SUSITNA HYDROELECTRIC PROJECT

WATER QUALITY INTERPRETATION 1981

FEBRUARY 1982

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SUSITNA HYDROELECTRIC PROJECT

TASK 3 - HYDROLOGY

WATER QUALITY INTERPRETATION - 1981

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1 - INTRODUCTION

The purpose of this report is to present a clear and concise summary of water quality data collected by the U.S. Geological Survey (USGS) and R&M Consultants, Inc. (R&M) in the mainstem and major tributaries of the Susitna River.

The objectives of the water quality baseline compilation were:

1. compile existing USGS data and data collected by R&M,

2. report seasonal (summer, winter, and breakup) ranges, means, and numbers of observations for all sample sites at which a sufficient data base exist,

3. reference the existing ranges of selected parameters to the State Water Quality Standards, and,

4. identify data gaps.

This report addresses each of the above objectives and also presents information regarding parameters exceeding criteria, aberrant data, and parameters exhibiting values less than their respective detection limits.

This report also presents a discussion of the probable post-project effects of the Watana and Devil Canyon Reservoirs on the water quality within the reservoirs and on the Susitna River downstream from these reservoirs. The discussion is written as if only one impoundment is on the Susitna River because the water quality impacts will be similar in both reservoirs. However, it is pointed out when impacts differ or are cumulative because of two impoundments.

2 - SUMMARY

Impoundment of the Susitna River will change its water quality. The following parameters will exhibit reductions in values in the reservoirs and downstream reaches as compared to the pre-project levels: suspended solids, turbidity, color, nutrients, iron, manganese, and some trace elements. Both reservoirs will be heat exporters, and the downstream reaches of the river will exhibit a reduced magnitude of seasonal temperature variation. Dissolved-oxygen concentrations will remain high, at or near saturation, in the epilimnion of both reservoirs and downstream in the river. Dissolved-oxygen concentrations will likely be reduced in the hypolimnion if a stable stratification develops. The potential for eutrophication to develop in either reservoir is low.

Although water quality changes will be effected by the project, none of these changes will be significantly adverse, and many changes may be beneficial. One possible exception to this is the change in downstream temperature.

3 - DATA COMPILATION AND SYNTHESIS

3.1 - Water Quality Criteria

Objectives 1 through 3 were met by synthesizing the data and graphically presenting it. These figures, appearing subsequent to the text, are organized in the following classifications: 1) physical properties, 2) inorganic, non-metallics, 3) radioactive parameters, 4) metals and ICAP Scan, and 5) organics. Each figure applies to one parameter and presents the maximum, mean, and minimum values recorded during the period of record, by season, for each water quality sampling station. The numbers of observations used to calculate the ranges and means are also presented. Data have been compiled for the mainstem Susitna River from stations located at Denali, Vee Canyon, Gold Creek, Sunshine, and Susitna Station. Data from two Susitna River tributaries, Chulitna and Talkeetna Rivers, have also been compiled. The periods of record for each station are presented below:

Station	Period of Record	Agency
Denali (D)	Apr. 9, 1957 - May 19, 1981	USGS
Vee Canyon (V)	Jul. 6, 1962 - May 11, 1981	USGS
	Jun. 19, 1980 - Oct. 8, 1981	R&M
Gold Creek (G)	Jun. 22, 1949 - Jul. 21, 1981	USGS
	Aug. 8, 1980 - Oct. 8, 1981	R&M
Chulitna (C)	Apr. 5, 1958 - Mar. 25, 1981	USGS
Talkeetna (T)	Apr. 29, 1954 - Oct. 4, 1977	USGS
Sunshine (S)	Jul. 2, 1971 - Jul. 23, 1981	USGS
Susitna Station (SS)	Aug. 17, 1955 - Aug. 12, 1981	USGS

Data have been compiled according to three seasons: breakup, summer, and winter. Breakup is usually short and extends from the time ice begins to break up until recession of spring runoff. Summer extends from the end of breakup until the water temperature drops to essentially 0°C in the fall, and winter is the period from the end of summer to breakup.

Reference is made to water quality guidelines and criteria on each figure. The original intent for this project was to use only the Alaska Water Quality Standards for guidelines and criteria. However, these standards do not present criteria for all parameters and they also specify the criteria for toxic and other deleterious organic and inorganic substances "shall not individually or in combination exceed 0.01 times the lowest measured 96-hour LC_{50} .... for life stages of species identified by the department [of Environmental Conservation] as being the most sensitive, biologically important to the location, or exceed criteria cited in EPA, Quality Criteria for Water or Alaska Drinking Water

Standards, ... whichever concentration is less." These criteria are somewhat confusing to the average reader who has little appreciation for a concentration expressed as 0.01 of the 96-hour LC_{50} (lethal concentration for half the population of test organisms) as determined through bioassay using a sensitive resident species. Consequently, the water quality guidelines and criteria as used herein were established from the following references.

ADEC, 1979. Water quality standards. Alaska Department of Environmental Conservation, Juneau, AK, 334 pp.

EPA, 1976. Quality criteria for water. U.S. Environmental Protection Agency, Washington, D.C., 255 pp.

McNeely, R.N., V.P. Neimanis, and L. Dwyer, 1979. Water quality sourcebook-- a guide to water quality parameters. Environment Canada, Inland Waters Directorate, Water Quality Branch, Ottawa, Canada, 88 pp.

Sitting, Marshall, 1981. Handbook of toxic and hazardous chemicals. Noyes Publications, Park Ridge, NJ, 729 pp.

EPA, 1980. Water quality criteria documents; availability. Environmental Protection Agency, Federal Register, 45, 79318-79379 (November 28, 1980).

The guidelines or criteria presented for the parameters were chosen based on a priority system. Alaska Water Quality Standards were the first choice, followed by criteria presented in EPA's Quality Criteria for Water. If a criterion expressed as a specific concentration was not presented in the above two references, the other cited references were consulted. Two criteria are presented for some parameters. Copper, for example, has: A) 0.01 of the 96-hour LC_{50} determined through bioassay (EPA, 1976), and B) 5.0 ug/l (McNeely et al, 1979). Also, some parameters have no criterion, which is stated on the respective figures. Some conversions between milligrams per liter (mg/l) and micrograms per liter (ug/l) were made so that the concentrations presented in the figures were the same as the criteria or vice versa. For example, the criteria of many metals are presented in ug/l in the references. These were converted to mg/l in many cases. It should be noted that all criteria, unless otherwise noted, apply to the total fraction rather than to the dissolved fraction. The R&M and USGS detection limits for each parameter are presented in Table 3.1.

A second priority system was used for selecting the guidelines or criteria presented for each parameter. This was required because the various references presented above cite levels of parameters that provide for the protection of identified water uses, such as (1) the propagation of fish and other aquatic organisms, (2) water supply for drinking, food preparation, industrial processes, and agriculture, and (3) water recreation. The first priority, therefore, was to present the guidelines or criteria that apply to the protection of freshwater aquatic organisms. The second priority was to present levels of parameters that are acceptable for water supply, and the third priority was to present other guidelines or criteria, if available. Statements pertaining to the selection of criteria are included on the figures. These statements are to inform the reader whether the criteria apply to the protection of aquatic organisms or water supply. It should be noted that water quality standards set criteria which limit man-induced pollution to protect identified water uses. Although the Susitna River Hydroelectric Project is in a pristine area, some parameters exceeded their respective criterion. The implications of such are discussed below in Section 3.3.

3.2 - Identification of Data Gaps

Compilation of the existing water quality data was useful in meeting the fourth objective, the identification of data gaps. Table 3.1 presents the number of data points by parameter, station, and season. As is typical in Alaska, the summer period is the most heavily sampled, followed by winter, and then breakup. No data exist for any parameters at the Denali, Chulitna, and Sunshine Stations during breakup, and the remaining stations have relatively small data bases during this season. The Denali, Vee Canyon, Chulitna, and Sunshine Stations have small winter data bases, typically 0 to 6 observations per parameter. The Gold Creek, Talkeetna, and Susitna Station stations generally have large winter data bases for the physical properties and for some of the inorganic, non-metallic parameters, but there are little or no data in the remaining classes of parameters: radioactive, metals and ICAP Scan, and organic parameters. There are a few exceptions to this statement, namely calcium, iron, magnesium, potassium, and sodium, which have been measured a large number of times at most stations. The summer data bases of physical and inorganic, non-metallic parameters are relatively large, except at Sunshine and for some parameters at Denali.

The data gaps identified above pertain only to the historical water quality data collected by the USGS and to data collected by USGS and R&M during Phase 1 of the Susitna Hydroelectric Project. The following comments/recommendations pertain to data gaps in a broader context. That is, the comments refer to information that may be required in addition to the existing data base to meet the major objectives of the water quality portion of this project, which are to provide sufficient baseline data to: (1) determine the normal and seasonal variability in water quality on a local and regional basis, and (2) predict and quantify the anticipated impacts that will occur during construction and operation. The following recommendations, many of which are predicated on FERC licensing requirements, are divided into station locations, parameters and frequency of analysis, reservoir processes, and groundwater.

The existing sample stations located at Denali, Vee Canyon, Watana, Gold Creek, Talkeetna, Sunshine, and Susitna Station are sufficient for describing the regional water quality. As stated above in the first paragraph of this section, seasonal data collection is the most complete for summer, followed by winter, and then breakup. The local water quality between the Devil Canyon Dam and Talkeetna will be important because of the distribution of spawning areas. Essentially, spawning occurs upstream on the Susitna River to the outlet of Devil Canyon (Portage Creek). Water quality impacts in the river are anticipated to be greatest immediately below Devil Canyon Dam. However, many impacts are expected to be attenuated in this reach, due to the extreme turbulence through Devil Canyon. It is recommended that a water quality sample station be located on the river near Portage Creek. It is important to obtain baseline water quality information within the productive fish area and as close as possible to the dam outlet. It is further recommended that trace element, nutrient, and major cation and anion parameters be collected at the Watana station during the winter low-flow period, at breakup, and at least once during the summer. Additionally, the major impoundment tributaries should be screened for trace elements during the winter low-flow period.

The frequency of sample collection should, at the least, remain the same as the past two years. That is, samples should be collected during spring breakup, summer low flow, summer after a heavy rainstorm, immediately prior to freeze-up, and during winter low flow. This statement does not apply to the Watana station, where a continuous record of field parameters is being made and where it is recommended that trace element, nutrient, and major cation and anion parameters be measured three times per year.

All field parameters should continue to be measured along with all of the nitrogen and phosphorus forms, chloride, color, hardness, sulfate, total dissolved solids, total suspended solids, turbidity, and chemical oxygen demand. Bacteria counts, such as total coliform, fecal coliform, and fecal streptococci, should be added to the list of parameters to be measured. Consideration should also be given to the addition of chlorophyll a and vertical illumination (as measured by a Secchi disk). The latter will be difficult to measure in the turbulent Susitna River. A possible alternative to measuring chlorophyll a and vertical illumination is to predict them through the use of an eutrophication equation. However, the predicted levels will only apply to the reservoirs.

Uranium and gross alpha radioactivity levels have consistently been low, so these parameters could be eliminated from the list of parameters to be measured. Also, organic concentrations have been low. However, only a few parameters have been measured. Table 3.3 lists the parameters and their detection limits recommended for future sampling. One sample for the analyses of PCB's, organo-chloride pesticides, and phenoxy acid herbicides should be collected from each station, and these samples should be collected during the summer low-flow period or immediately prior to freeze-up. The parameters listed in Table 3.3 can be analyzed for essentially the same price as the organics analyzed the past 2 years. Total organic carbon should also be included in the list of organics.

Measurement of many of the elements analyzed by the ICAP Scan method can be discontinued because they were consistently at or below their respective detection limits. The ICAP Scan should be used for the following parameters: aluminum, calcium, iron, potassium, magnesium, manganese, sodium, and silicon. Also, the ICAP Scan does <u>not</u> provide sufficiently low detection limits for arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc. These parameters should be analyzed with methods capable of detecting the levels (or less than the levels) cited as criteria for freshwater aquatic organisms, presented in the figures appearing at the end of this report.

The potential impacts of reservoir processes should be assessed in light of the existing information. This assessment would be beneficial because it will, for each process, either (1) show the total predicted impact and whether this impact is adverse or beneficial, or (2) delineate the information that will need to be developed before impacts can be predicted. Impacts within and downstream from the reservoirs need to be considered. Comments pertaining to each process appear below.

<u>Stratification</u>. Although it is predicted that stratification will occur during both summer and winter, the stability of stratification is unkown. Consequently, mixing within the reservoirs will be important to assess. One of the most important questions that should be addressed regards the oxygen resource: will dissolved oxygen be depleted in the hypolimnion?

<u>Leaching</u>. Leaching is directly related to aerobic/anaerobic conditions in reservoirs. Consequently, an estimate of the potential for leaching, the leaching rate, and the characteristics of leachate needs to be assessed. Some methods for accomplishing this are presented in the literature, and these methods should be reviewed for their applicability to the Susitna Hydroelectric Project.

Eutrophication. The potential for eutrophication needs to be assessed for each reservoir. Although this has already been done, some of the assumptions may be inappropriate. Consequently, the existing predictions should be reviewed and refined if necessary. Characteristics that should be included in this discussion include phosphorus, nitrogen, and organic loading, lack of light during winter, and cold water conditions. Consideration should also be given to using the eutrophication prediction equation for the assessment of chlorophyll a and vertical illumination (Secchi disc depth) in both reservoirs. It may also be enlightening to use this equation to predict the population equivalent that would have to live along the shores of each reservoir to have eutrophic conditions develop.

Sedimentation. It has been predicted that 70 to 100 percent of the suspended material entering Watana Reservoir will settle to the bottom. The implications of this situation on water quality need to be assessed. For example, will clear water in the reservoir promote the growth of algae, eventually leading to eutrophic conditions? Also, the characteristics of the sediment may be important. If the sediment is organic, leaching may be enhanced because organic material has an oxygen demand and usually reduces the pH. Both of these characteristics promote leaching. Conversely, if the sediment is inorganic, as suspected, leaching would be reduced because the inorganic sediment will form a layer on the reservoir bottom. The effects of sedimentation are likely to be different at Devil Canyon because it is predicted that most sediment will be retained in the Watana Reservoir. The effect of little or no sedimentation in the Devil Canyon Reservoir on water quality needs to be considered.

Evaporation. Evaporation was predicted to have little effect on water quality in the reservoirs. Calculation of the potential effects of evaporation should be reviewed and refined with a consideration for stratification. A quantification of the effects of sublimation on water quality may also be in order.

Ice Cover. A review of the potential effects that ice cover may have on water quality should be included.

Superimposed on each process are the interactions between these processes and potential water quality impacts resulting from these interactions. Each potential interaction should be assessed.

A baseline description of groundwater conditions and potential impacts on groundwater resulting from the project are required. Information should be included regarding the groundwater table, artesian conditions, the hydraulic gradient, and hydraulic connections between surface and groundwater. A short discussion about permafrost may be worthy because any permafrost existing in the reservoir areas will likely melt subsequent to impoundment closure.

3.3 - Parameters Exceeding Criteria, Aberrant Data, and Parameters Exhibiting Values Less Than Their Respective Detection Limits

Although not a part of the original scope of this project, this report presents a summary of the parameters that have exceeded their criteria (Table 3.4), a discussion of aberrant data, and a list of parameters that exhibited values less than their respective detection limits.

The identification of aberrant data was considered because of the extreme values manifested by some parameters. The following parameters were suspected of having aberrant data.

D.O. % Saturation. The high values measured at Gold Creek during summer exceeded the criterion. The four highest values measured by R&M, 116, 115, 114, and 113 percent saturation, are probably in error because of a faulty barometer and should be eliminated from the data set. R&M's fifth highest value was similar to the USGS's highest values of 106, 104, 103, and 102 percent saturation.

Free Carbon Dioxide. The five highest values measured by R&M at Gold Creek during summer were 36, 35, 20, 16, and 16 mg/l. The two highest values may be aberrant, but there are no acceptable reasons to eliminate them.

Ortho-Phosphate. One high value, 0.49 mg/l, measured at Vee Canyon during summer appears unrealistic and should be eliminated. The next highest value was 0.1 mg/l. The high value measured at Talkeetna during breakup may also be unrealistic, but there are no data with which to compare this value so it should stand.

Phosphorus. The high value of 0.49 mg/l measured at Vee Canyon during summer is likely to be aberrant because the next highest is 0.1 mg/l. Likewise, a high value of 0.36 mg/l is significantly different from the next highest value of 0.05 mg/l measured at Susitna Station during winter. It is recommended that both of the high values be eliminated.

Turbidity. The five highest turbidity values measured at Susitna Station during summer were 790, 590, 430, 430, and 260 NTU. There is no reason to eliminate any of these values.

Total Organic Carbon. The four concentrations measured at Gold Creek during winter are 39, 34, 27, and 5.5 mg/l, and one measurement at Vee Canyon during winter was 23 mg/l. Although the four high values appear unrealistic, there is no apparent reason to eliminate them.

The following parameters exhibited levels that were less than their respective detection limits at all stations and times they were analyzed: endrin; lindane; methoxychlor; toxaphene; 2,4-D; 2,4,5-TP (Silvex); and the dissolved fractions of antimony, boron, gold, molybdenum, platinum, tin, vanadium, and zirconium.

A number of parameters, listed in Table 3.4, exceeded their respective criteria. The implications of this to freshwater aquatic organisms are related to the rationale behind the criteria and to the fact that the Susitna River is largely unaffected by man's activity.

As noted in Table 3.4, three parameters have criteria that have been suggested but are not law, or the criteria are set at a level which natural waters usually do not exceed. The criteria for aluminum and bismuth have been suggested on the basis of human health effects. The criterion for total organic carbon (TOC) was established at 3 mg/l because waters containing less than this concentration have been observed to be relatively clean. However, streams in Alaska receiving tundra runoff commonly exceed this level. The maximum TOC concentration reported herein, 20 mg/l, is likely the result of natural conditions. The criterion for manganese was established to protect water supplies. The criteria presented for the remaining parameters appearing in Table 3.4 are established by law for the protection of freshwater aquatic organisms. The water quality standards apply to man-made alterations and constitute the degree of degradation which may not be exceeded. Because there are no industries, no significant agricultural areas, and no major cities adjacent to the Susitna, Talkeetna, and Chulitna rivers, the measured levels of these parameters are considered to be a natural condition. Also, these rivers support diverse populations of fish and other aquatic life. Consequently, it is concluded that the parameters exceeding their criteria have little, if any, detrimental effect on aquatic organisms.

It is worthy to note that the range displayed in the figures for pH and color are typical for streams in Alaska receiving tundra runoff. It is not uncommon for pH to be 6.5 (the criterion) or slightly less and color to be as high as 100 color units (the maximum reported herein). It should also be noted that the four highest levels of percentage saturation of dissolved oxygen are probably in error (see statement on Page 3-7). If these data are eliminated, all the dissolved oxygen percentage saturation values are less than the criterion of 110 percent.

TABLE 3.1

DETECTION LIMITS FOR

WATER QUALITY PARAMETERS

	R&M Detection Limit(1)	U.S.G.S. Detection Limit(5)
Field Parameters		
Dissolved Oxygen	0.1	-
Percent Saturation	1	-
pH, pH Units	±0.01	-
Conductivity, umhos/cm @ 25°C	1	-
Temperature, °C	0.1	-
Free Carbon Dioxide	1	-
Alkalinity, as $CaCO_3$	2	-
Settleable Solids, ml/l	0.1	-
Laboratory Parameters		
Ammonia Nitrogen	0.05	.01
Organic Nitrogen	0.1	-
Kjeldahl Nitrogen	0.1	.1
Nitrate Nitrogen	0.1	.01
Nitrite Nitrogen	0.01	.01
Total Nitrogen	0.1	.01
Ortho-Phosphate	0.01	.01
Total Phosphorus	0.01	.01
Chemical Oxygen Demand	1	-
Chloride	0.2	.01
Color	1	1
Hardness,	1	-
Sulfate	1	.05
Total Dissolved Solids(2)	1	1
Total Suspended Solids(3)	1	1
Turbidity	0.05	1
Uranium	0.075	-
Gross Alpha, picocurie/liter	3	-
Total Organic Carbon	1.0	-
Total Inorganic Carbon	1.0	-

TABLE 3.1 - CONTINUED

	R&M Detection Limit(1)	U.S.G.S. Detection Limit(5)
Laboratory Parameters (Cont'd)		
Organic Chemicals		
Endrin	0.0002	.00001
Lindane	0.004	.00001
Methoxychlor	0.1	.00001
Toxaphene	0.005	.001
2, 4-D	0.1	.00001
2, 4, 5-TP Silvex	0.01	.00001
ICAP Scan(4)		
Ag, Silver	0.05	.001
Al, Aluminum	0.05	.01
As, Arsenic	0.10	.001
Au, Gold	0.05	-
B, Boron	0.05	.01
Ba, Barium	0.05	.1
Bi, Bismuth	0.05	-
Ca, Calcium	0.05	.01
Cd, Cadmium	0.01	.001
Co, Cobalt	0.05	.001
Cr, Chromium	0.05	.001
Cu, Copper	0.05	.001
Fe, Iron	0.05	.01
Hg, Mercury	0.1	.0001
K, Potassium	0.05	.1
Mg, Magnesium	0.05	.1
Mn, Manganese	0.05	.001
Mo, Molybdenum	0.05	.001
Na, Sodium	0.05	.1
Ni, Nickel	0.05	.001
Pb, Lead	0.05	.001
Pt, Platinum	0.05	-
Sb, Antimony	0.10	.001
Se, Selenium	0.10	.001
Si, Silicon	0.05	-
Sn, Tin	0.10	.1
Sr, Strontium	0.05	.01
Ti, Titanium	0.05	-
W, Tungsten	1.0	-

TABLE 3.1 - CONTINUED

	R&M Detection Limit(1)	U.S.G.S. Detection Limit(5)
Laboratory Parameters (Cont'd)		
V, Vanadium	0.05	-
Zn, Zinc	0.05	.01
Zr, Zirconium	0.05	-

---

(1) All values are expressed in mg/l unless otherwise noted.

(2) TDS - (filterable) material that passes through a standard glass fiber filter and remains after evaporation (SM p 93).

(3) TSS - (nonfilterable) material retained on a standard glass fiber filter after filtration of a well-mixed sample.

(4) ICAP SCAN - thirty two (32) element computerized scan in parts/million (Ag, Al, As, Au, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, Pb, Pt, Sb, Se, Si, Sn, Sr, Ti, V, W, Zn, Zr).

(5) U.S.G.S. detection limits are taken from "1982 Water Quality Laboratory Services Catalog" U.S.G.S. Open-File Report 81-1016. The limits used are the limits for the most precise test available.

