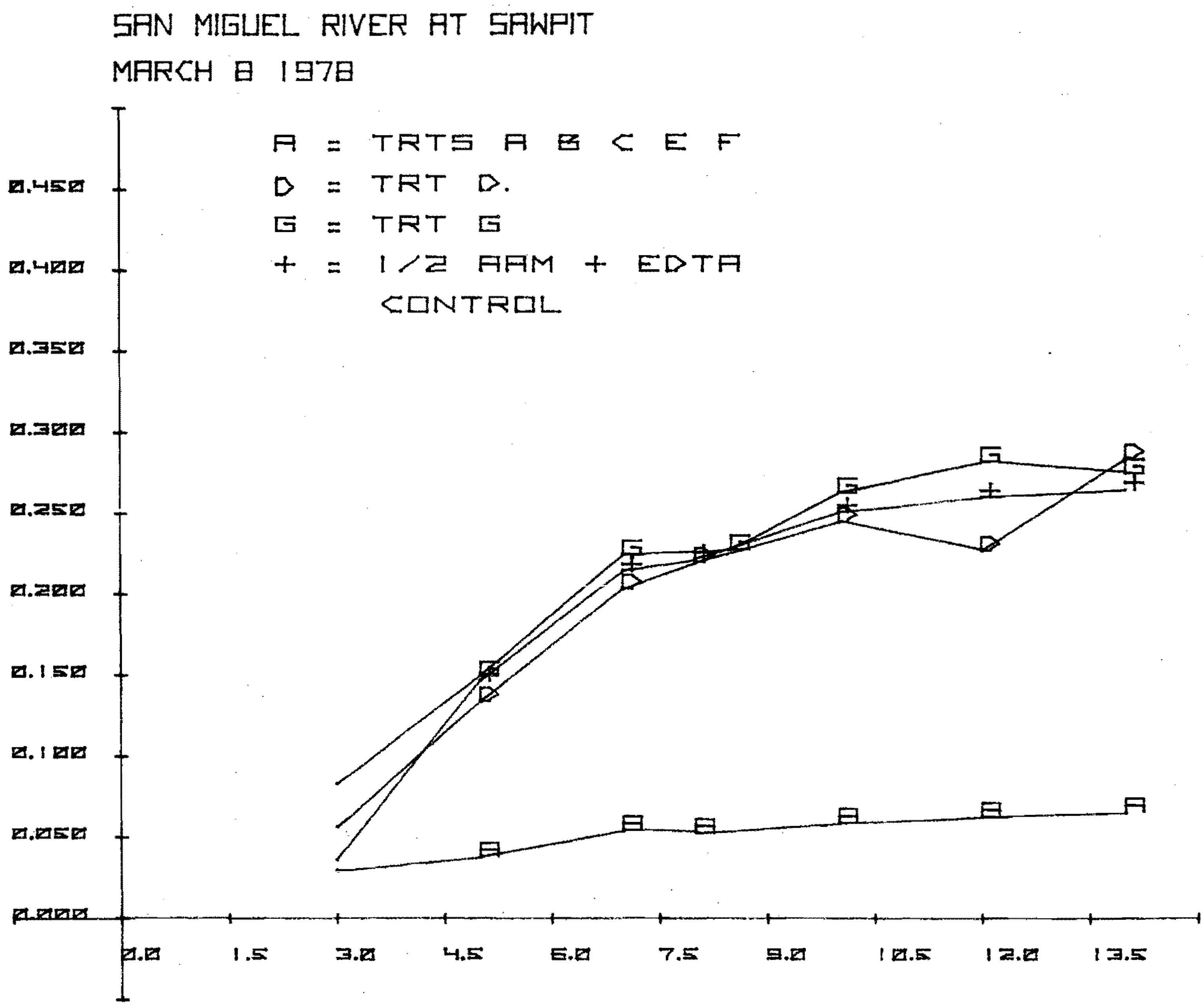

SAN MIGUEL RIVER AT SAWPIT
MARCH 8 1978
A = TRTS A B C E F
D = TRT D.
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5

Figure 75.

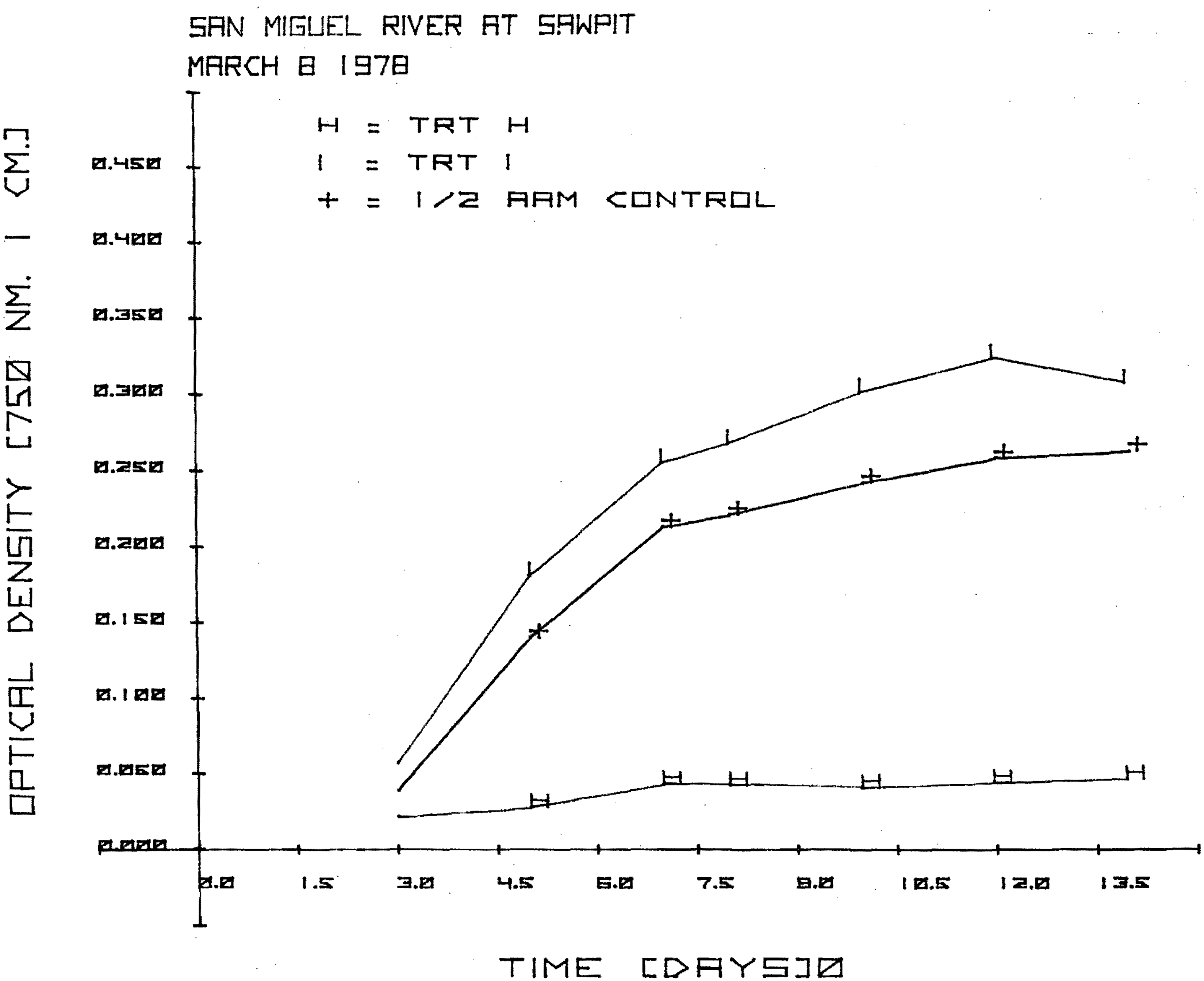

SAN MIGUEL RIVER AT SAWPIT
MARCH 8 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 76.

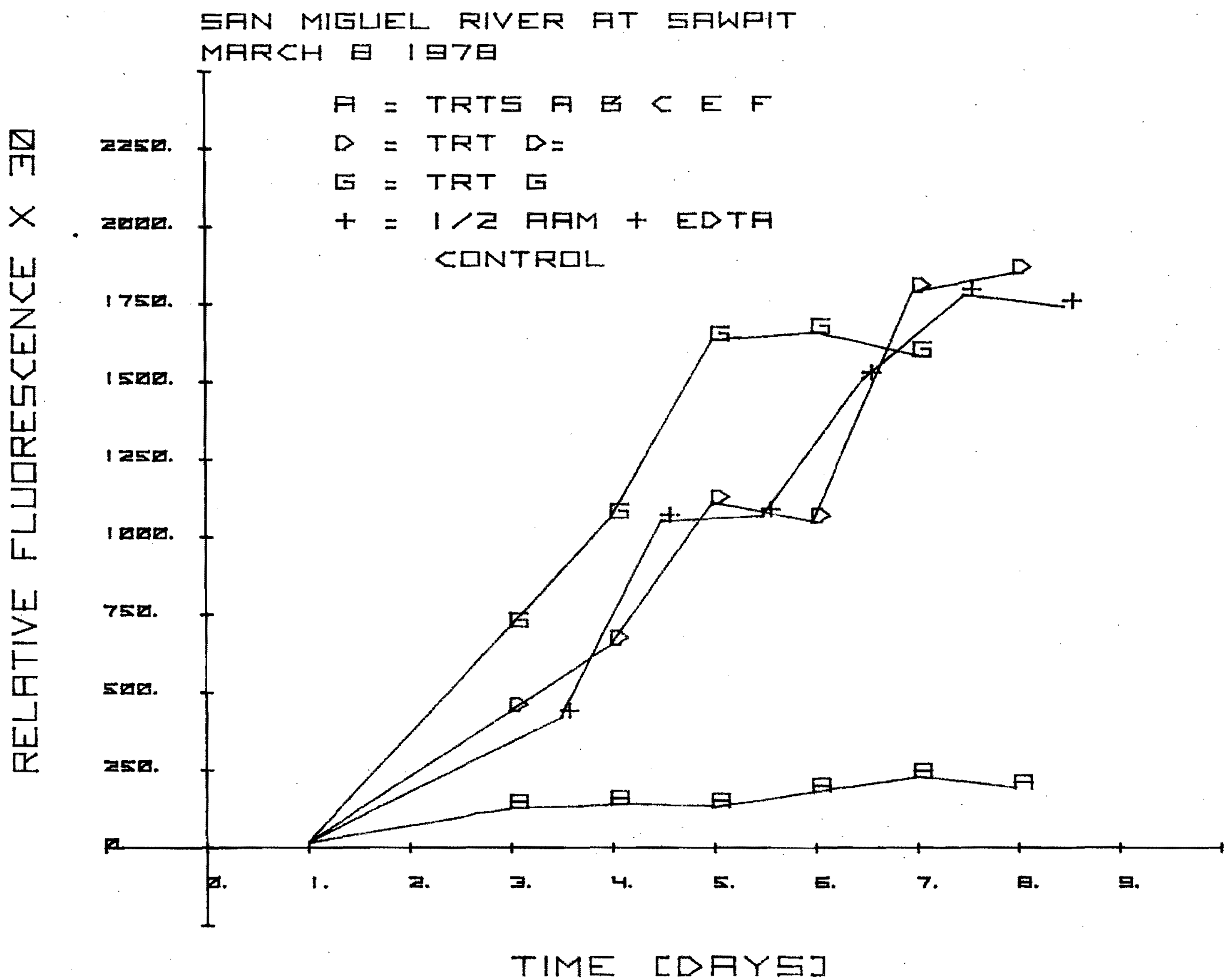

SAN MIGUEL RIVER AT SAWPIT
MARCH 8 1978
A = TRTS A B C E F
D = TRT D=
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 77.

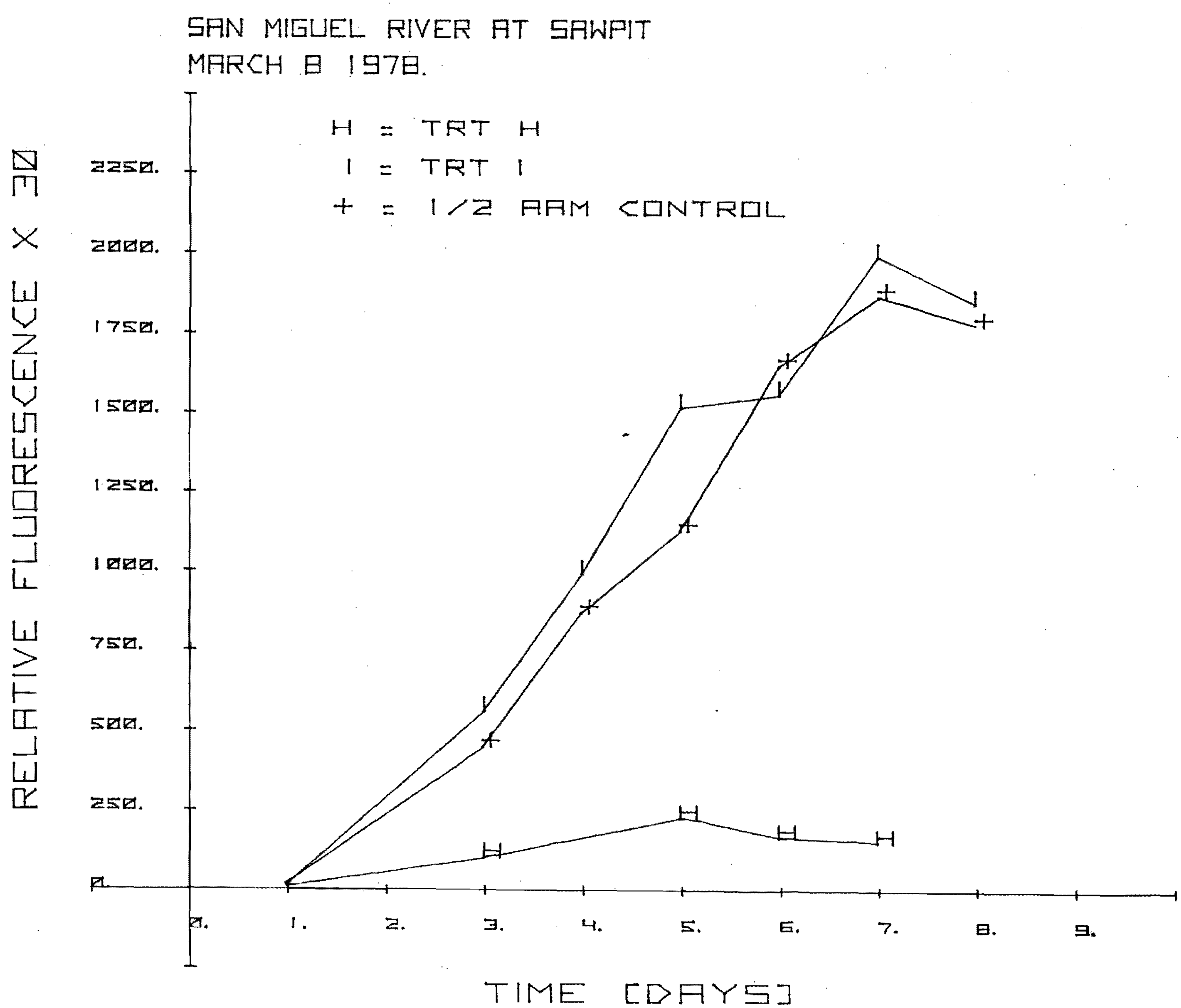

SAN MIGUEL RIVER AT SAWPIT
MARCH 8 1978.
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 78.

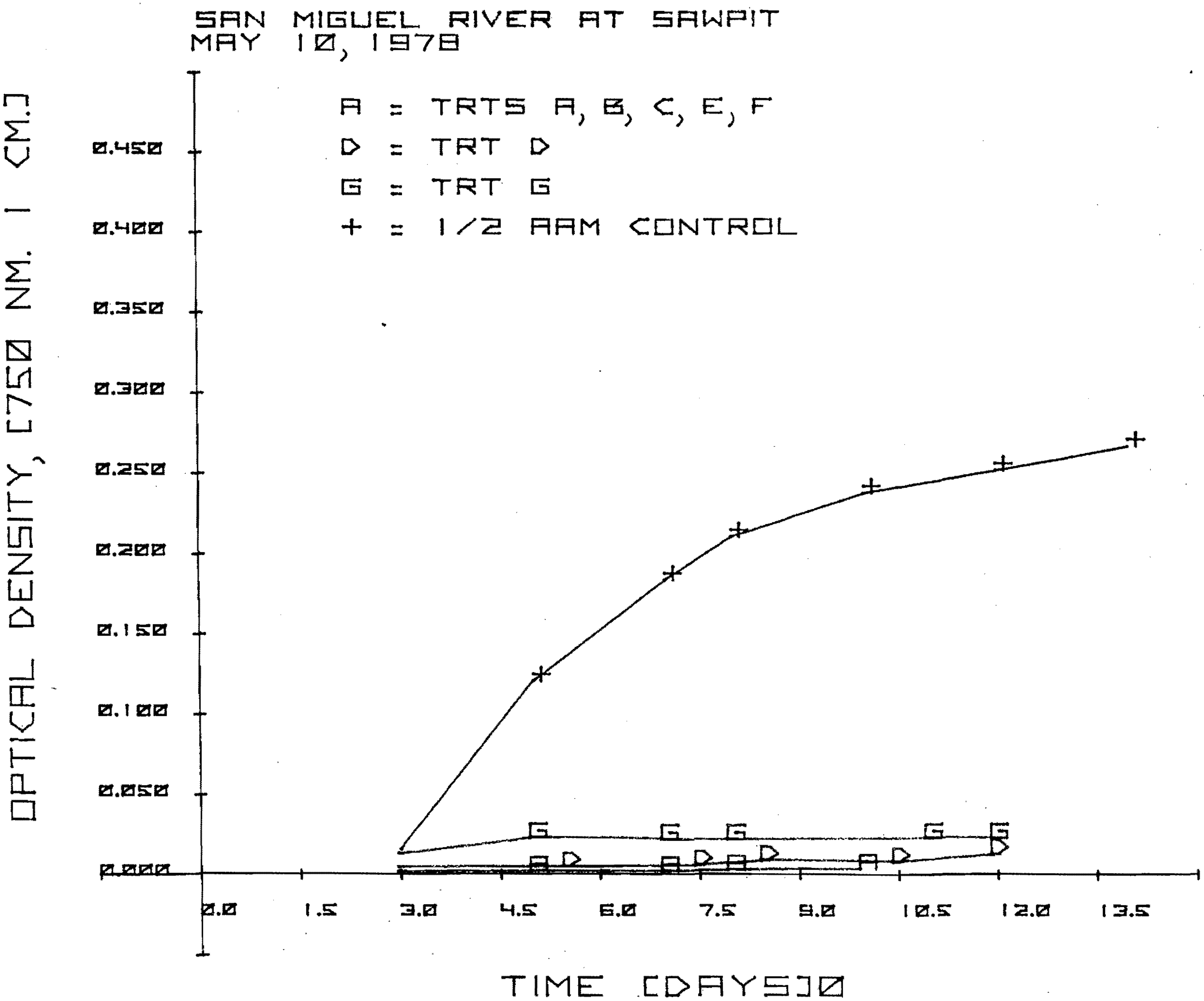

SAN MIGUEL RIVER AT SAWPIT
MAY 10, 1978
A = TRTS A, B, C, E, F
D = TRT D
G = TRT G
+ = 1/2 AAM CONTROL
OPTICAL DENSITY, [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]0

Figure 79.

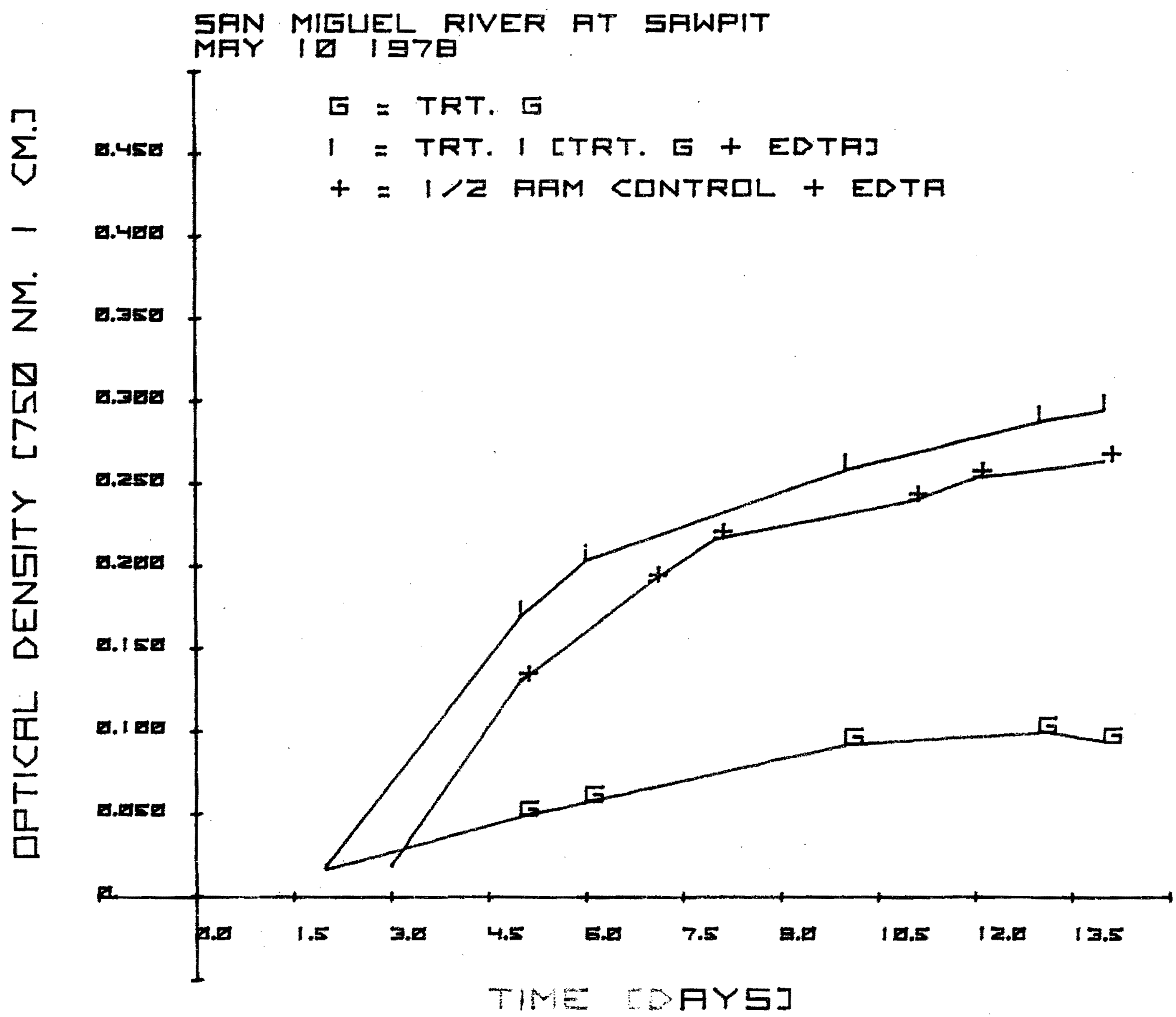

SAN MIGUEL RIVER AT SAWPIT
MAY 10 1978
G = TRT. G
I = TRT. I [TRT. G + EDTA]
+ = 1/2 AAM CONTROL + EDTA
OPTICAL DENSITY [750 NM. I CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 80.