TABLE 3.2
NUMBER OF DATA POINTS BY PARAMETER, STATION, AND SEASON

	Summer							Winter							Break-up						
	D	V	G	C	T	S	SS	D	V	G	C	T	S	SS	D	V	G	C	T	S	SS
PHYSICAL PROPERTIES																					
Color	0	9	52	6	30	3	4	0	0	20	4	14	1	4	0	0	6	0	7	0	0
Conductivity	18	34	70	19	108	5	21	4	3	30	6	52	2	20	0	1	9	0	22	0	6
Hardness	11	20	67	6	59	5	20	4	3	27	4	30	2	20	0	1	5	0	17	0	6
PH	15	20	41	6	71	3	62	4	3	26	4	41	1	45	0	1	11	0	16	0	18
Temperature	50	48	20	18	102	5	109	0	3	41	5	41	1	47	0	1	9	0	20	0	33
Total Dissolved Solids	11	20	68	6	56	0	24	4	3	29	4	30	0	20	0	1	5	0	16	0	4
Total Suspended Soilds	58	48	60	19	54	0	67	0	3	11	6	24	0	22	0	1	12	0	12	0	5
Turbidity	8	10	7	0	0	2	13	0	3	3	0	0	1	10	0	1	2	0	0	0	4
INORGANIC, NON-METALLICS																					
Alkalinity	11	7	71	6	59	3	52	4	3	26	4	30	2	30	0	0	3	0	15	0	6
Chloride	11	20	69	6	59	5	23	4	3	28	4	30	2	21	0	1	6	0	17	0	6
Nitrogen, ammonia (d)	0	9	10	0	2	2	15	0	3	6	0	4	2	7	0	1	6	0	1	0	3
Nitrogen, Kjeldahl (d)	0	9	6	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0
Nitrogen, Nitrate (d)	15	20	67	6	45	0	1	0	3	25	4	19	0	2	0	1	5	0	12	0	0
Nitrogen, Organic (d)	0	9	10	0	3	2	12	0	3	6	0	2	2	9	0	1	2	0	1	0	2
Nitrogen, Total (d)	0	9	10	0	2	2	22	0	3	6	0	3	2	17	0	1	2	0	1	0	5
Oxygen, Dissolved	0	8	11	0	38	3	12	0	3	5	0	24	1	12	0	1	2	0	5	0	4
D.O., % Saturation	0	8	11	0	19	0	53	0	3	5	0	14	1	19	0	1	2	0	0	0	11
Phosphate, Ortho (d)	0	9	16	0	11	3	0	0	3	5	0	4	1	0	0	1	2	0	1	0	1
Phosphate, Total (d)	0	9	10	0	3	2	12	0	3	4	0	3	2	10	0	1	2	0	1	0	3
Sulfate	11	20	72	6	59	5	23	4	3	25	4	30	2	21	0	1	4	0	17	0	6
Total Inorganic Carbon	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0
Free Carbon Dioxide	11	17	66	1	1	3	1	4	3	25	1	1	0	1	0	0	5	0	1	0	1

TABLE 3.2 (Continued)

	Summer							Winter							Break-up						
	D	V	G	C	T	S	SS	D	V	G	C	T	S	SS	D	V	G	C	T	S	SS
RADIOACTIVE PARAMETERS																					
Gross Alpha	0	1	3	0	2	0	0	0	1	2	0	2	0	0	0	0	0	0	1	0	0
Uranium	0	5	4	0	4	0	0	0	2	2	0	4	0	0	0	0	0	0	2	0	0
METALS AND ICAP SCAN																					
Aluminum (d)	0	10	6	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0
Aluminum (t)	0	0	3	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Antimony (d)	0	10	7	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0
Arsenic (d)	0	10	7	0	0	2	10	0	3	3	0	0	1	8	0	1	2	0	0	0	5
Arsenic (t)	0	0	0	0	0	5	12	0	0	0	0	0	1	8	0	0	0	0	0	0	5
Barium (d)	0	10	9	0	5	2	7	0	3	3	0	5	1	5	0	1	2	0	1	0	2
Barium (t)	0	0	5	0	9	5	8	0	0	0	0	4	0	4	10	0	0	0	4	0	2
Bismuth (d)	0	10	7	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0
Boron (d)	0	10	7	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0
Cadmium (d)	0	10	2	0	5	2	8	0	3	3	0	5	1	4	0	1	2	0	1	0	2
Cadmium (t)	0	0	4	0	8	4	11	0	0	0	0	0	4	0	7	0	0	0	4	0	4
Calcium (d)	11	20	67	6	58	5	23	4	3	29	4	30	2	21	0	1	2	0	17	0	6
Chromium (d)	0	10	2	0	5	2	8	0	3	3	0	4	1	4	0	1	2	0	0	0	2
Chromium (t)	0	0	5	0	10	5	11	0	0	0	0	4	1	3	0	0	0	0	5	0	3
Cobalt (d)	0	0	2	0	4	2	12	0	0	0	0	2	1	8	0	0	0	0	0	0	0
Cobalt (t)	0	0	2	0	0	2	7	0	0	0	0	0	1	3	0	0	0	0	0	0	3
Copper (d)	0	10	2	0	4	2	10	0	3	3	0	5	1	9	0	1	2	0	1	0	4
Copper (t)	0	0	5	0	10	5	11	0	0	0	0	4	1	3	0	0	0	0	4	0	5
Gold (d)	0	10	7	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0
Iron (d)	11	10	30	6	25	2	12	4	0	21	4	9	1	8	0	0	0	0	7	0	5
Iron (t)	0	0	5	0	11	5	12	0	0	0	0	4	1	9	0	0	0	0	5	0	5
Lead (d)	0	10	9	0	5	2	12	0	3	3	0	5	1	8	0	1	2	0	1	0	4
Lead (t)	0	0	5	0	8	5	12	0	0	0	0	4	1	8	0	0	0	0	3	0	5
Magnesium (d)	11	20	64	6	58	5	23	4	3	30	4	30	2	21	0	1	6	0	17	0	5

TABLE 3.2 (Continued)

	Summer							Winter							Break-up						
	D	V	G	C	T	S	SS	D	V	G	C	T	S	SS	D	V	G	C	T	S	SS
Manganese (d)	10	10	35	3	11	4	12	3	3	29	3	8	2	8	0	1	2	0	1	0	5
Manganese (t)	0	0	5	0	9	5	12	0	0	0	0	4	1	8	0	0	0	0	5	0	5
Mercury (d)	0	0	2	0	4	2	4	0	0	0	0	2	1	2	0	0	0	0	0	0	0
Mercury (t)	0	0	5	0	8	5	5	0	0	0	0	5	1	2	0	0	0	0	3	0	1
Molybdenum (d)	0	10	7	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0
Molybdenum (t)	0	0	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nickel (d)	0	0	2	0	0	2	4	0	0	0	0	1	1	2	0	0	0	0	0	0	0
Nickel (t)	0	0	2	0	0	2	4	0	0	0	0	0	1	2	0	0	0	0	0	0	0
Platinum (d)	0	10	7	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0
Potassium (d)	11	20	58	6	58	5	23	4	3	20	4	30	2	21	0	1	5	0	18	0	6
Selenium (d)	0	10	9	0	5	2	11	0	3	3	0	5	1	8	0	1	2	0	1	0	5
Selenium (t)	0	0	5	0	9	5	12	0	0	0	0	5	1	8	0	0	0	0	4	0	5
Silver (d)	0	10	2	0	6	2	6	0	3	3	0	5	1	2	0	1	2	0	1	0	0
Silver (t)	0	0	5	0	8	5	6	0	0	0	0	4	1	4	0	0	0	0	4	0	2
Sodium (d)	11	20	55	6	58	5	23	4	3	22	4	30	2	21	0	1	4	0	17	0	6
Silicon (d)	0	10	7	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0
Strontium (d)	0	10	7	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0
Tin (d)	0	10	7	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0
Titanium (d)	0	10	7	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0
Tungsten (d)	0	9	7	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0
Vanadium (d)	0	10	7	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0
Zinc (d)	0	10	9	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0
Zinc (t)	0	0	5	0	9	5	10	0	0	0	0	5	1	7	0	0	0	0	4	0	4
Zironium (d)	0	10	7	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0

TABLE 3.2 (Continued)

	Summer							Winter							Break-up						
	D	V	G	C	T	S	SS	D	V	G	C	T	S	SS	D	V	G	C	T	S	SS
ORGANICIS																					
Chemical Oxygen Demand	0	8	7	0	0	0	0	0	3	3	0	0	0	0	0	1	2	0	0	0	0
Total Organic Carbon	0	0	6	0	1	0	8	0	1	4	0	2	0	10	0	0	3	0	1	0	4
Endrin	0	5	3	0	4	0	0	0	2	1	0	1	0	0	0	0	0	0	1	0	0
Lindane	0	3	3	0	5	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0
Methoxychlor	0	3	3	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Toxaphene	0	3	3	0	3	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0
2,4-D	0	3	3	0	4	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0
2,4,5-TP Silvex	0	3	3	0	4	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0

<u>Note:</u>
(d) is dissolved
(t) is total

<u>Sample Stations</u>
D - Denali
V - Vee Canyon
G - Gold Creek
C - Chulitna
T - Talkeetna
S - Sunshine
SS - Susitna Station

TABLE 3.3

ORGANIC PARAMETERS RECOMMENDED FOR ANALYSIS

Parameters	Detection Limits	Parameters	Detection Limits
PCB's		PHENOXY ACID HERBICIDES	
Arochlor 1016 (μg/l)	0.05	2,4 D (μg/l)	1.
Arochlor 1221 "	"		
Arochlor 1232 "	"	2,4, 5 T (μg/l)	0.5
Arochlor 1242 "	"		
Arochlor 1248 "	"	2,4, 5 TP (μg/l)	0.5
Arochlor 1254 "	"		
Arochlor 1260 "	"		
ORGANOCHLORIDES			
Aldrin (μg/l)	0.003	p,p^1 DDE (μg/l)	0.006
α BHC (μg/l)	0.002	p,p^1 DDT (μg/l)	0.016
δ BHC (μg/l)	0.004	α Endosulfan (μg/l)	0.01
β BHC (μg/l)	0.004	β Endosulfan (μg/l)	0.01
γ BHC (μg/l)	0.002	Endrin (μg/l)	0.01
α Chlordane (μg/l)	0.005	Heptachlor (μg/l)	0.002
γ Chlordane (μg/l)	0.005	Heptachlor Epoxide (μg/l)	0.004
p,p^1 DDD (μg/l)	0.012	Toxaphene (μg/l)	0.40
		Methoxychlor (μg/l)	0.01

TABLE 3.4
PARAMETERS EXCEEDING CRITERIA BY STATION AND SEASON

Parameter	Station	Season	Criteria
D.O. % Saturation	G	S	L
pH	T	S, W, B	L
	G	B	
Color	T, S	S	L
Phosphorus, Total (d)	V,G,T,S,SS	S, W, B	L
Total Organic Carbon	G, SS	S	S
	V, G, SS	W	
	SS	B	
Aluminum (d)	V, G	S, W	S
Aluminum (t)	G, S, SS	S	
Bismuth (d)	V, G	S	S
	G	W	
Cadmium (d)	T, SS	S, W	L
	SS	B	
Cadmium (t)	G, T, S, SS	S	
	T, SS	W, B	
Copper (d)	T, SS	S	A
	T	W	
	SS	B	
Copper (t)	G, T, S, SS	S	
	T, S, SS	W	
	T, SS		
Iron (d)	D, V, C	S	L
Iron (t)	G, T, S, SS	S	
	T	B	
Lead (t)	G, T, S, SS	S	A
	T, SS	W, B	
Manganese (d)	D, V, G, C	S	L
Manganese (t)	G, T, S	S	
	T, SS	B	

TABLE 3.4 (Continued)

Parameter	Station	Season	Criteria
Mercury (d)	G, S,	S	L
	S	W	
Mercury (t)	G, T, S, SS	S	
	T, S, SS	W	
	T, SS	B	
Nickel (t)	G, S, SS	S	A
Zinc (d)	V	S	A
Zinc (t)	G, S, SS	S	
	T, S, SS	W	
	SS	B	

Stations

D - Denali
V - Vee Canyon
G - Gold Creek
C - Chulitna
T - Talkeetna
S - Sunshine
SS - Susitna Station

Seasons

S - Summer
W - Winter
B - Breakup

Criteria

L - Established by law as per Alaska Water Quality Standards

S - Criteria that have been suggested but are not law, or levels which natural waters usually do not exceed.

A - Alternate level to 0.01 of the 96-hour LC_{50} determined through bioassay.

4 - PRE-PROJECT WATER QUALITY AND HYDROLOGY

Wide seasonal fluctuations in discharge are characteristic of the Susitna River. Discharge declines during the fall and winter, typically reaching a minimum in March. Breakup occurs in late April or early May; discharge sharply increases then and varies throughout the summer, depending on temperature and rainfall. The maximum average monthly flow usually occurs in June, and the minimum usually occurs in March. Table 4.1 presents basin and runoff characteristics for the Watana and Devil Canyon damsites and for Gold Creek. The U.S. Geological Survey (USGS) has maintained a gaging station at Gold Creek for the past 31 years and has also sampled water quality and suspended sediment during that time. Analysis of regional flow characterstics has been done by the USGS and by R&M Consultants, Incorporated (R&M), and is contained in "Flood Characteristics of Alaskan Streams" (Lamke, 1979), "Regional Flood Peak Studies" (R&M, 1981); and "River Morphology Studies", (R&M, 1982b). The average annual runoff at the two proposed damsites is 1.5 cubic feet per second per square mile of drainage basin (cfspsm), and at Gold Creek it is 1.6 cfspsm. The maximum recorded discharge at Gold Creek is 90,700 cfs (USGS, 1981), which amounts to 15 cfspsm.

The wide seasonal fluctuations in discharge have a significant effect on water quality. The glacial character of the river also affects water quality. Suspended sediment concentrations and turbidity levels are low during late fall and winter, but sharply increase at breakup and remain high throughout summer during the glacial melt period. Dissolved solids concentrations and conductivity values are high during low-flow periods and low during the summer during high flows.

The Susitna River is a fast-flowing, cold-water stream of the calcium bicarbonate type containing soft to moderately hard water during breakup and in the summer and moderately hard water in the winter. Nutrient concentrations, namely nitrate and orthophosphate, exist in low to moderate concentrations. Dissolved-oxygen concentrations typically remain high, averaging about 12 mg/l during the summer and 13 mg/l during winter. Percentage saturation of dissolved oxygen always exceeds 80 percent but averages near 100 percent in the summer; in the winter, saturation levels decline slightly from the summer levels. pH values typically range between 7 and 8 and exhibit a wider range in the summer as compared to the winter. During summer, pH occasionally drops below 7, which is attributed to tundra runoff. True color, also resulting from tundra runoff, displays a wider range during summer than winter. Color levels in the vicinity of the damsites have been measured as high as 40 color units. Temperature remains at or near 0°C during winter, and the summer maximum is 13°C. Alkalinity concentrations, with bicarbonate as the dominant anion, are low to moderate during summer and moderate to high during winter. The buffering capacity of the river is relatively low on occasion.

The concentrations of many trace elements monitored in the river were low or within the range characteristic of natural waters. However, the concentrations of some trace elements exceeded water quality guidelines for the protection of freshwater aquatic organisms. These concentrations are the result of natural processes because there are no man-induced sources of these elements in the Susitna River basin.

Concentrations of organic pesticides and herbicides, uranium, and gross alpha radioactivity were either less than their respective detection limits or were below levels considered to be potentially harmful.

TABLE 4.1

SUSITNA RIVER, BASIN AND RUNOFF CHARACTERISTICS

	Watana Damsite	Devil Canyon Damsite	Gold (1) Creek Gage Site
Drainage Area, Mi^2	5,180	5,810	6,160
Average Annual Flow, cfs	7,860	8,960	9,647
Maximum Average Monthly Flow, cfs	23,100	26,200	27,900
Minimum Average Monthly Flow, cfs	890	1,030	1,100

(1) USGS, 1981.

5 - RIVER REGIME EFFECTS OF IMPOUNDMENT

Construction of hydroelectric dams and their reservoirs has a profound effect on the water regime of downstream river reaches. The effects are summarized here; more detailed discussion is presented in "River Morphology Studies" (R&M, 1982c). Since the rate of reservoir water outflow is controlled, the downstream reach is no longer subject to the fluctuations of a normal river regime, with the consequence that the flow becomes more seasonally uniform throughout the year (Kellerhals and Gill, 1973; Turkheim, 1975). The minimum flow rate is significantly increased, and peak flows are decreased. The decrease in spring flood magnitude, especially during the initial impoundment, may result in negative effects on the downstream environment. It is reasonable to expect that the interference with natural Susitna River flows will cause a change in stream levels and bank storage levels for some distance downstream from the dams.

The number of upstream hydrologic effects are few compared to at-reservoir and downstream effects. Due to an aggradation process whereby reservoir water levels are increased in an upstream direction, the reservoir can increase the amount of evaporation from a river (Turkheim, 1975). However, the amount of evaporation from the river will be a small percentage of the total evaporation from the Watana and Devil Canyon reservoirs, and evaporation at these reservoirs will be insignificant.

6 - WATER QUALITY IMPACTS

6.1 - Impoundment Characteristics

The Watana Dam will be 860 feet high and will retain 9.6 million acre-feet of water at full storage. The area of the reservoir at the maximum operating level will be 38,000 acres. The Devil Canyon Reservoir will be smaller, covering 7,800 acres at the maximum operating level, with 1.1 million acre-feet at full storage. The Devil Canyon Dam will be 650 feet high. Either multi-level outlets or single outlets at a depth no greater than 200 feet will be used. Consequently, neither dam will have an outlet near the reservoir bottom.

The environmental conditions in an impoundment differ from those in a flowing stream in many ways, including change in water depth, increased detention time, and the possibility of stratification, eutrophication, evaporation, sedimentation, and leaching. Each of these has an influence on the normal physical, chemical, and biologic processes that cause changes in water quality. Additional detention time allows natural processes to proceed far beyond the extent feasible in a flowing stream. If stratification exists, the bottom portion of the water (hypolimnion) is trapped and does not contact aerated water or the atmosphere, thereby having a marked effect on the natural processes that occur in water and leading to creation of poor-quality water. Leaching also results in poor quality of the hypolimnion. Eutrophication leads to algal blooms and nuisance conditions throughout an impoundment, and evaporation concentrates the dissolved fractions in water.

6.2 - Impoundment Processes and Interactions

The impoundment processes (stratification, eutrophication, evaporation, sedimentation, leaching, and ice cover) are defined in this section, and a summary of their interactions is presented.

Stratification. Stratification is a layering of water because of density differences, which can be caused by temperature or sediment load. Stratification occurs in the summer due to the warming of the surface water by short and long-wave radiation, conduction, and advection (Roesner, 1971), and winter stratification can occur in cold regions because 0°C water at the surface is lighter than the warmer water below (Kittrel, 1965). Winter stratification is not as stable as summer stratification, which is stable with dense water at the bottom and lighter water at the top and very little vertical mixing. The top layer of the reservoir (the epilimnion) is of nearly uniform temperature, the region of changing temperature below the epilimnion is the thermocline, and the bottom layer is the hypolimnion (Symons, 1969). Only weak thermal stratification has been observed in glacial lakes (R&M, 1982a).

Eutrophication. Eutrophication is a term meaning enrichment of waters by nutrients, either man-induced or through natural means (Mackenthun, 1969). Phosphorus and nitrogen are the fertilizing elements most responsible for lake eutrophication, but iron and other trace elements are also important.

Evaporation. The major effect of evaporation on water quality is the resulting higher concentration of dissolved substances (Symons, 1969; Love, 1961). In Alaska, cool temperatures and abundant water indicate that evaporation may not be critical. Sublimation from ice and snow, however, may cause significant water loss (Smith and Justice, 1976).

Sedimentation. The quiescent conditions in impoundments indicate that sedimentation will occur, and the type of material that will settle is dependent on upstream conditions. The rate of settling is a function of particle size, shape, and density (Weiss et al., 1973).

Leaching. Leaching is the exchange of chemicals from an impoundment bottom to the water mass, and the process of exchange is more rapid under reducing conditions than under oxidizing conditions (Mortimer; 1941, 1942).

Ice Cover. An ice cover has one direct effect on impoundment water quality and some indirect effects. The direct effect was noted by Mortimer (1941, 1942), who discussed the increased concentration of solutes just below the ice. As water freezes, the dissolved solids are exuded from the ice and concentrated. The indirect effects include (1) the prevention of atmospheric reaeration, (2) stratification, and (3) a reduction in light penetration after snow covers the ice.

Each of the six processes defined above interact with one another in impoundments. The cumulative effect of these interactions on water quality is usually to further degrade it. The process interactions described below are from Smith and Justice (1976).

Stratification-Leaching. In a stratified reservoir, no vertical mixing occurs between the epilimnion and the hypolimnion; thus no oxygen is transferred to the lower water. If anaerobic conditions result, the redox potential will decrease, and leaching rates will increase.

Stratification-Sedimentation. Stratification causes inflowing water to enter at a depth with equal density, thereby controlling the distance the sediment load has to fall before being effectively removed from the incoming water. In some cases, stratification determines whether or not the suspended material will be removed at all. Also, loss of sediment reduces the water density, which can affect stratification.

Stratification-Evaporation. Stratification increases evaporation because the warm, less dense water remains near the surface. On the other hand, surface cooling by evaporation and heat loss can cause convective currents if the heat loss is greater than the energy added by the sun's radiation. The convective currents keep the epilimnion isothermal and mixed.

Stratification-Eutrophication. Nutrient-rich hypolimnion water is prevented from mixing with surface water, thus controlling algae growth if the concentration of the limiting nutrient is controlled.

Eutrophication-Leaching. The dying and settling of algae adds organic matter to the bottom. Upon degradation, the organic matter depletes oxygen and releases chemicals. Nutrients are released by the leaching of detritus material. If the nutrients are transported to the surface, algae growth may be stimulated.

Eutrophication-Sedimentation. Dead algae settle to the bottom. Settling of dead algae and of some precipitates removes nutrients from the zone of algae growth. Increased light penetration due to turbidity removal can stimulate algae growth.

Eutrophication-Evaporation. Active algae growths at a water surface cause an increase in evaporation rates.

Sedimentation-Leaching. Settling of inorganic material will reduce leaching by covering or diluting organic deposits. If the settled material is high in organic content, anoxic conditions, and thus leaching, will be favored.

Ice Cover-Evaporation. Water loss by evaporation will be reduced if an ice cover exists, but sublimation will still occur and will remove some of the ice and snow cover.

Ice Cover-Eutrophication. The decreased light penetration due to snow and ice cover will slow the growth of algae. However, rapid algae growth has been observed under ice cover.

Ice Cover-Stratification. Winter stratification is protected from wind mixing by an ice cover.

Ice Cover-Leaching. Winter reaeration can only come from advection of oxygen-rich water or through cracks in the ice cover. If anaerobic conditions develop, leaching will increase.

Evaporation-Sedimentation. Loss of water by evaporation leaves the dissolved solids more concentrated, thus forcing precipitation reactions to the solid phase with possible settling of reaction products.

6.3 - Impoundment Impacts on Water Quality

When a turbulent, sediment-laden stream such as the Susitna River enters a reservoir, the quiescent conditions will allow much of the material to settle to the bottom. Weiss et al. (1973), Simmons (1972), and Love (1961) substantiate the reduction of turbidity by impoundment of sediment-laden waters in reservoirs. According to reservoir sedimentation studies, 70-97 percent of sediment entering Watana Reservoir would settle (most likely on the high end of this range), even shortly after filling of the reservoir starts (R&M, 1982a). The Devil Canyon Reservoir would have a slightly lower trap efficiency than Watana due to its smaller volume. However, most sediment will be deposited in Watana, the upstream reservoir. Turbidity levels and suspended solids concentrations downstream from the reservoir will decrease sharply from natural levels during the summer months due to the sediment trapping characteristics of the reservoirs. The turbidity of water released during winter will be substantially reduced from summer conditions, as suspended sediment in near-surface waters should rapidly settle once the reservoir ice cover forms and essentially quiescent conditions occur. However, it is possible that glacial flour that entered the reservoir during summer will pass through and out the reservoir during winter. If this occurs, the turbidity of water released during winter, although low, will be higher than pre-project levels.

Sedimentation affects other water quality parameters besides turbidity and suspended solids. Color (Drachev, 1962), particulate phosphorus (Wright and Soltero, 1973), dead microorganisms such as plankton and algae (Erickson and Reynolds, 1969), and precipitated chemicals (Mortimer; 1941, 1942) are removed in the sedimentation process. Consequently, color levels and total phosphorus concentrations ought to be reduced in and downstream from the reservoir. Metal concentrations, such as iron, manganese, and some of the trace elements, will also be reduced as they are precipitated and settle to the bottom. Leaching under anaerobic conditions will cause some of these characteristics to redissolve into the water near the reservoir bottom. However, if the deposited material is inorganic, it can form a mat on the reservoir bottom, thereby effectively blocking leachate from entering the water column (Neal, 1967). This is expected to occur in the Watana Reservoir but is likely to be a minor factor in the Devil Canyon Reservoir.

The range and seasonal variation in temperature of the Susitna River will change after impoundment. Bolke and Waddell (1975) noted in an impoundment study that the resevoir not only reduced the magnitude of variation in temperature but also changed the time period of the high and low temperature. This will also be the case for the Susitna River, where pre-project temperatures generally range from 0°C to 13°C with the lows occurring in

October/November through March/April and the highs in July or August. After closure of the dam gates, the temperature range will be reduced and low temperatures will occur in November through March. The period of highest temperature will be July and August, as is the pre-project case. Reservoirs releasing water from the surface are "heat exporter" reservoirs (Turkheim, 1975), and both Susitna River reservoirs fall into this category.

Thermal stratification is likely to occur in both reservoirs during summer and winter as a result of density differences within the water column, although stratification is often relatively weak. Winter stratification would be less stable than summer stratification because the maximum temperature difference would be 4°C, the temperature of water at its maximum density. It is expected that vertical mixing will occur in the spring as a result of the large input of water, wind effects, and surface-water warming. During stratified conditions, vertical mixing is inhibited or eliminated. Thus, the transport of oxygen from the surface, where reaeration occurs, to the bottom, where biologic and chemical processes use oxygen, is severely inhibited.

Anaerobic bottom conditions can harm aquatic life and cause the reduction and release of undesirable chemicals into the water (Fish, 1959). The leaching process, which is more efficient under anaerobic conditions, degrades bottom water quality by releasing such chemicals as alkalinity, iron, manganese (Symons et al., 1965), hydrogen sulfide, and nutrients (Turkheim, 1975). Also, leaching problems become more severe as the organic content in the soils increases. The potential for leaching at the Watana Reservoir should decline over time as the inorganic glacial sediment carried in by the river settles and blankets the reservoir bottom.

The products of leaching are not anticipated to be abundant enough to affect more than a small layer of water near the reservoir bottoms. Also, leaching products will not degrade downstream water quality over the long term because water will be released from the reservoir surface. A short-term increase in dissolved solids, conductivity, and most of the major ions may be evident immediately after closure of the dam. The magnitude of increase cannot be quantified with available data, but it is anticipated that the increase will not result in detrimental effects to freshwater aquatic organisms. Bolke and Waddell (1975) reported that the highest concentration of all major ions, except magnesium, occurred immediately after closure of the dam they were studying. They attributed the increase in concentration to the initial inundation and leaching of rocks and soils in the reservoir area. However, effects such as these are temporary and diminish as the reservoir matures (Baxter and Glaude, 1980).

Although evaporation has been noted to cause the dissolved solids concentrations to increase (Symon, 1969; Love, 1961), this potential effect on water quality at the Watana and Devil Canyon Reservoirs is not significant. The average annual evaporation predicted for May through September at Watana is 10.0 inches, and at Devil Canyon is 11.1 inches. There is no evaporation during the period of ice cover which will be October through April. The percentage of the reservoirs lost to evaporation during summer will be 0.3 percent at Watana and 0.6 percent at Devil Canyon. A less-than 1 percent increase in concentration of most water quality parameters is not significant. Local effects may be noted from evaporation, and sublimation may cause some water loss, creating local effects. These are not anticipated to be significant.

Eutrophication occurs when nutrients accumulate in the photic zone of lakes and reservoirs. If water is released from a reservoir surface, the reservoir is a "nutrient trap" (Turkheim, 1975), much like a lake. Both Susitna River reservoirs will release water from at or near the surface. Hence, they can be expected to become nutrient traps. However, the probability of eutrophic conditions developing in these reservoirs is not necessarily high because they are nutrient traps. The major criteria that influence eutrophication include nutrient concentrations, algal populations, solar radiation, and the effects of reservoir processes. More detailed discussion on assessment of eutrophication potential is presented in Attachment B.

The critical concentration of nitrogen in a lake at the beginning of the growing season above which excessive algae blooms may be expected to occur is 0.2 - 0.3 mg/l when phosphorus concentrations are from 0.01 to 0.02 mg/l (Mackenthun, 1960). Symons (1969) reports that phosphorus is the controlling nutrient and blooms could be expected if the level exceeded 0.01 mg/l. The pre-project concentrations of nitrogen and phosphorus measured at Vee Canyon, upstream from the proposed reservoir locations, have exceeded the critical concentration levels cited above. These critical concentration levels were developed from work done in temperate regions, and may not be applicable in the subarctic. LaPerriere et al. (1978), in their study of the nutrient chemistry of a large, deep subarctic lake, reported nitrogen and phosphorus concentrations similar to those measured at Vee Canyon. The lake they studied was not eutrophic, and the peak algal biomass and productivity occurred under the spring ice rather than in the summer. They also predicted that a large number of cottages could be added around the lake without eutrophic conditions developing. Based on this work, it seems reasonable to expect that eutrophic conditions will not develop in the Watana and Devil Canyon Reservoirs.