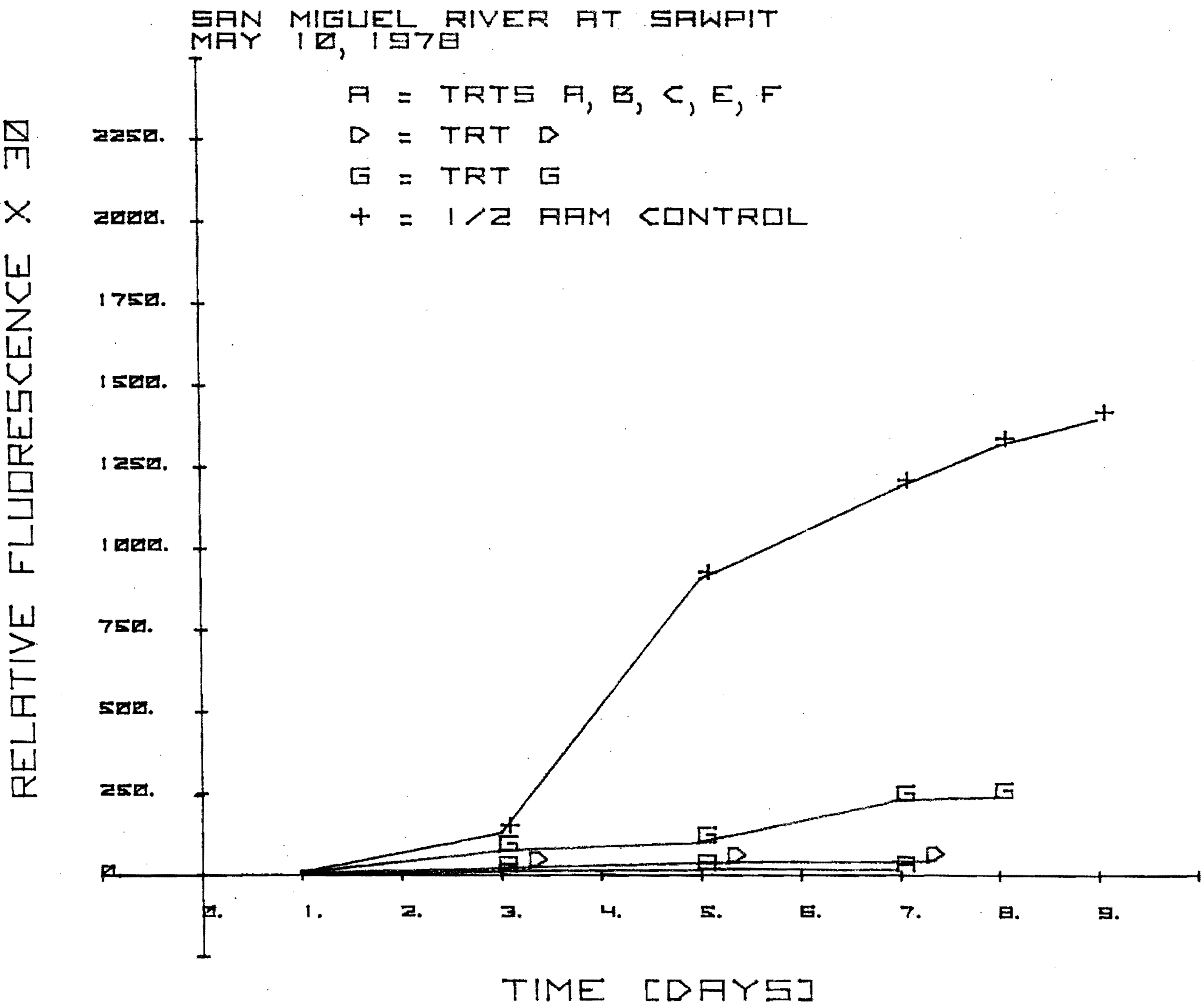
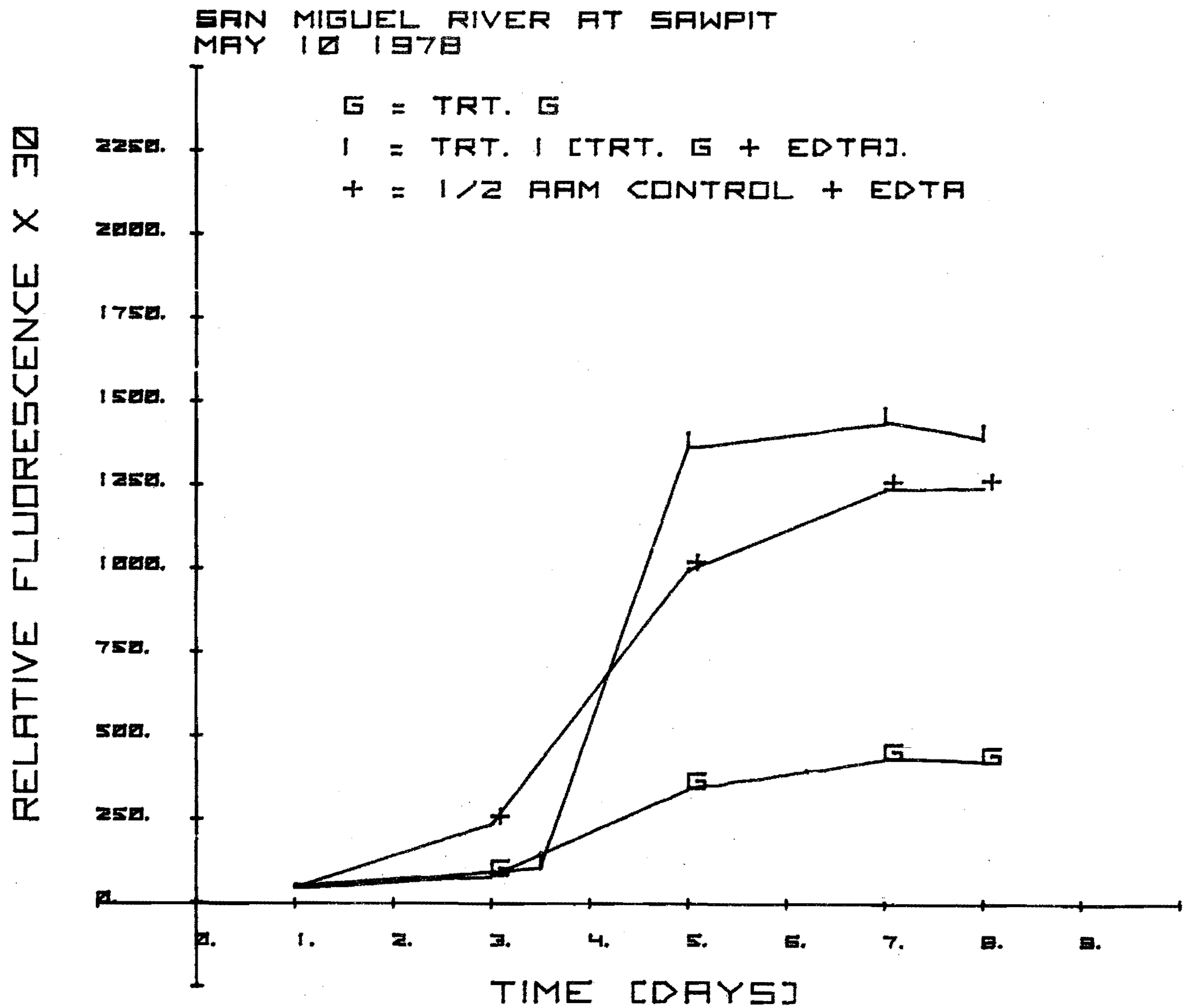

SAN MIGUEL RIVER AT SAWPIT
MAY 10, 1978
A = TRTS A, B, C, E, F
D = TRT D
G = TRT G
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 81.



SAN MIGUEL RIVER AT SAWPIT
MAY 10 1978
G = TRT. G
I = TRT. I [TRT. G + EDTA].
+ = 1/2 AAM CONTROL + EDTA
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 82.

c. Heavy metal toxicity was indicated during the spring possibly as a result of spring turnover.

d. An oligotrophic to mesotrophic condition can be expected at this site. Metal toxicity may play some role in this body of water remaining nonproductive.

3. Leopard Creek (Figures 83 - 100)

The conditions on Leopard Creek can be described in a very few sentences. Chemical analysis pointed in the direction of phosphorus limitation but upon closer examination it become obvious that this sample would be limited by both nitrogen and phosphorus simply because it contained such low concentrations of both. During the nine month period of the bioassays the highest of concentration of TSIN was 232 μg/l and of OP was 11. Both of these values occurred during the spring turnover, and even when the nutrient values were at their high point productivity was low.

Conclusions:

a. The sample was limited by both nitrogen and phosphorus during each sampling period with phosphorus being the most limiting.

b. Algal bioassay and chemical analyses correlated well.

c. No metal toxicity was observed.

d. This sample represents an oligotrophic body of water. Increased productivity is possible upon addition of nitrogen and phosphorus but substantial quantities of both would be necessary.

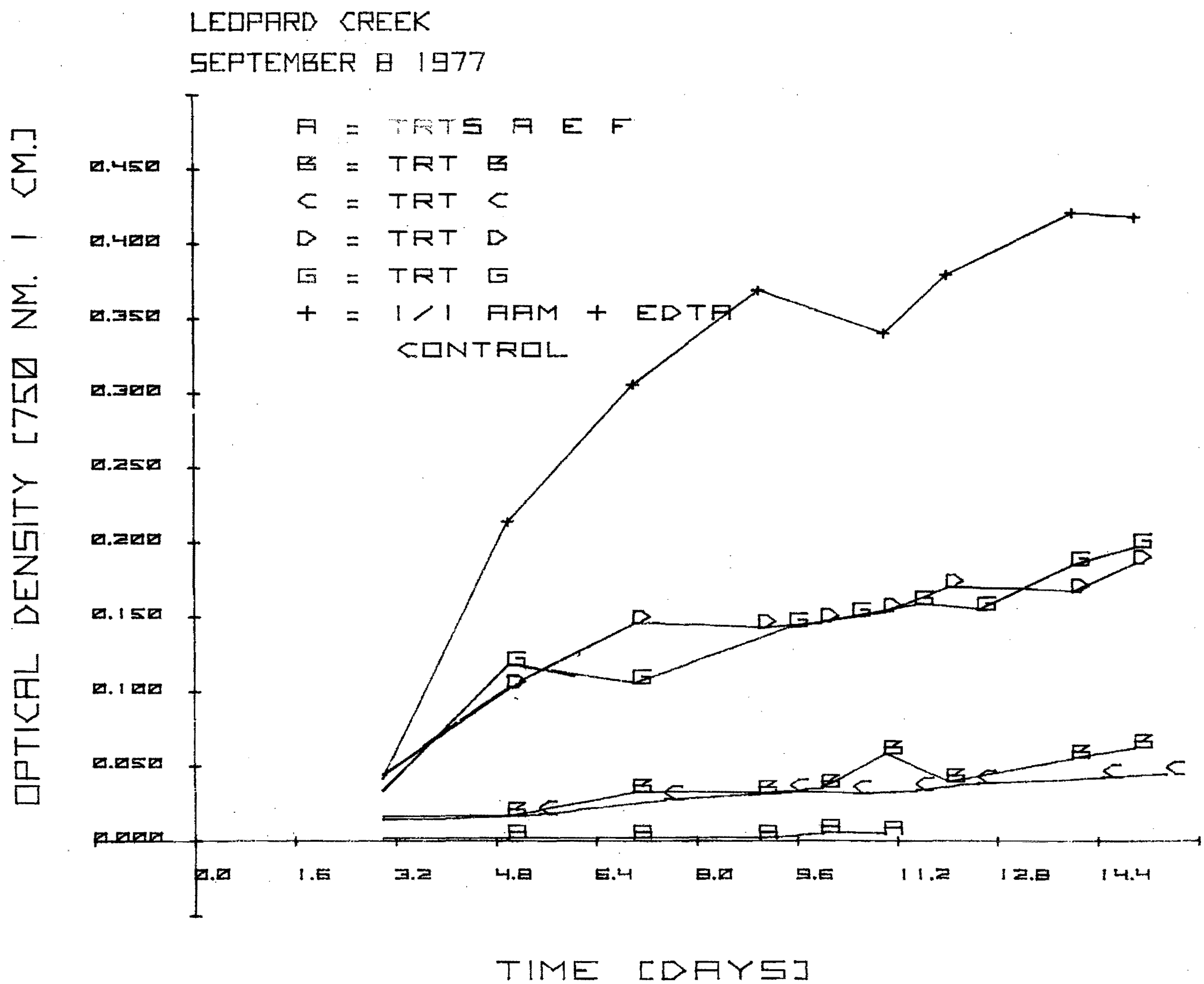

LEOPARD CREEK
SEPTEMBER 8 1977
A = TRTS A E F
B = TRT B
C = TRT C
D = TRT D
G = TRT G
+ = 1/1 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.6
3.2
4.8
6.4
8.0
9.6
11.2
12.8
14.4
TIME [DAYS]

Figure 83.

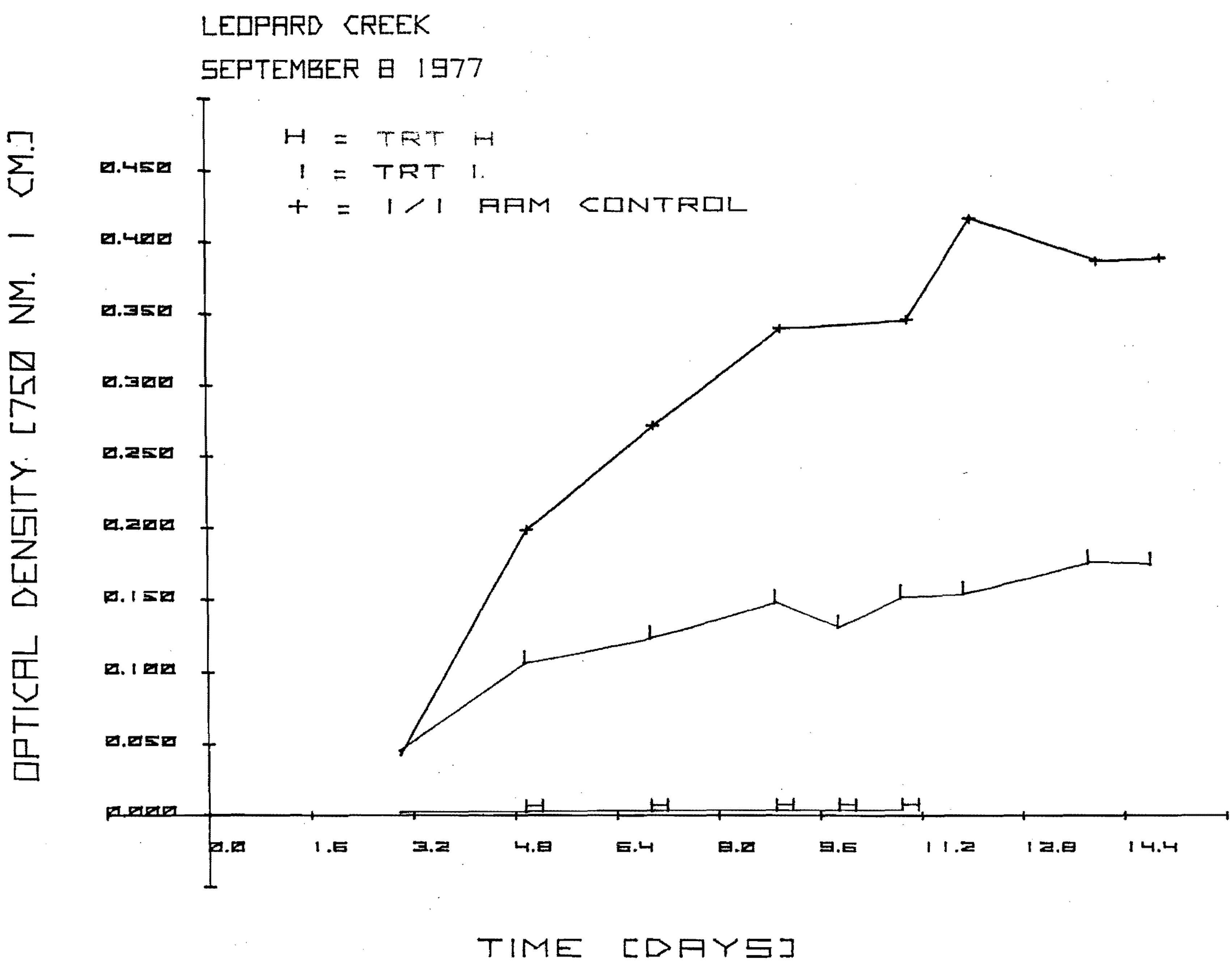

LEOPARD CREEK
SEPTEMBER 8 1977
H = TRT H
I = TRT I
+ = 1/1 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.6
3.2
4.8
6.4
8.0
9.6
11.2
12.8
14.4
TIME [DAYS]

Figure 84.

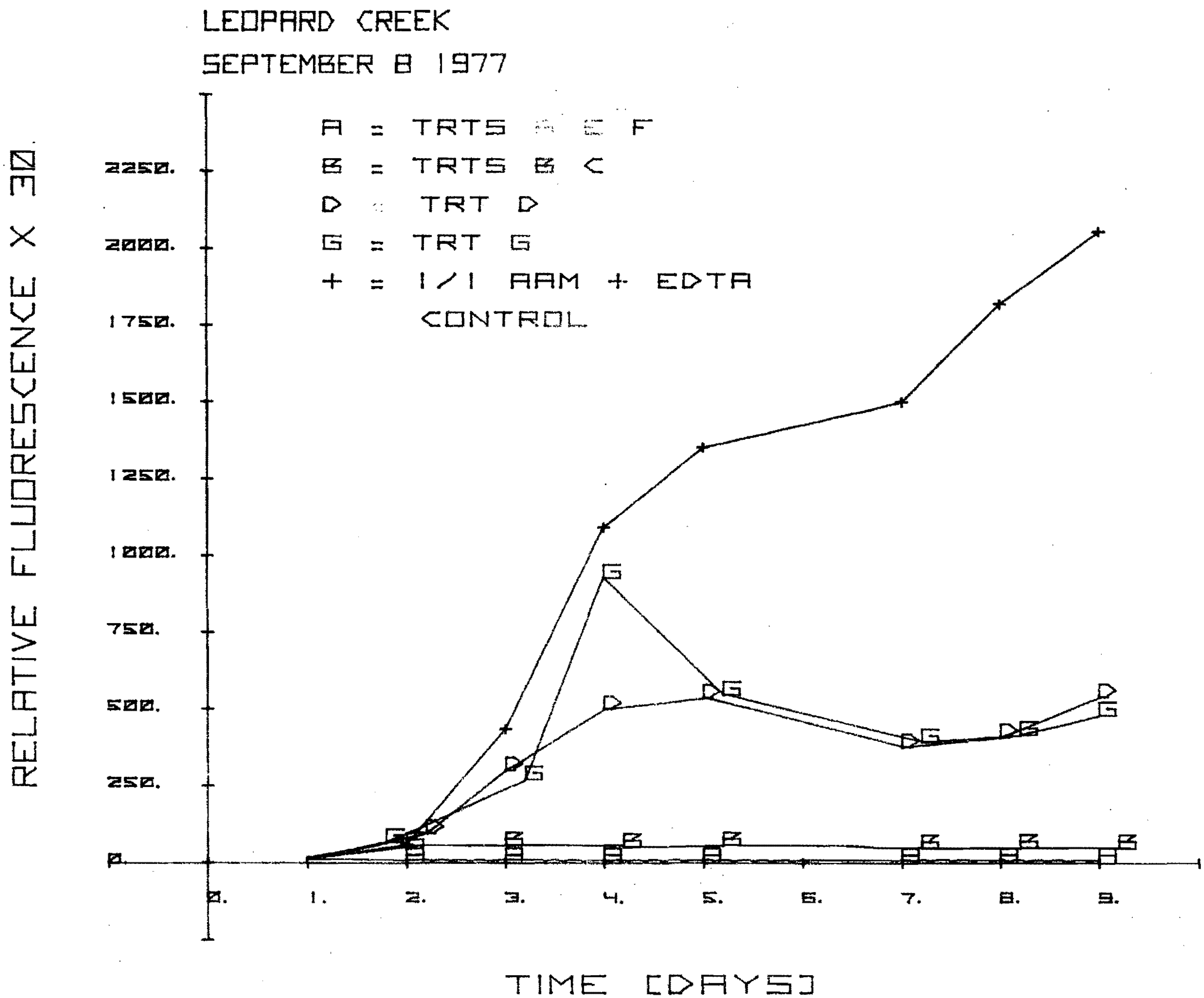

LEOPARD CREEK
SEPTEMBER 8 1977
A = TRTS A E F
B = TRTS B C
D = TRT D
G = TRT G
+ = 1/1 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 85.

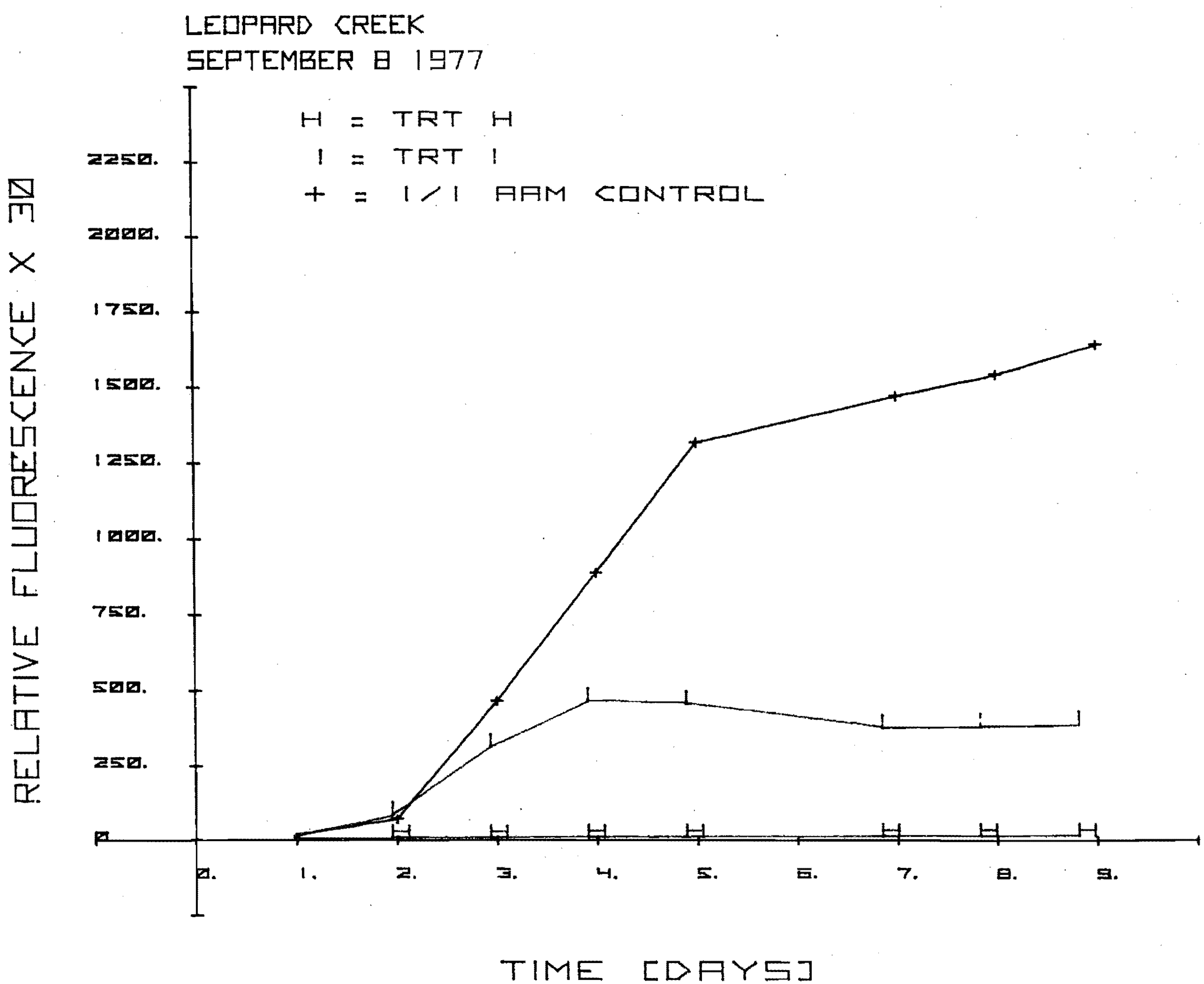
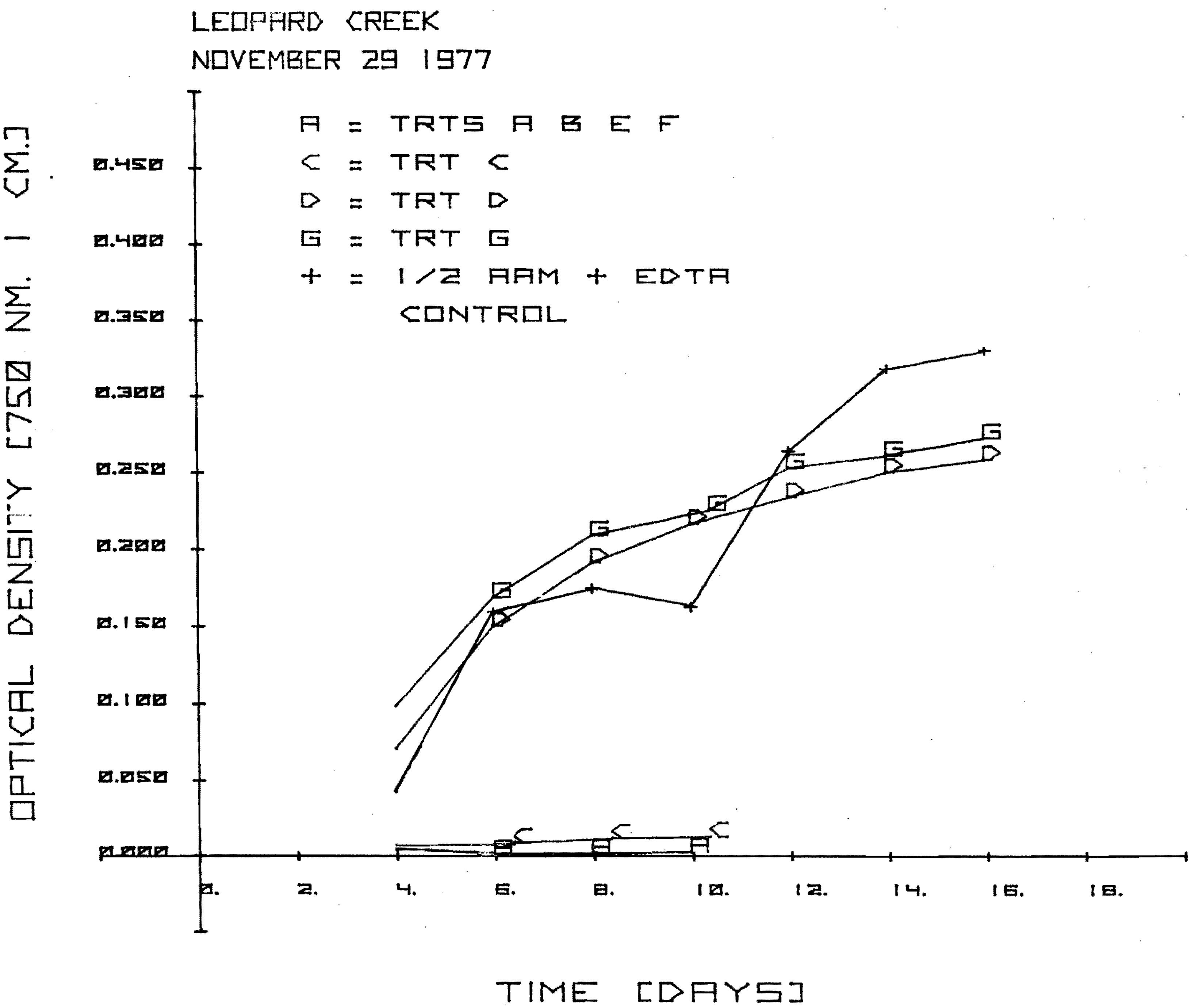

LEOPARD CREEK
SEPTEMBER 8 1977
H = TRT H
I = TRT I
+ = 1/1 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 86.



LEOPARD CREEK
NOVEMBER 29 1977
A = TRTS A B E F
< = TRT <
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.000
0.050
0.100
0.150
0.200
0.250
0.300
0.350
0.400
0.450
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 87.