Turkheim (1975) reports that nitrogen supersaturation of water below a dam is possible in certain seasons, extending an unknown distance downstream. This is certainly a possibility below both Susitna dams. However, the ultimate impact of nitrogen supersaturation is its effect on fish. Nitrogen supersaturation problems will be solved structurally through the use of Howell-Bunger valves, eliminating plunging spills up to the 1:50 year flood. Portage Creek, just below Devil Canyon, is essentially the upstream limit for spawning salmon. Consequently, water supersaturated with nitrogen leaving the dams must travel through Devil Canyon before reaching an important fisheries area. It is reasonable to expect that, with the natural plunging and turbulence of the canyon, post-project nitrogen super-saturation levels will be the same as the pre-project levels at the downstream end of Devil Canyon.

7 - REFERENCES

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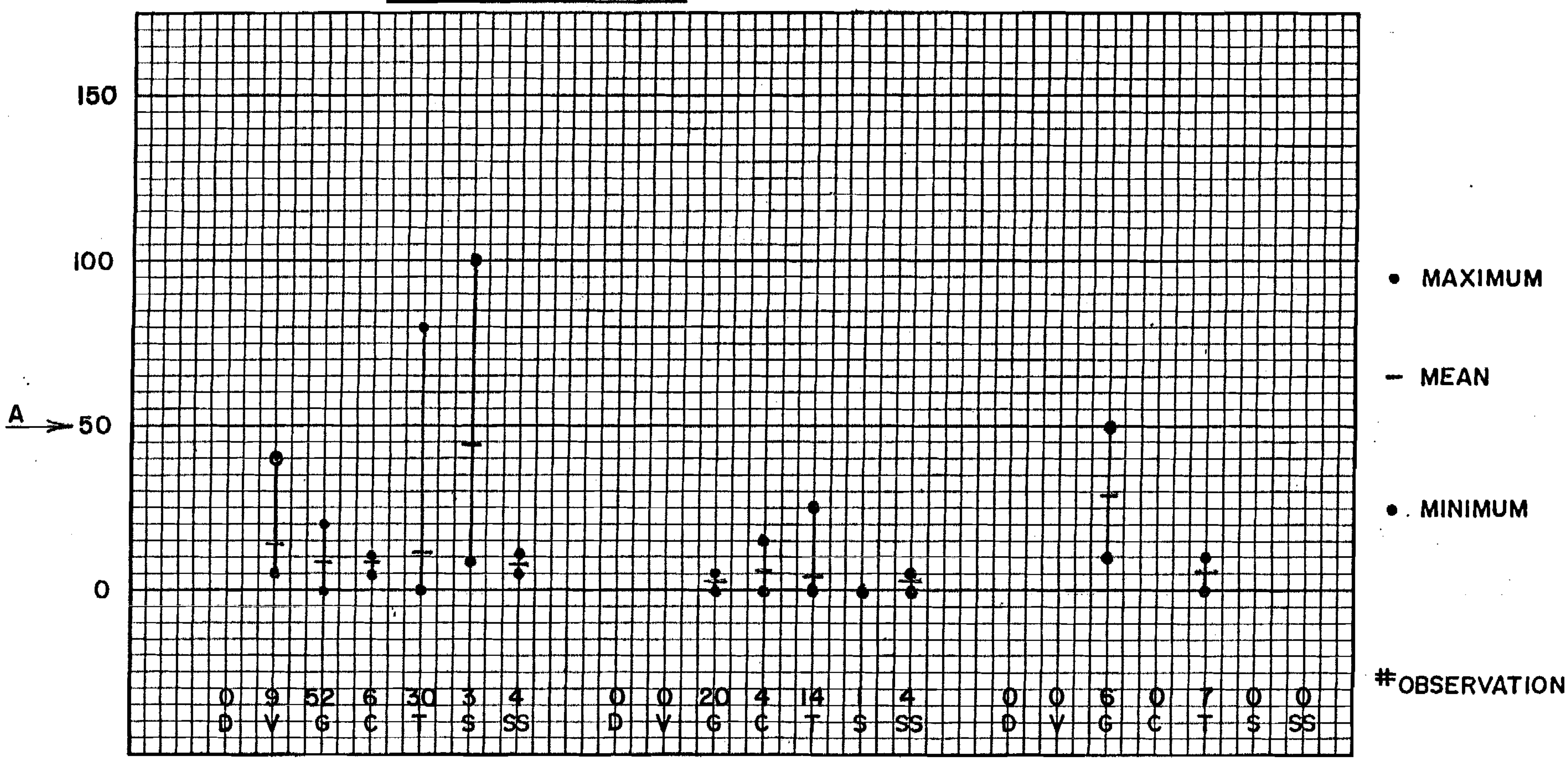
ATTACHMENT A

GRAPHICAL SUMMARIES OF WATER QUALITY DATA

s14/c1

PARAMETER: TRUE COLOR, PLATINUM COBALT UNIT



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

Shall not exceed 50 units (ADEC, 1979)

Established to prevent the reduction of photosynthetic activity which may have deleterious effects on aquatic life.

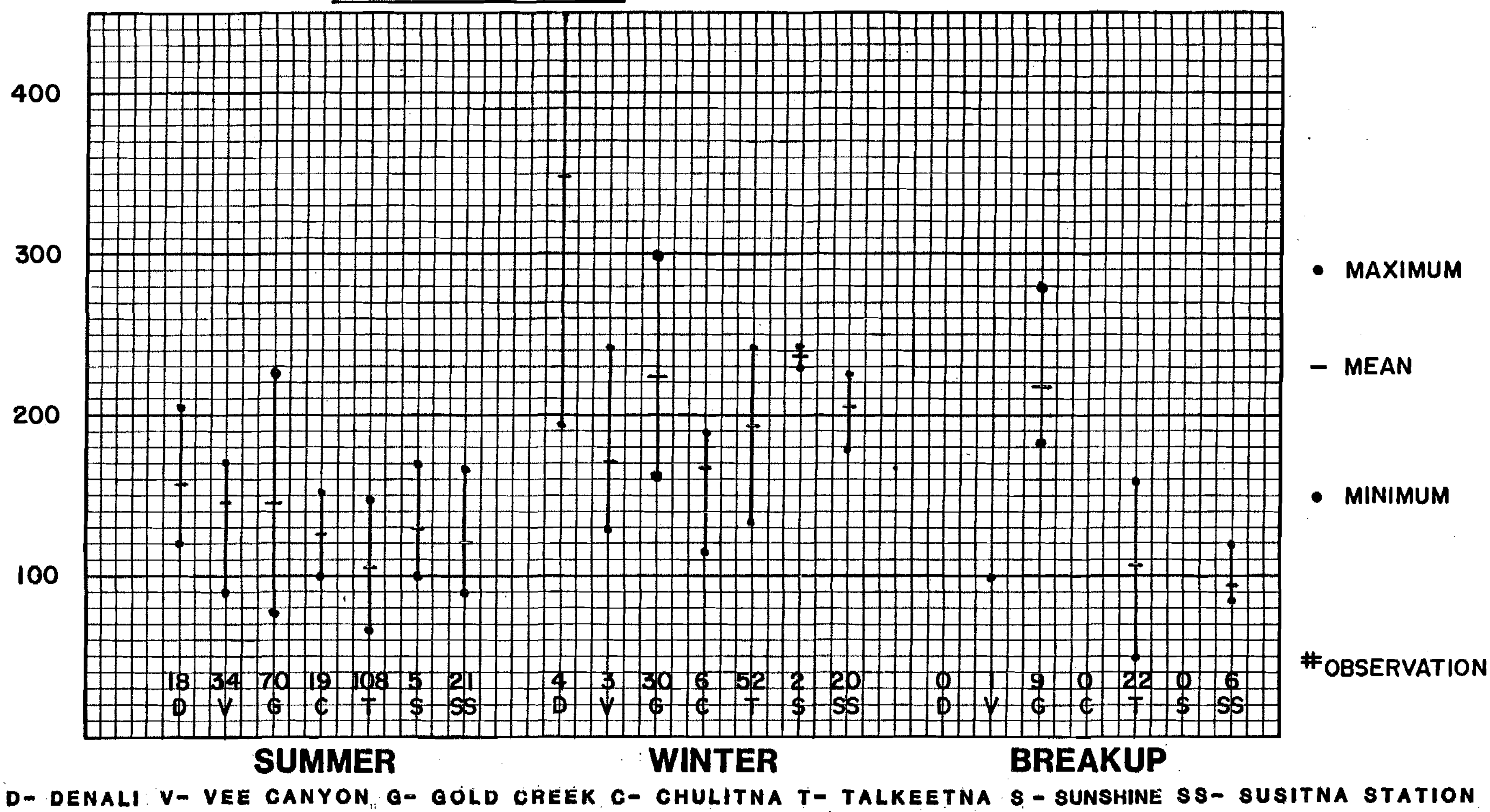
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - COLOR

FIGURE : 1

ACRES

PARAMETER: CONDUCTIVITY, µmhos/cm @ 25°C



No criterion established

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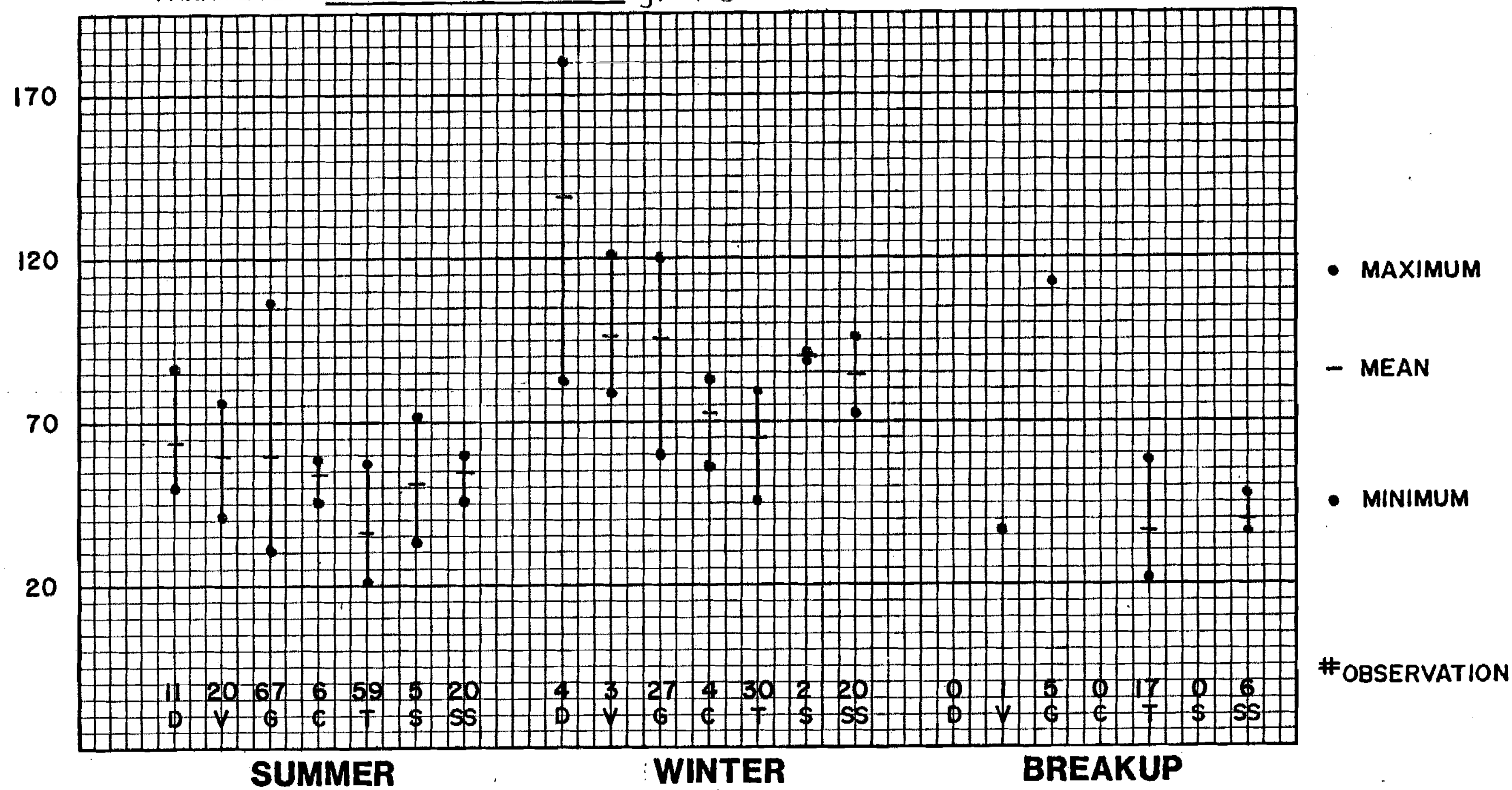
DATA SUMMARY - CONDUCTIVITY

FIGURE : 2

ACRES

PARAMETER: HARDNESS, as Ca CO_3, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established

Some metals have variable synergistic effects with hardness, dependent on the prevailing hardness in the water. The criteria for cadium, for example, is 0.0012 mg/l in hard water and 0.0004 mg/l in soft water.

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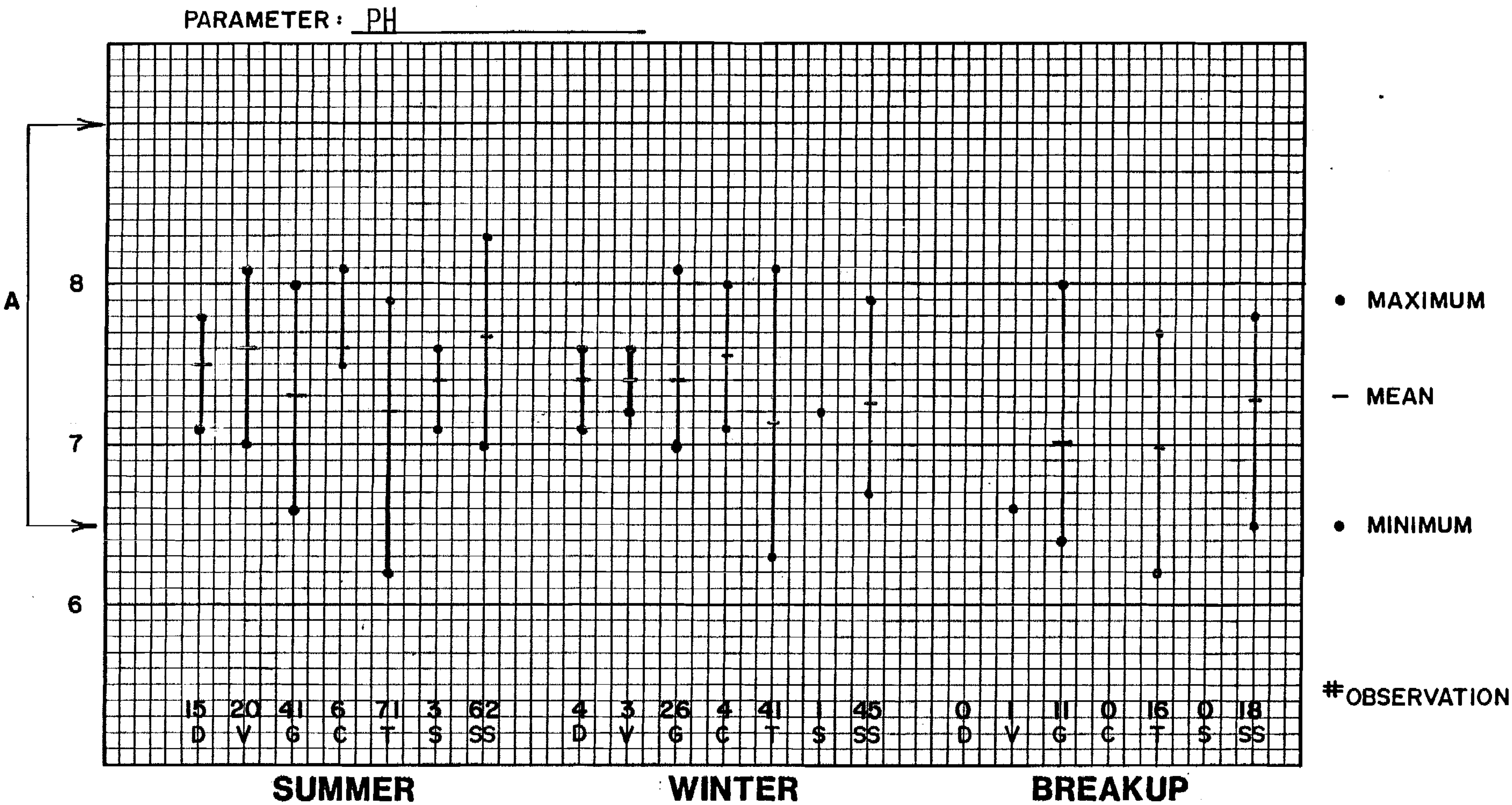
DATA SUMMARY - HARDNESS

FIGURE : 3

ACRES



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Not less than 6.5 or greater than 9.0. Shall not vary more than 0.5 pH unit from natural condition (ADEC, 1979).

Established to protect freshwater aquatic organisms.

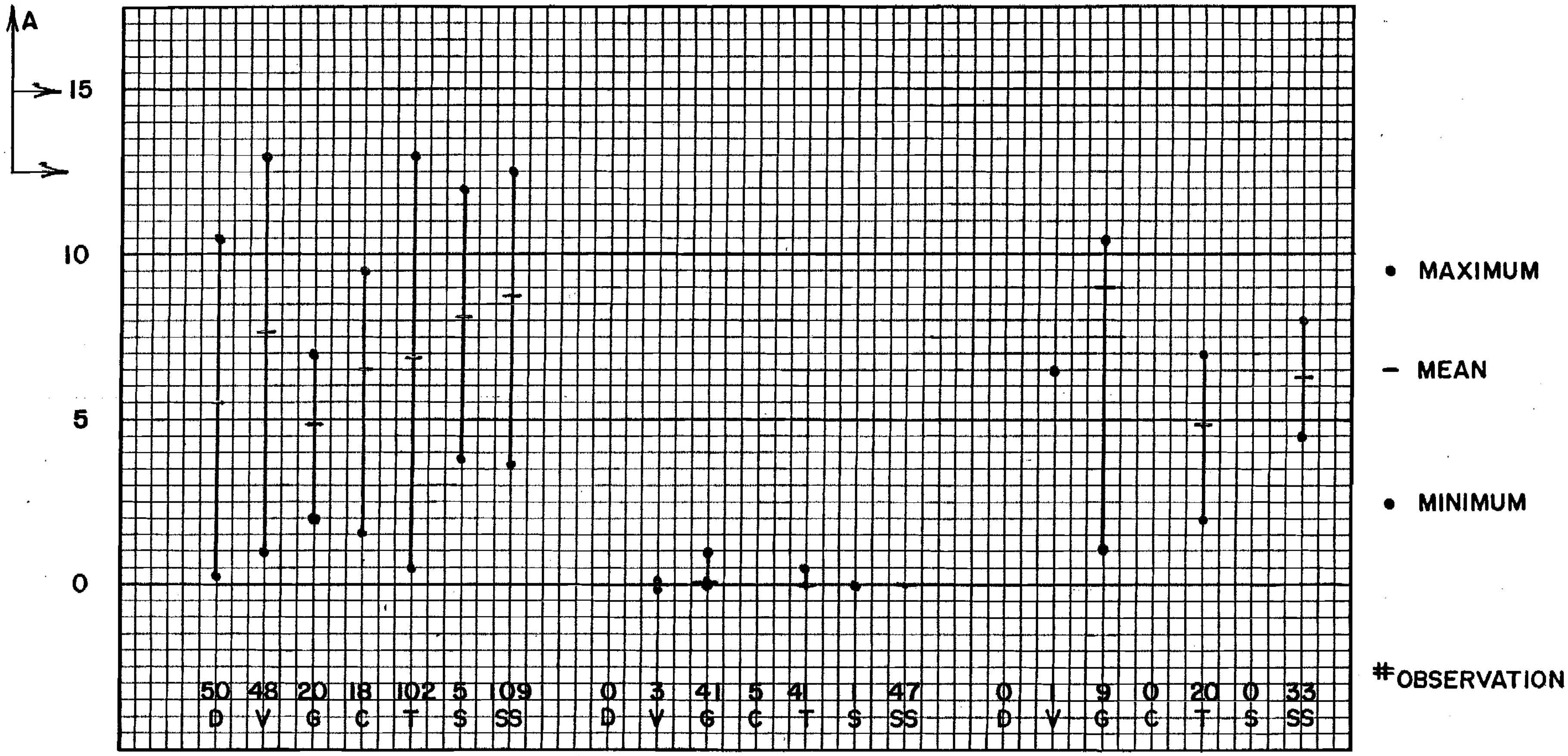
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - PH

FIGURE: 4

ACRES

PARAMETER: TEMPERATURE, °C



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Shall not exceed 20°C at any time. The following maximum temperature shall not be exceeded where applicable: migration routes and rearing areas--15°C, spawning areas and egg and fry incubation--13°C (ADEC,1979)

Established to protect sensitive important fish species, and for the successful migration, spawning, egg-incubation, fry-rearing, and other reproductive functions of important species.

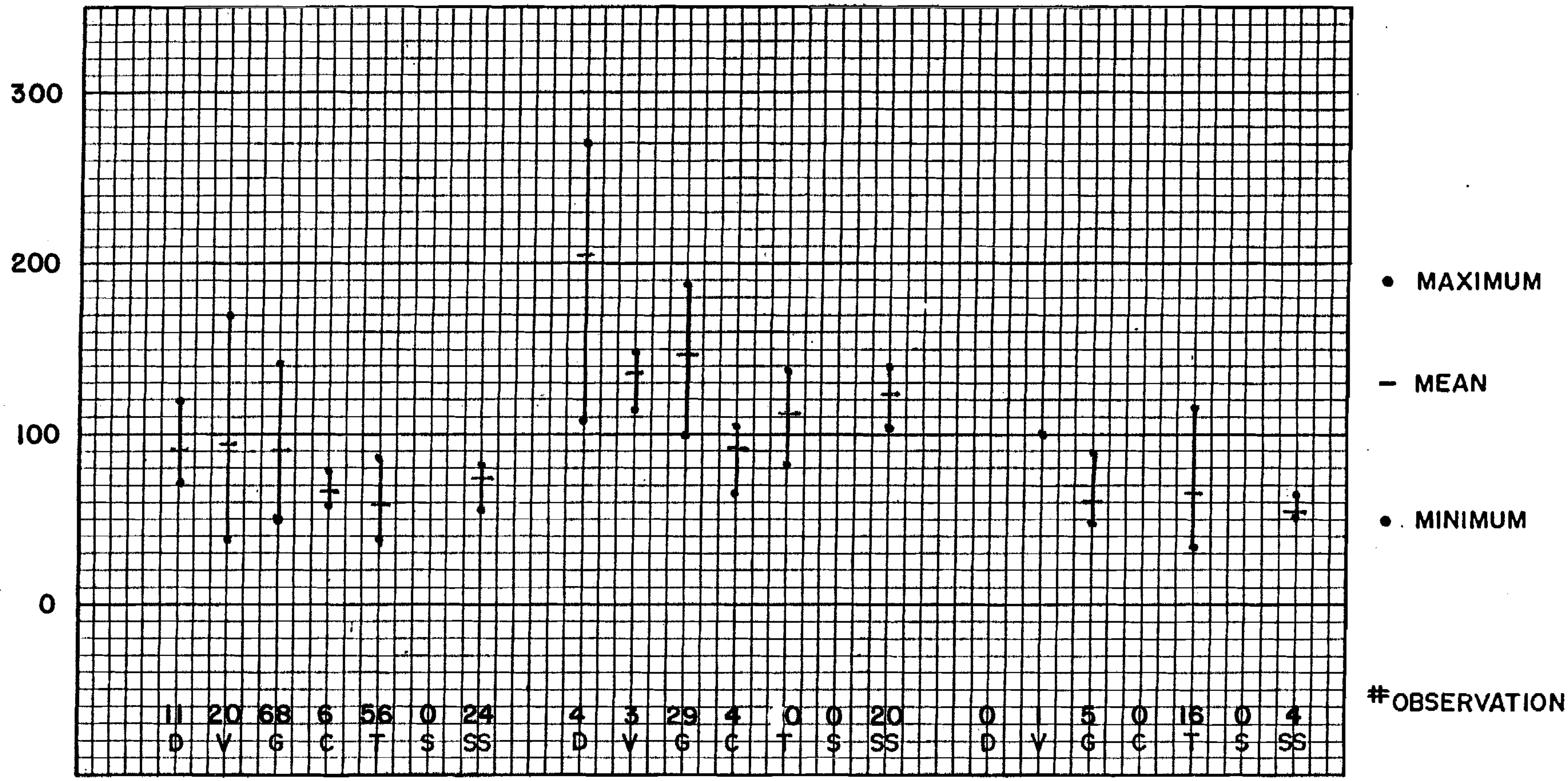
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY -TEMPERATURE

FIGURE: 5

ACRES

PARAMETER: TOTAL DISSOLVED SOLIDS, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S- SUNSHINE SS- SUSITNA STATION

A. 1,500 mg/1 (ADEC, 1979).

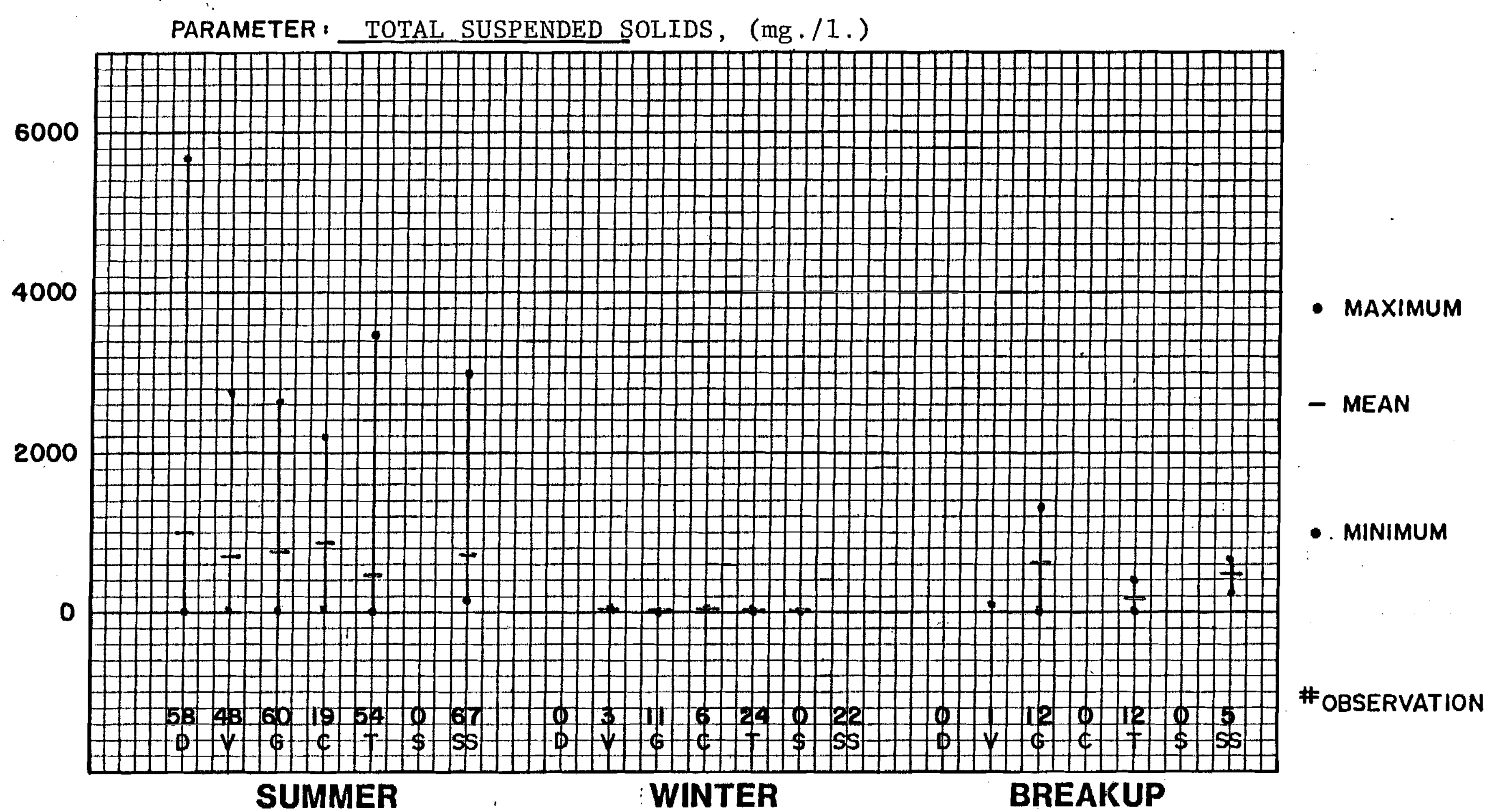
Established to protect natural condition of freshwater ecosystems (500 mg/1 is the criterion for water supplies).

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - TOTAL DISSOLVED SOLIDS

FIGURE: 6

ACRES



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No measurable increase above natural conditions (ADEC,1979).

Established to prevent deleterious effects on aquatic animal and plant life, their reproduction and habitat.

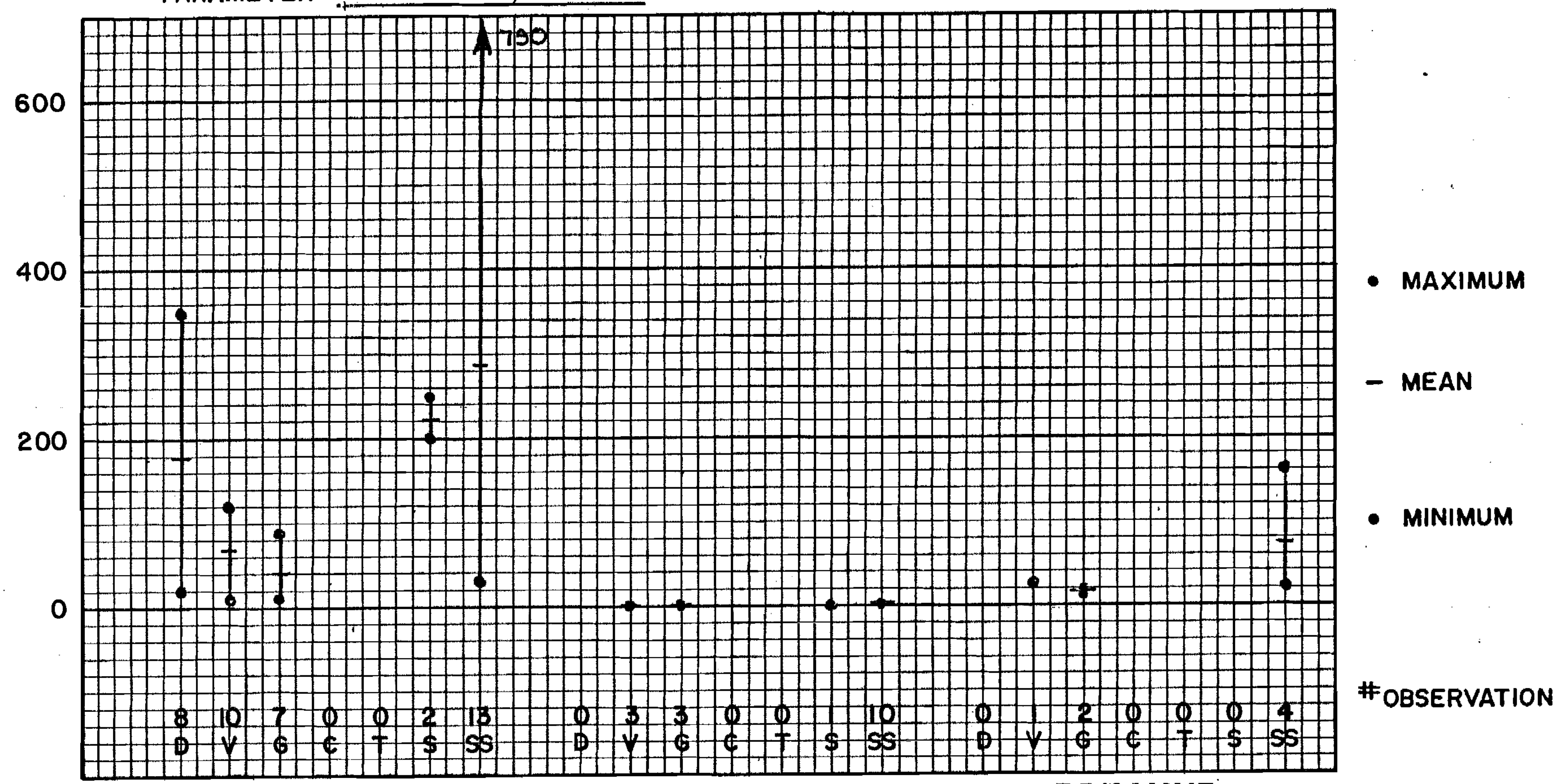
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - TOTAL SUSPENDED SOLIDS

FIGURE : 7

ACRES

PARAMETER: TURBIDITY, NTU



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S- SUNSHINE SS- SUSITNA STATION

Shall not exceed 25 NTU above natural conditions (ADEC, 1979)

Established to prevent the reduction of the compensation point for photosynthetic activity, which may have adverse effects on aquatic life.

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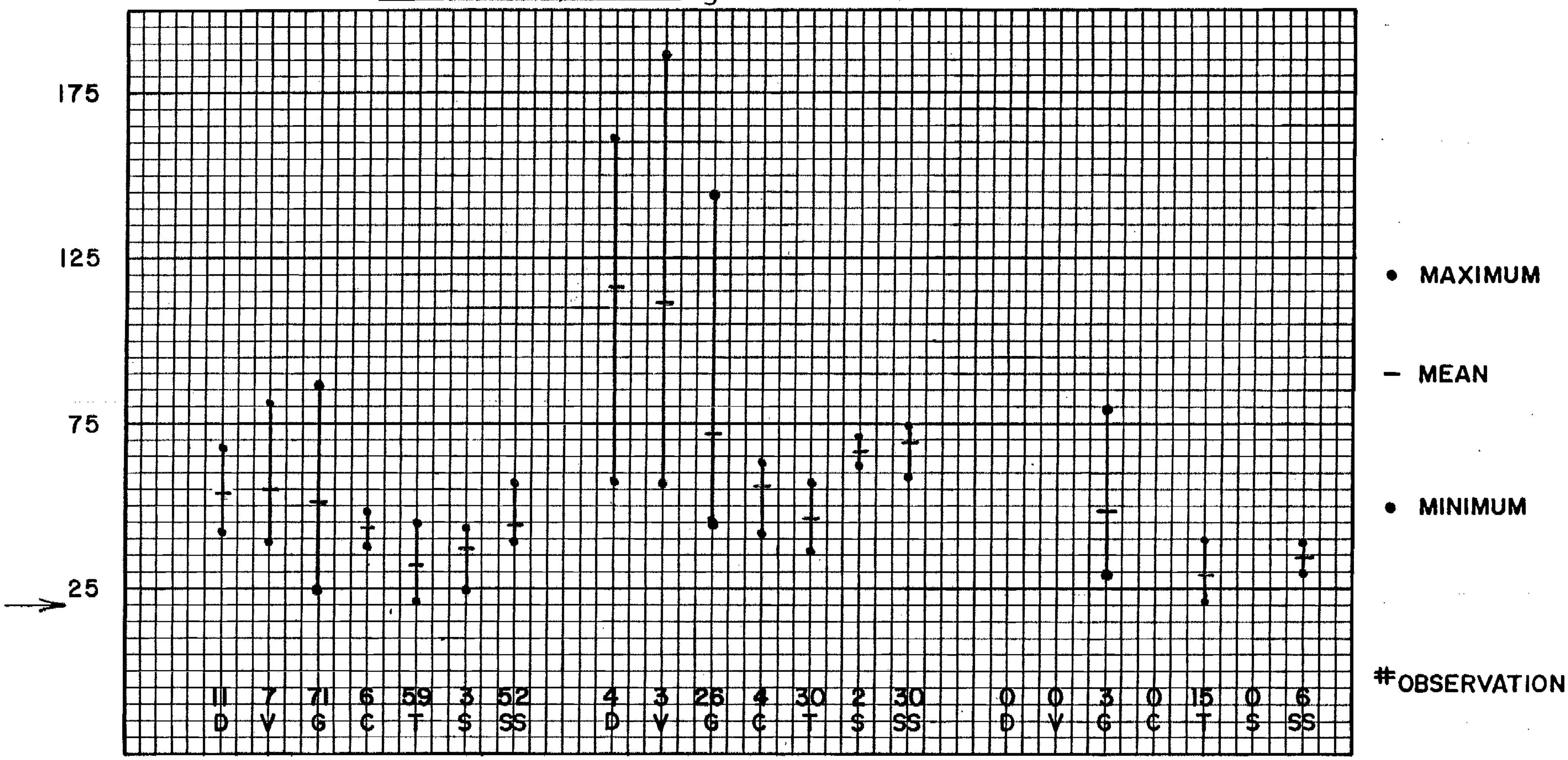
DATA SUMMARY - TURBIDITY

FIGURE: 8

ACRES

PARAMETER: ALKALINITY, as $CACO_3$, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

20mg/1 or more except where natural conditions are less. (EPA, 1976).

Established to protect freshwater aquatic organisms.

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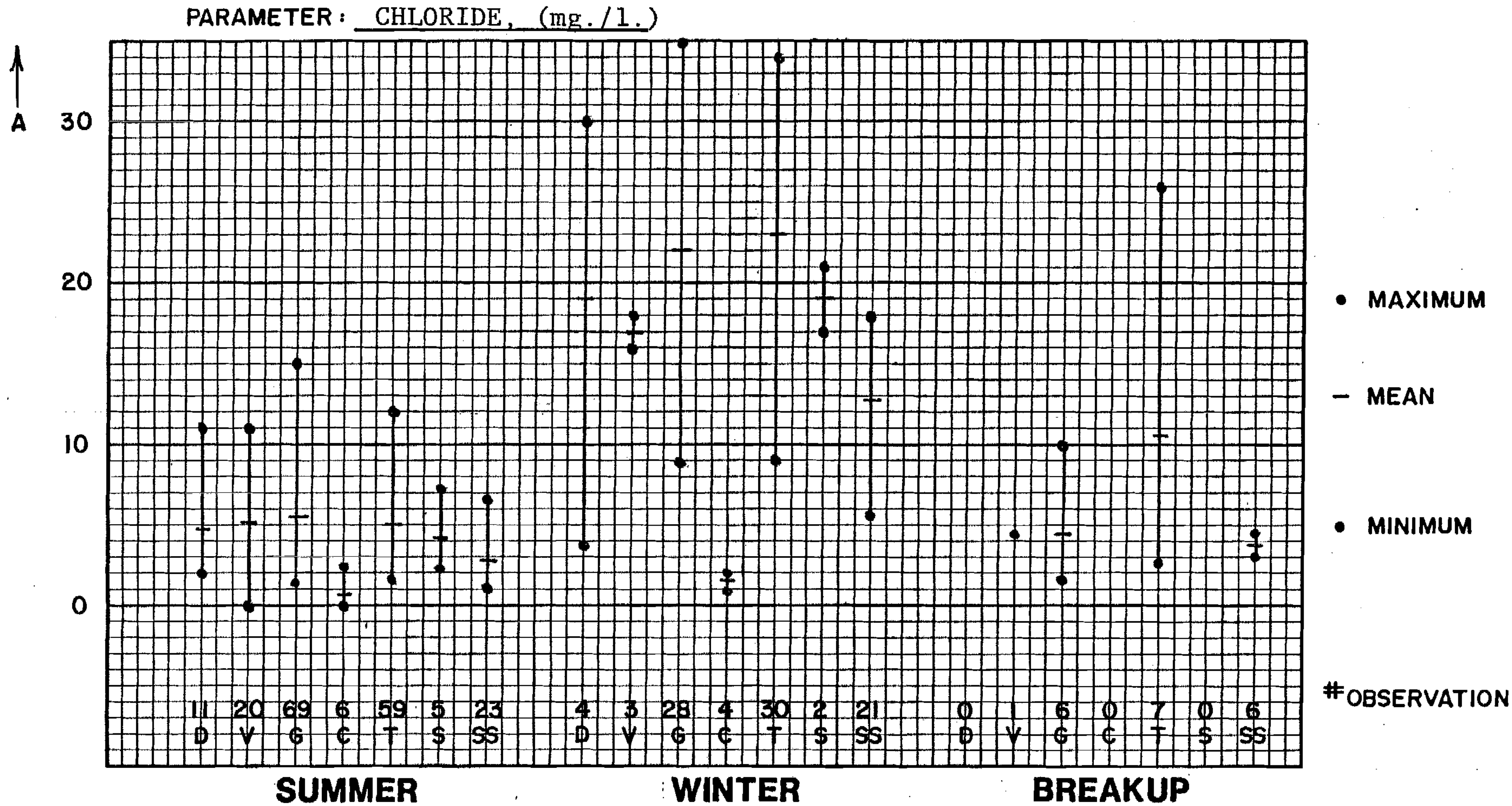
DATA SUMMARY - ALKALINITY

FIGURE : 9

ACRES



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

Less than 200 mg/l_x (ADEC, 1979)

Established to protect water supplies.

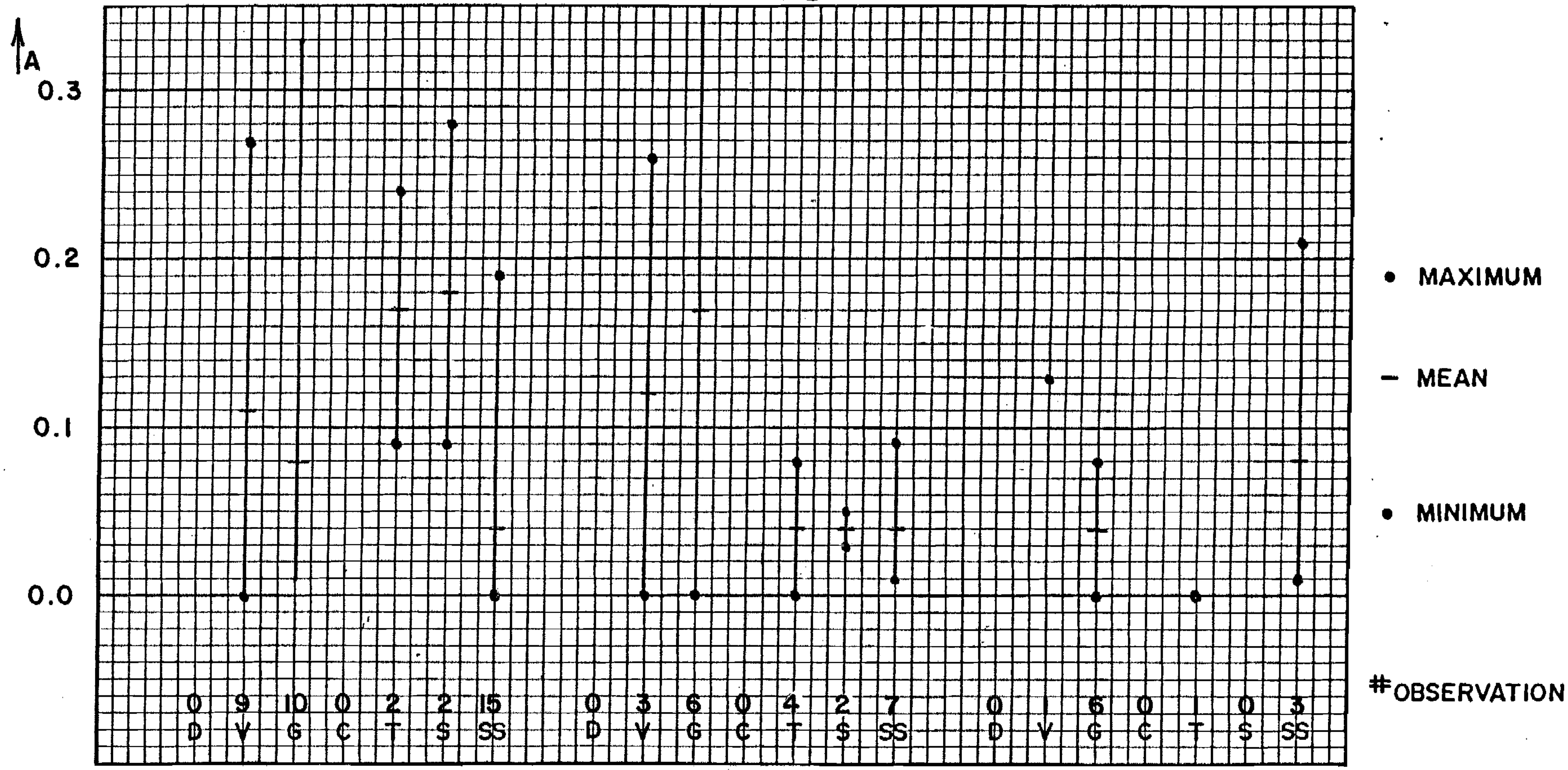
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - CHLORIDE

FIGURE : 10

ACRES

PARAMETER: AMMONIA NITROGEN, as N, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S- SUNSHINE SS- SUSITNA STATION

A. Less than 0.02mg/l as un-ionized ammonia (EPA, 1976). Data appearing above are total dissolved ammonia. The concentration of un-ionized ammonia is pH and temperature dependant. The maximum ammonia nitrogen concentration appearing in this figure is less than the stated criterion.

Established to protect freshwater aquatic organisms.

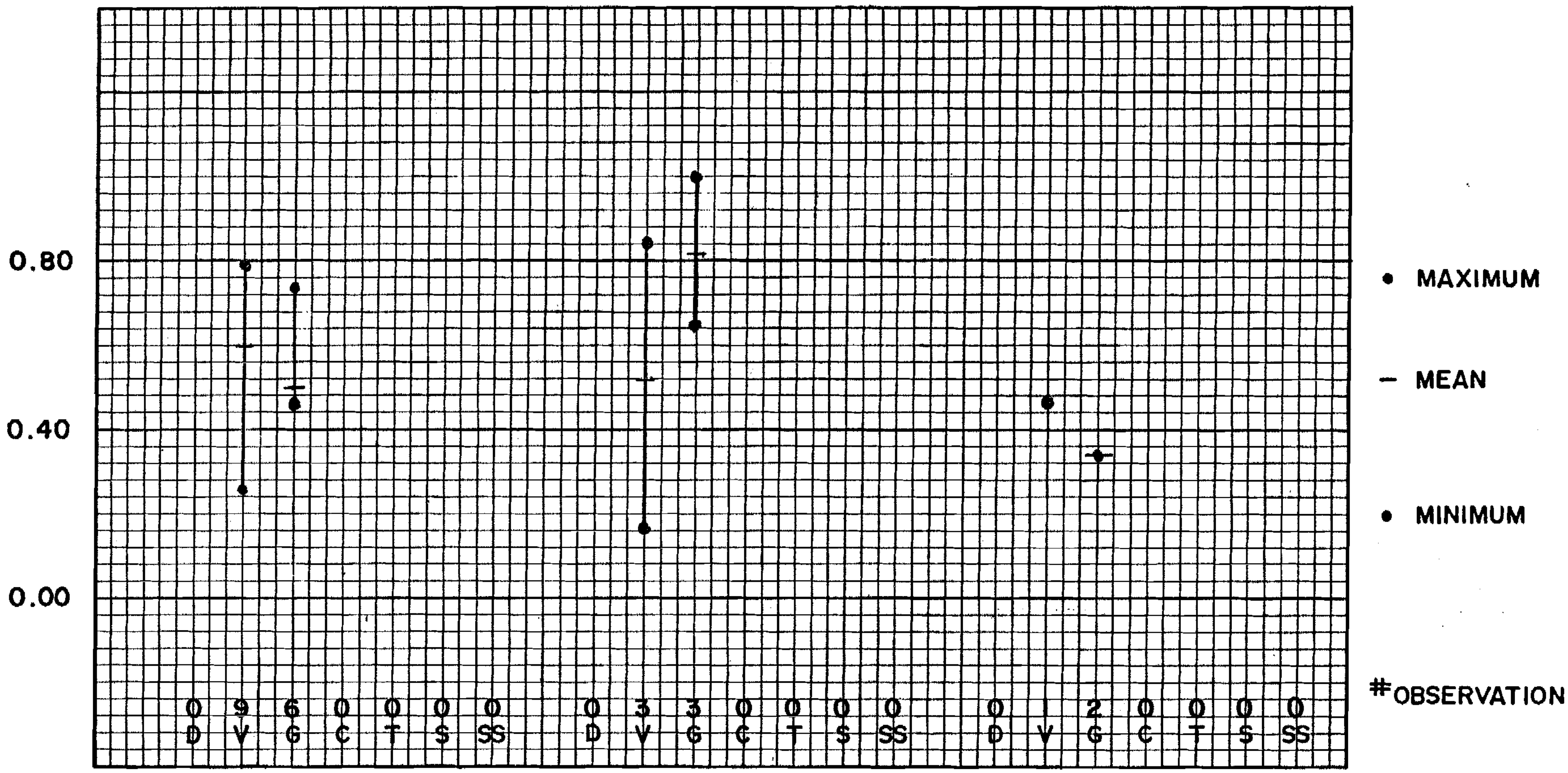
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - AMMONIA NITROGEN

FIGURE: 11

ACRES

PARAMETER: KJELDAHL NITROGEN, as N, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established

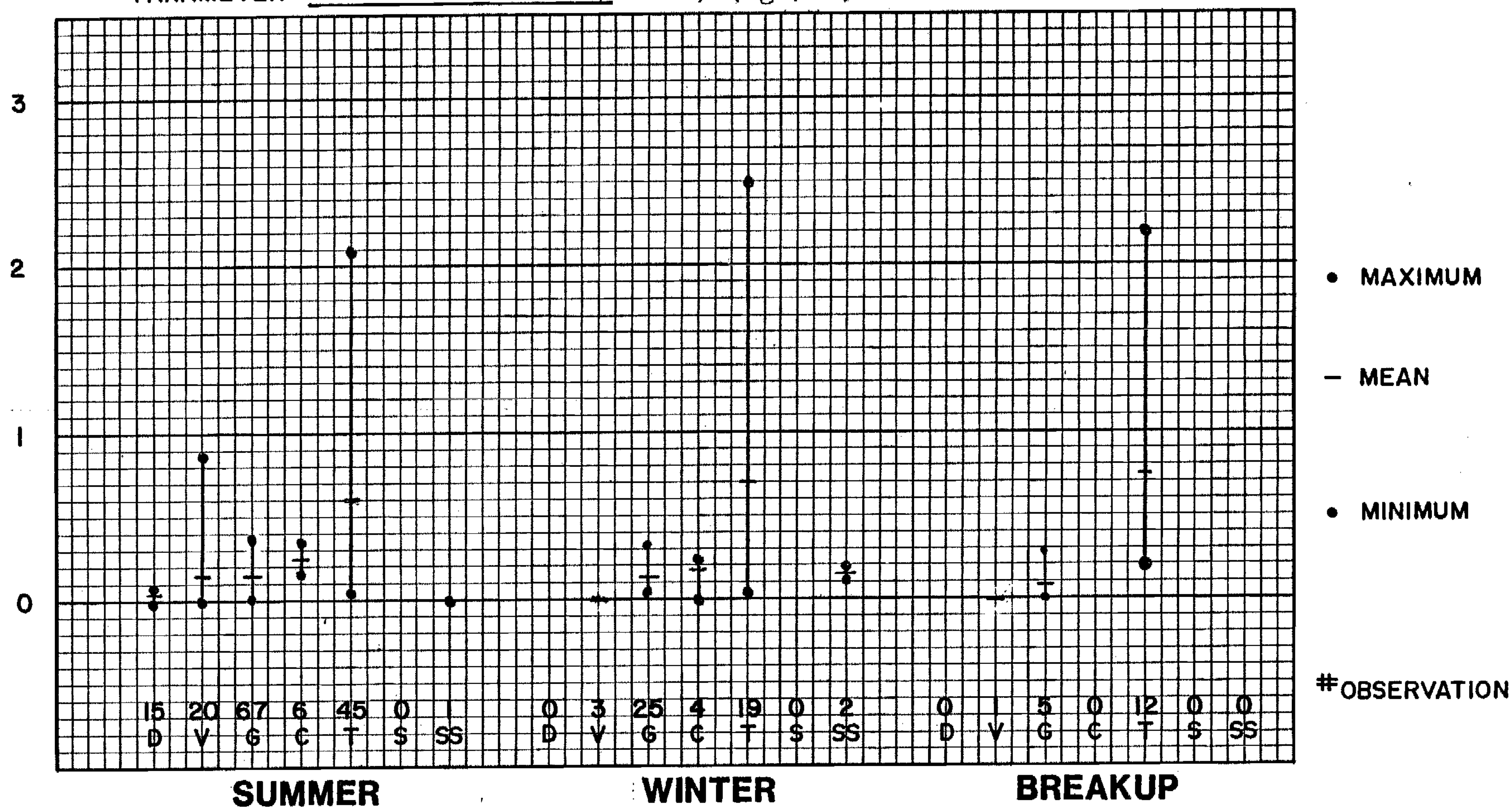
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - KJELDAHL NITROGEN

FIGURE : 12

ACRES

PARAMETER: NITRATE NITROGEN, as N, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S- SUNSHINE SS- SUSITNA STATION

Less than 10 mg/l (water supply). (EPA, 1976).