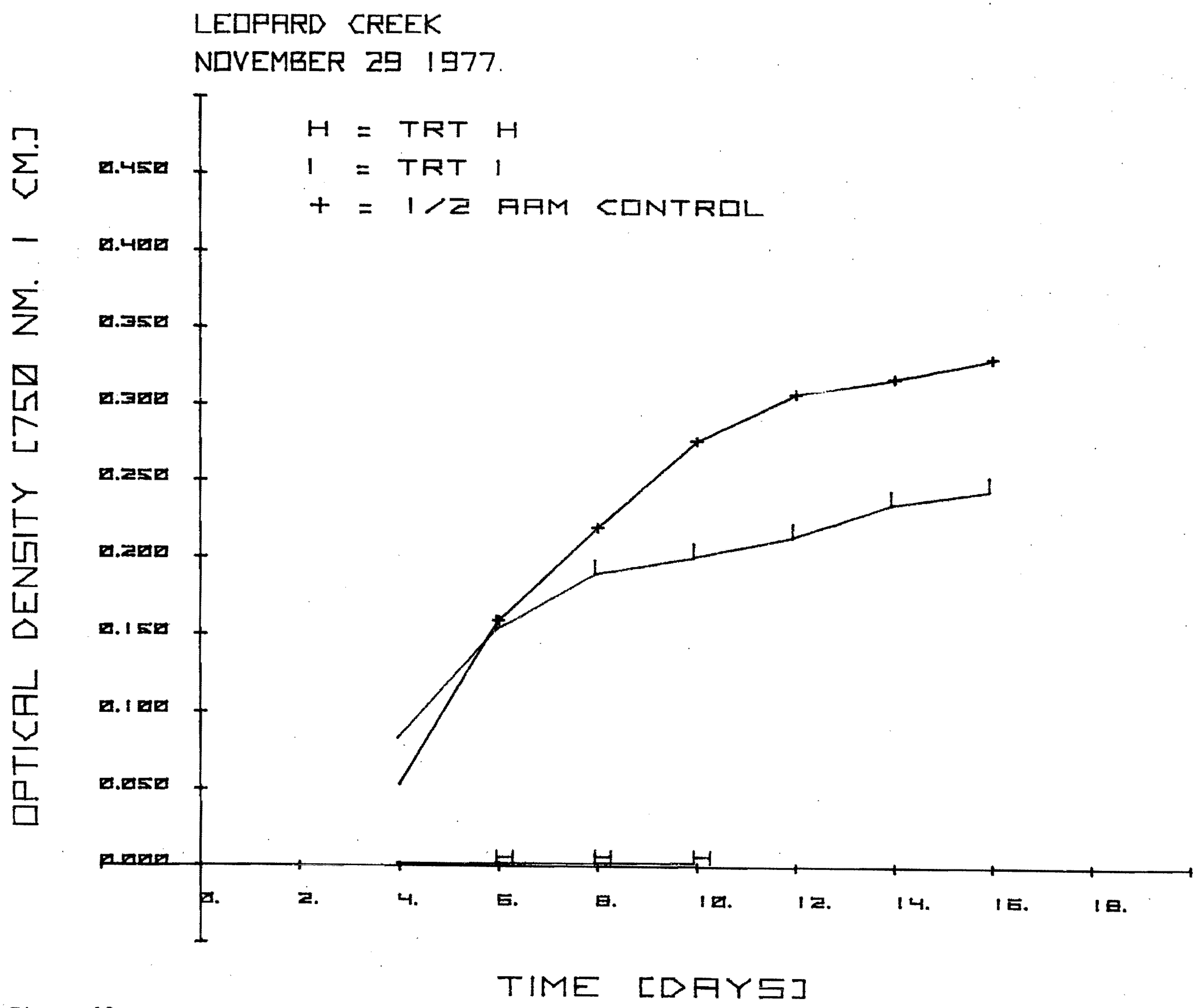

LEOPARD CREEK
NOVEMBER 29 1977
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 88.

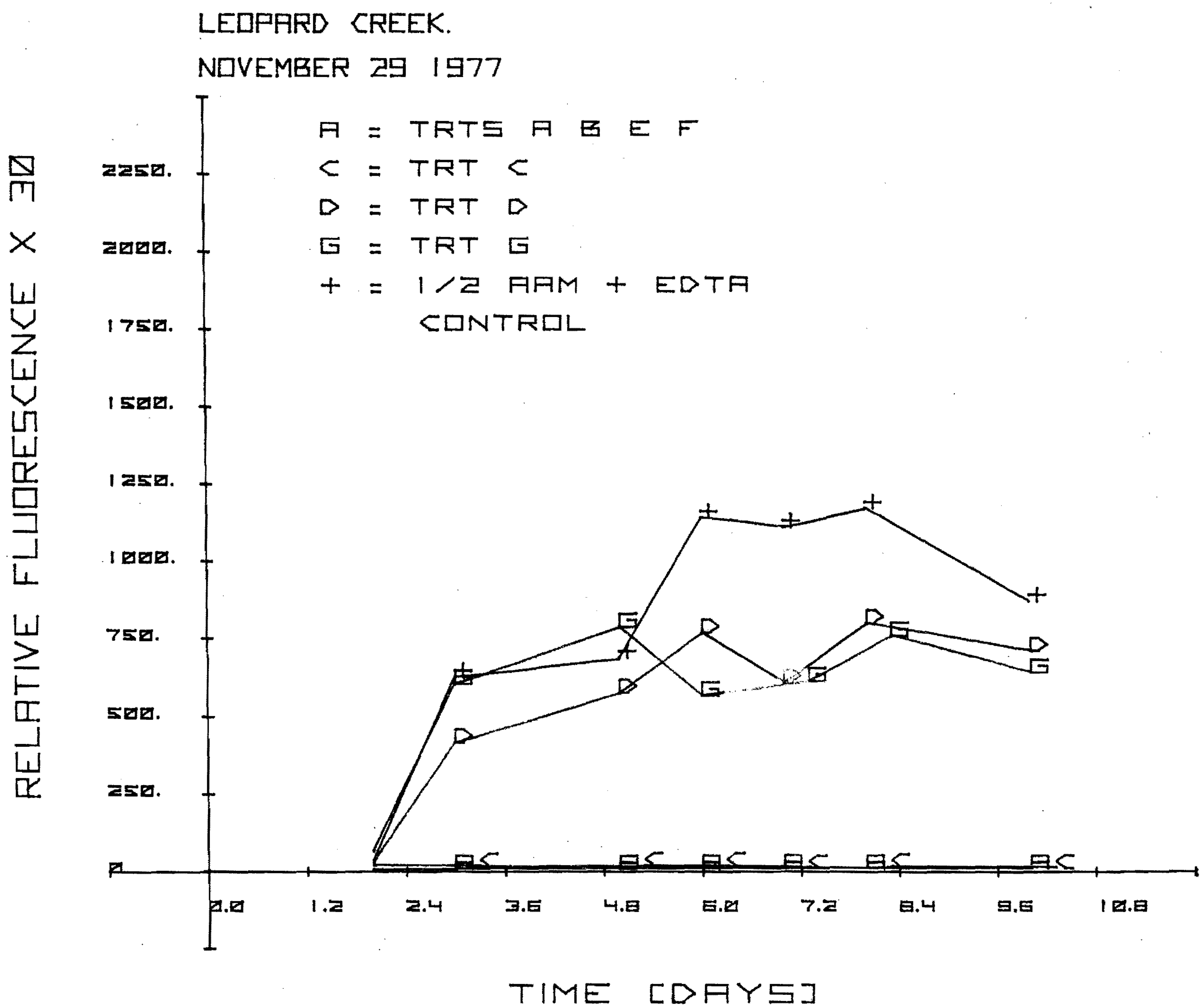
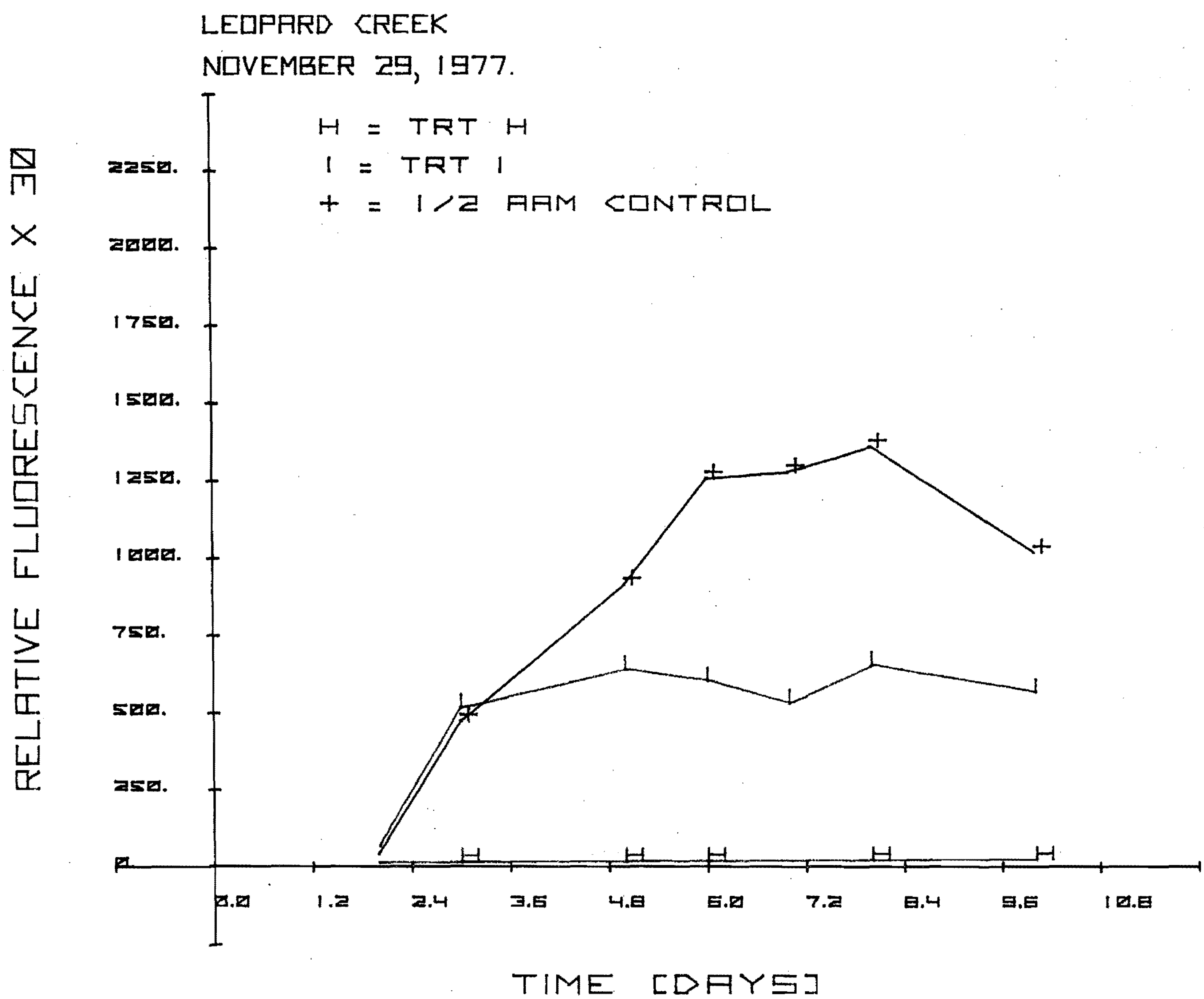

LEOPARD CREEK.
NOVEMBER 29 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.0
1.2
2.4
3.6
4.8
6.0
7.2
8.4
9.6
10.8
TIME [DAYS]

Figure 89.



LEOPARD CREEK
NOVEMBER 29, 1977.
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.0
1.2
2.4
3.6
4.8
6.0
7.2
8.4
9.6
10.8
TIME (DAYS)

Figure 90.

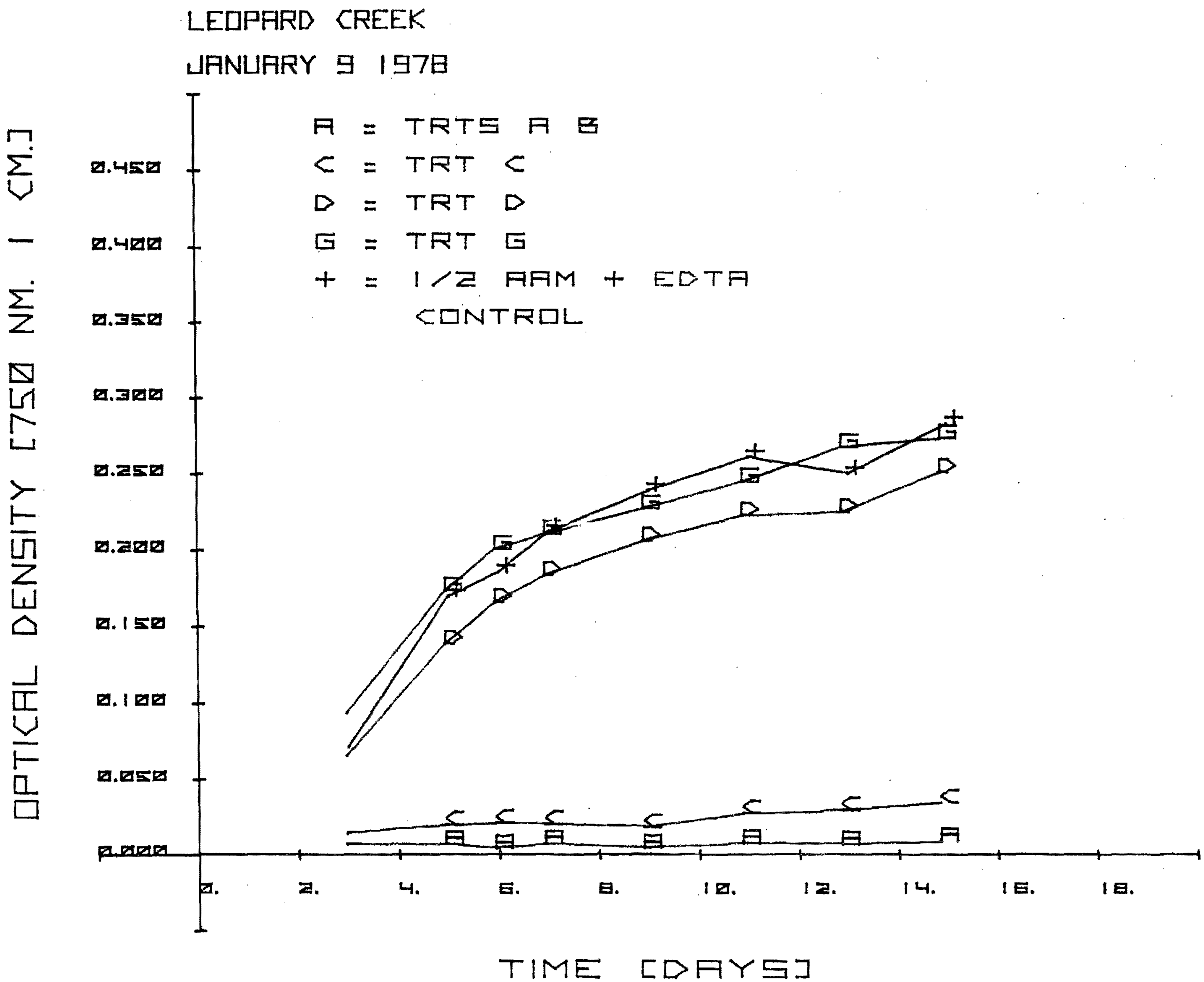

LEOPARD CREEK
JANUARY 9 1978
A = TRTS A B
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 91.

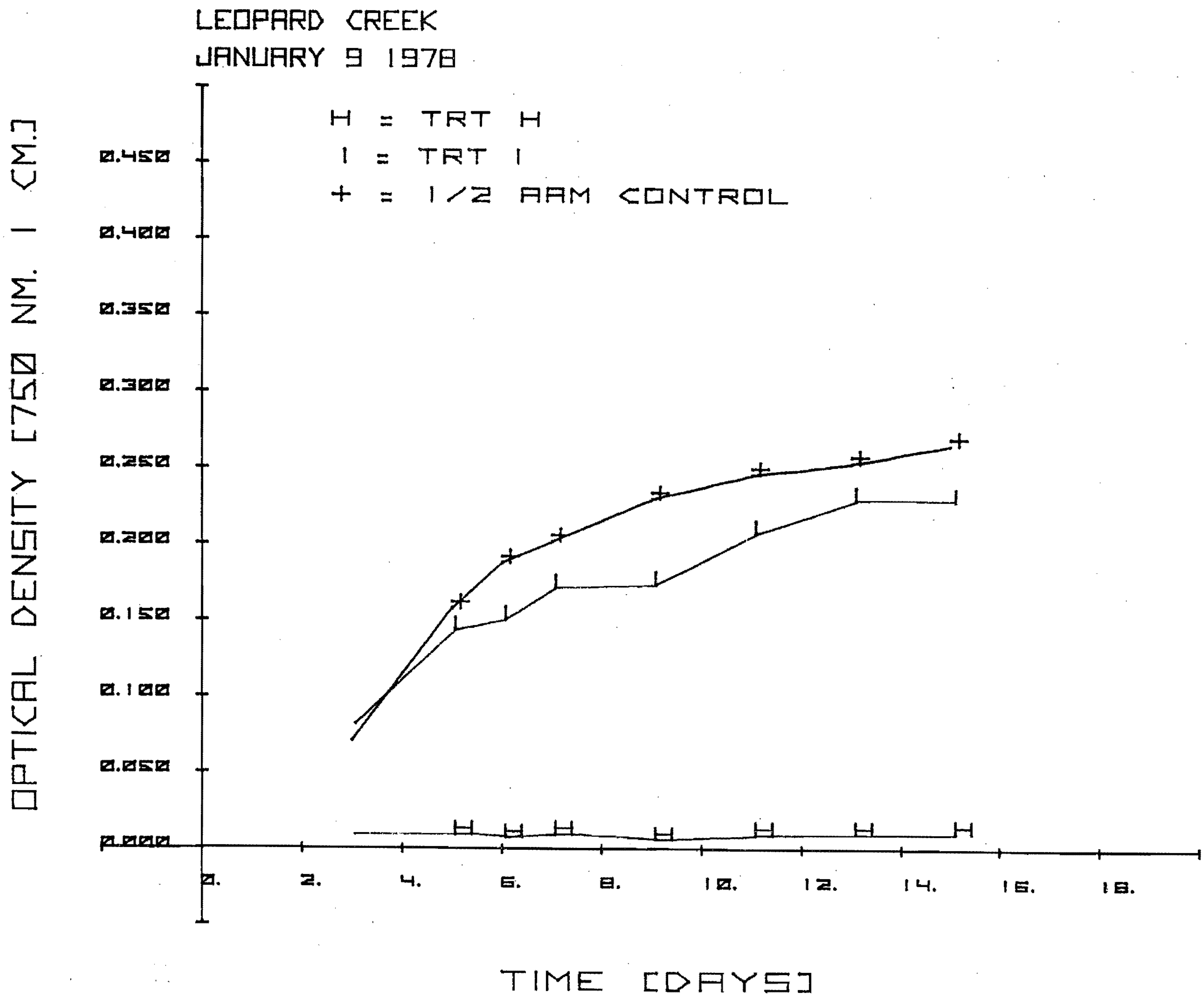

LEOPARD CREEK
JANUARY 9 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 92.

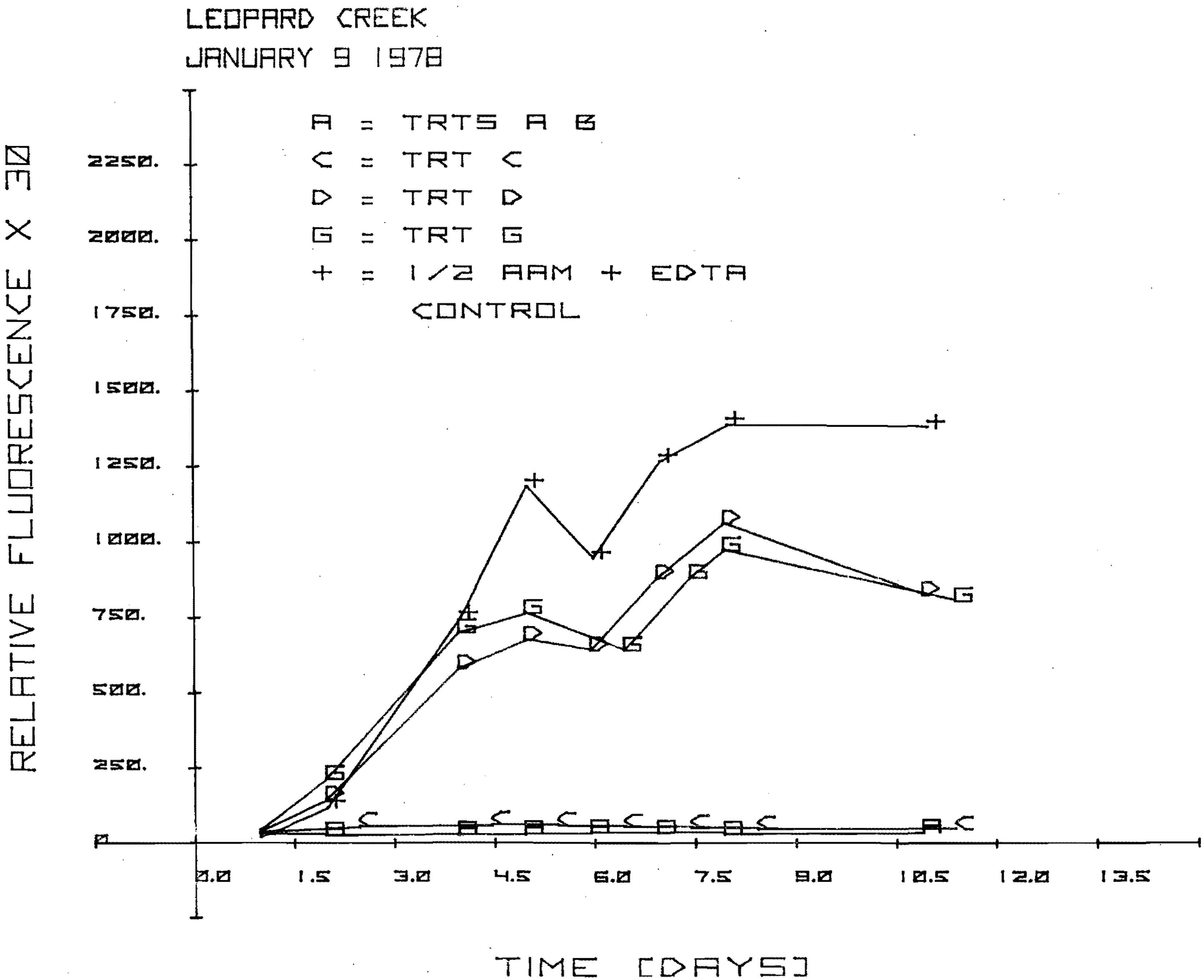

LEOPARD CREEK
JANUARY 9 1978
A = TRTS A B
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 93.

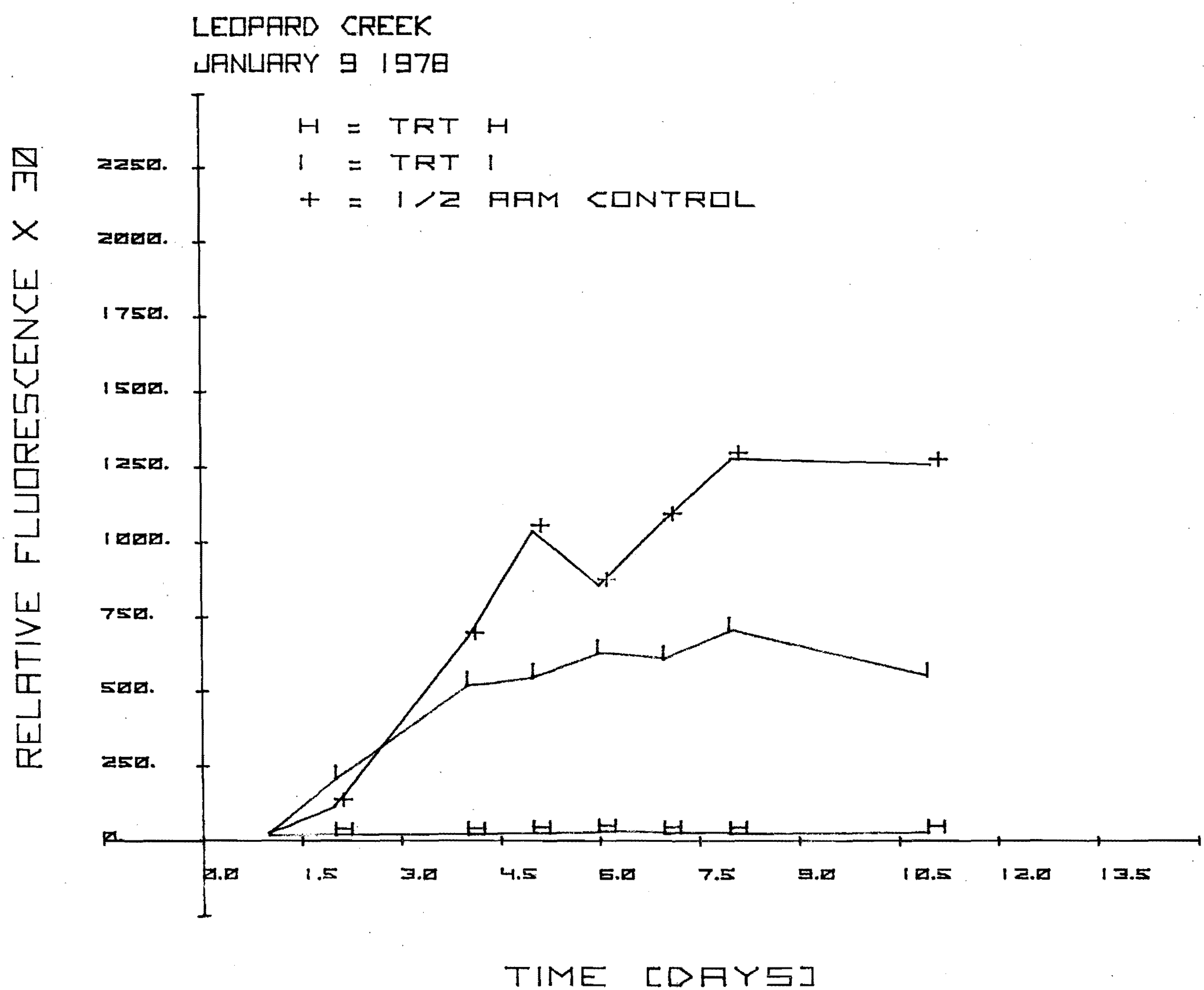

LEOPARD CREEK
JANUARY 9 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME (DAYS)

Figure 94.