Established to protect water supplies.

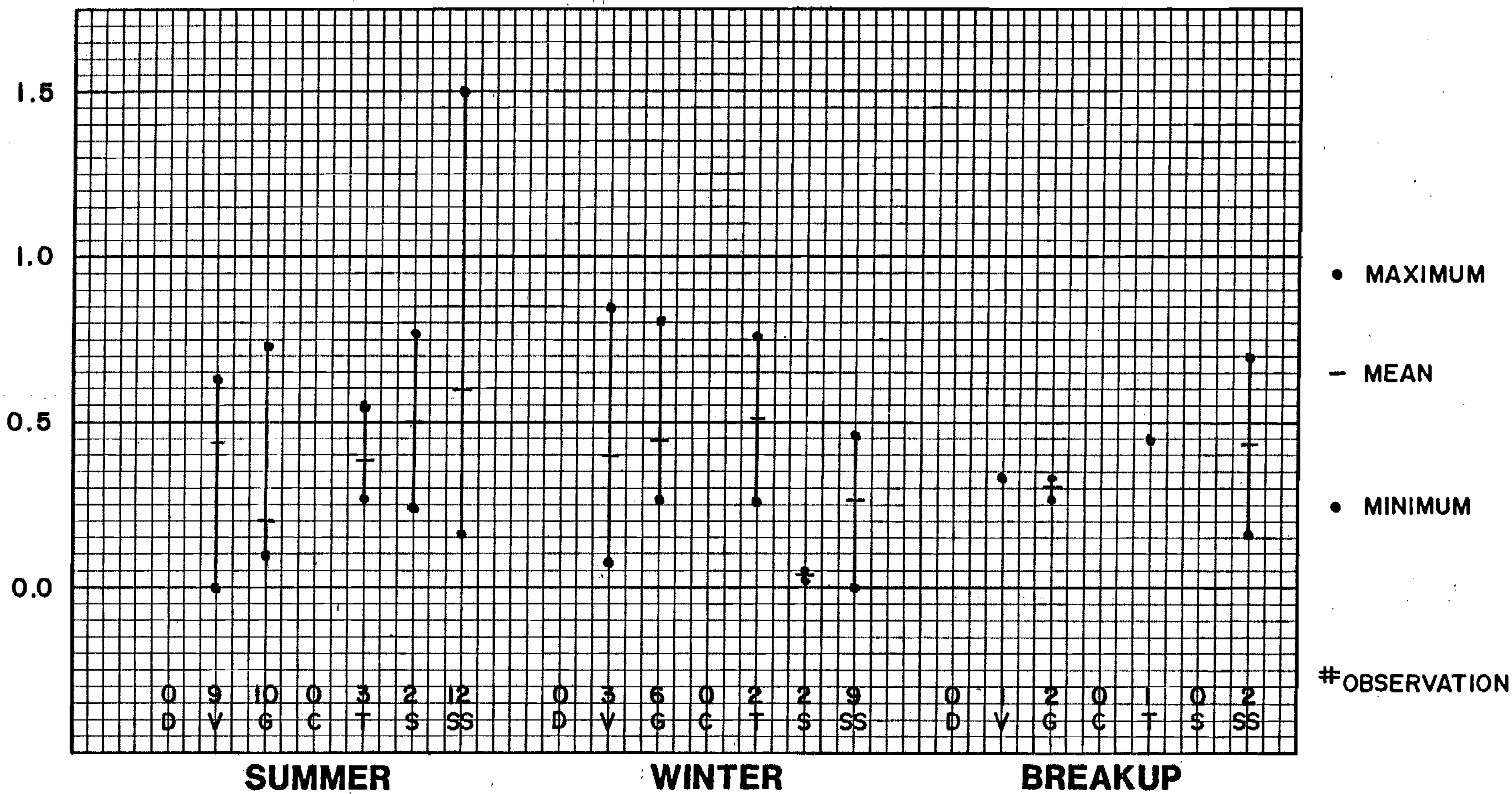
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - NITRATE NITROGEN

FIGURE: 13

ACRES

PARAMETER: ORGANIC NITROGEN, as N, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established

R&M CONSULTANTS, INC.
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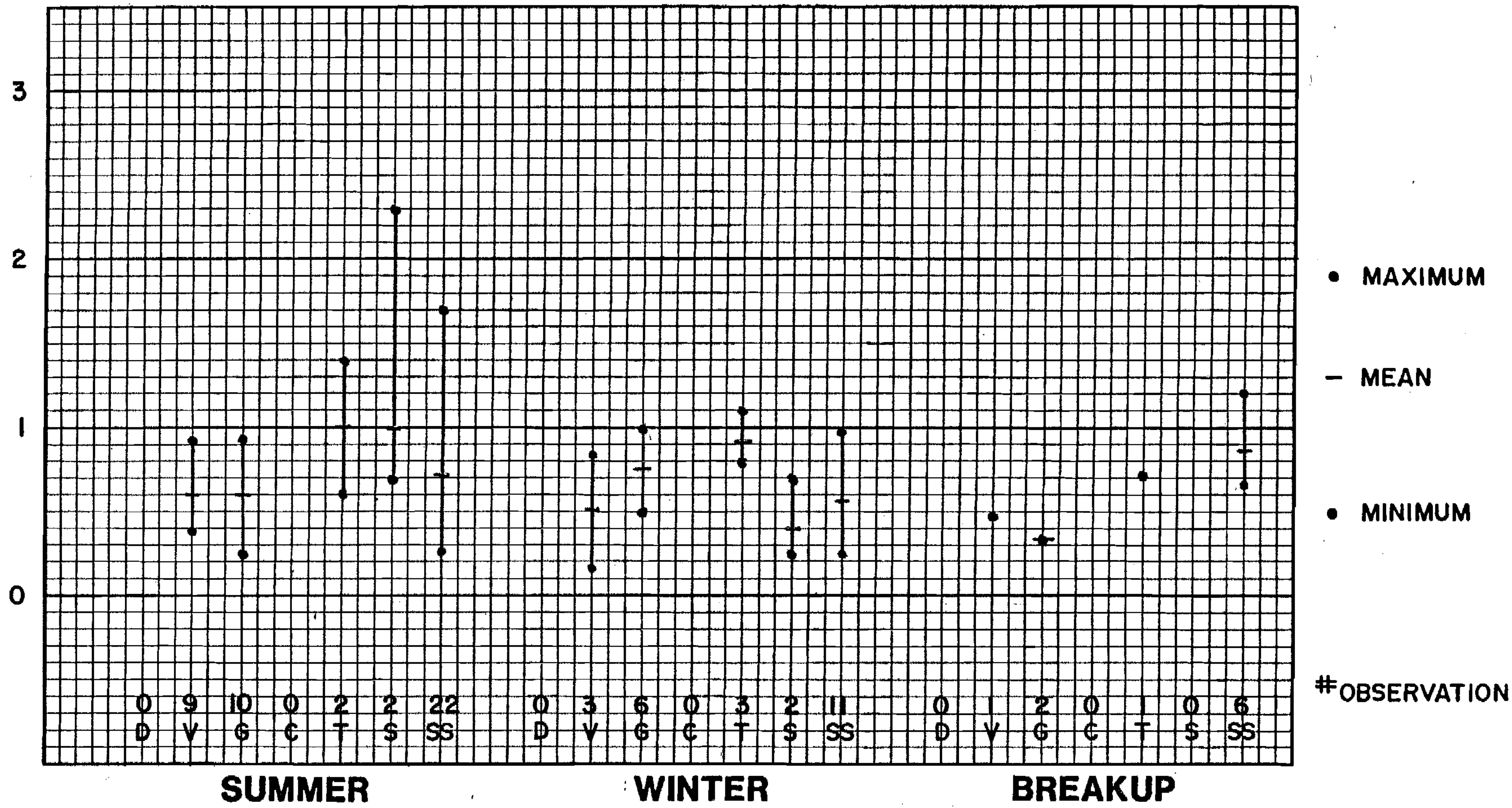
DATA SUMMARY - ORGANIC NITROGEN

FIGURE : 14

ACRES

PARAMETER: TOTAL NITROGEN, as N, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established

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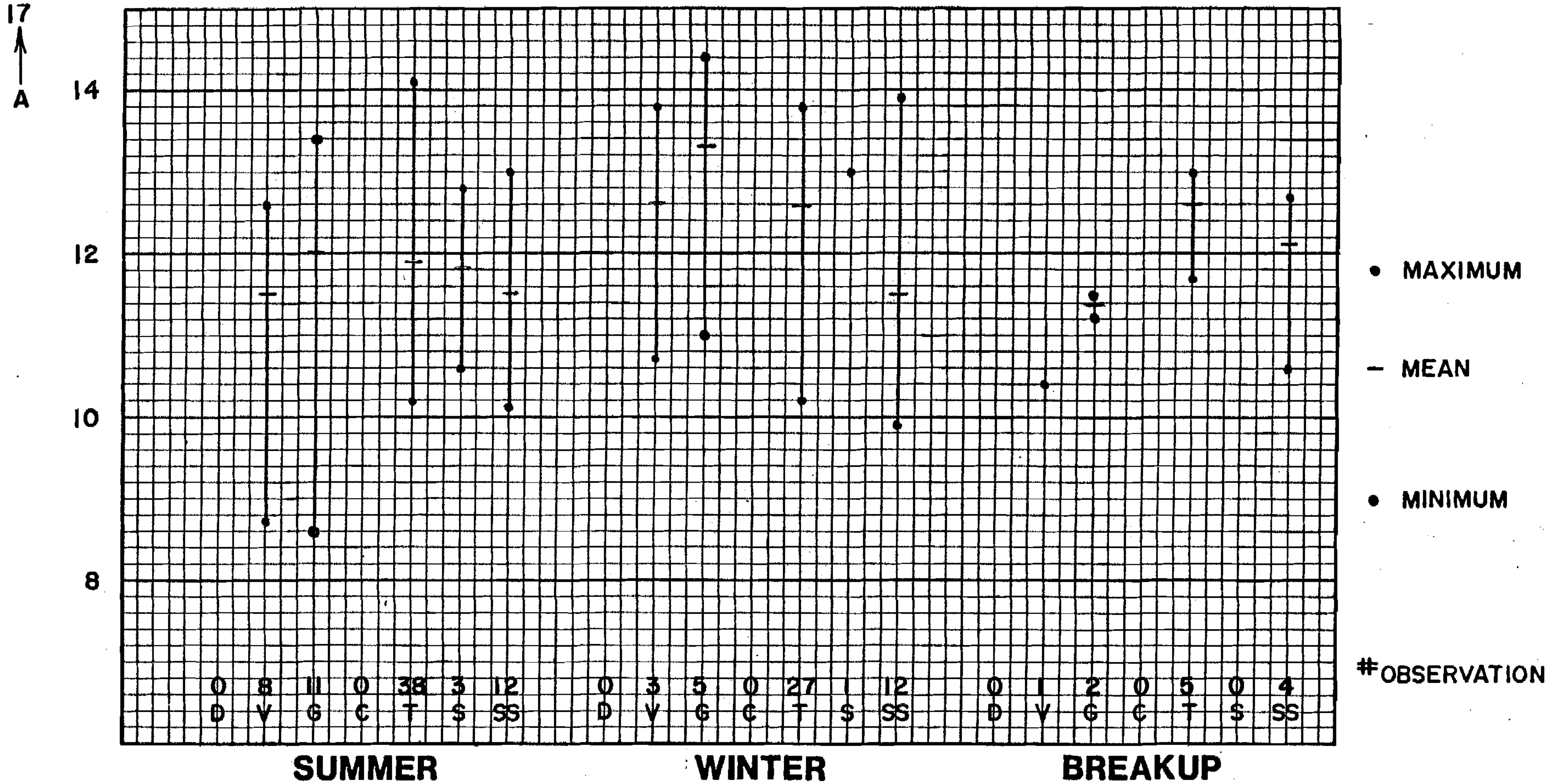
DATA SUMMARY - TOTAL NITROGEN

FIGURE : 15

ACRES

PARAMETER: DISSOLVED OXYGEN, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S- SUNSHINE SS- SUSITNA STATION

A. Greater than 7mg/1, but in no case shall D.O. exceed 17mg/1 (ADEC, 1979).

Established for the protection of anadromous and resident fish.

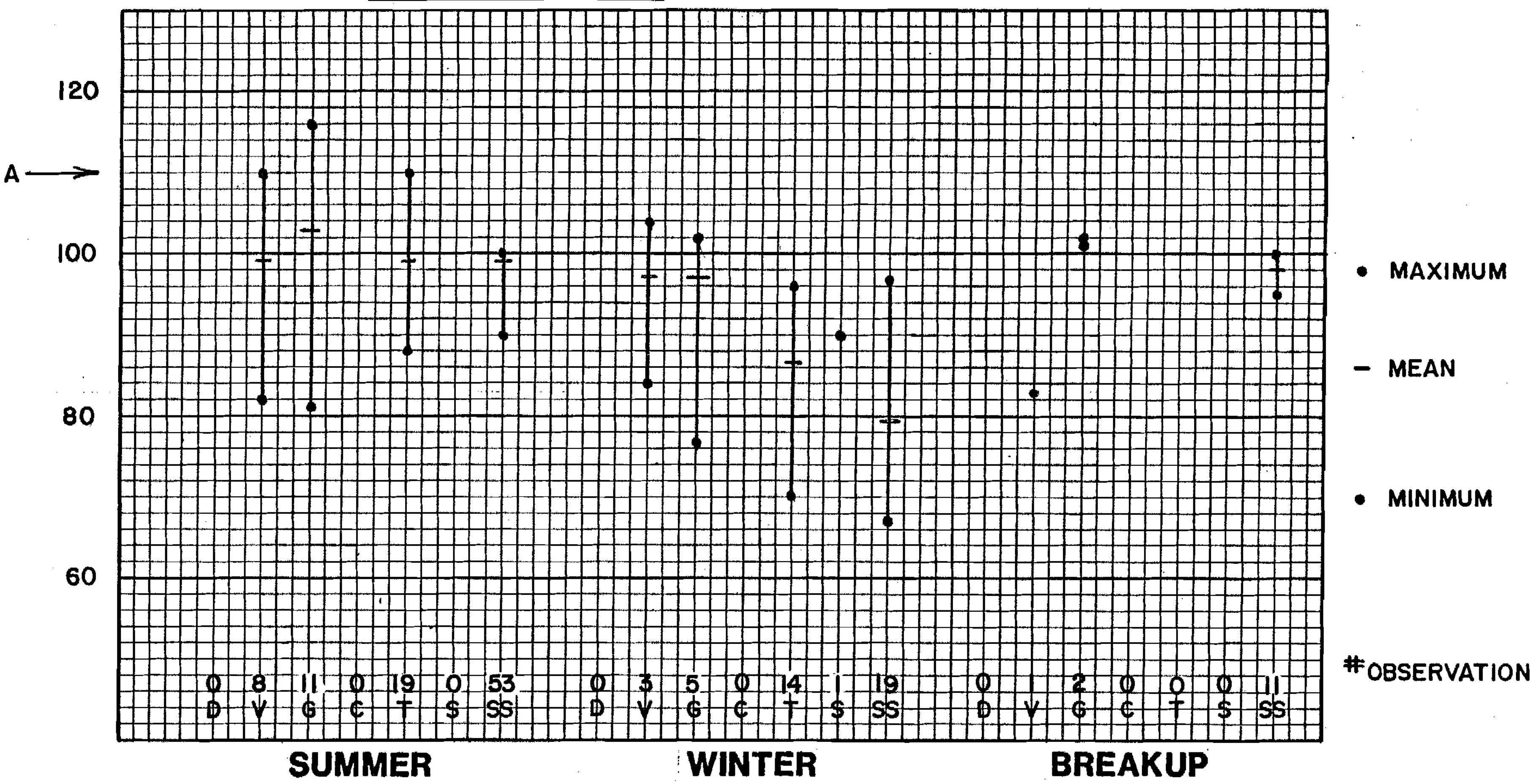
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - OXYGEN, DISSOLVED

FIGURE: 16

ACRES

PARAMETER: D.O., PERCENT SATURATION



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. The concentration of total disolved gas shall not exceed 110% saturation at any point. (ADEC, 1979).

Established for the protection of anadromous and resident fish.

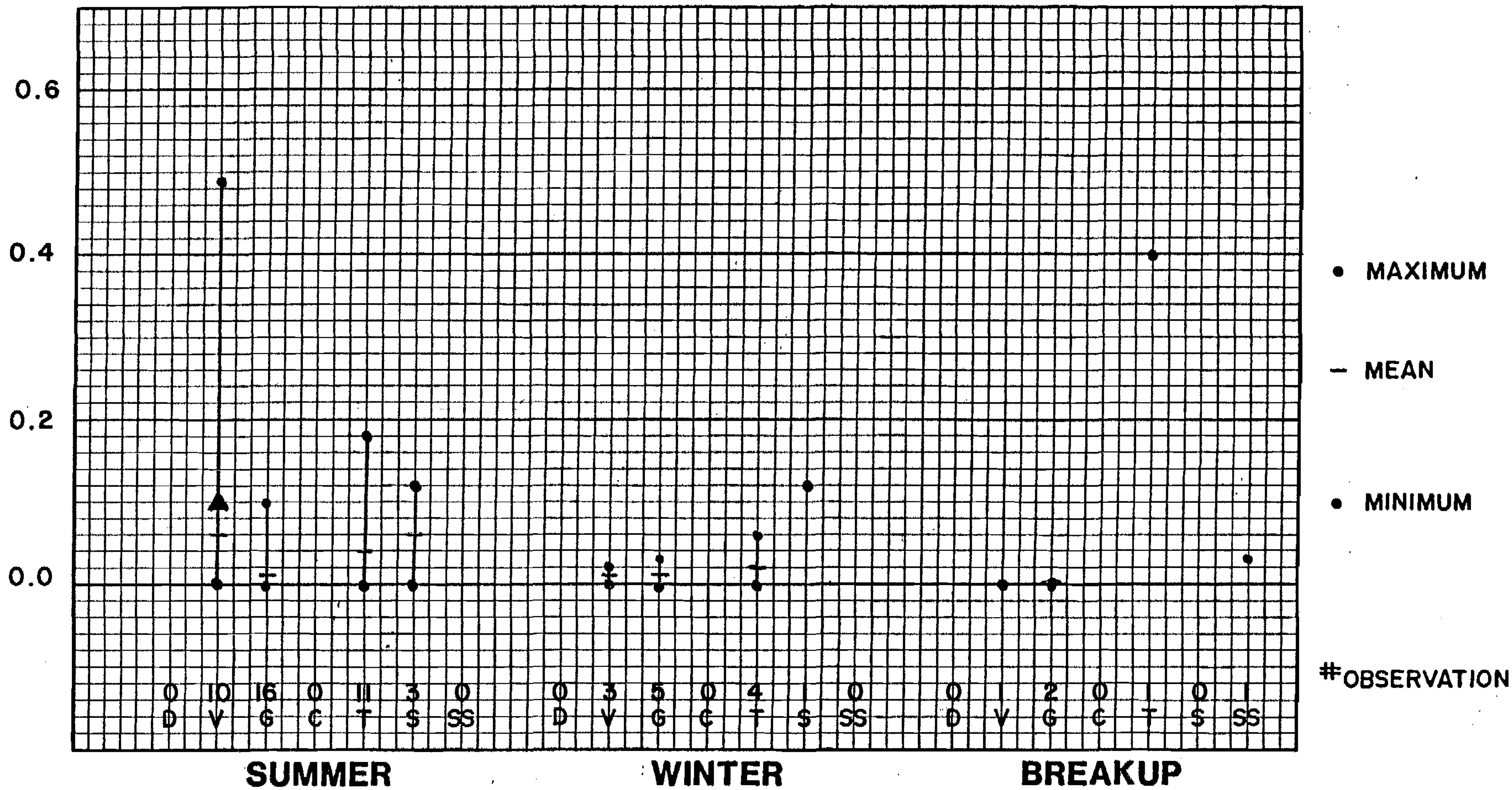
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - D.O., % SATURATION

FIGURE: 17

ACRES

PARAMETER: ORTHO PHOSPHATE, as P, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

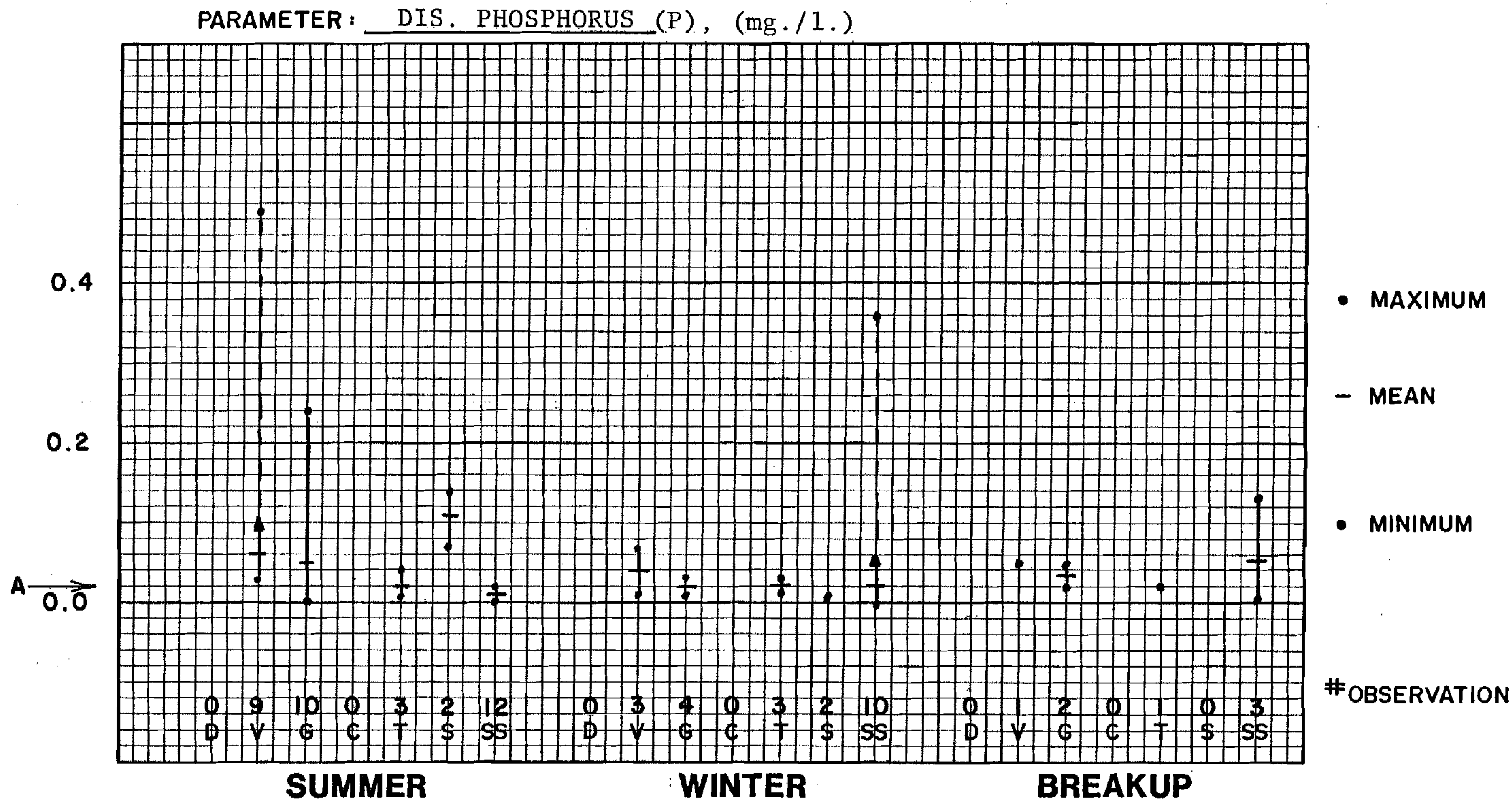
No criterion established

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - ORTHO PHOSPHATE

FIGURE : 18

ACRES



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 0.01 mg/l for elemental phosphorus (EPA, 1976)

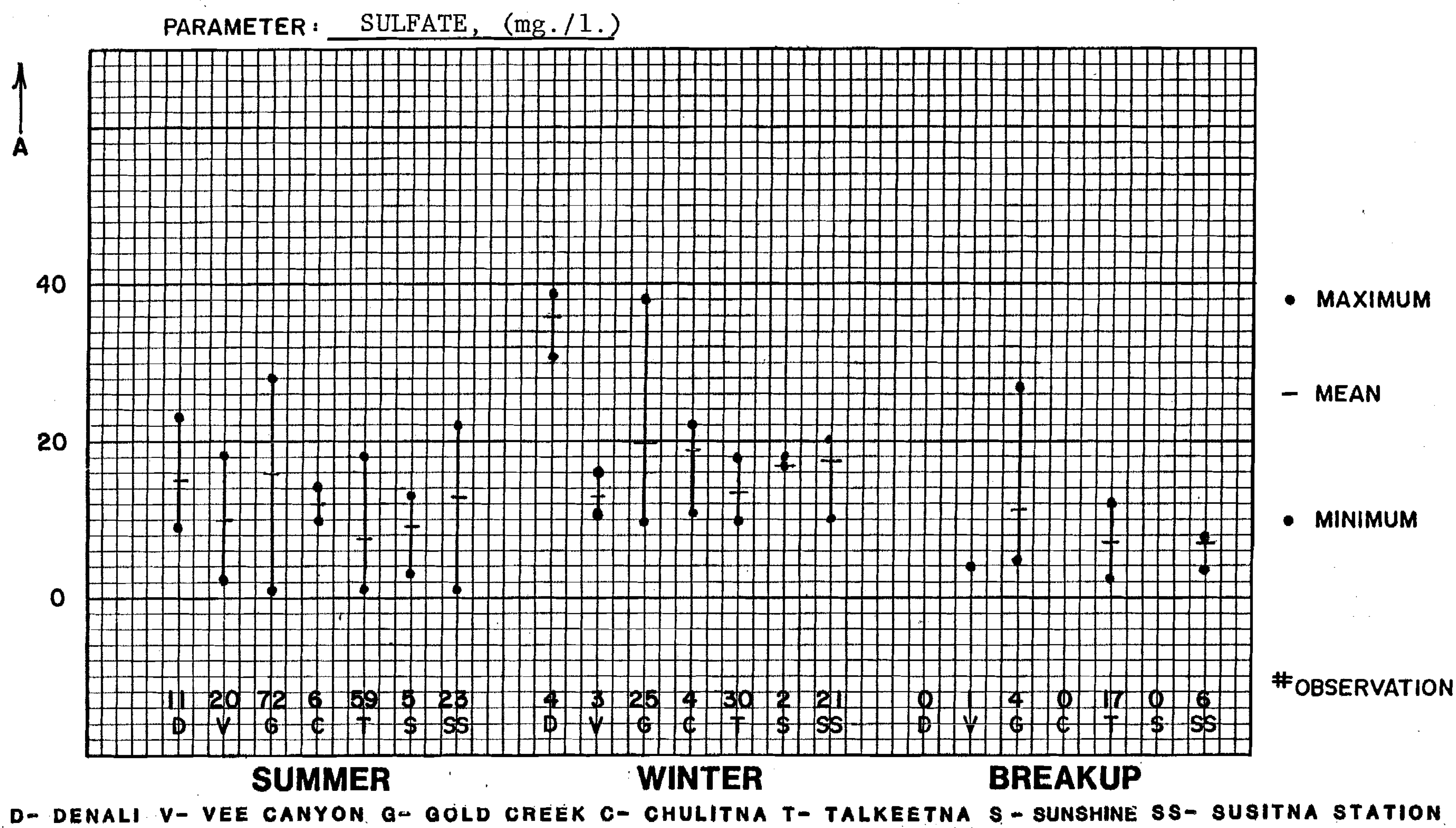
Established to protect freshwater aquatic organisms.

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - PHOSPHORUS

FIGURE : 19

ACRES



A. Shall not exceed 200 mg/l. (ADEC, 1979).

Established to protect water supplies.

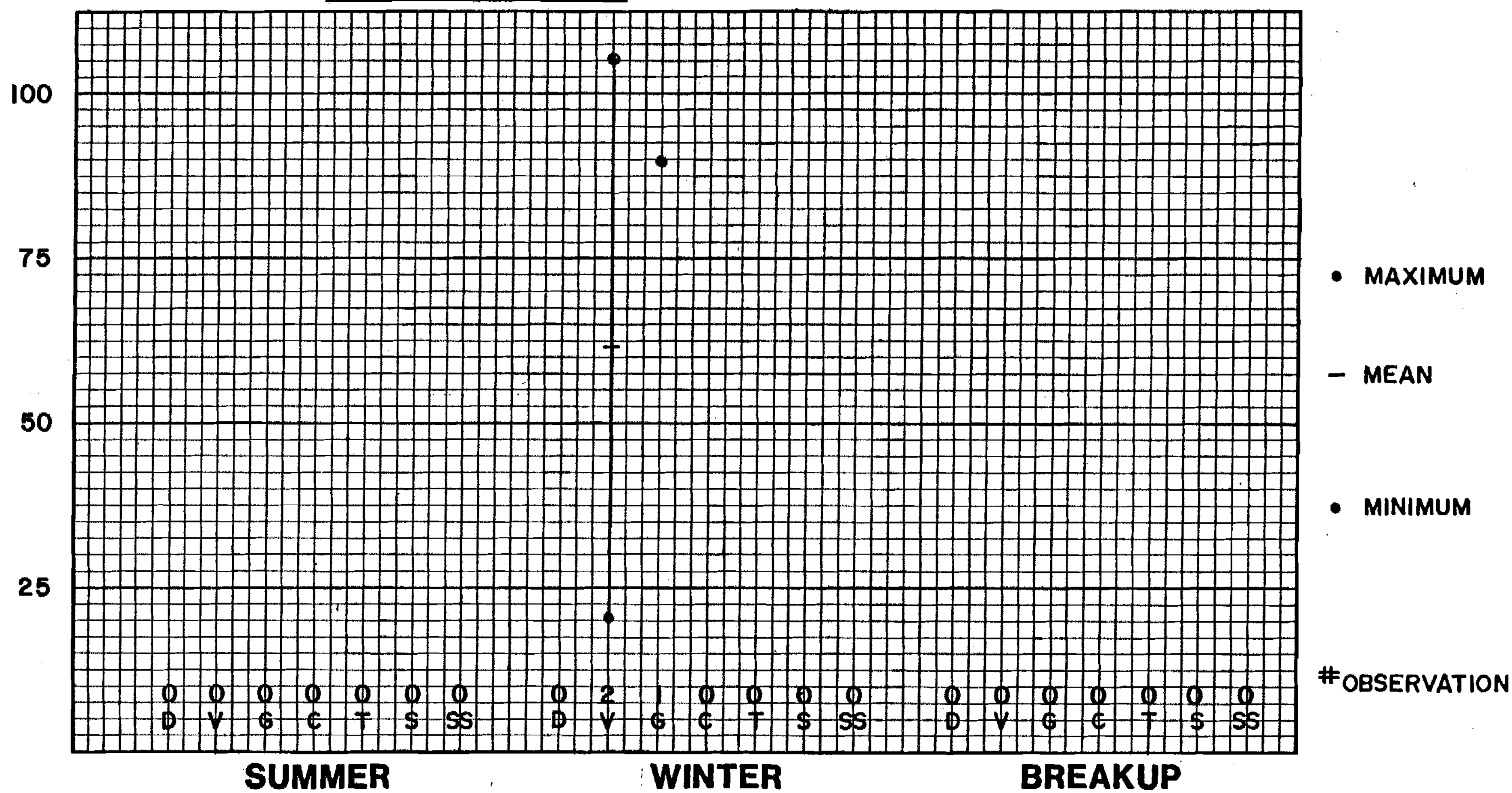
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - SULFATE

FIGURE: 20

ACRES

PARAMETER: TOTAL INORGANIC CARBON, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established.

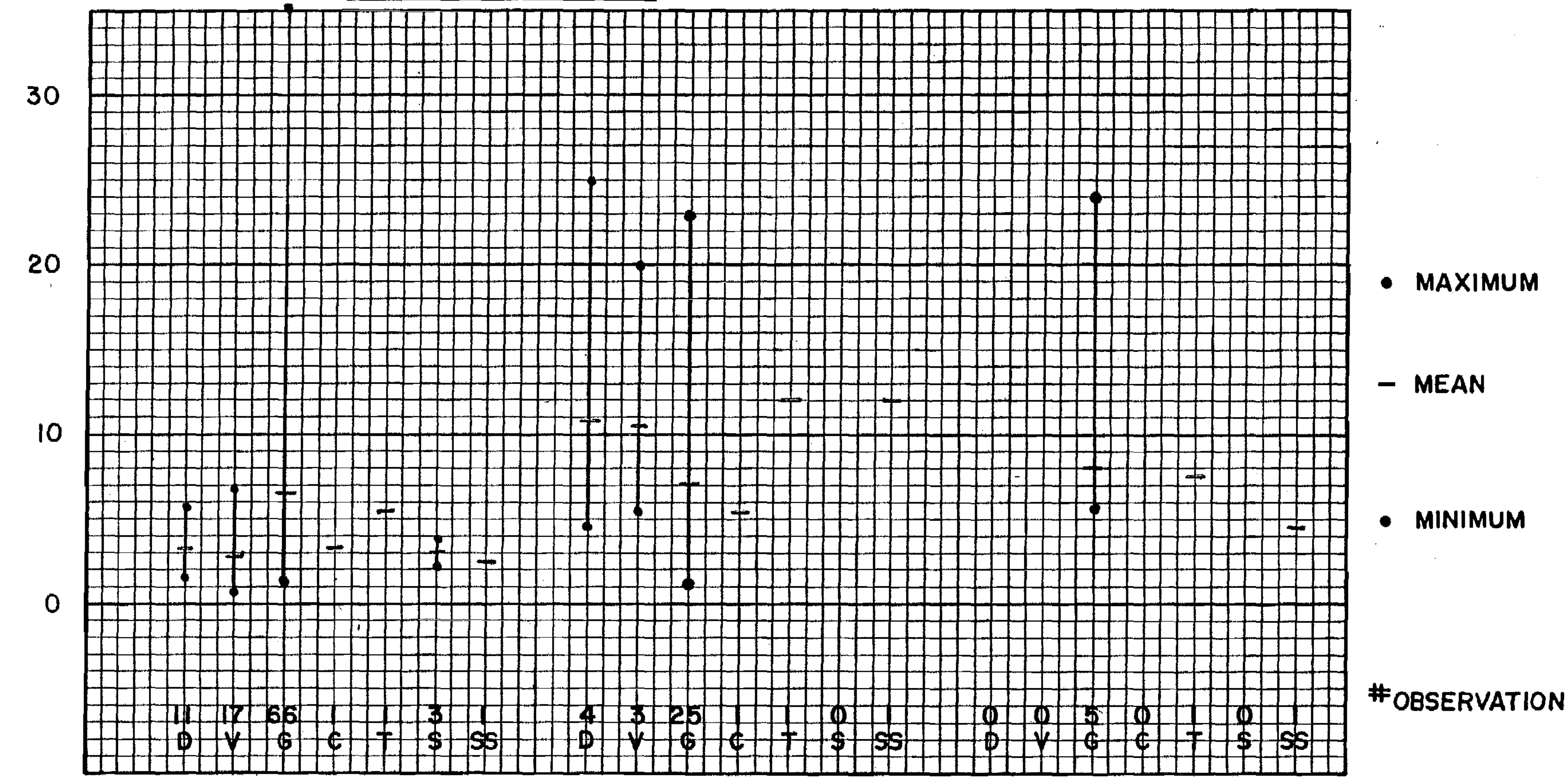
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - TOTAL INORGANIC CARBON

FIGURE : 21

ACRES

PARAMETER: FREE CARBON DIOXIDE, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established

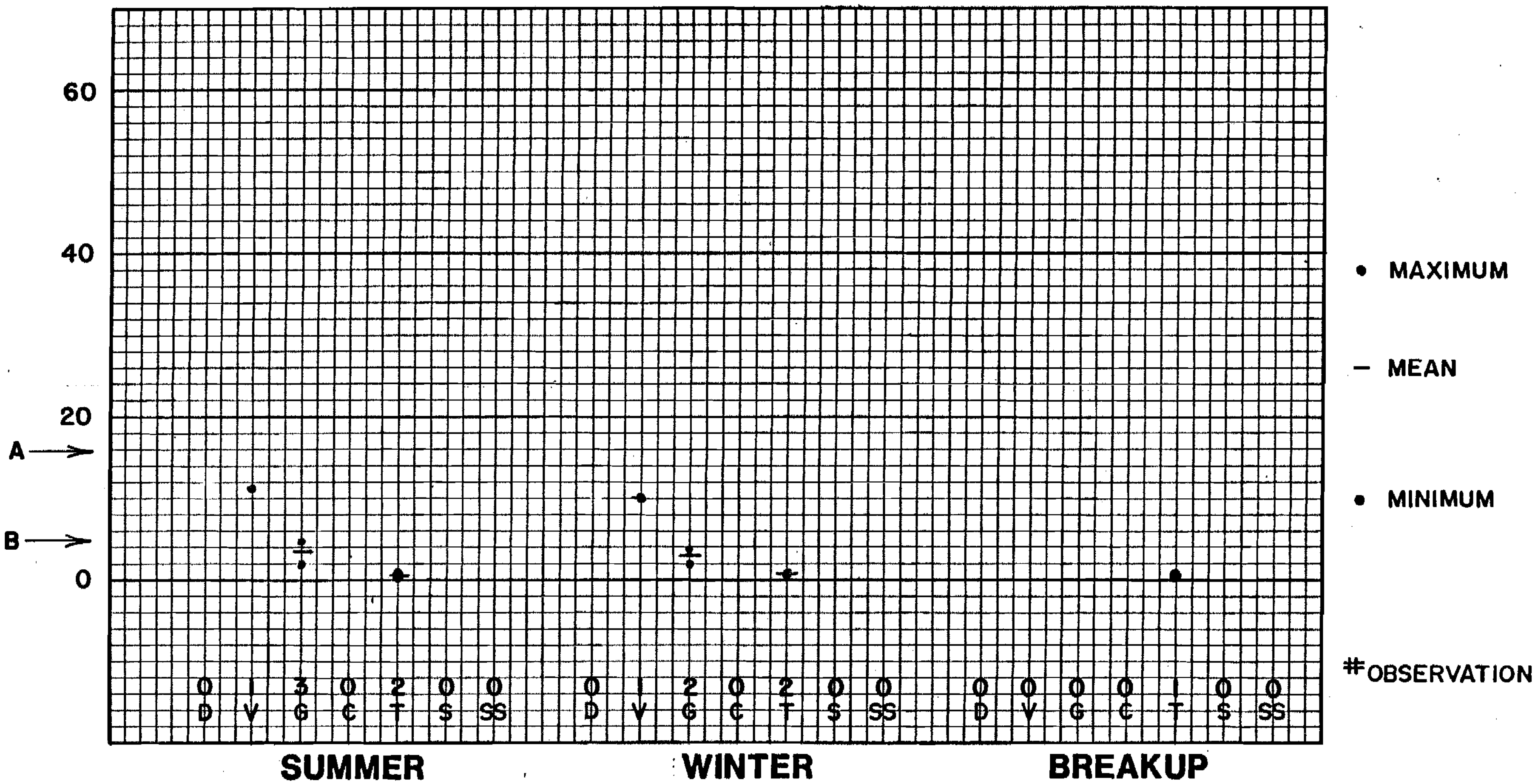
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - FREE CARBON DIOXIDE

FIGURE : 22

ACRES

PARAMETER: RADIOACTIVITY, GROSS ALPHA, (pCi/l)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S- SUNSHINE SS- SUSITNA STATION

A. 15 pCi/l (ADEC, 1979).

B. 5 pCi/l (McNeely, 1979).

Established to prevent detrimental radionuclide concentrations in aquatic organisms.

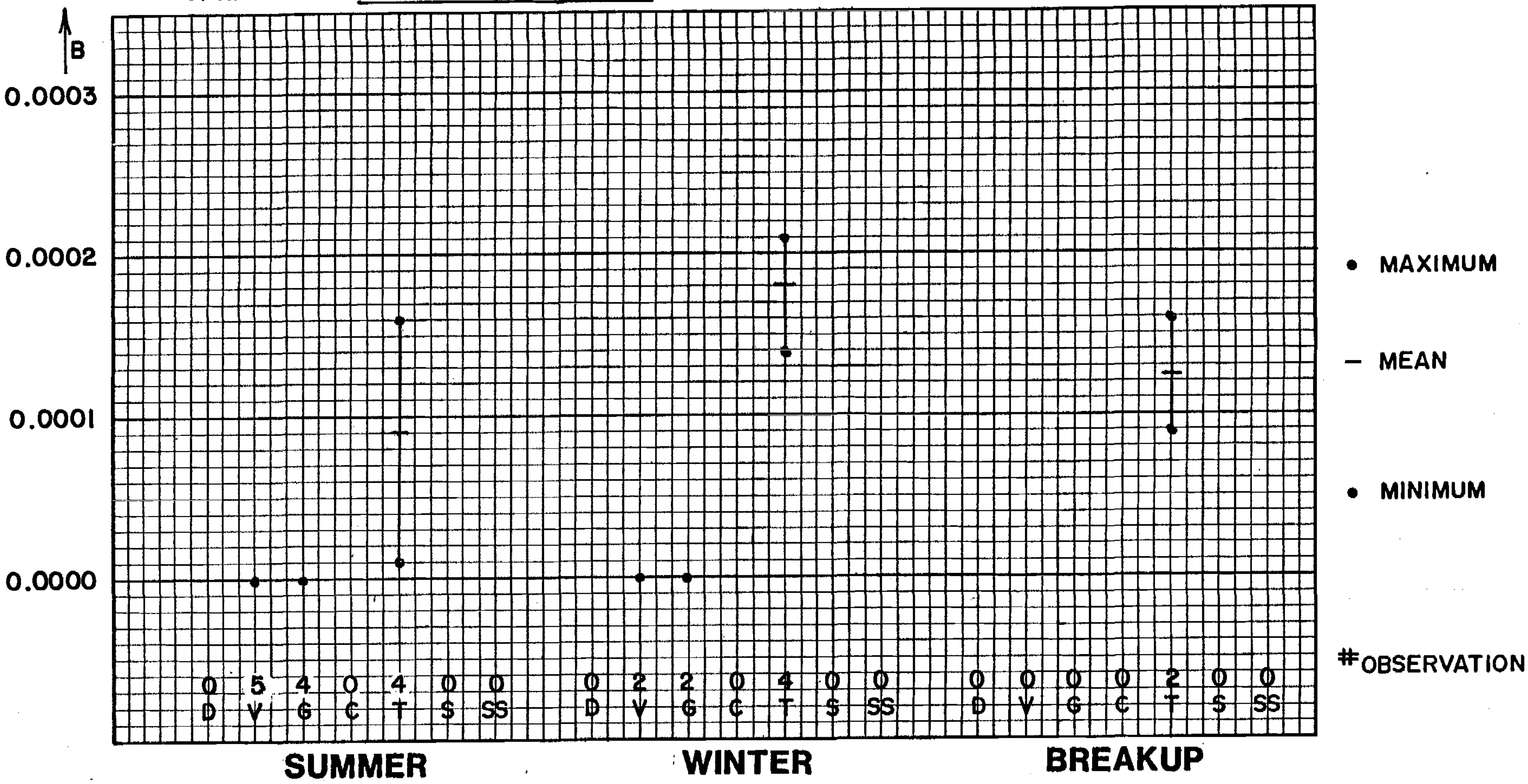
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY -GROSS ALPHA

FIGURE: 23

ACRES

PARAMETER: URANIUM, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. No criterion established.

B. EPA has suggested a possible ambient goal of 0.003 mg/l, (Sittig, 1981).

This goal is based on the effect of uranium on human health.

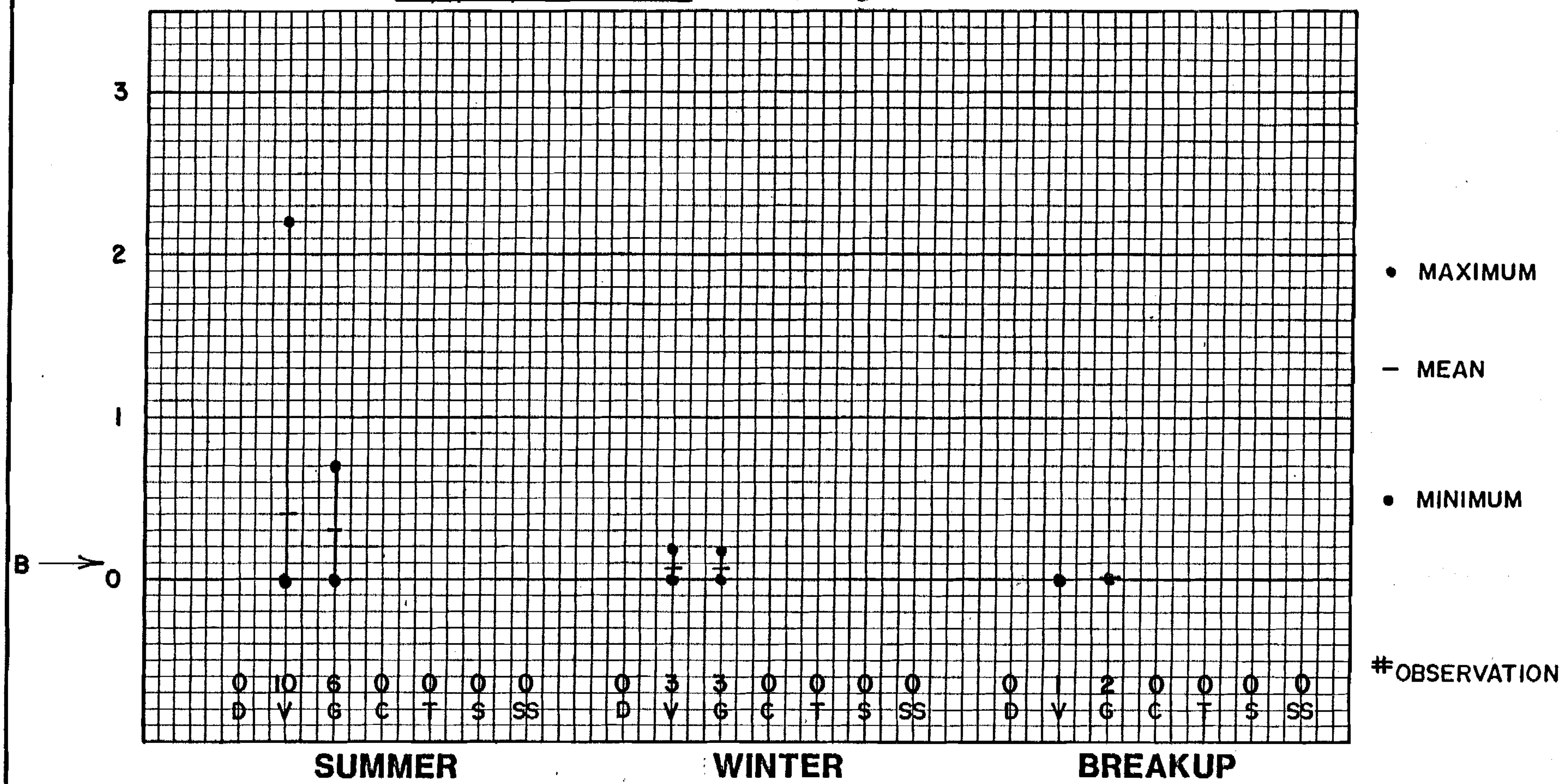
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - URANIUM

FIGURE: 24

ACRES

PARAMETER: ALUMINUM (Al) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. No criterion established

B. A limit of 0.073 mg/1 has been suggested by EPA (Sittig, 1981).

This suggested limit is based on the effects of aluminum on human health.

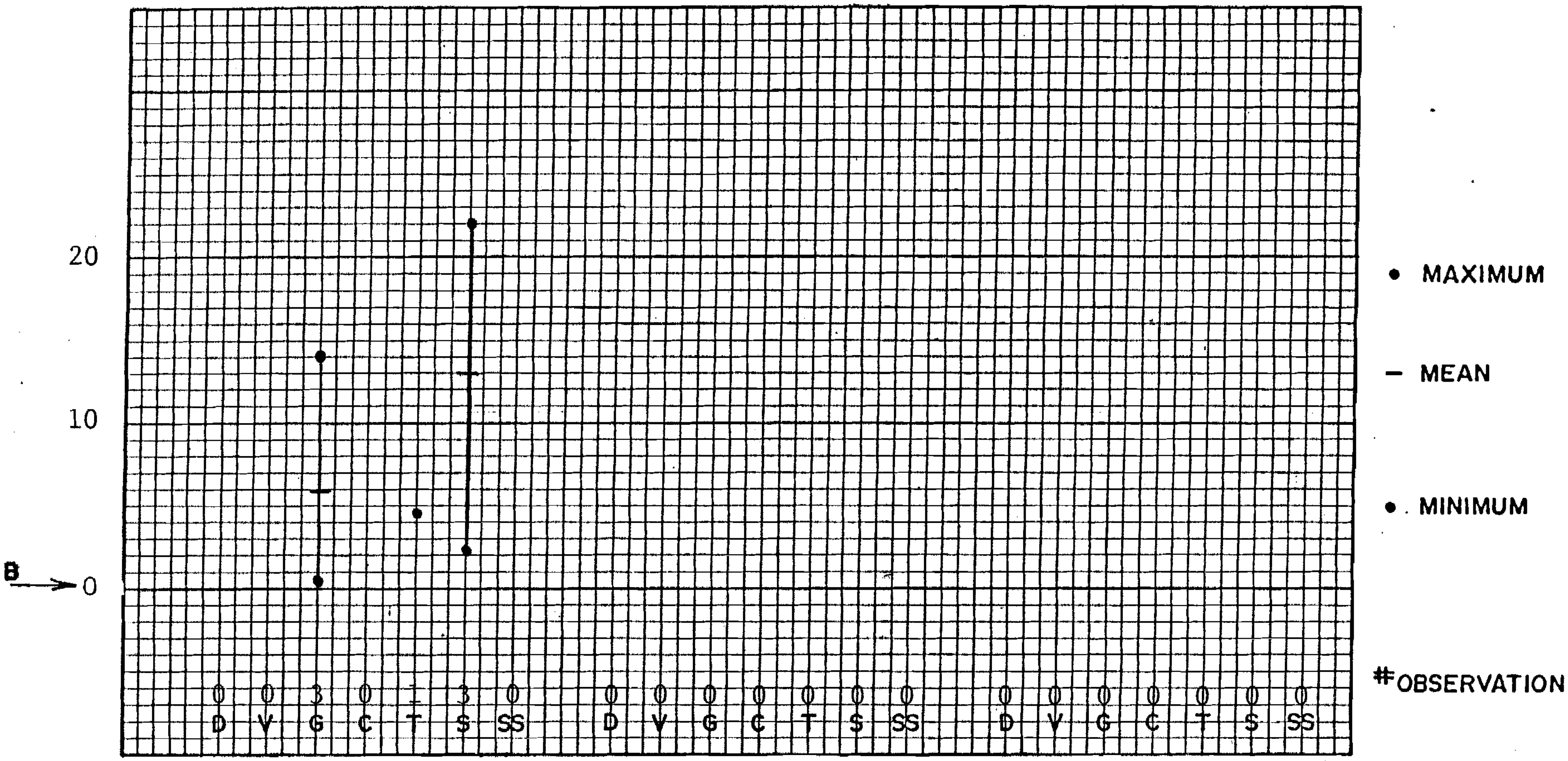
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - ALUMINUM (d)

FIGURE : 25

ACRES

PARAMETER: ALUMINUM (Al) Total Recoverable (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. No criterion established

B. A limit of 0.073 mg/l has been suggested by EPA (Sittig, 1981)

This suggested limit is based on the effects of aluminum on human health.