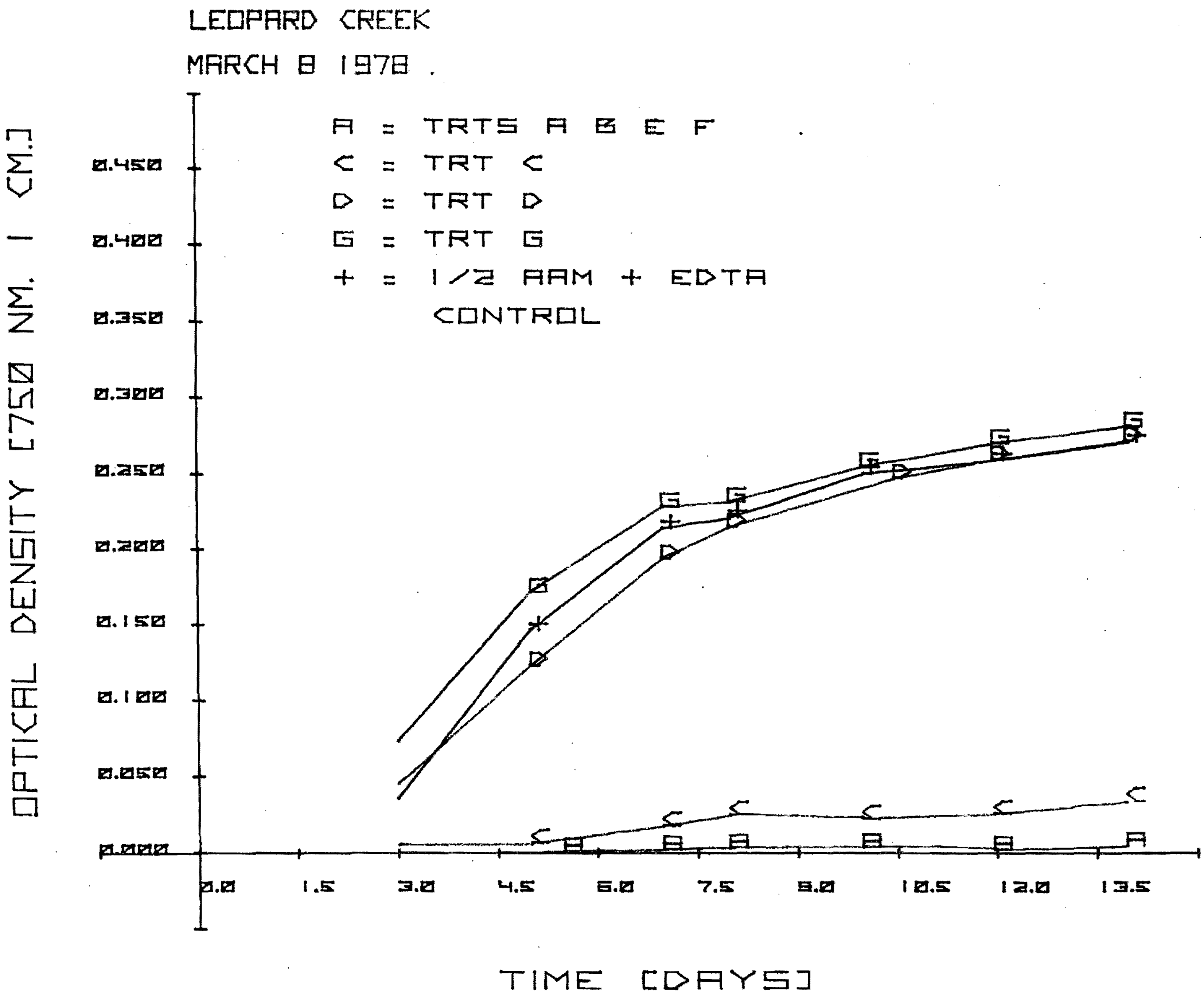

LEOPARD CREEK
MARCH 8 1978 .
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 95.

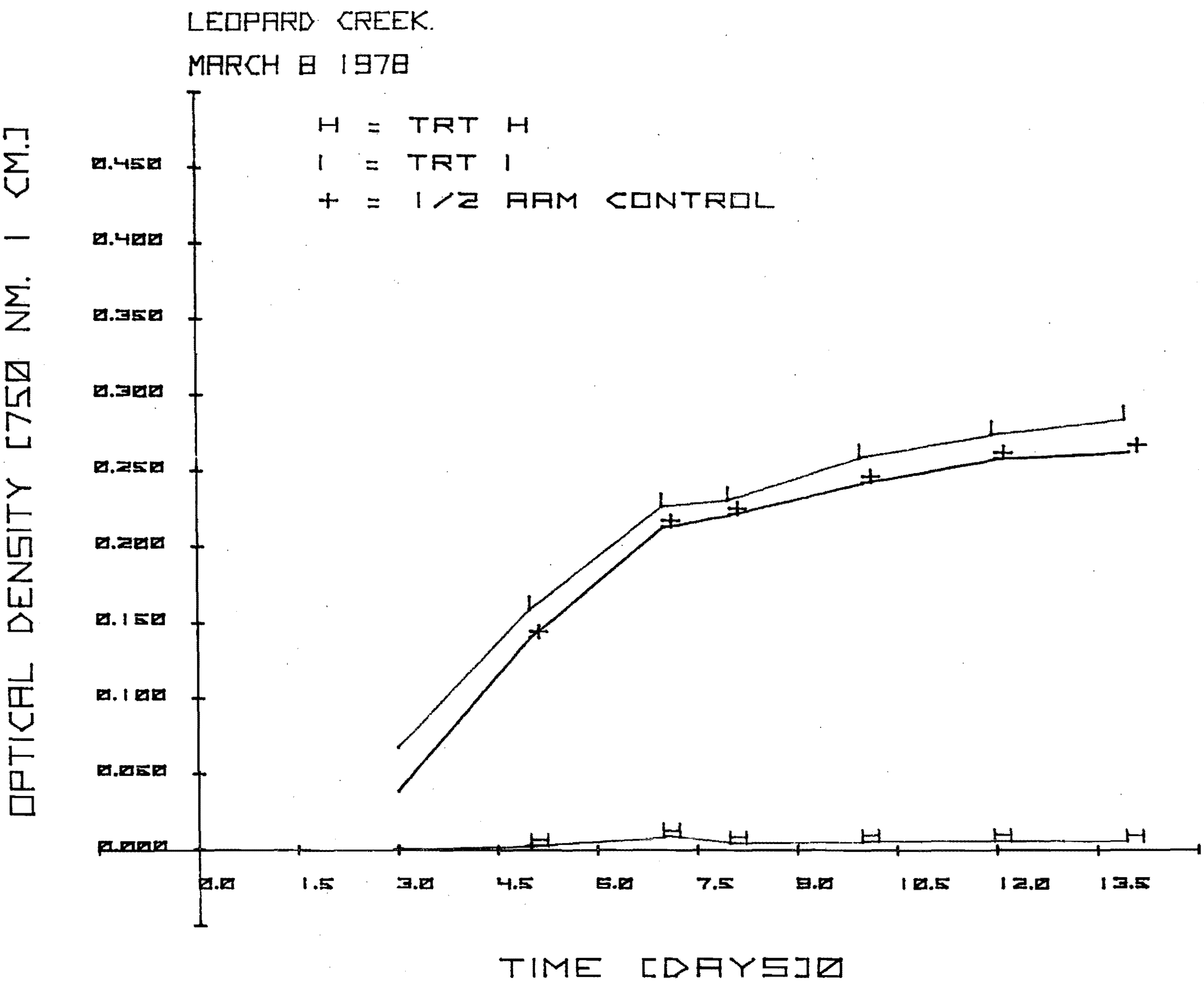
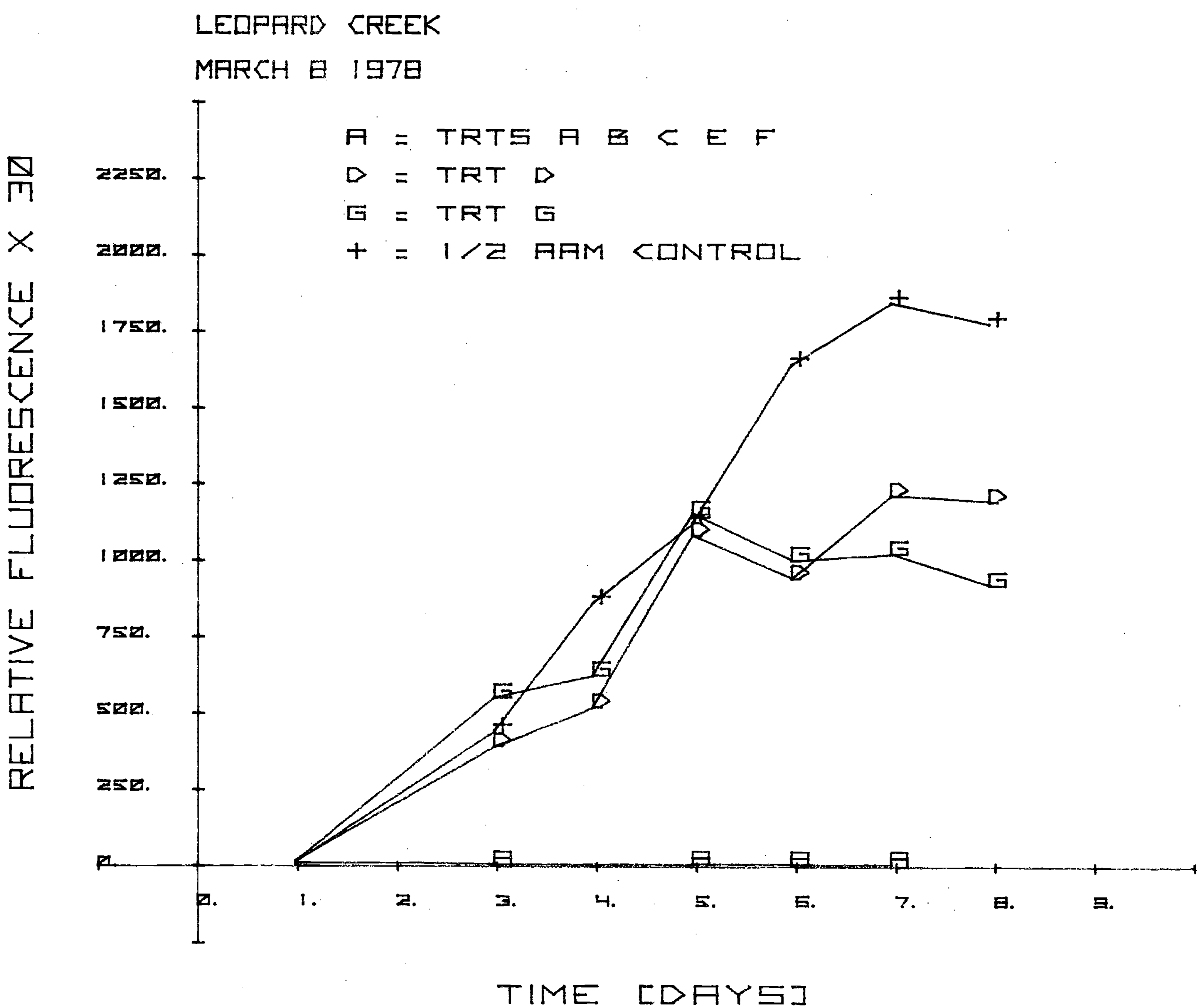

LEOPARD CREEK.
MARCH 8 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. I CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]0

Figure 96.



LEOPARD CREEK
MARCH 8 1978
A = TRTS A B C E F
D = TRT D
G = TRT G
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 97.

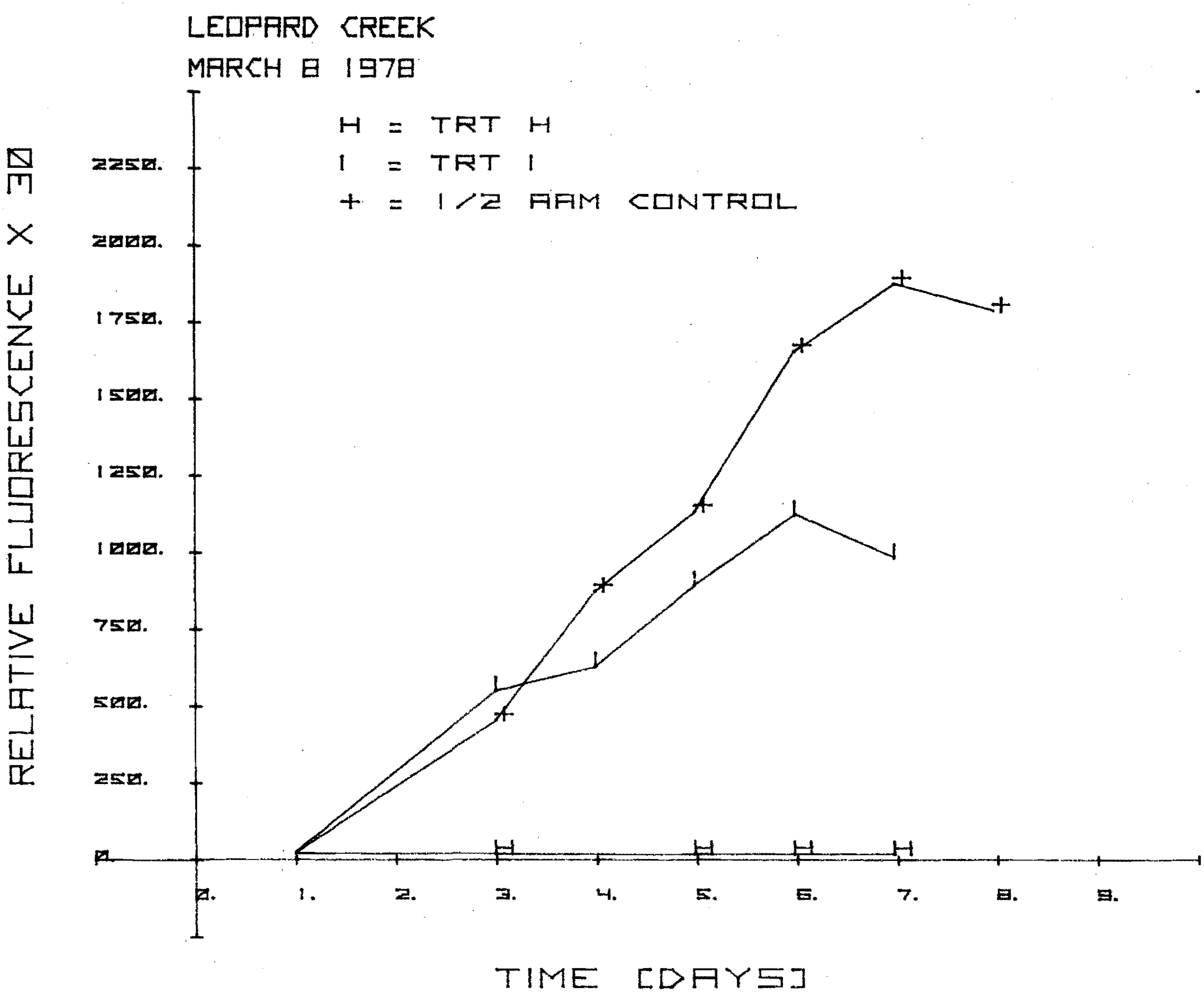

LEOPARD CREEK
MARCH 8 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME (DAYS)

Figure 98.

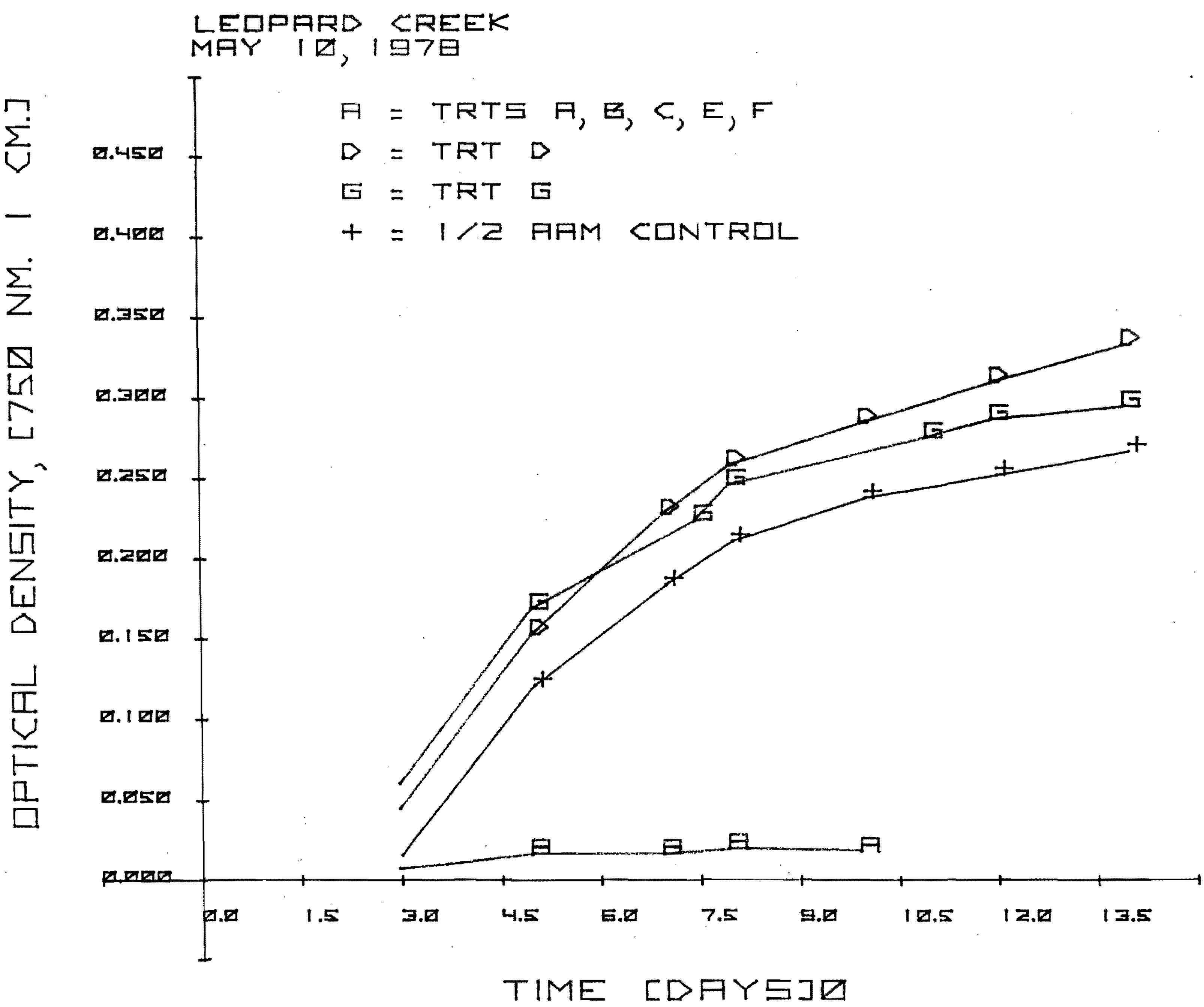

LEOPARD CREEK
MAY 10, 1978
A = TRTS A, B, C, E, F
D = TRT D
G = TRT G
+ = 1/2 AAM CONTROL
OPTICAL DENSITY, [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]0

Figure 99.

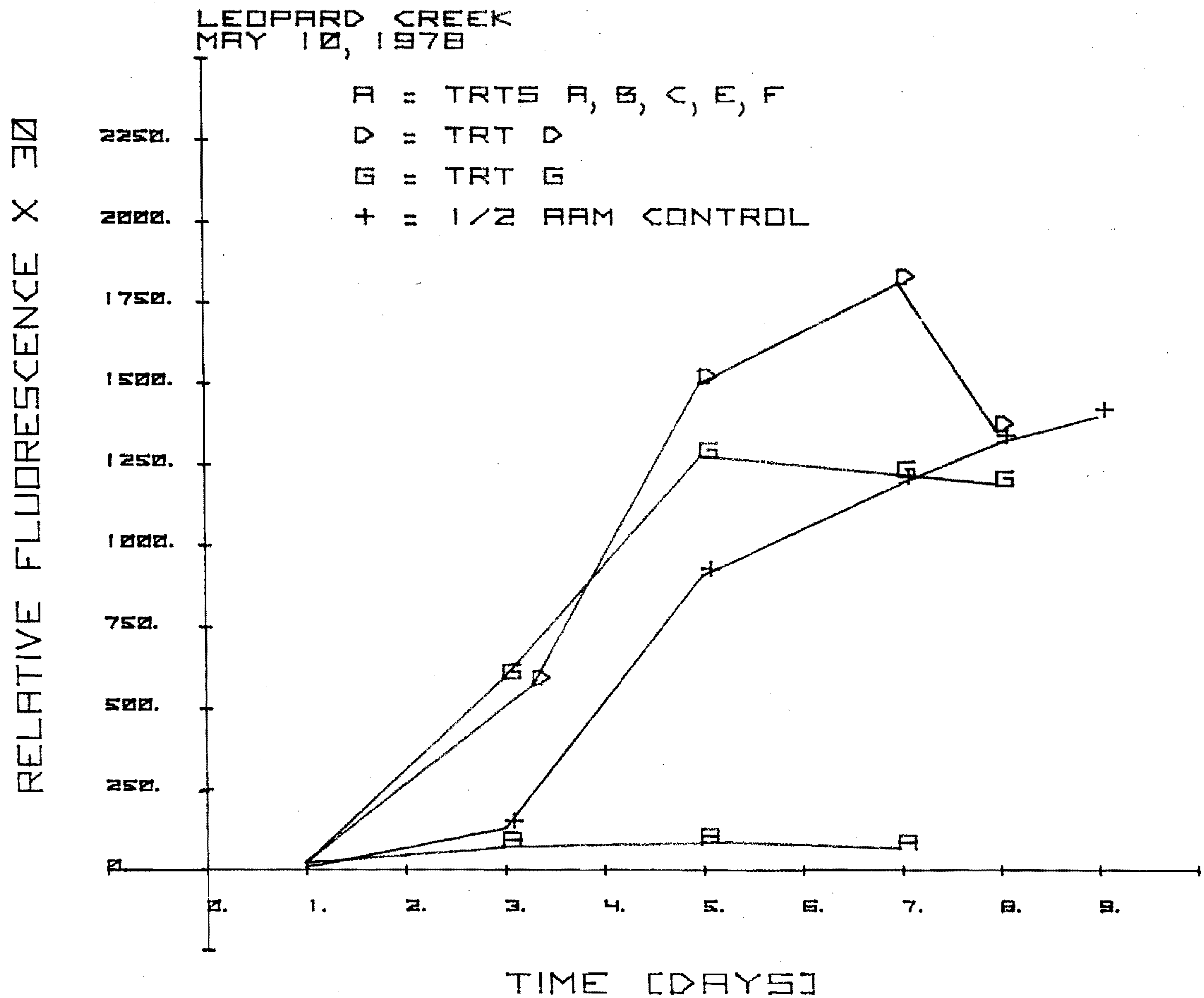

LEOPARD CREEK
MAY 10, 1978
A = TRTS A, B, C, E, F
D = TRT D
G = TRT G
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 100.

D. West Divide Project

Colorado River at Newcastle (upstream) (Figures 101 - 114)

Colorado River at Newcastle (downstream) (Figures 115 - 128)

The results of the bioassays on these two sites will be presented together because the two mimick each other so closely. The initial bioassay in November, 1977 indicated a tendency toward nitrogen limitation based on chemical analysis alone. However the bioassay procedure pointed in the opposite direction of an N and P limitation with phosphorus being the most limiting. Bioassays during the following months reflected a similar tendency of both nitrogen and phosphorus limitation and chemical analysis correlated a bit more closely than before.

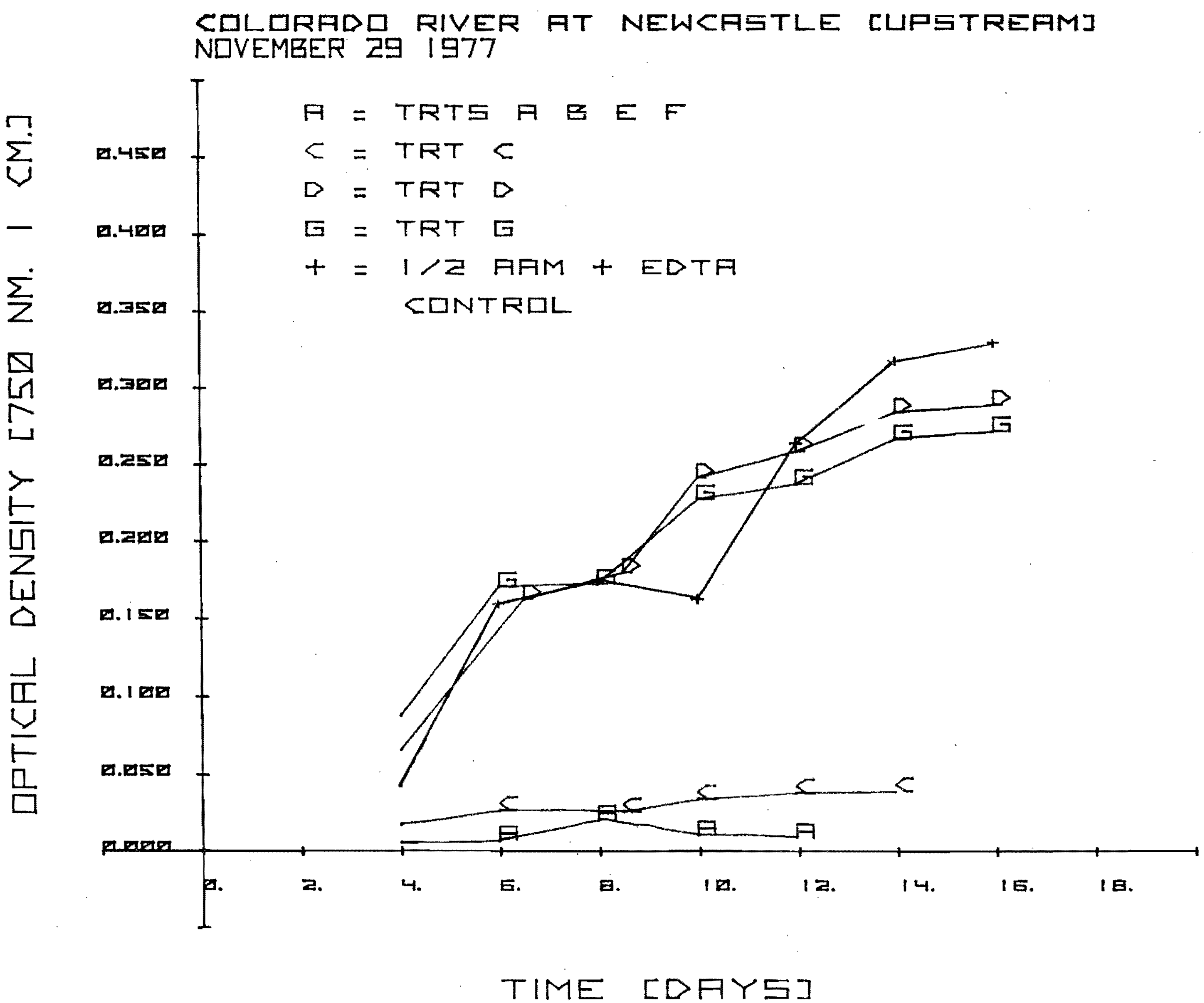
Conclusions:

1. The samples were limited by both nitrogen and phosphorus during each sampling period with phosphorus being the most limiting.
2. Algal bioassays correlated well with chemical analysis except during November, 1977 when nutrient concentrations were so low an accurate assumption could not be made on chemical analysis alone.
3. No metal toxicity was observed.
4. At the present time this body of water would be classified as oligotrophic. The water does have a high growth potential as indicated by good response when nutrients are made available but addition of both nitrogen and phosphorus would have to occur in order for this to happen. In the short term future it appears this river will remain essentially the same.