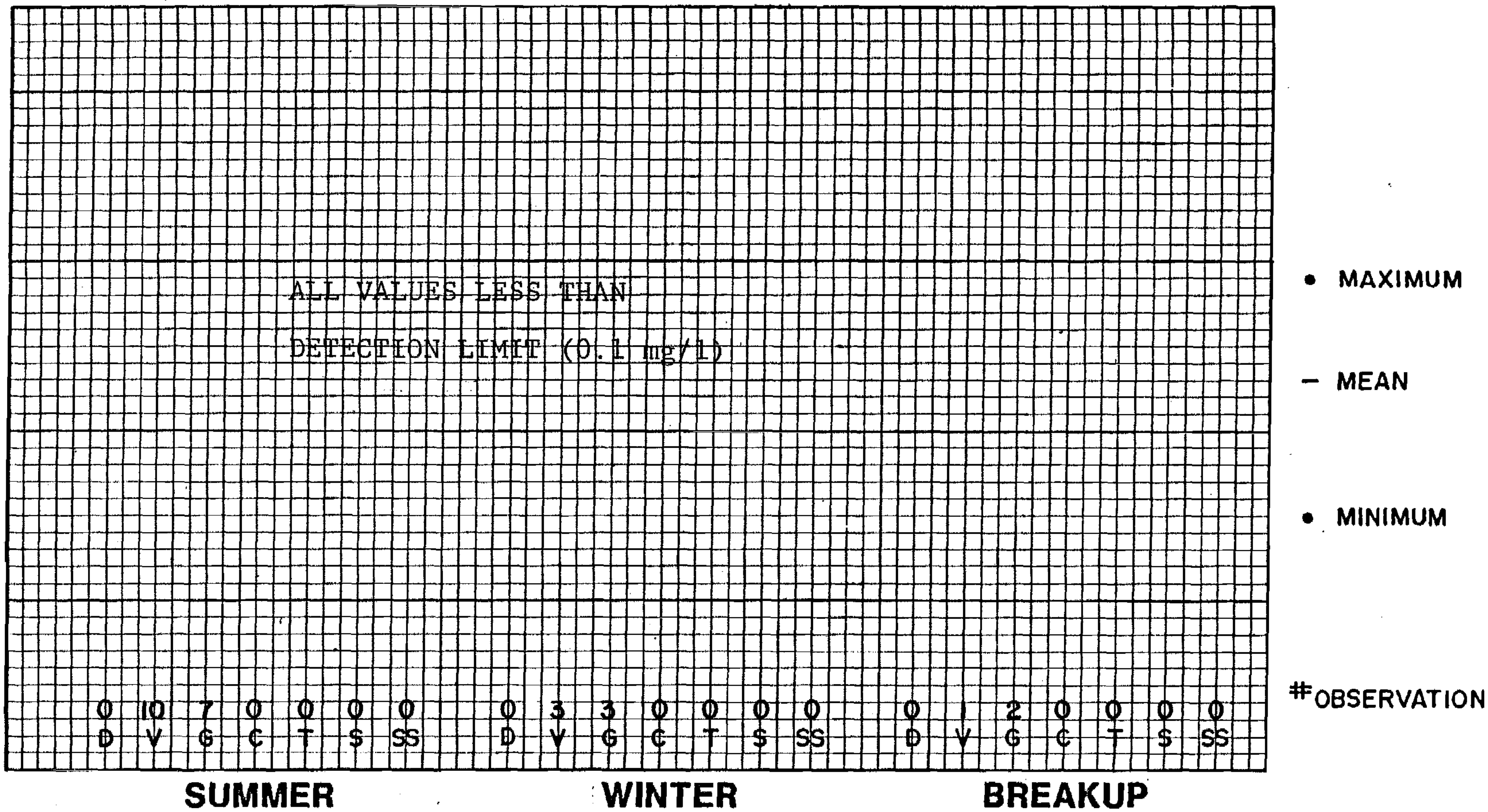
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - ALUMINUM (t)

FIGURE: 26

ACRES

PARAMETER: ANTIMONY (Sb) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 9mg/1 on an acute basis, and less than 1.6 mg/1 on a chronic basis. (EPA, 1980; Sittig, 1981).

Established to protect freshwater aquatic organisms.

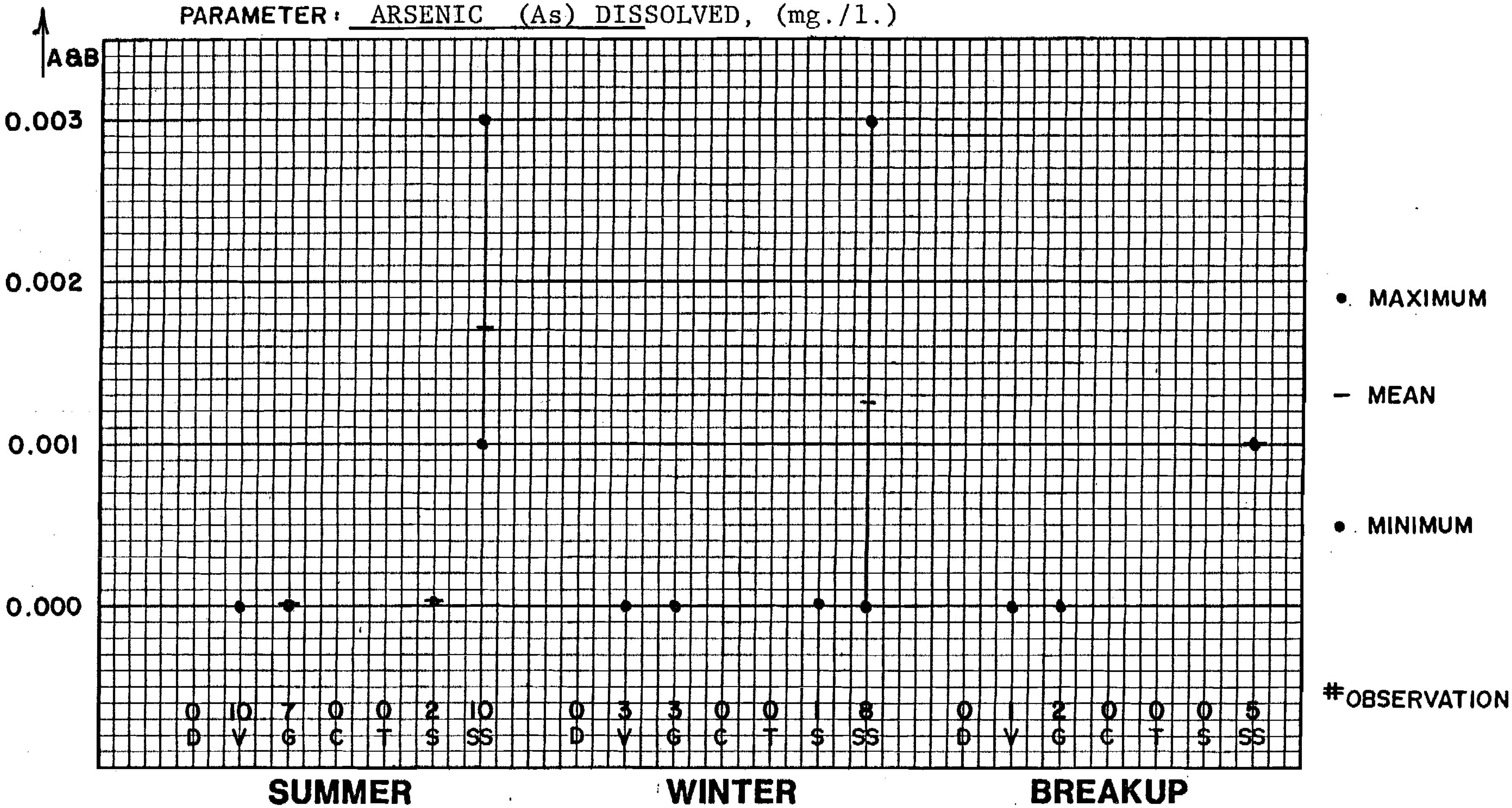
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - ANTIMONY (d)

FIGURE : 27

ACRES

PARAMETER: ARSENIC (As) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than .440 mg/1. (EPA, 1980; Sittig 1981).

B. .050 mg/1 for domestic water supplies (EPA, 1976)

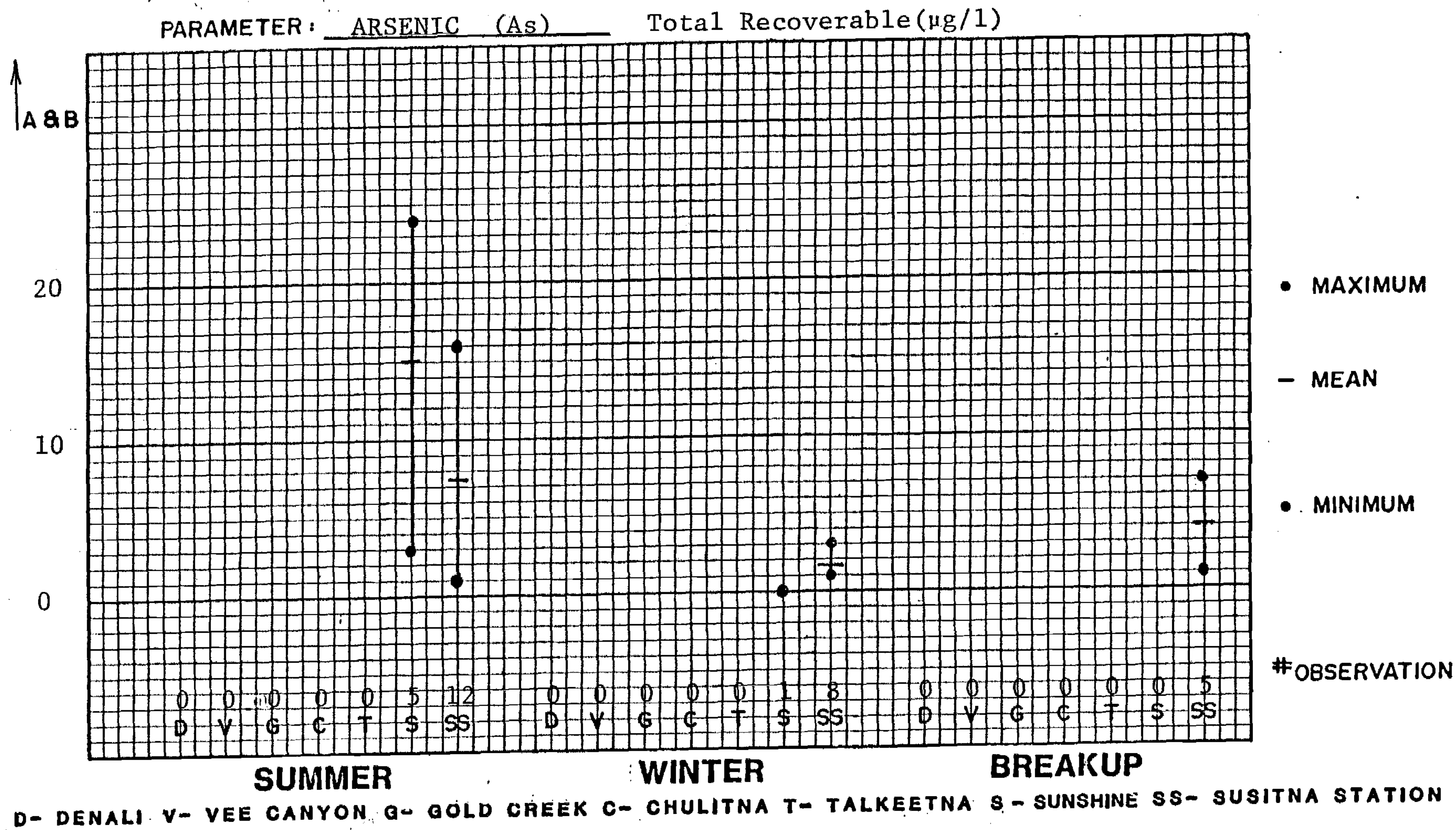
Established for the protection of freshwater aquatic life (A), and (B) for the protection of drinking water.

R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - ARSENIC (d)

FIGURE 28

ACRES



A. Less than 440 µg/1 (EPA, 1980; Sittig, 1981)

B. 50 µg/1 for domestic water supplies (EPA, 1976)

Established for the protection of freshwater aquatic life (A), and (B) for the protection of drinking water.

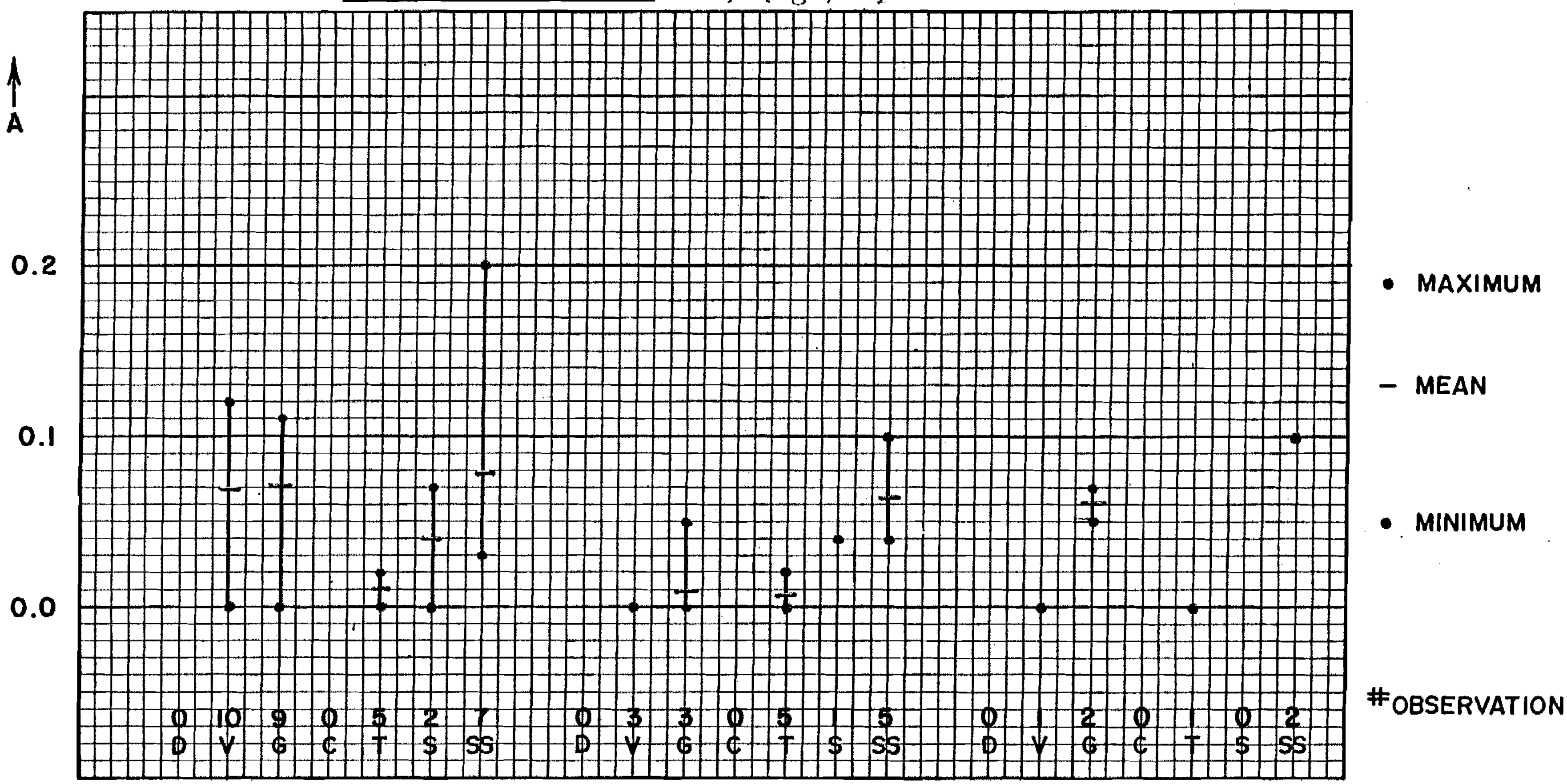
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - ARSENIC (t)

FIGURE: 29

ACRES

PARAMETER: BARIUM (Ba) DISSOLVED, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 1.0 mg/l. (EPA, 1976; Sittig, 1981).

Established to protect water supplies.

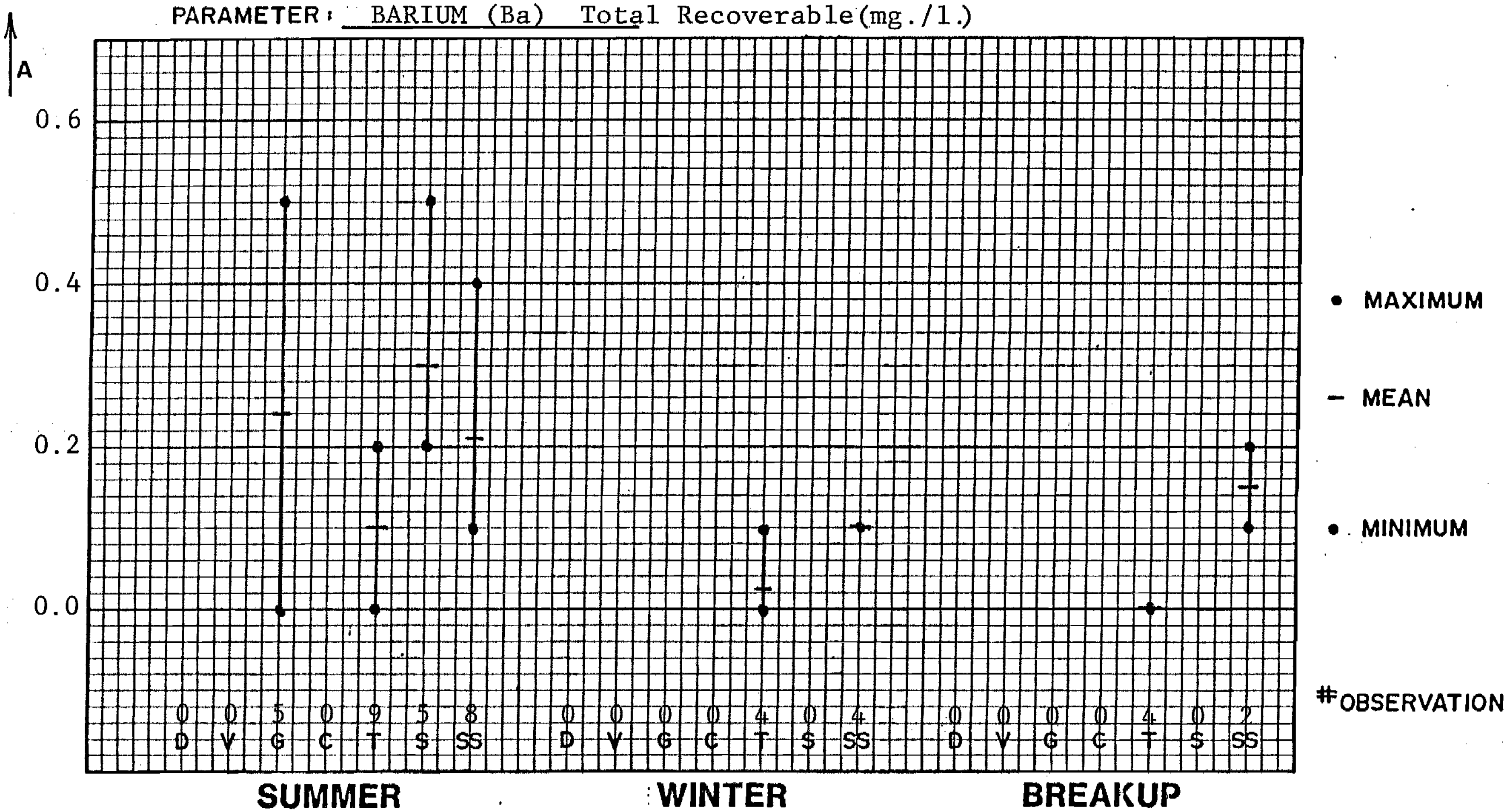
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - BARIUM (d)

FIGURE: 30

ACRES

PARAMETER: BARIUM (Ba) Total Recoverable (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 1.0 mg/1 (EPA, 1976; Sittig, 1981)

Established to protect water supplies.

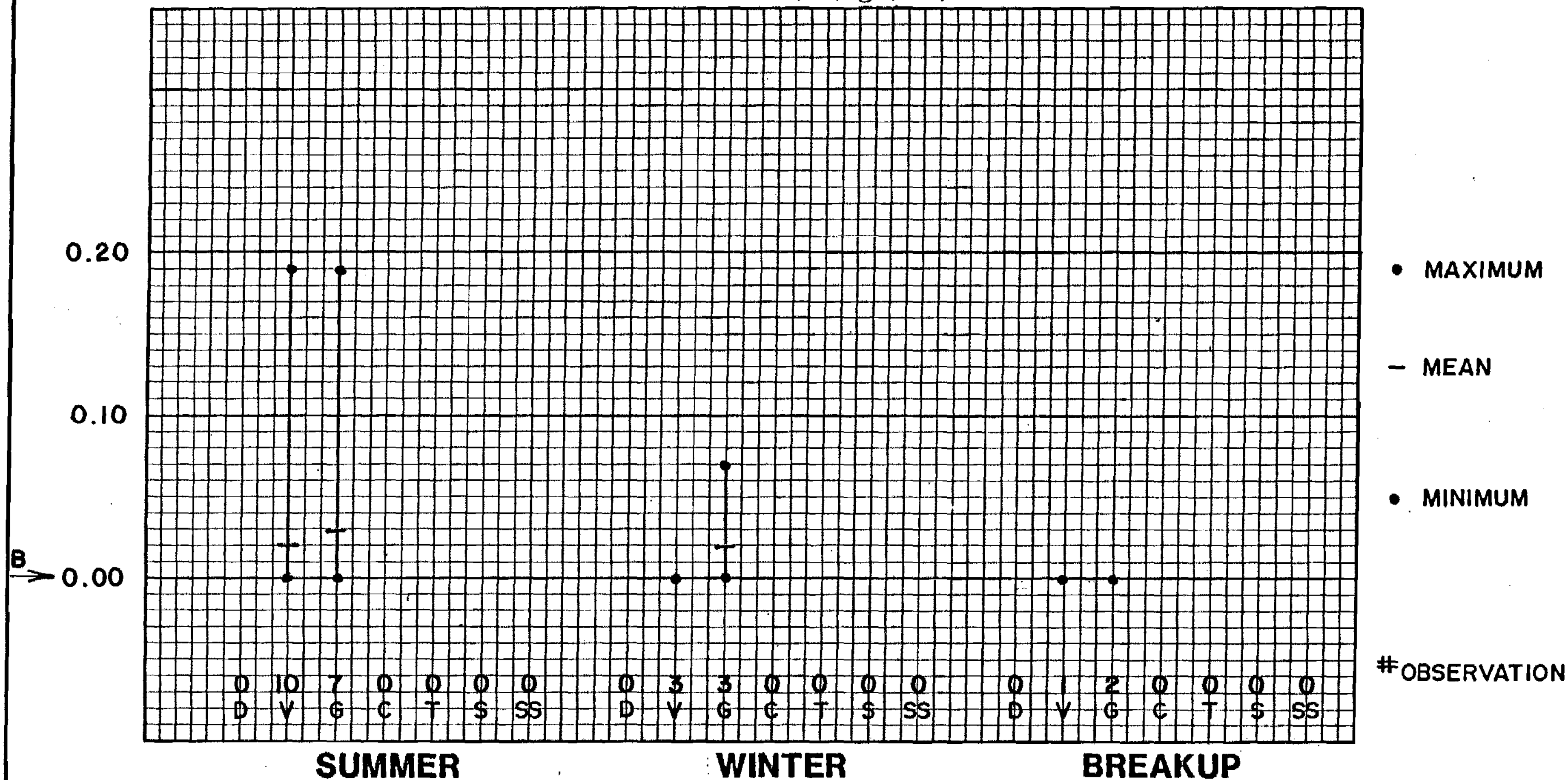
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - BARIUM (t)

FIGURE: 31

ACRES

PARAMETER: BISMUTH (Bi) DISSOLVED, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. No criterion established

B. EPA has suggested an ambient limit of 0.0035 mg/l. (Sittig, 1981).

This suggested limit for bismuth is based on human health effects.

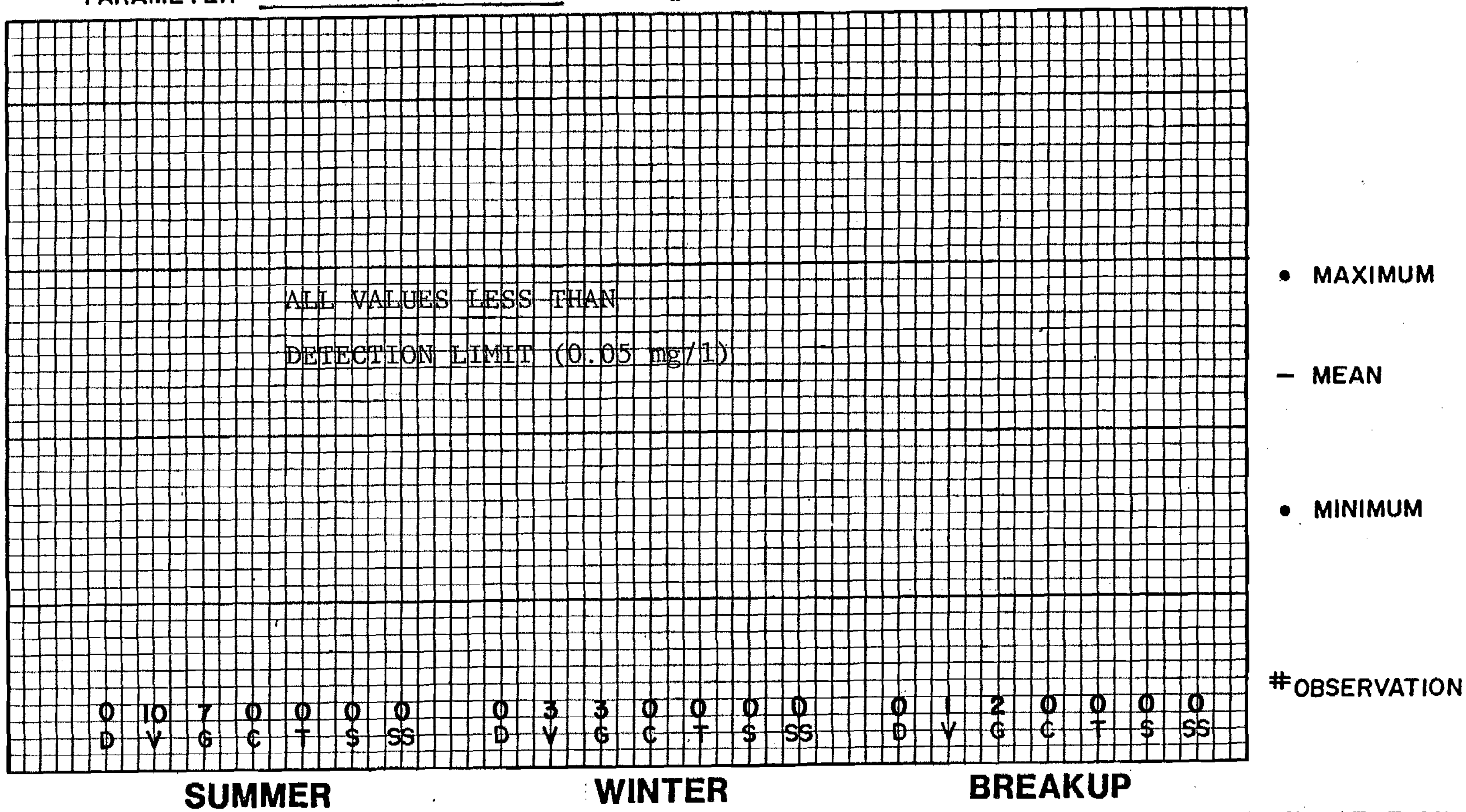
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - BISMUTH (d)

FIGURE: 32

ACRES

PARAMETER: BORON (B) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S- SUNSHINE SS- SUSITNA STATION

43 µg/1, (Sittig, 1981).