Table 29.
West Divide Project
Limiting Nutrients

Sample	Limiting Nutrient(s)	
	Chemical Analysis	Bioassay
<u>11/29/77</u>		
Colorado River @ Newcastle (Upstream)	Nitrogen	Nitrogen & Phosphorus
Colorado River @ Newcastle (Downstream)	Nitrogen	Nitrogen & Phosphorus
<u>1/9/78</u>		
Colorado River @ Newcastle (Upstream)	Phosphorus	Phosphorus[a]
Colorado River @ Newcastle (Downstream)	Phosphorus	Phosphorus & Nitrogen
<u>3/8/78</u>		
Colorado River @ Newcastle (Upstream)	Phosphorus & Nitrogen	Phosphorus & Nitrogen
Colorado River @ Newcastle (Downstream)	Phosphorus & Nitrogen	Phosphorus & Nitrogen
<u>5/10/78</u>		
Colorado River @ Newcastle (Upstream)	Phosphorus	Phosphorus[a]
Colorado River @ Newcastle (Downstream)	Phosphorus	Phosphorus[a]

[a]Addition of phosphorus substantially increased the maximum specific growth rate, $\hat{\mu}_b$, indicating phosphorus limitation. However, due to the low level of both indigenous phosphorus and nitrogen growth was only minimal upon phosphorus addition as nitrogen became limiting as well.



COLORADO RIVER AT NEWCASTLE [UPSTREAM]
NOVEMBER 29 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 101.

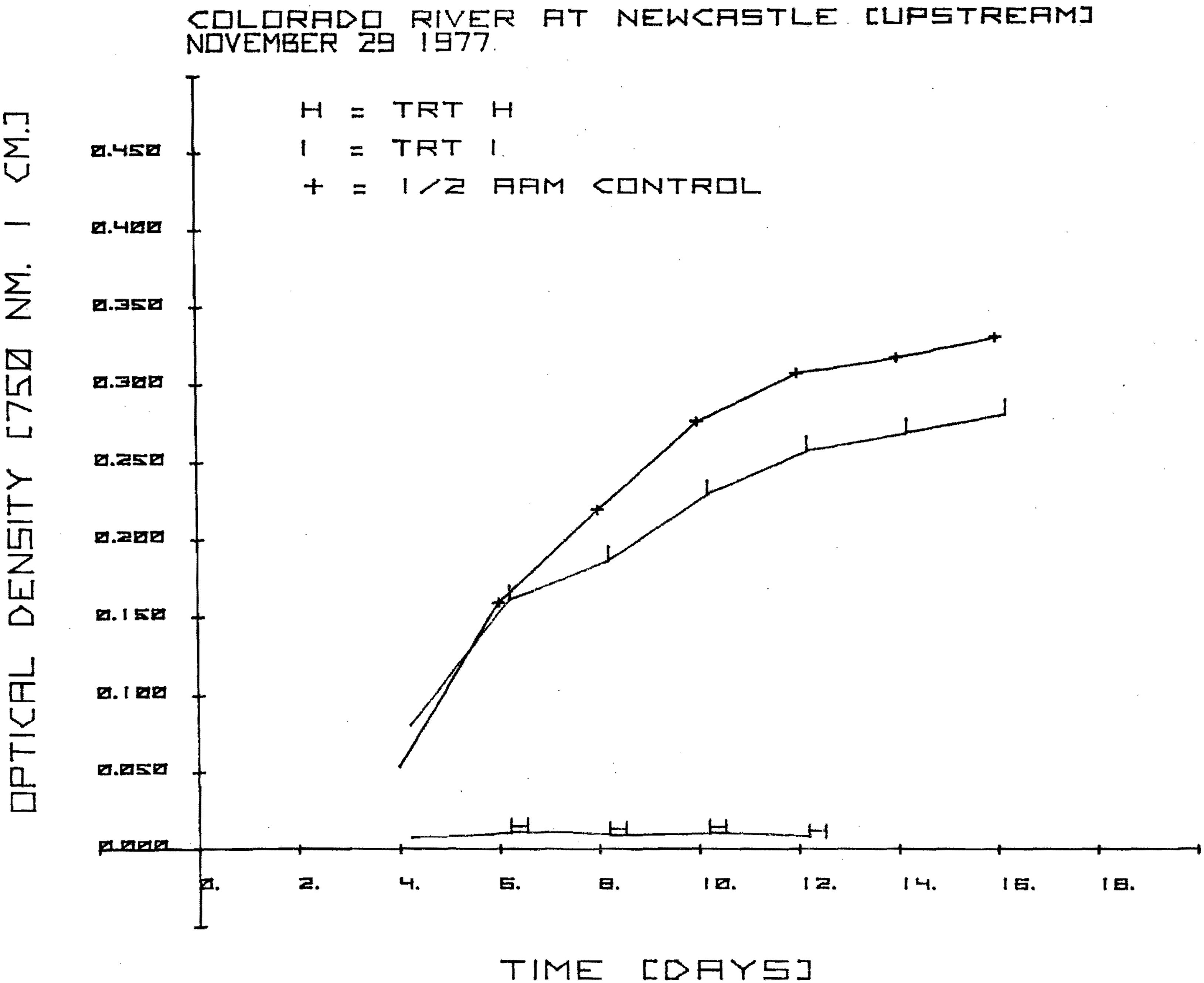
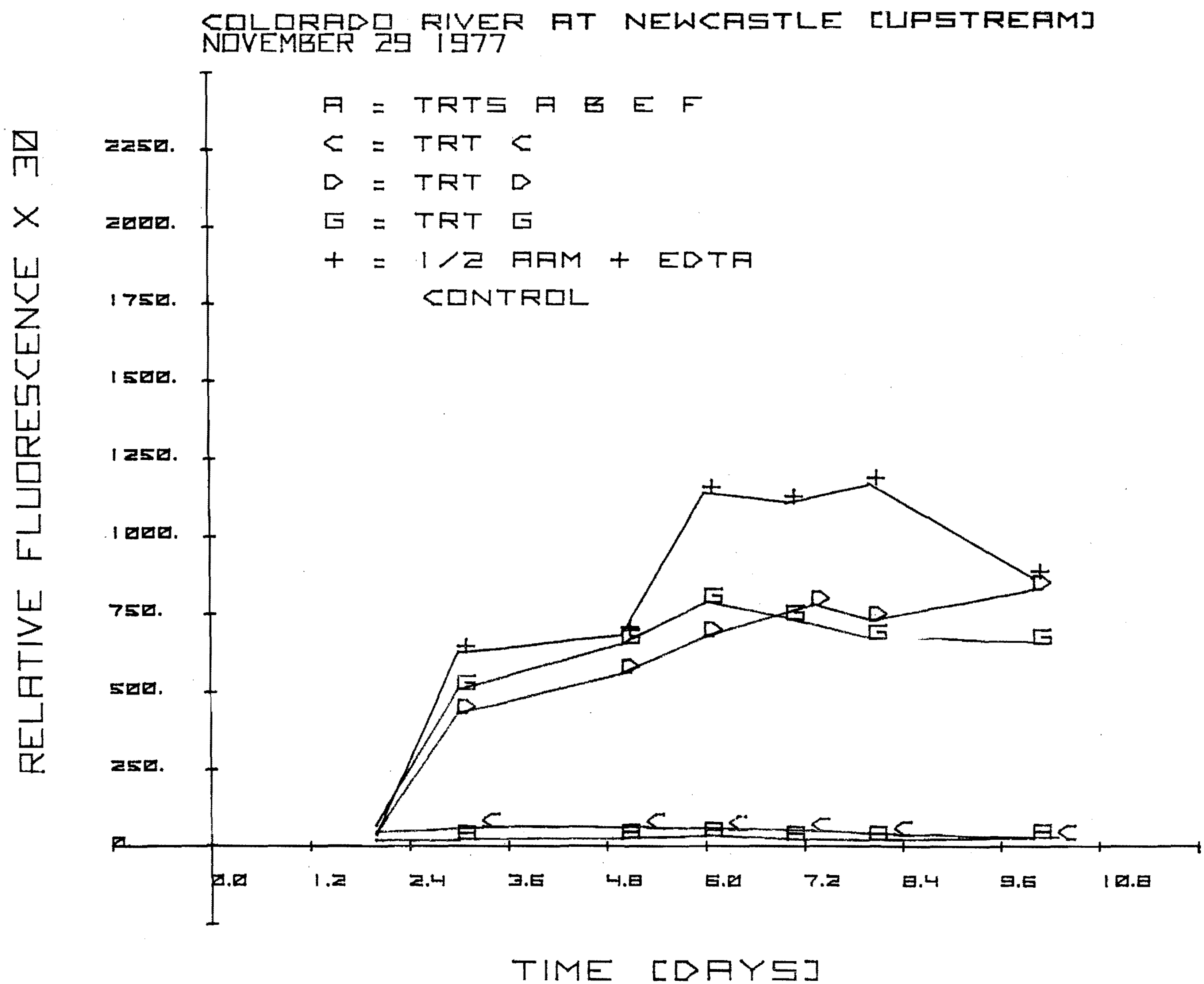

COLORADO RIVER AT NEWCASTLE [UPSTREAM]
NOVEMBER 29 1977
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 102.



COLORADO RIVER AT NEWCASTLE (UPSTREAM)
NOVEMBER 29 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.0
1.2
2.4
3.6
4.8
6.0
7.2
8.4
9.6
10.8
TIME (DAYS)

Figure 103.

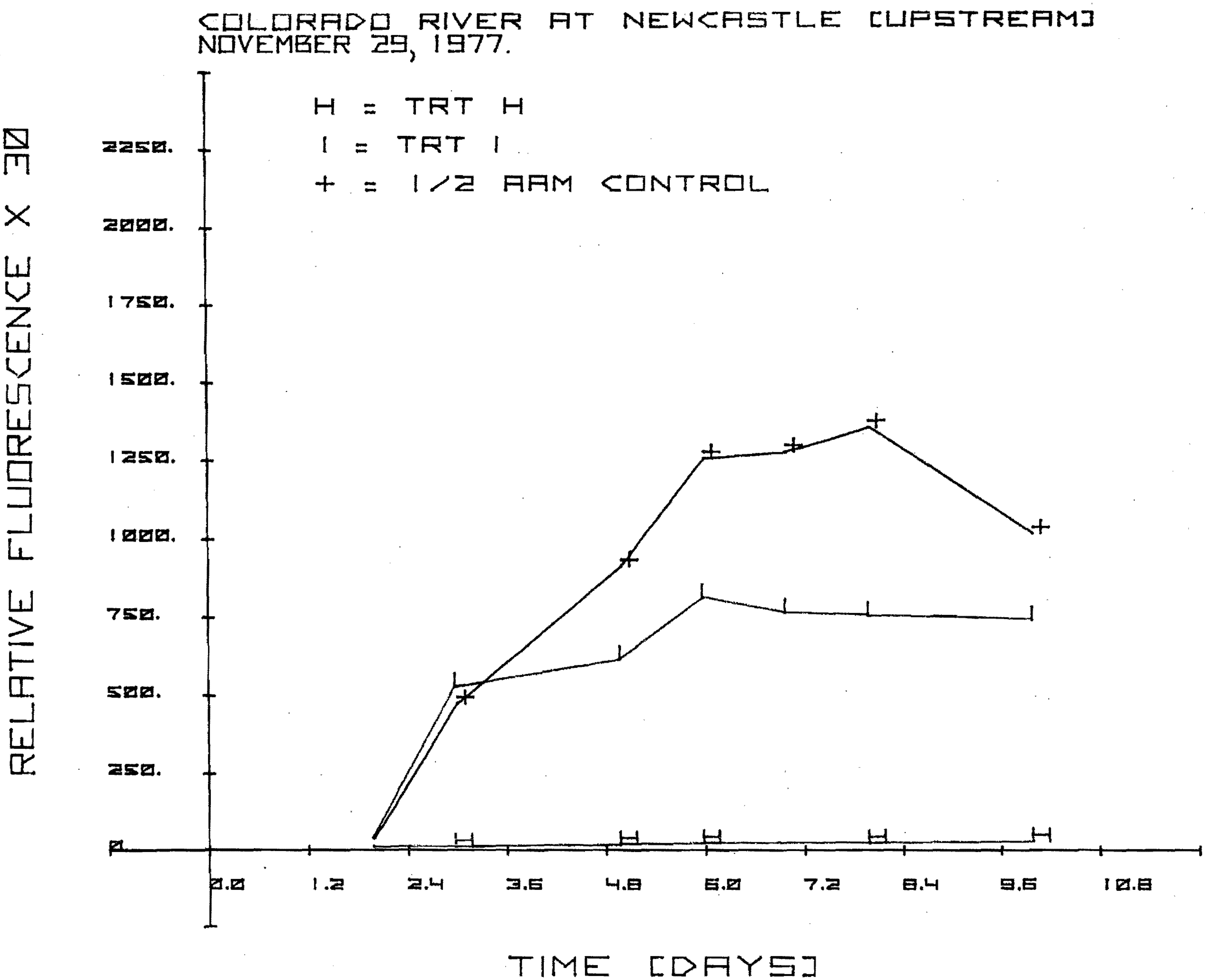
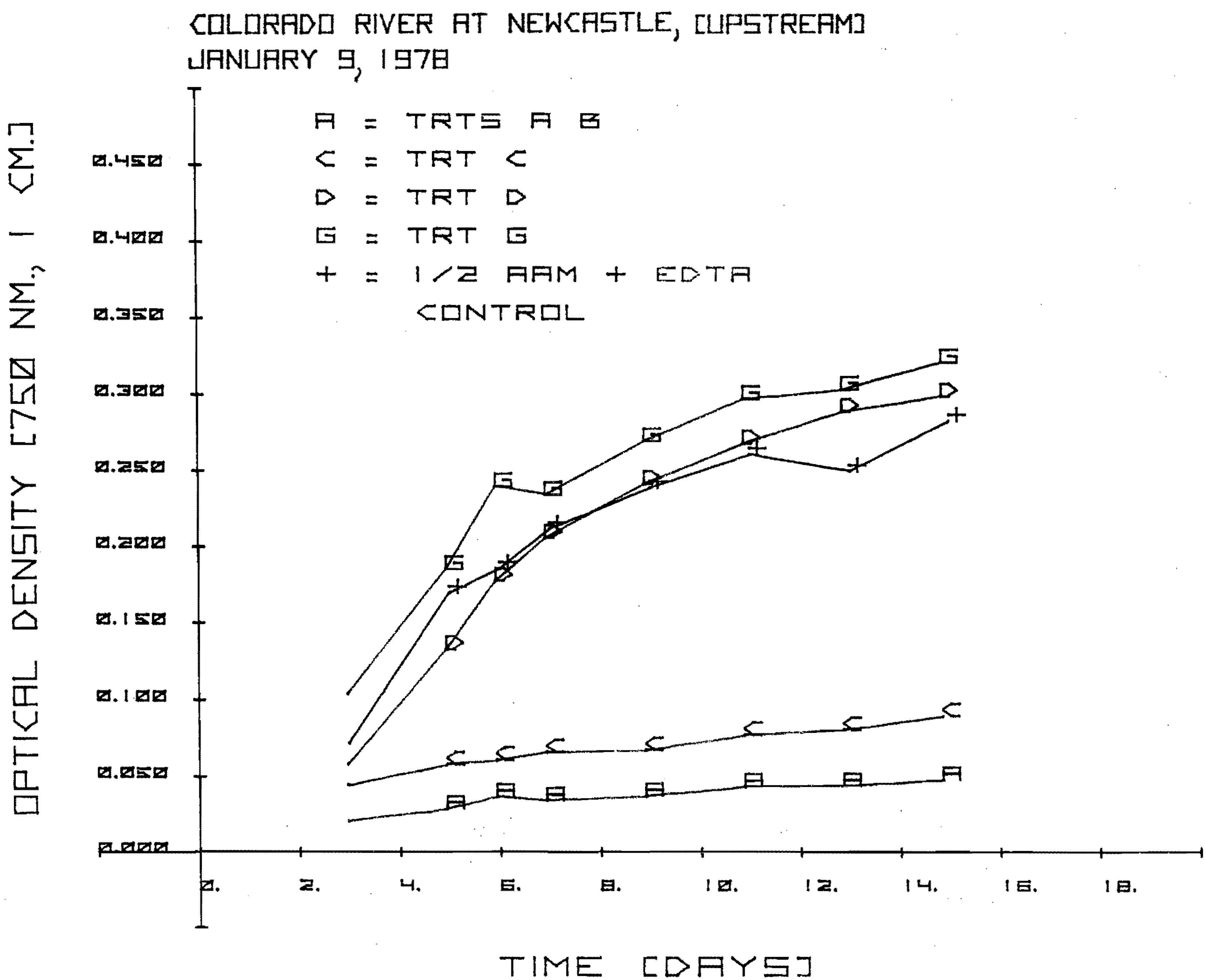

COLORADO RIVER AT NEWCASTLE [UPSTREAM]
NOVEMBER 29, 1977.
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.0
1.2
2.4
3.6
4.8
6.0
7.2
8.4
9.6
10.8
TIME [DAYS]

Figure 104.



(COLORADO RIVER AT NEWCASTLE, (UPSTREAM)
JANUARY 9, 1978
A = TRTS A B
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
(CONTROL
OPTICAL DENSITY (750 NM., 1 CM.)
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME (DAYS)

Figure 105.

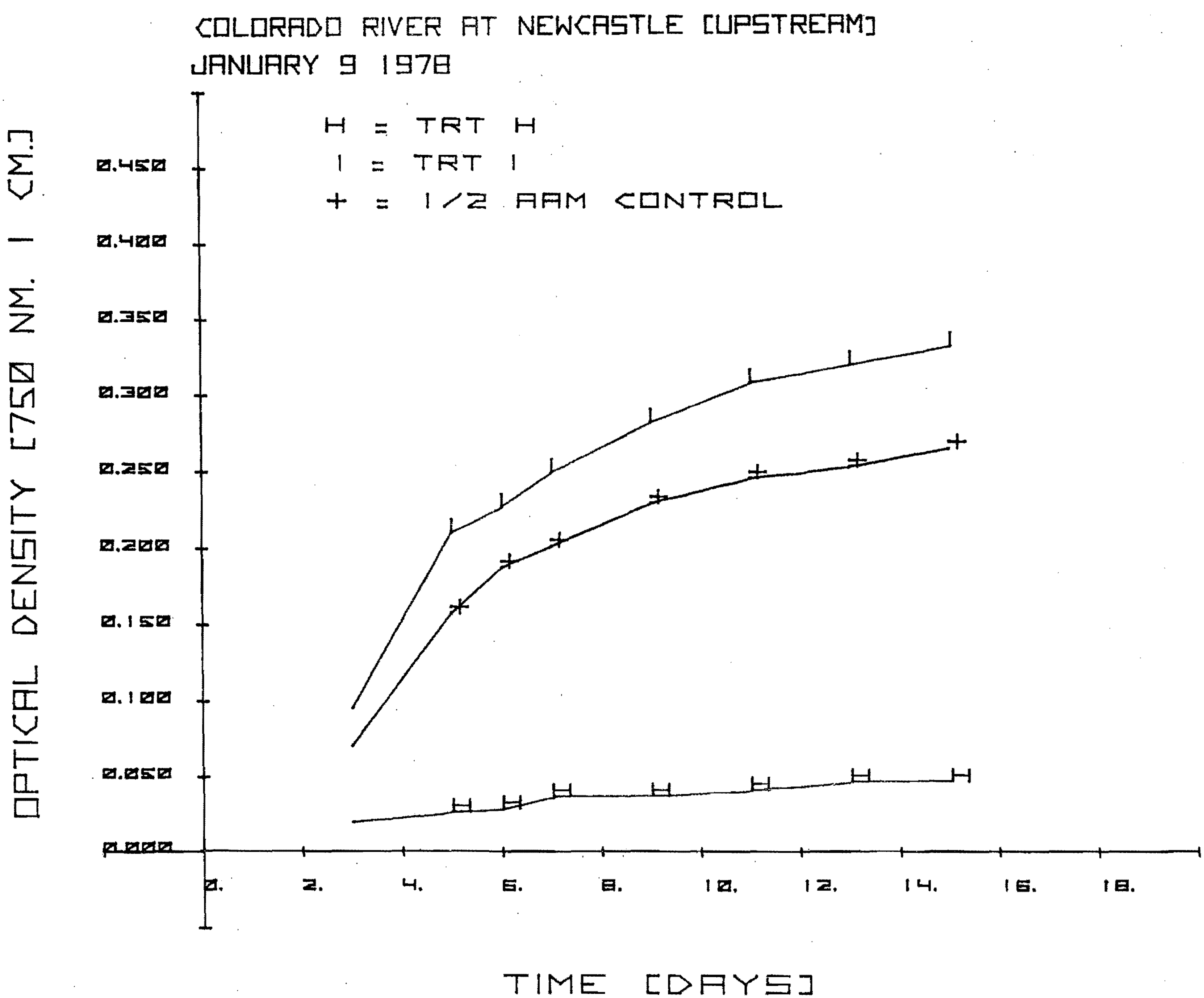

COLORADO RIVER AT NEWCASTLE [UPSTREAM]
JANUARY 9 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 106.

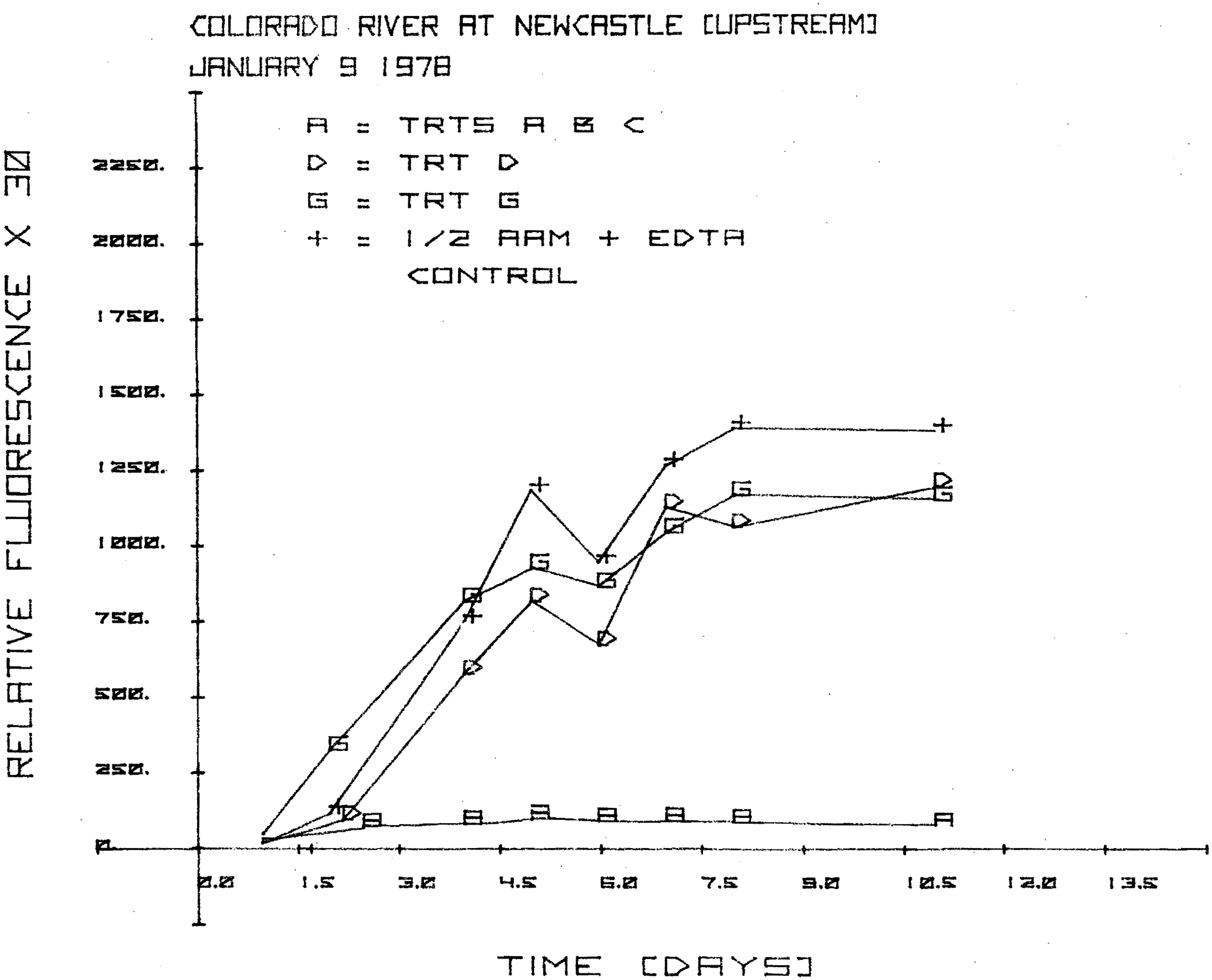
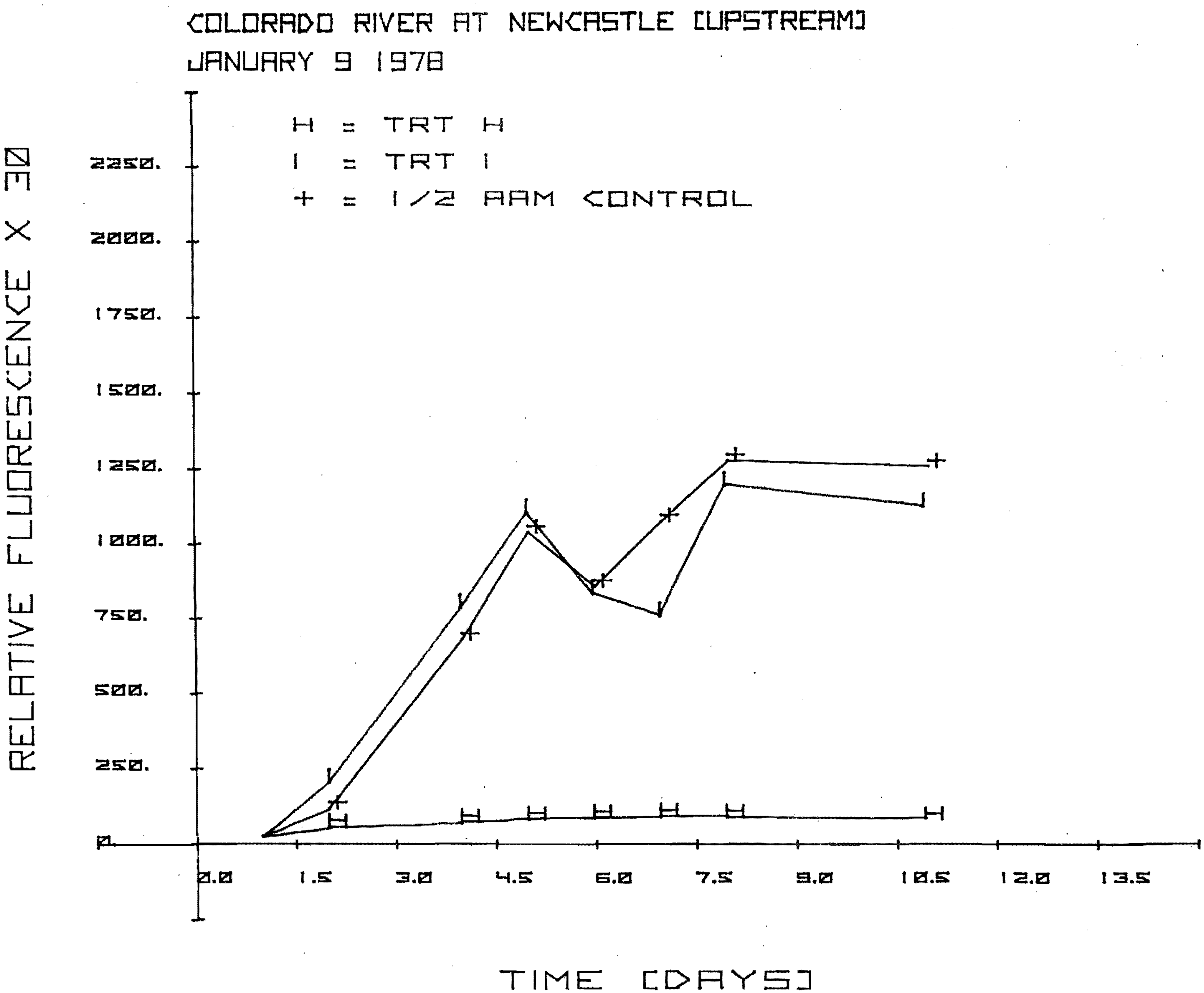

COLORADO RIVER AT NEWCASTLE [UPSTREAM]
JANUARY 9 1978
A = TRTS A B C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 107.



COLORADO RIVER AT NEWCASTLE [UPSTREAM]
JANUARY 9 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 108.

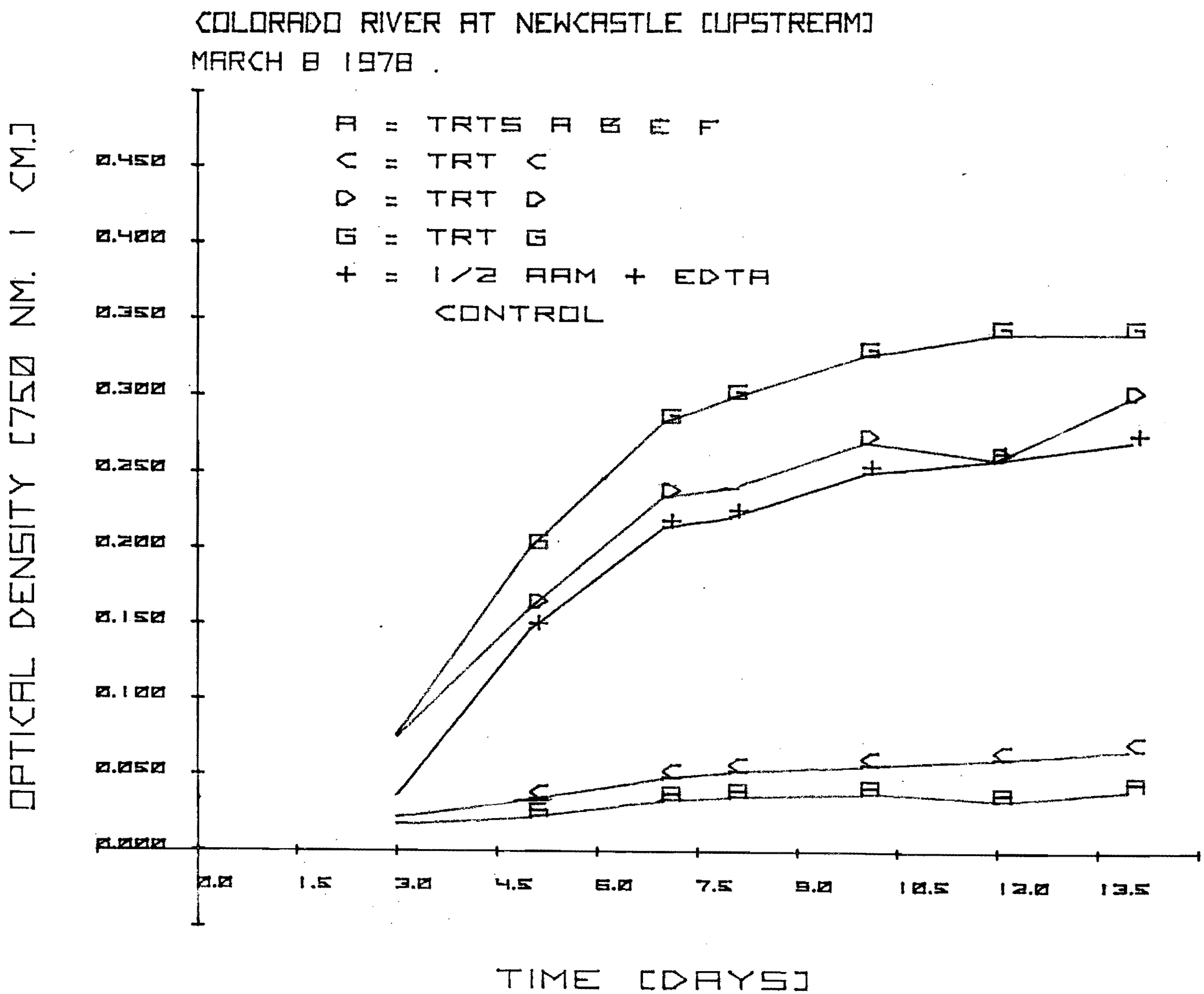

COLORADO RIVER AT NEWCASTLE [UPSTREAM]
MARCH 8 1978 .
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 109.

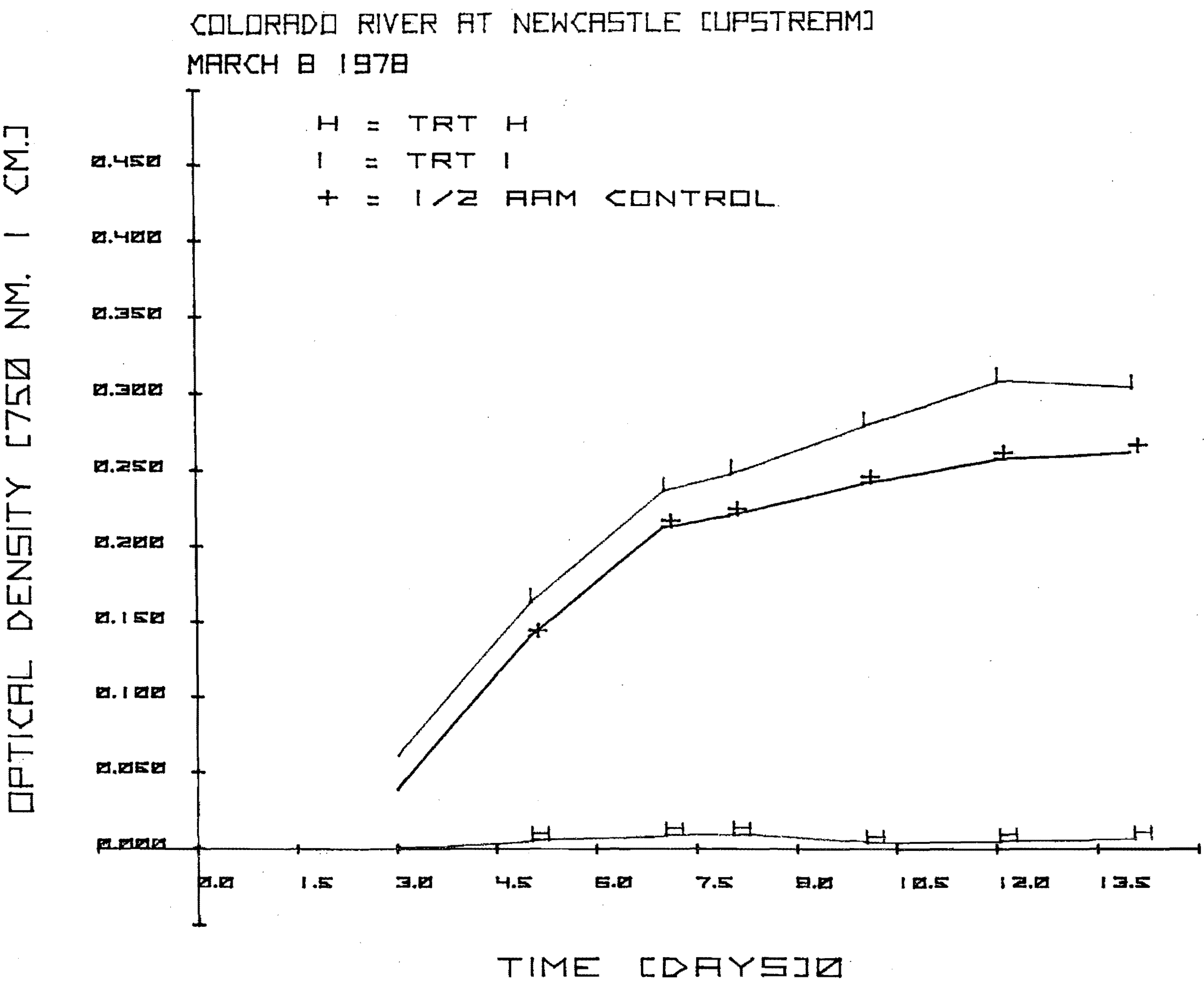

COLORADO RIVER AT NEWCASTLE [UPSTREAM]
MARCH 8 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 110.

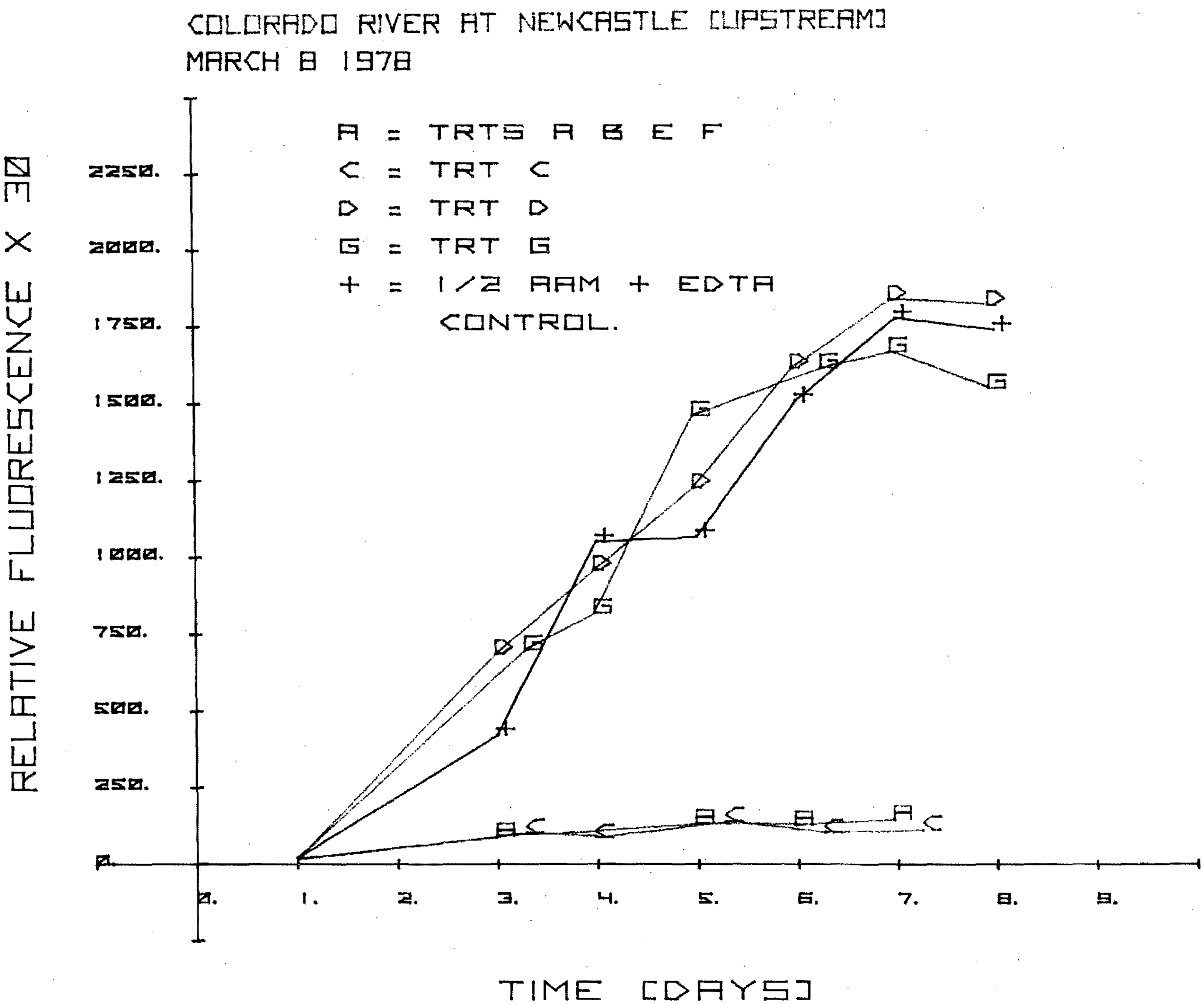
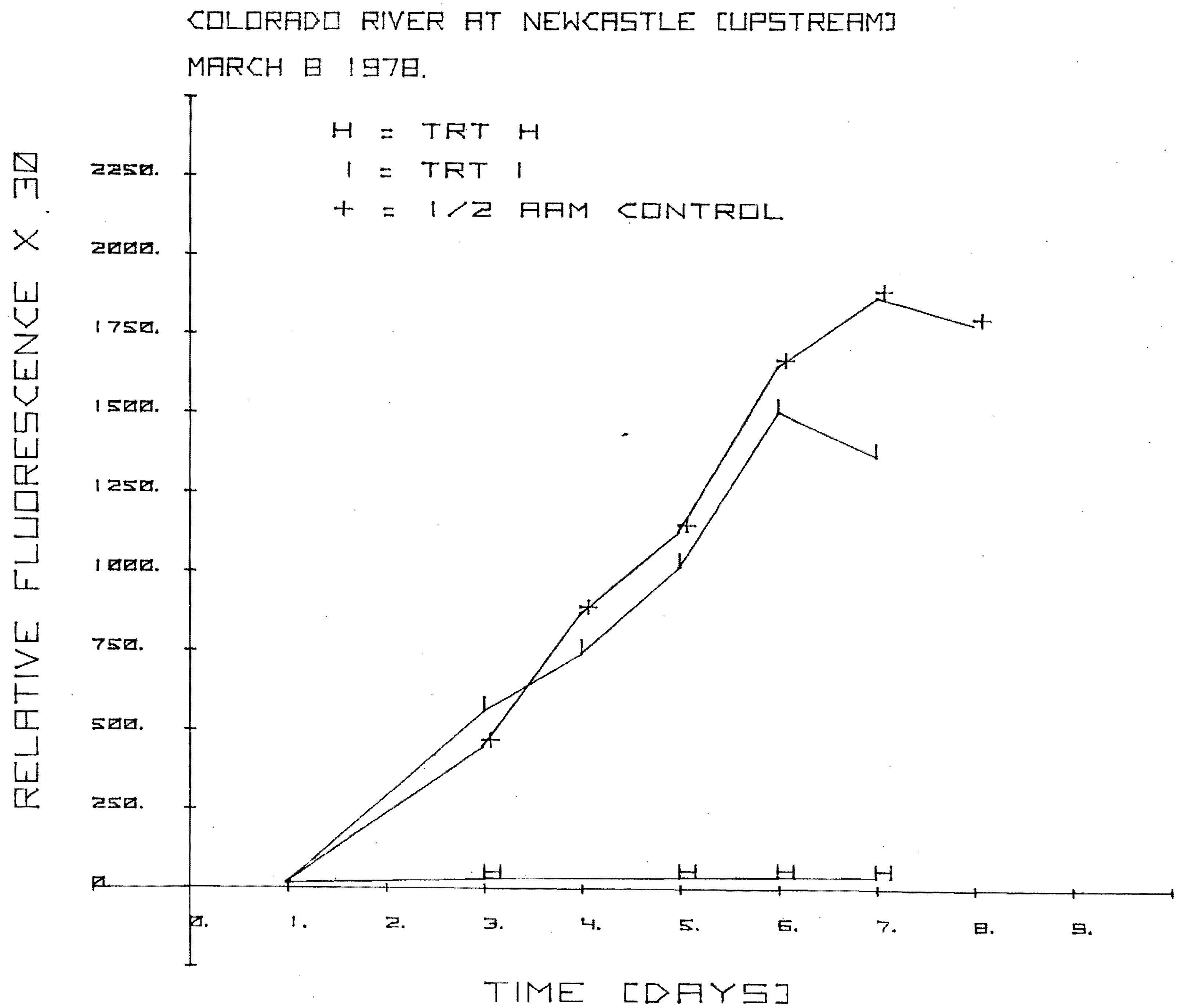

COLORADO RIVER AT NEWCASTLE [UPSTREAM]
MARCH 8 1978
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL.
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 111.



COLORADO RIVER AT NEWCASTLE (UPSTREAM)
MARCH 8 1978.
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME (DAYS)

Figure 112.

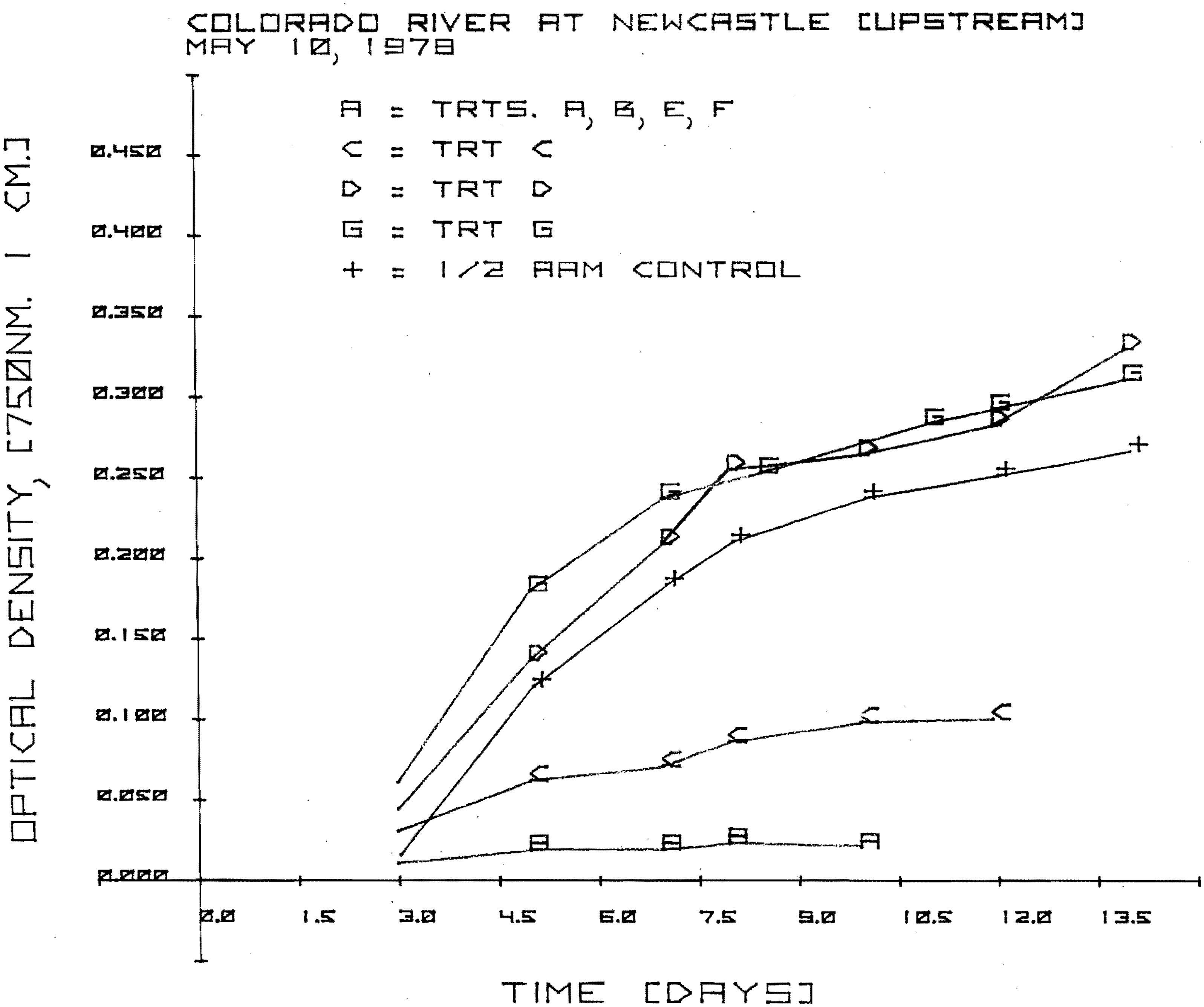
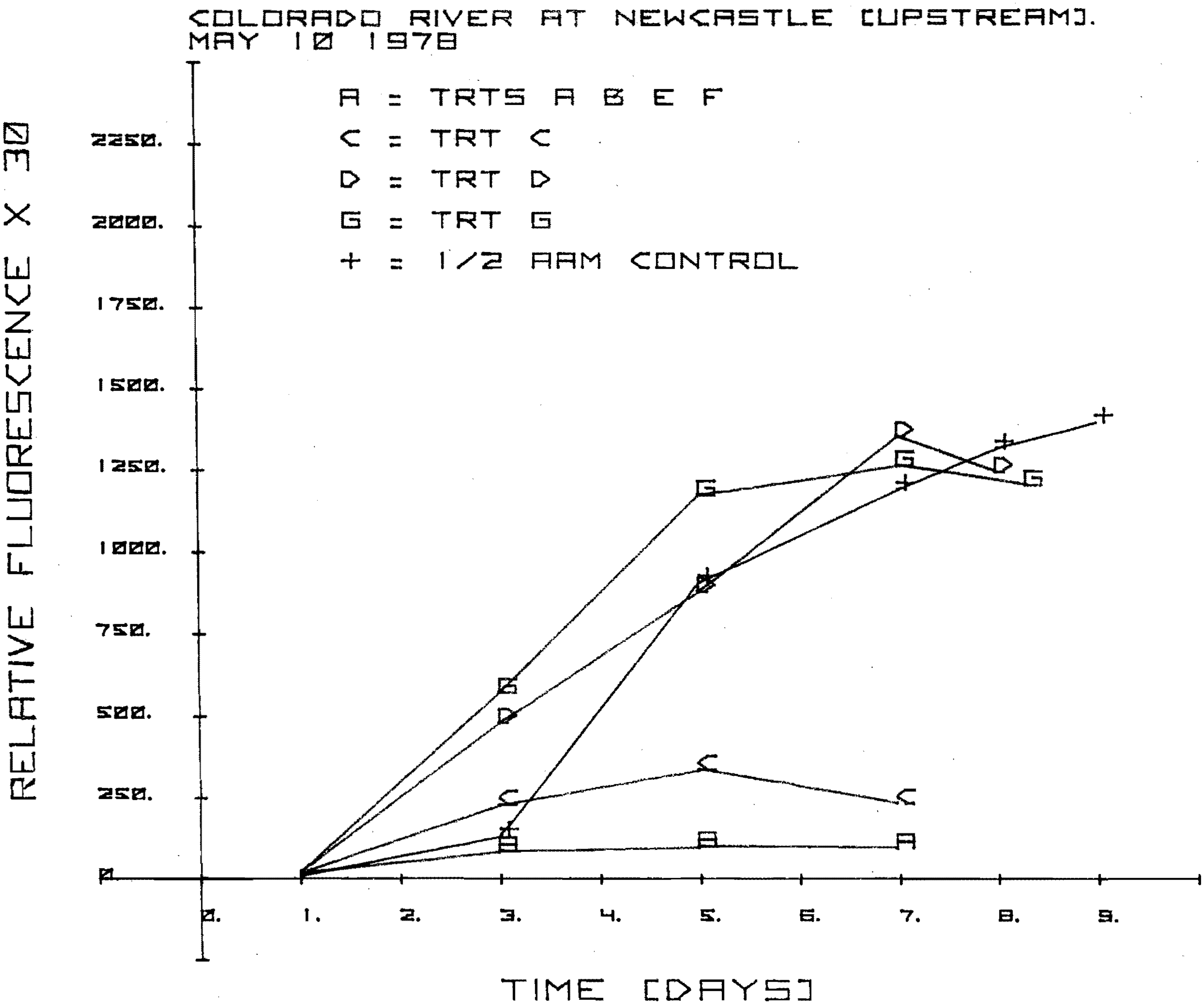
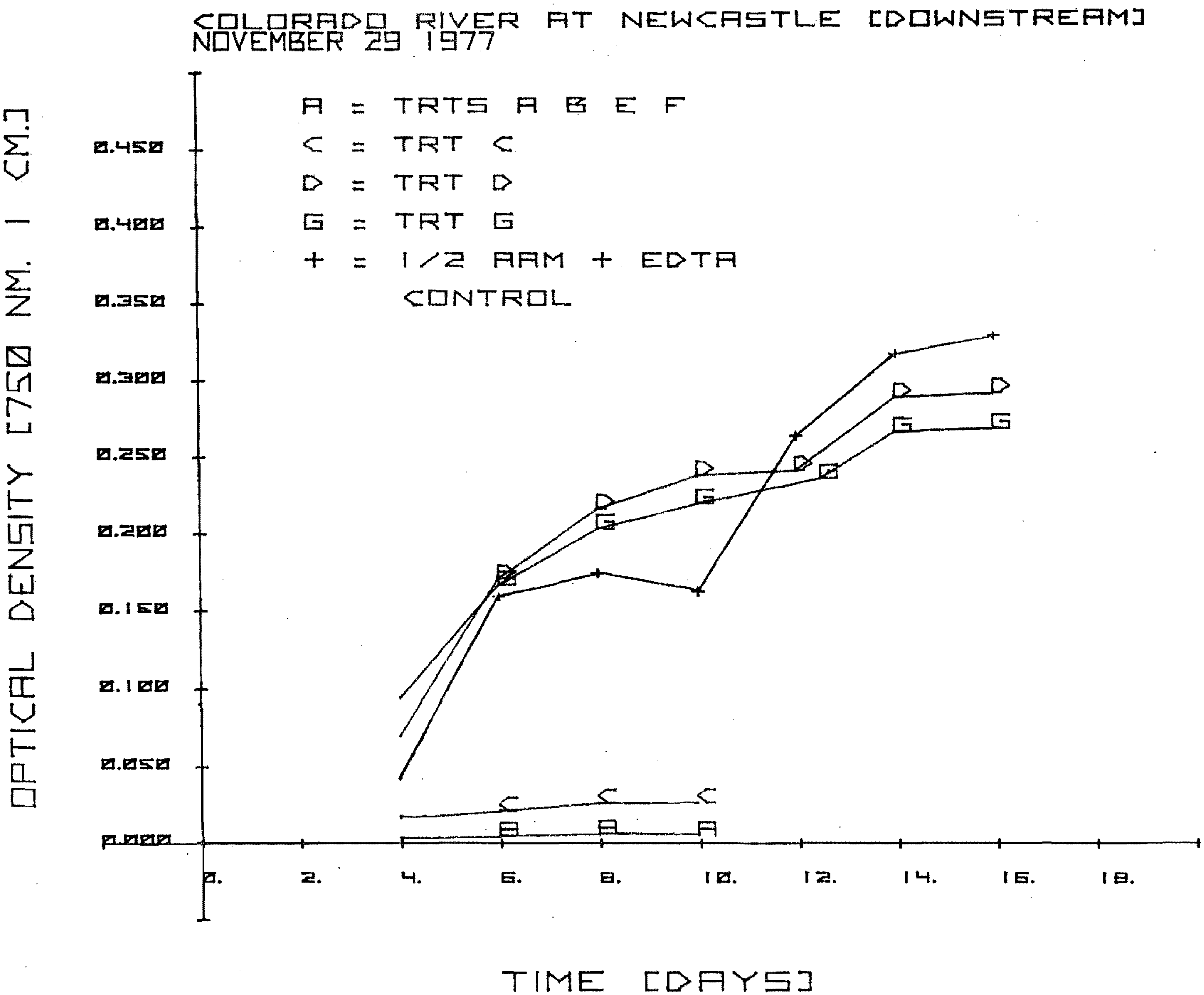

COLORADO RIVER AT NEWCASTLE [UPSTREAM]
MAY 10, 1978
A = TRTS. A, B, E, F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM CONTROL
OPTICAL DENSITY, [750NM. 1 CM.]
0.000
0.050
0.100
0.150
0.200
0.250
0.300
0.350
0.400
0.450
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 113.



COLORADO RIVER AT NEWCASTLE [UPSTREAM].
MAY 10 1978
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 114.



COLORADO RIVER AT NEWCASTLE (DOWNSTREAM)
NOVEMBER 29 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY (750 NM. 1 CM.)
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME (DAYS)

Figure 115.

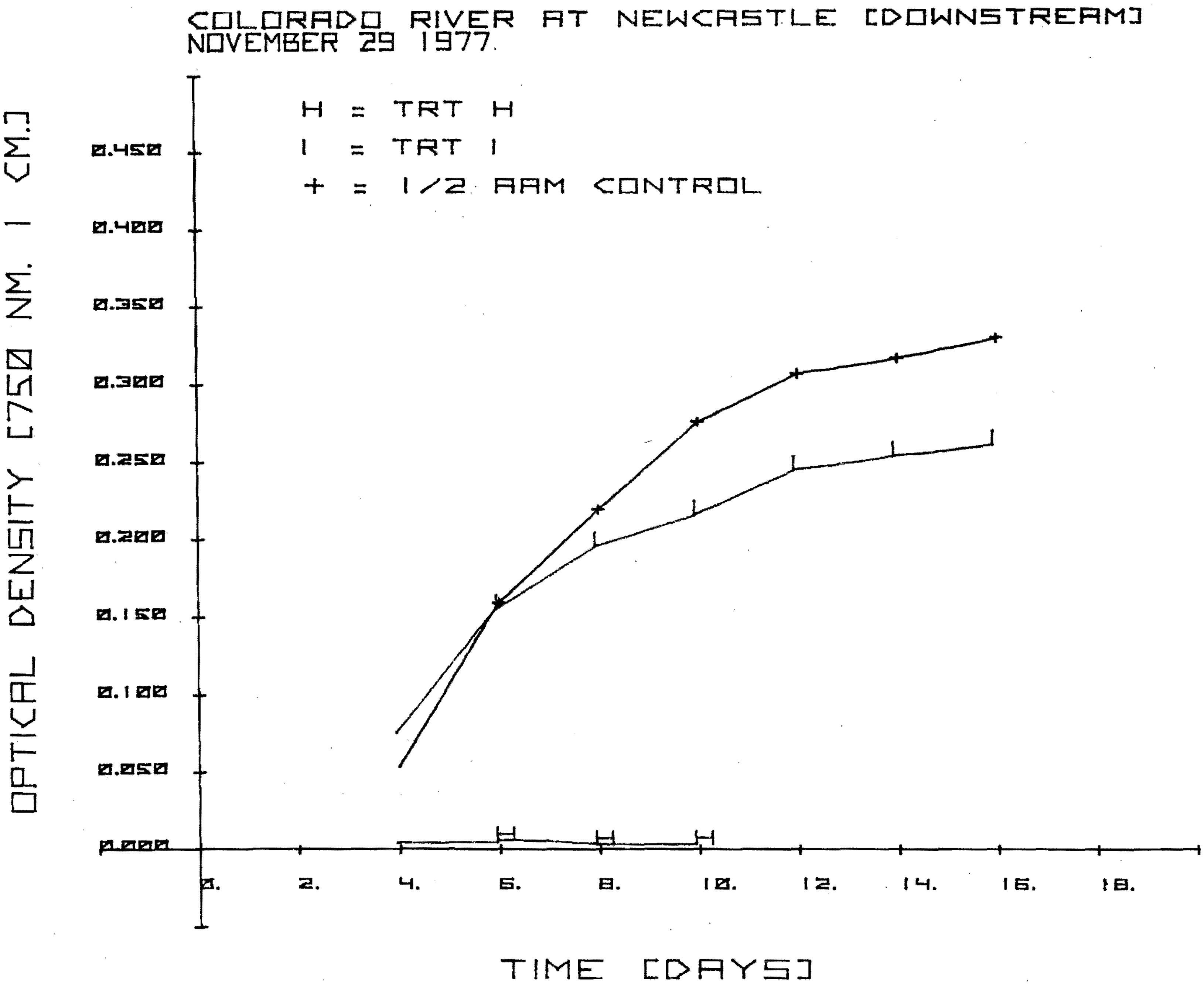

COLORADO RIVER AT NEWCASTLE [DOWNSTREAM]
NOVEMBER 29 1977
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 116.

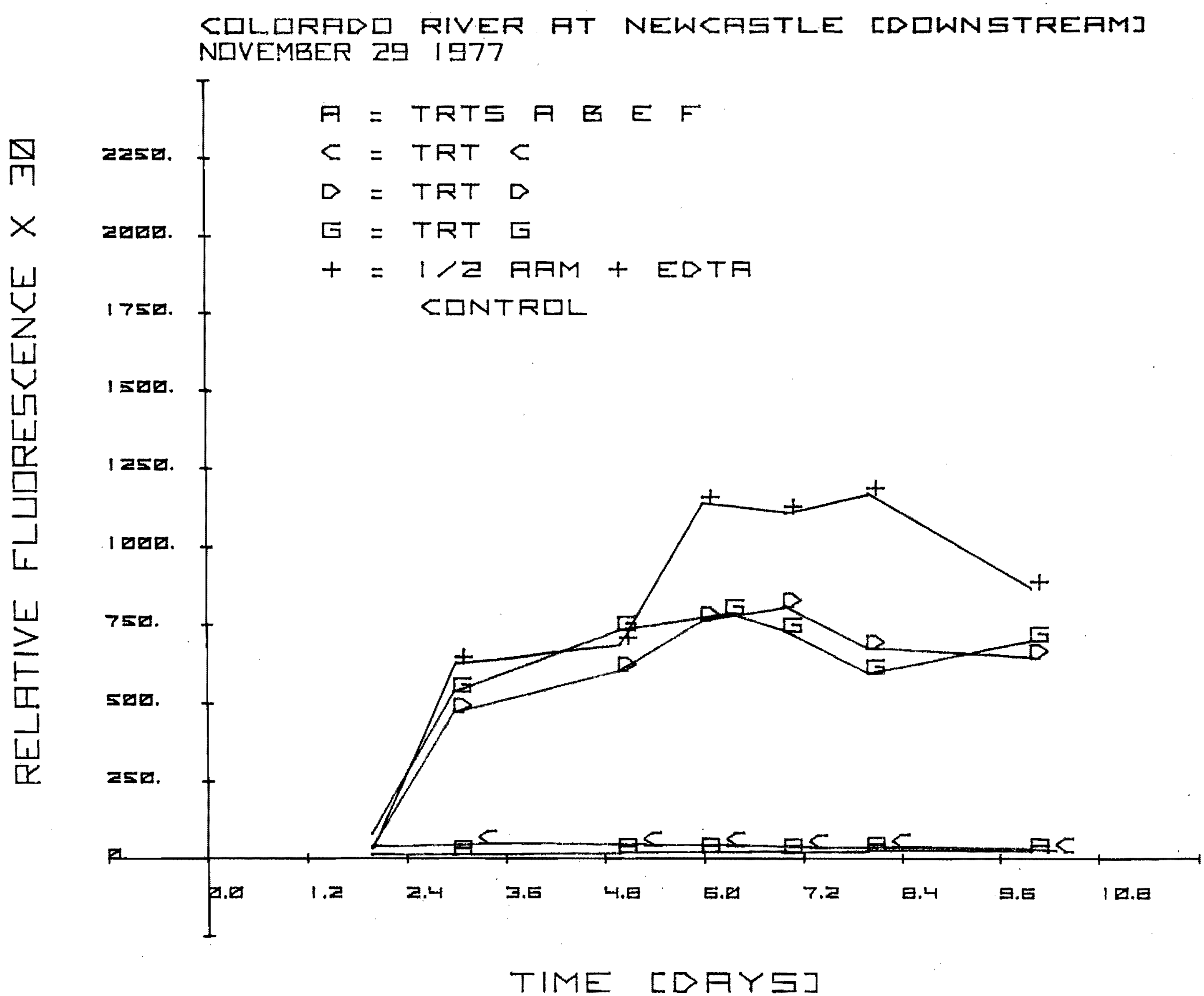

COLORADO RIVER AT NEWCASTLE [DOWNSTREAM]
NOVEMBER 29 1977
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.0
1.2
2.4
3.6
4.8
6.0
7.2
8.4
9.6
10.8
TIME [DAYS]

Figure 117.

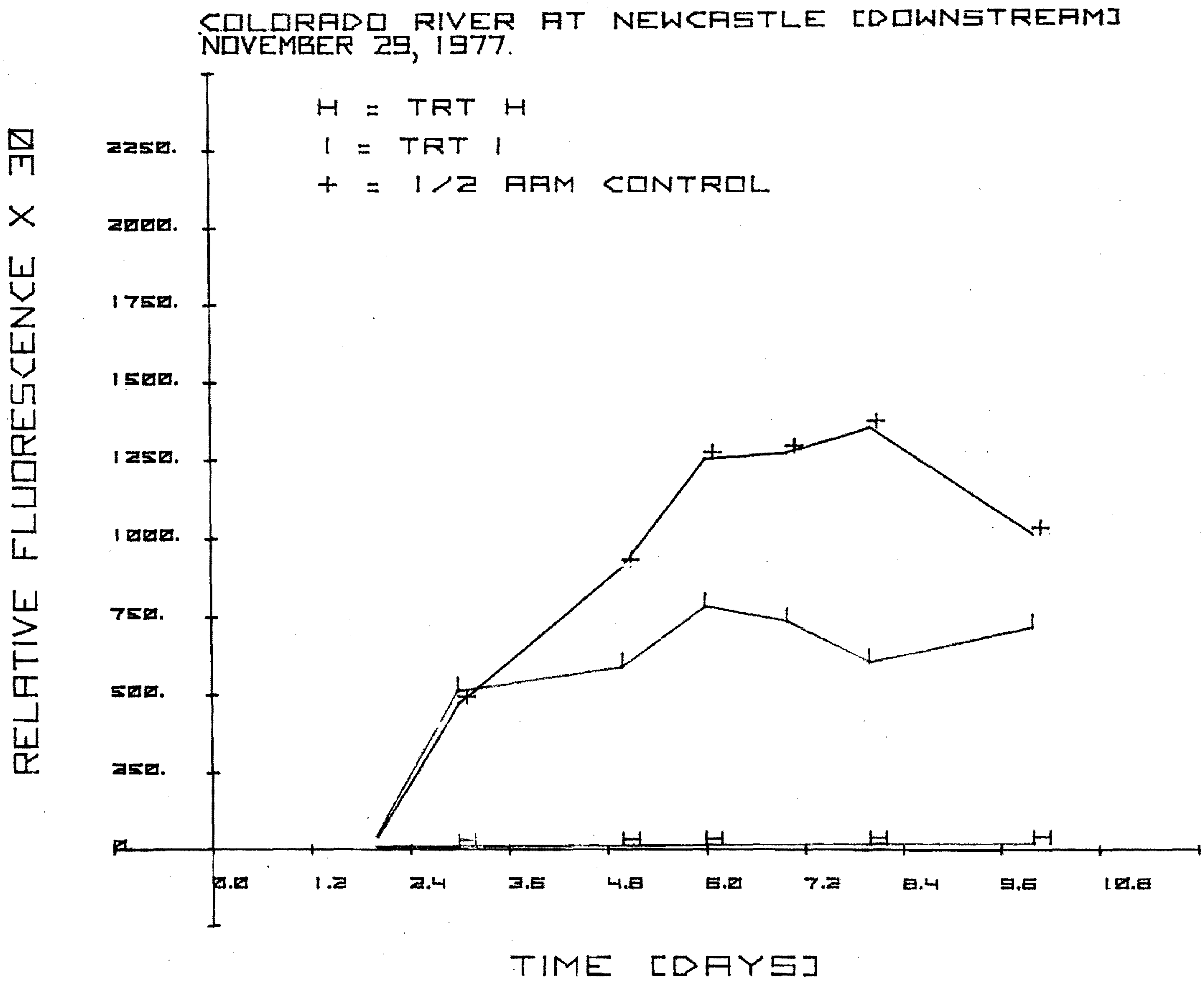

COLORADO RIVER AT NEWCASTLE [DOWNSTREAM]
NOVEMBER 29, 1977.
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
TIME [DAYS]
0.
250.
500.
750.
1000.
1250.
1500.
1750.
2000.
2250.
0.0
1.2
2.4
3.6
4.8
6.0
7.2
8.4
9.6
10.8

Figure 118.

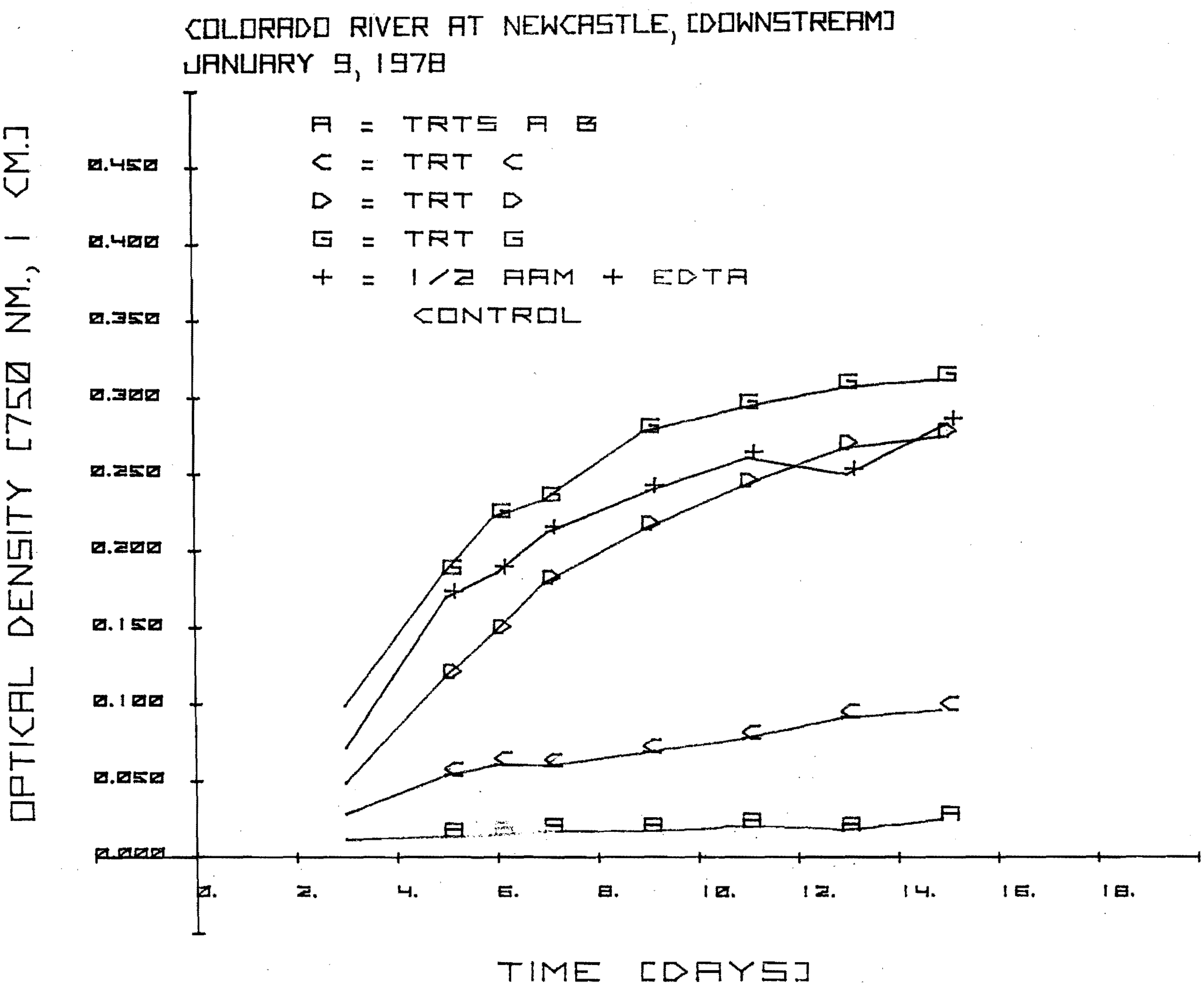
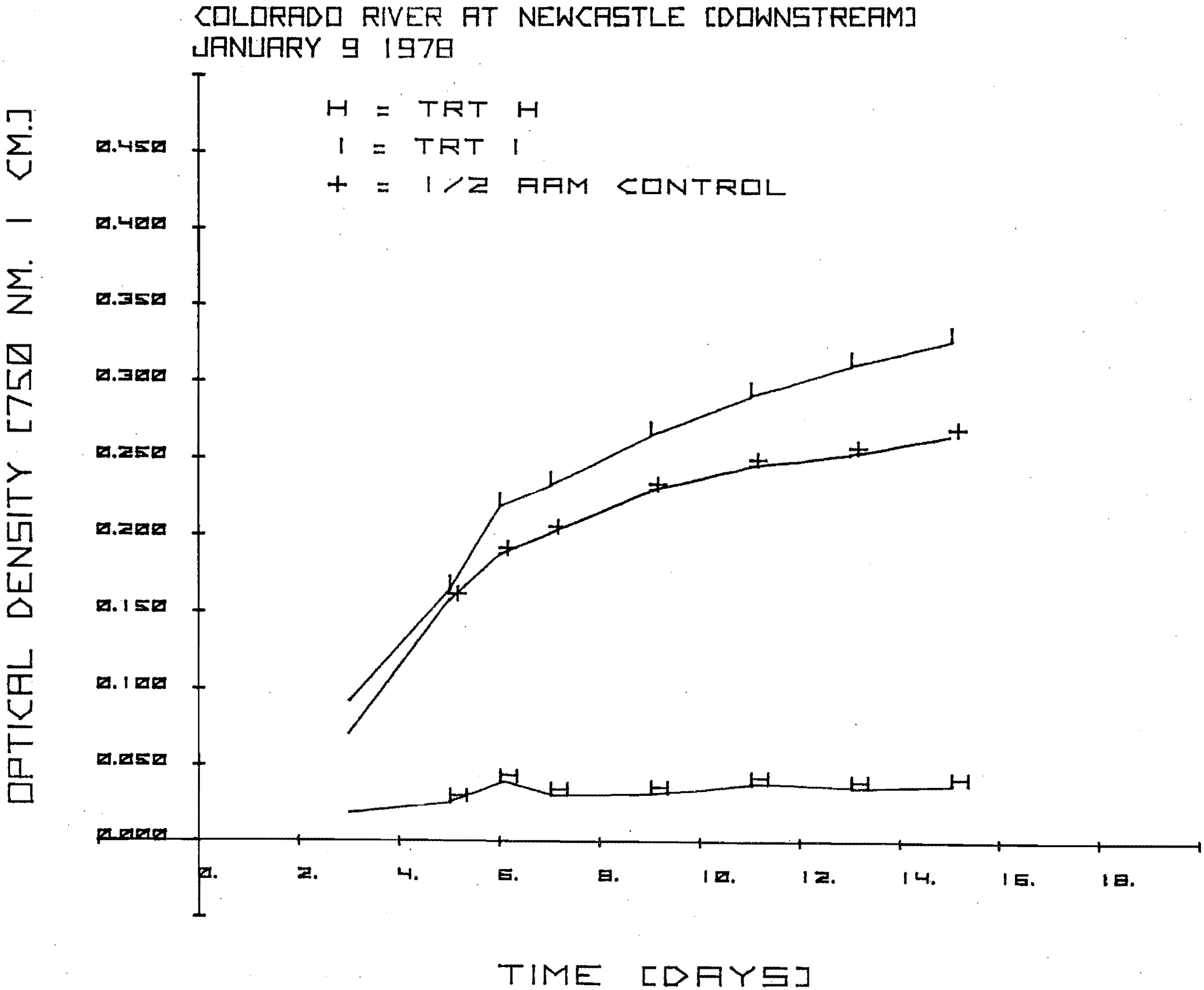
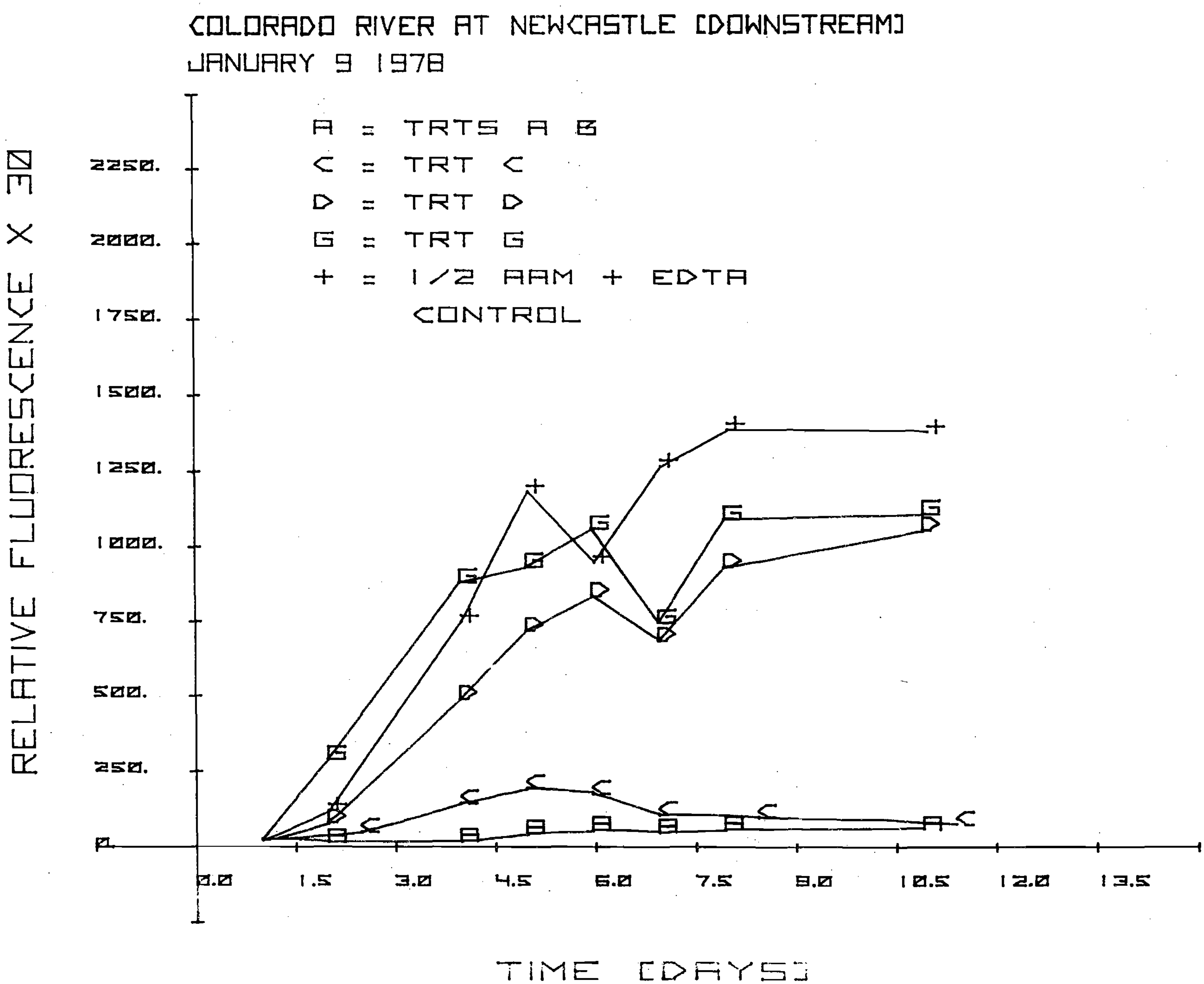

COLORADO RIVER AT NEWCASTLE, [DOWNSTREAM]
JANUARY 9, 1978
A = TRTS A B
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM., 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 119.



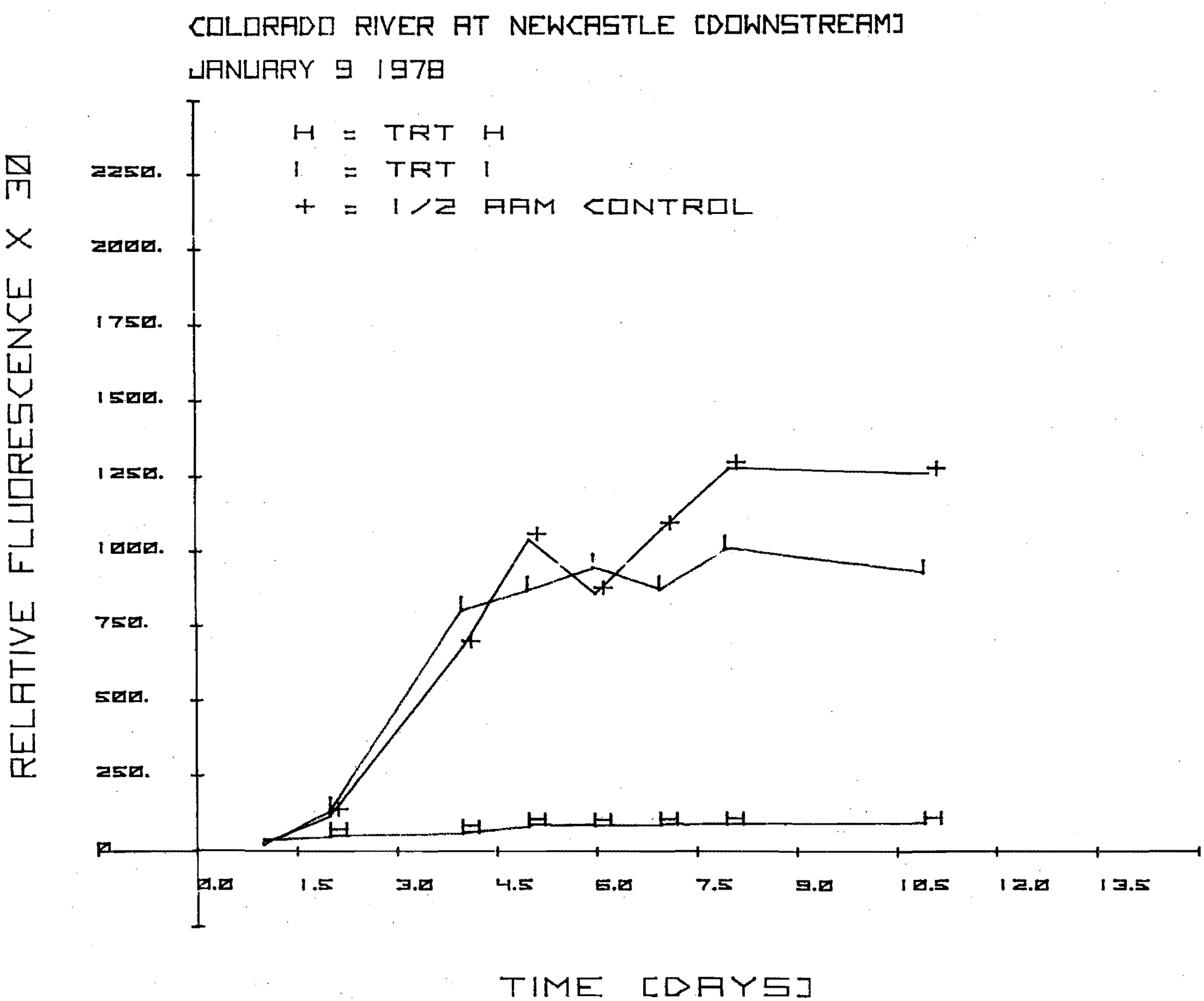
<COLORADO RIVER AT NEWCASTLE [DOWNSTREAM]
JANUARY 9 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY [750 NM. I <M.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
TIME [DAYS]

Figure 120.



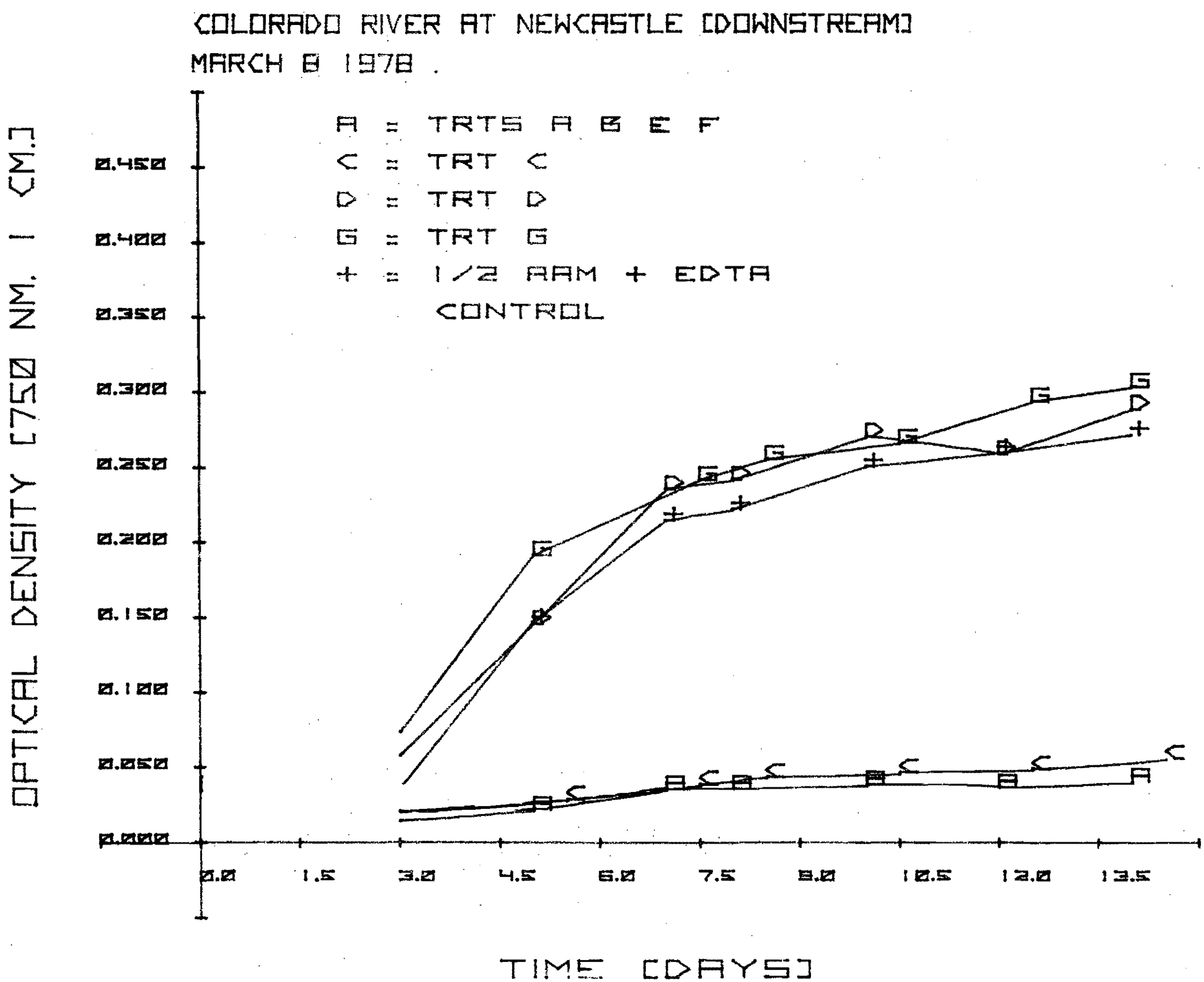
COLORADO RIVER AT NEWCASTLE [DOWNSTREAM]
JANUARY 9 1978
A = TRTS A B
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 121.



COLORADO RIVER AT NEWCASTLE [DOWNSTREAM]
JANUARY 9 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 122.



COLORADO RIVER AT NEWCASTLE [DOWNSTREAM]
MARCH 8 1978 .
A = TRTS A B E F
< = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL
OPTICAL DENSITY [750 NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 123.

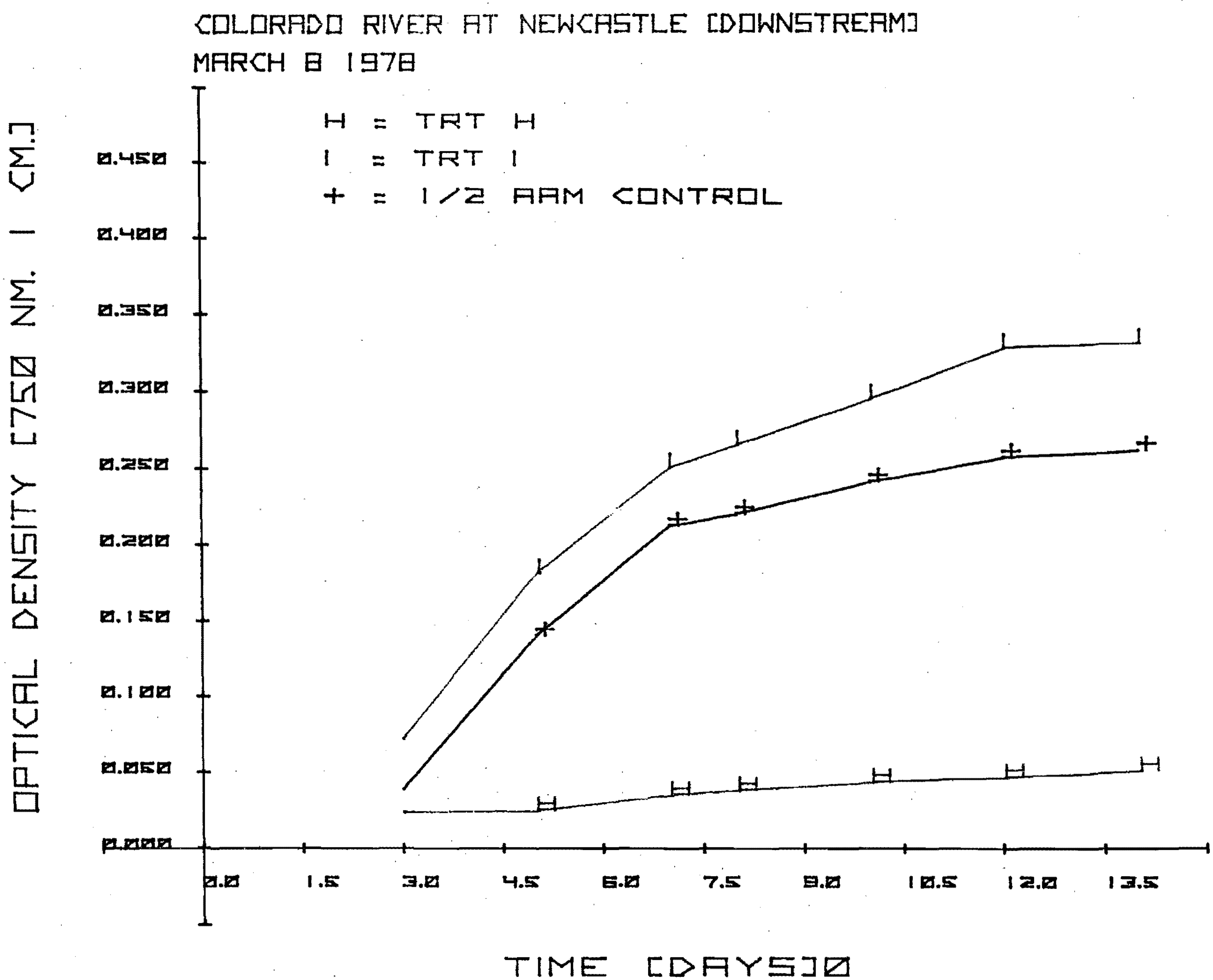

COLORADO RIVER AT NEWCASTLE (DOWNSTREAM)
MARCH 8 1978
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
OPTICAL DENSITY (750 NM. I CM.)
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME (DAYS)

Figure 124.

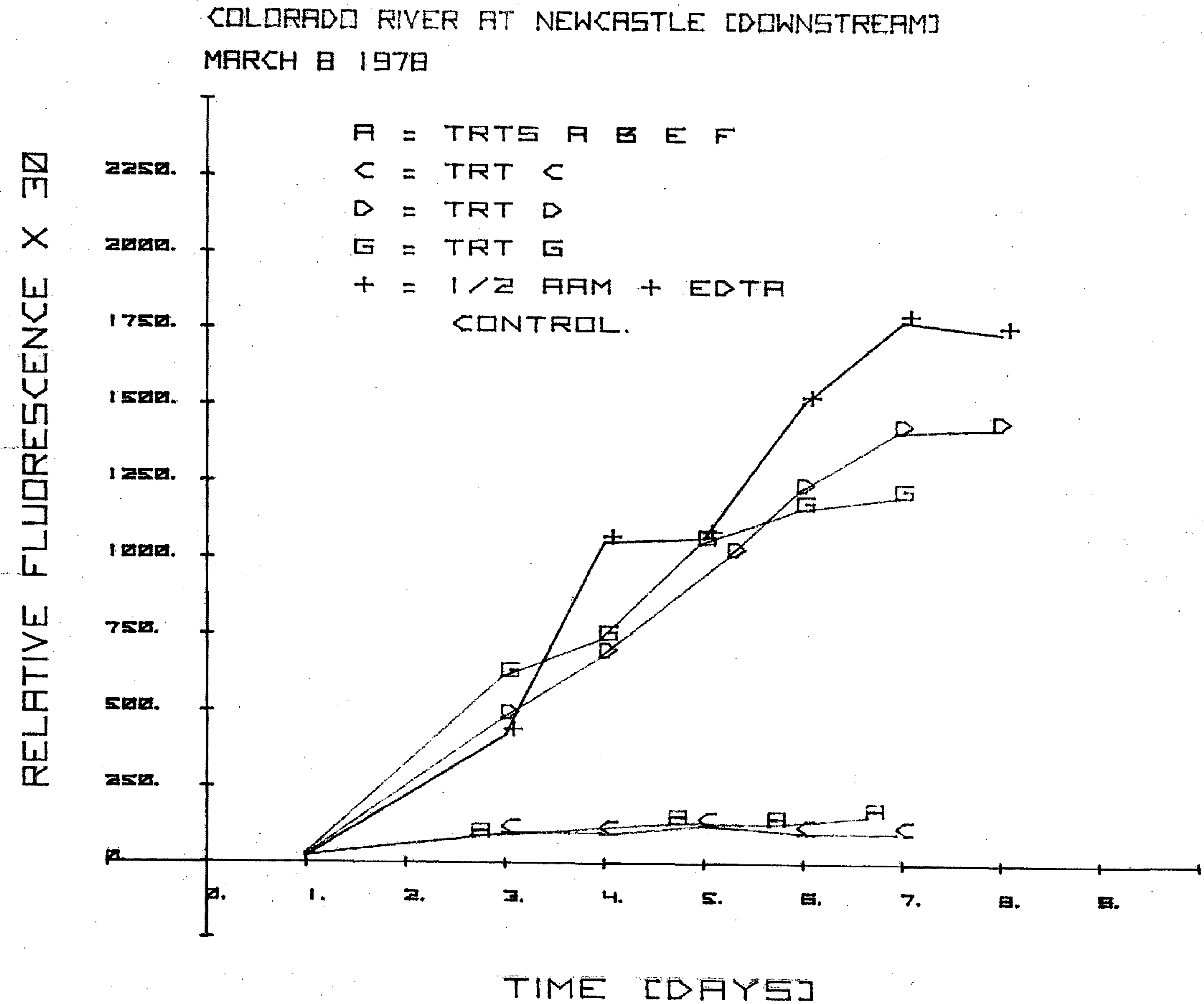
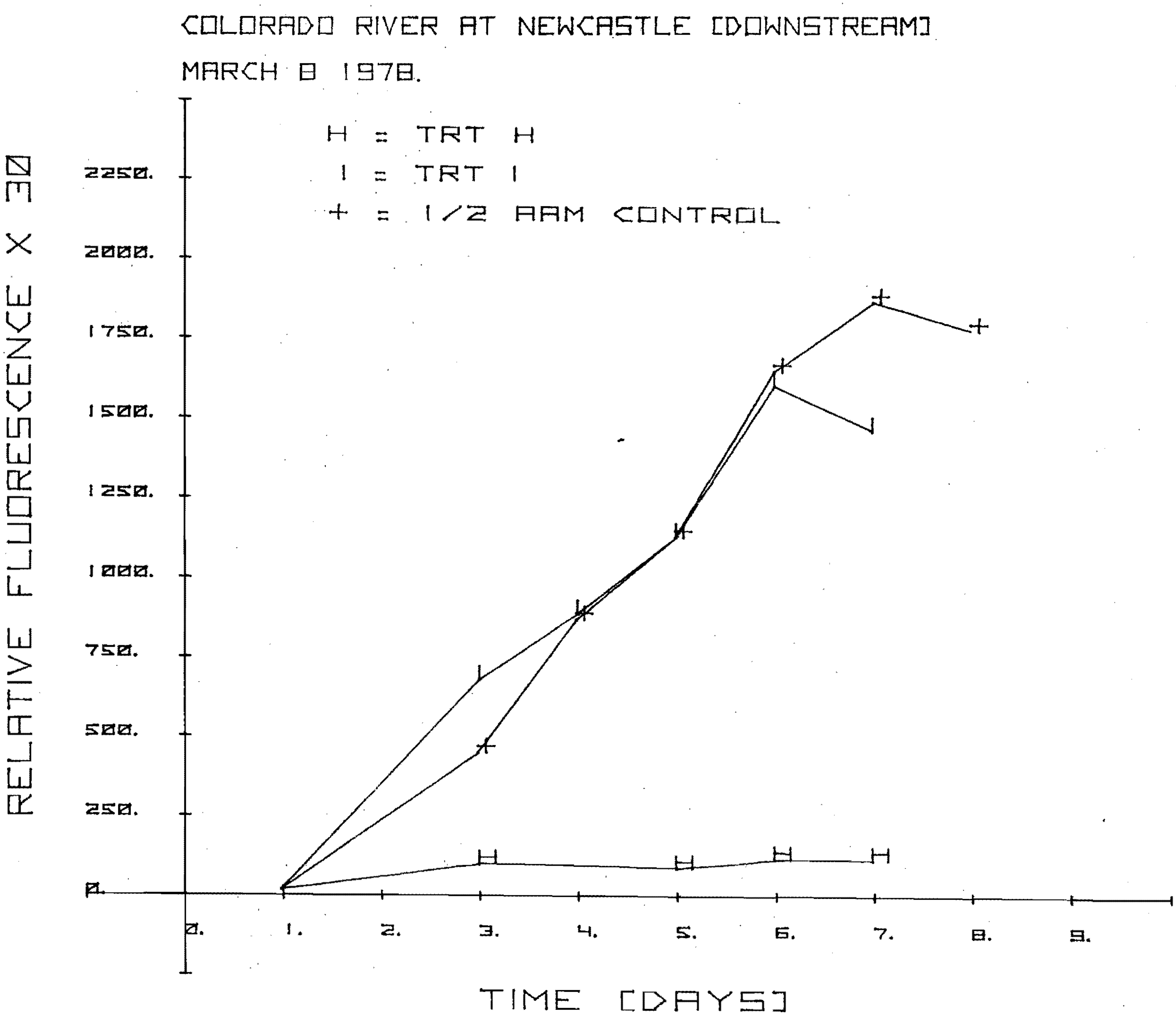

COLORADO RIVER AT NEWCASTLE (DOWNSTREAM)
MARCH 8 1978
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM + EDTA
CONTROL.
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME (DAYS)

Figure 125.



COLORADO RIVER AT NEWCASTLE [DOWNSTREAM]
MARCH 8 1978.
H = TRT H
I = TRT I
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0.
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME [DAYS]

Figure 126.

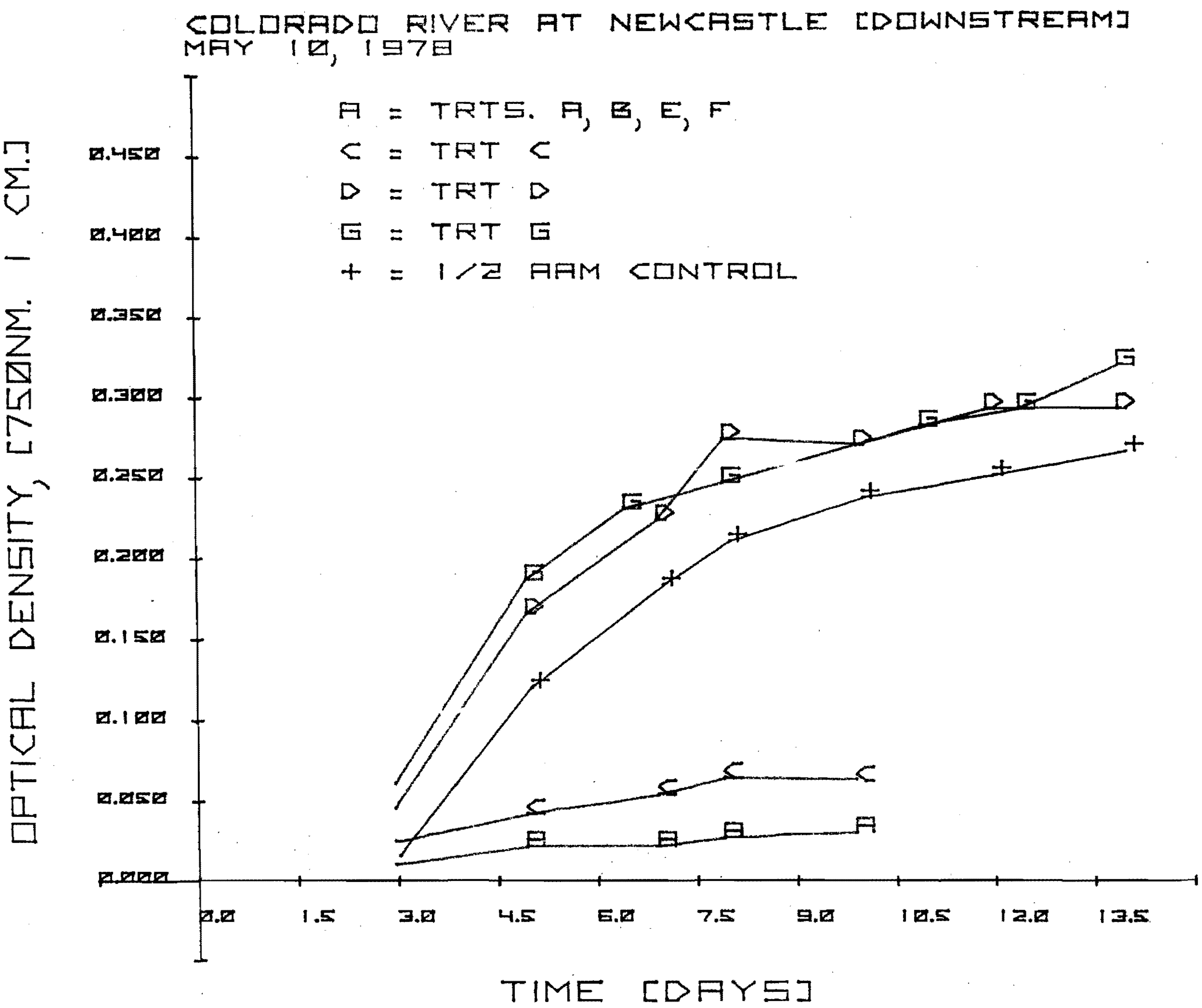

COLORADO RIVER AT NEWCASTLE [DOWNSTREAM]
MAY 10, 1978
A = TRTS. A, B, E, F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM CONTROL
OPTICAL DENSITY, [750NM. 1 CM.]
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
TIME [DAYS]

Figure 127.

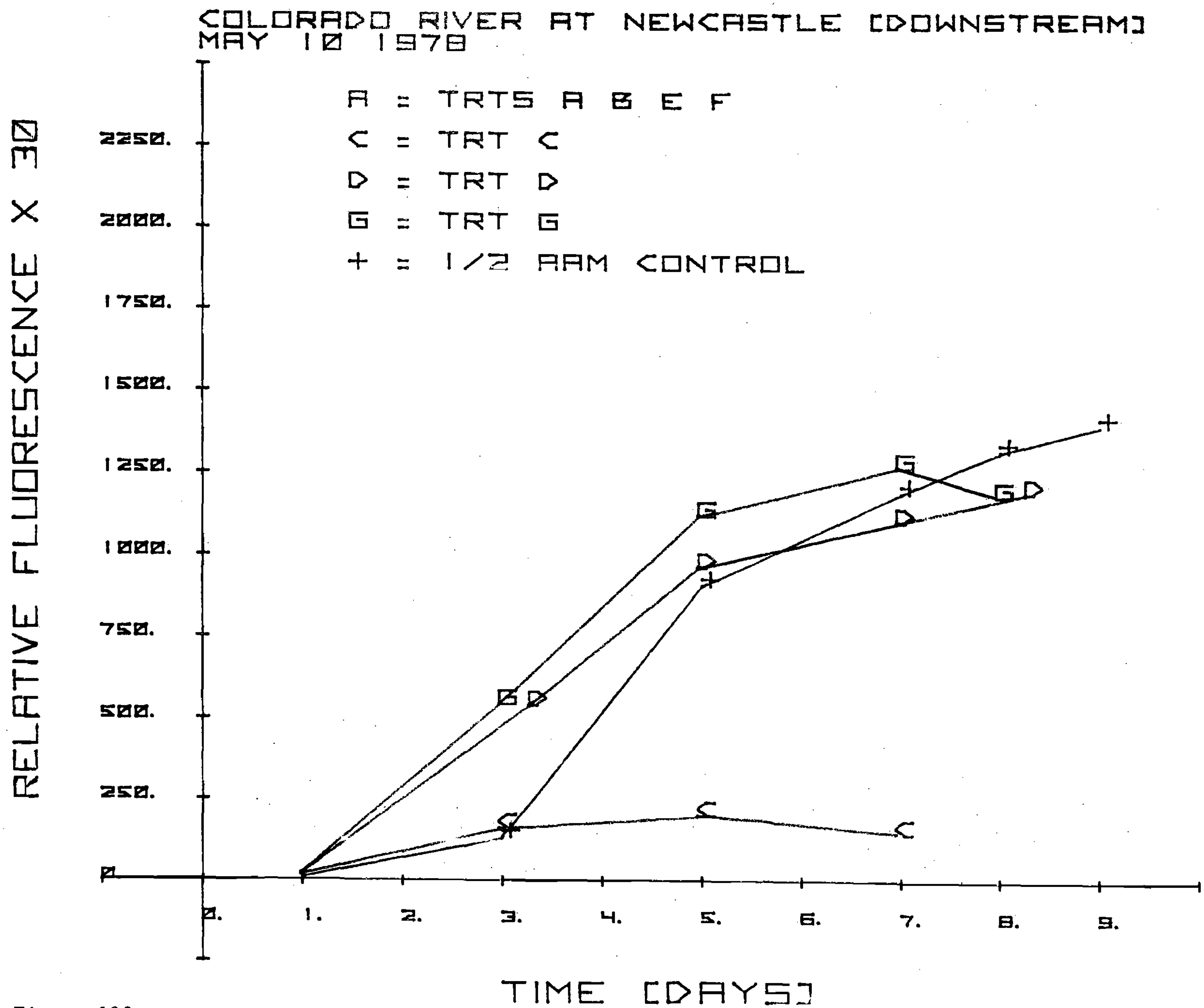

COLORADO RIVER AT NEWCASTLE (DOWNSTREAM)
MAY 10 1978
A = TRTS A B E F
C = TRT C
D = TRT D
G = TRT G
+ = 1/2 AAM CONTROL
RELATIVE FLUORESCENCE X 30
2250.
2000.
1750.
1500.
1250.
1000.
750.
500.
250.
0
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
TIME (DAYS)

Figure 128.

REFERENCES

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