Established to protect water supplies.

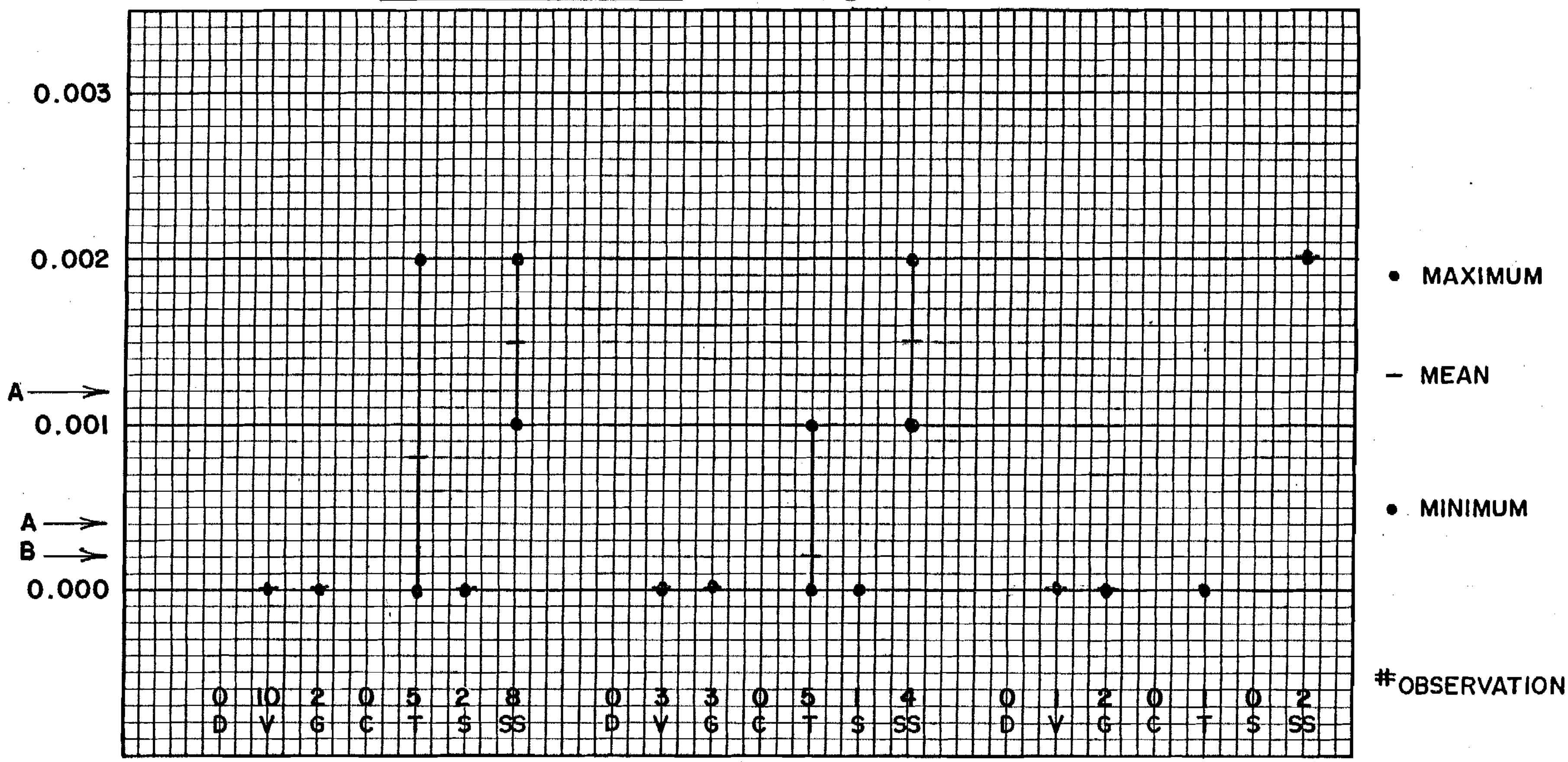
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - BORON (d)

FIGURE: 33

ACRES

PARAMETER: CADMIUM (Cd) DISSOLVED, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. 0.0012 mg/l in hard water and 0.0004 in soft water. (EPA, 1976)

B. Less than 0.0002 mg/l. (McNeely, 1979)

Established to protect freshwater aquatic organisms.

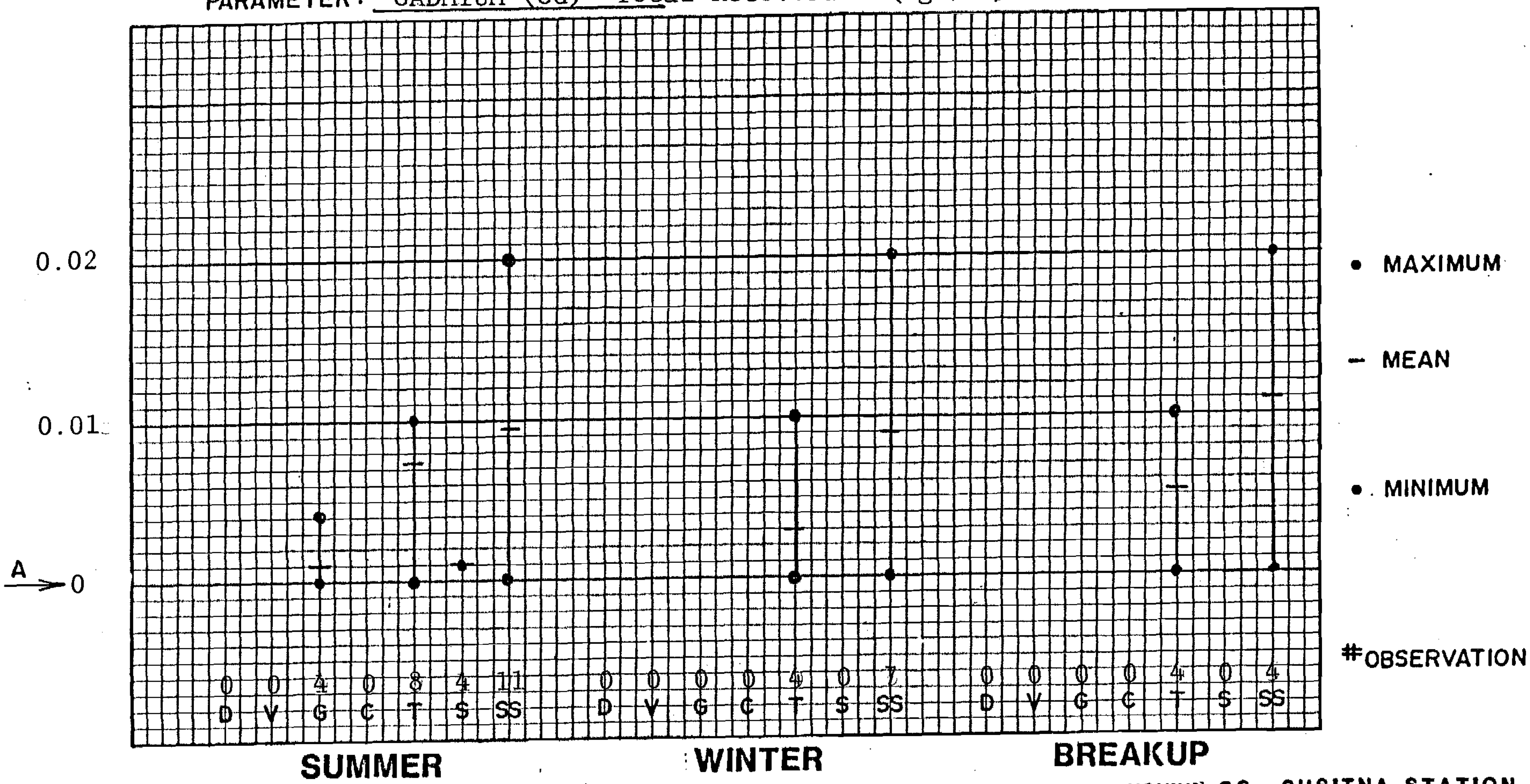
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - CADMIUM (d)

FIGURE : 34

ACRES

PARAMETER: CADMIUM (Cd) Total Recoverable (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. 0.0012 in hard water and 0.0004 mg/1 in soft water (EPA, 1976).

B. Less than 0.0002 mg/1 (McNeely et al, 1979).

Established to protect freshwater aquatic organisms.

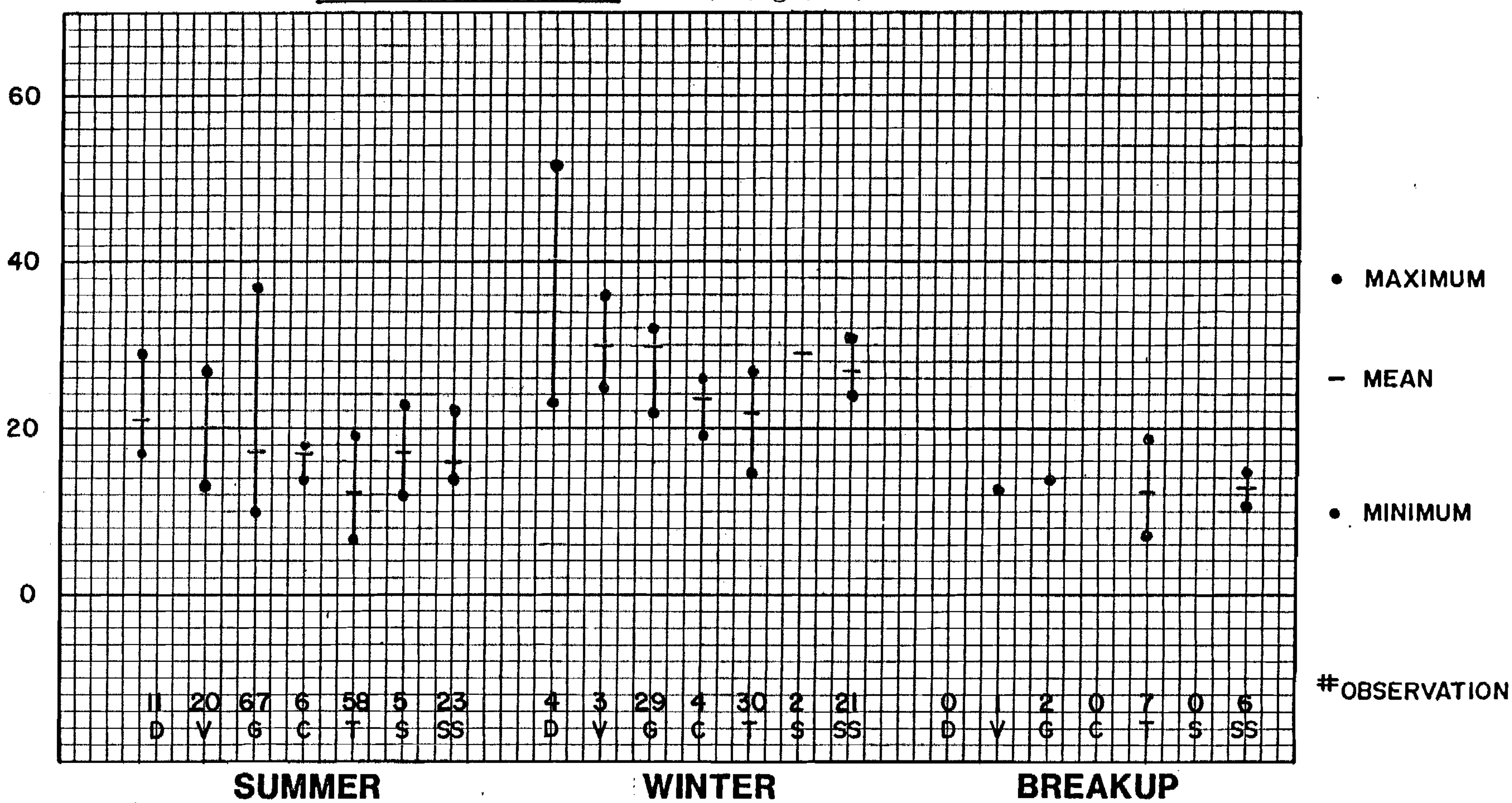
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - CADMIUM (t)

FIGURE: 35

ACRES

PARAMETER: CALCIUM (Ca) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established

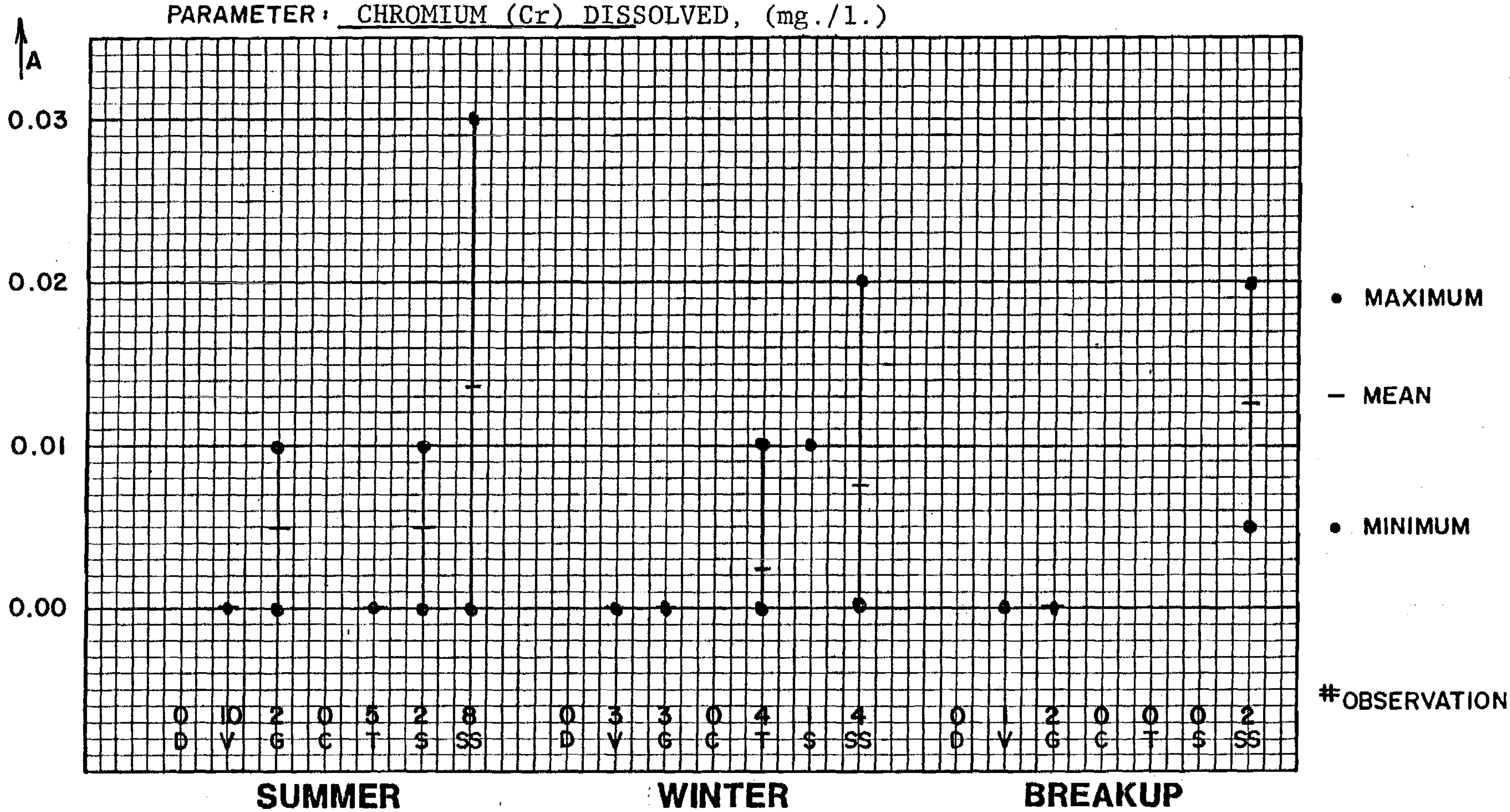
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - CALCIUM (d)

FIGURE : 36

ACRES

PARAMETER: CHROMIUM (Cr) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. 0.1 mg/1 (EPA, 1976).

B. Less than 0.29 µg/1 as a 24-hour average, not to exceed 21 µg/1 at any time. (EPA, 1980; Sittig, 1981).

Established to protect freshwater aquatic organisms.

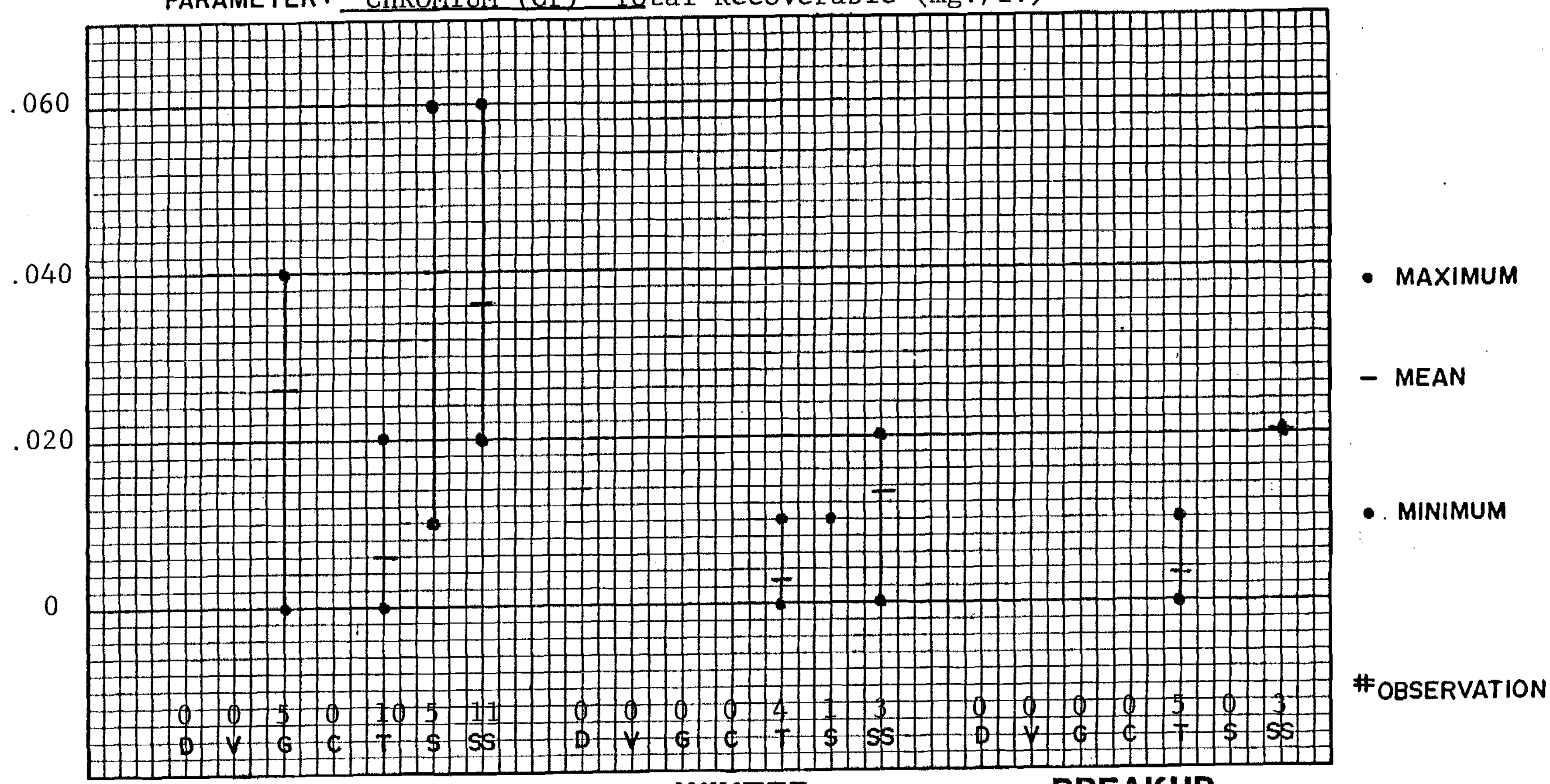
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - CHROMIUM (d)

FIGURE : 37

ACRES

PARAMETER: CHROMIUM (Cr) Total Recoverable (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. 0.1 mg/1, (EPA, 1976).

B. Less than 0.29 µg/1 as a 24 - hour average, not to exceed 21 µg/1 at any time (EPA, 1980; Sittig, 1981).

Established to protect freshwater aquatic organisms.

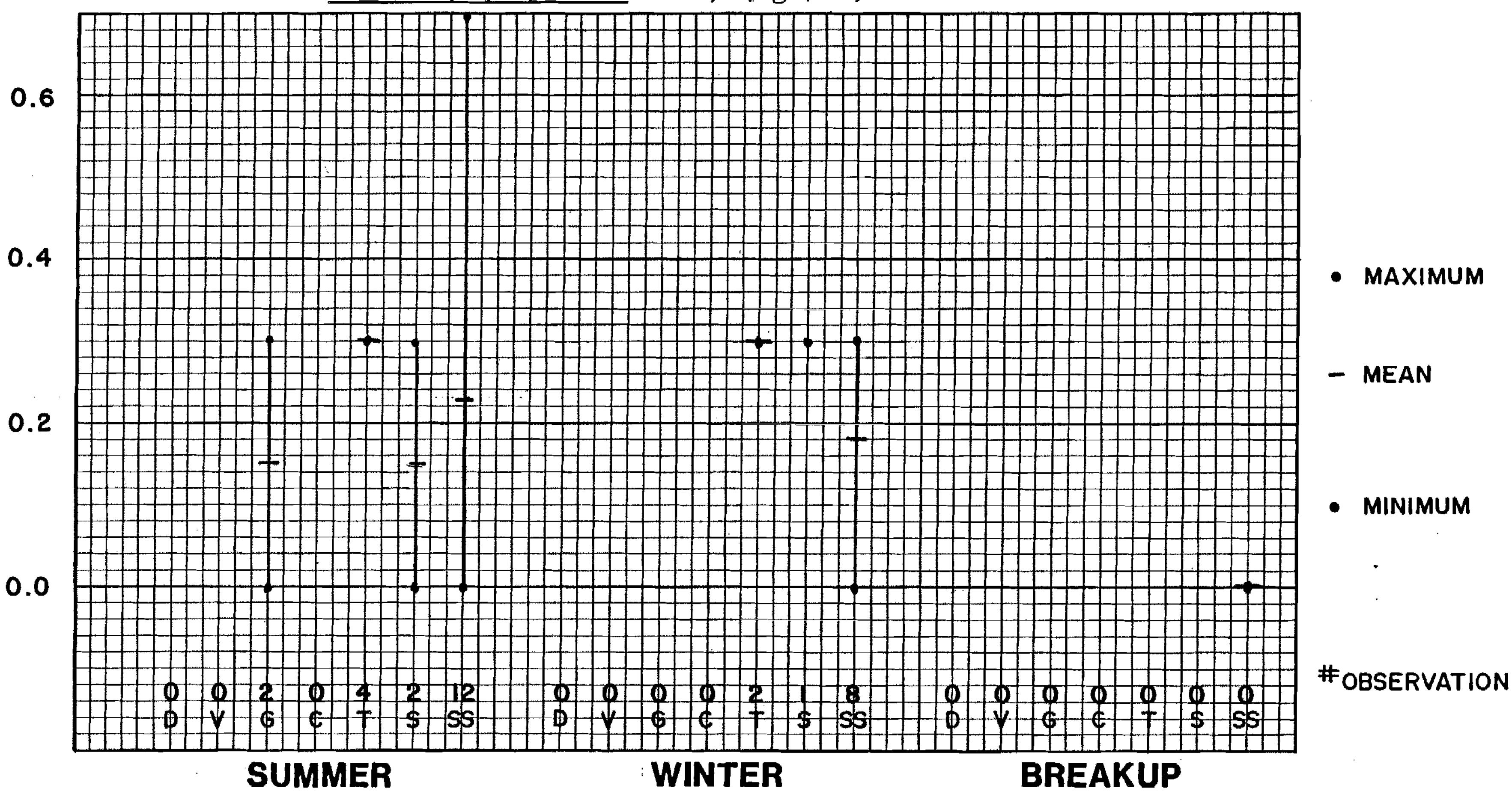
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - CHROMIUM (t)

FIGURE: 38

ACRES

PARAMETER: COBALT, (Co) DISSOLVED, (mg./1.)



D– DENALI V– VEE CANYON G– GOLD CREEK C– CHULITNA T– TALKEETNA S – SUNSHINE SS– SUSITNA STATION

No criterion established

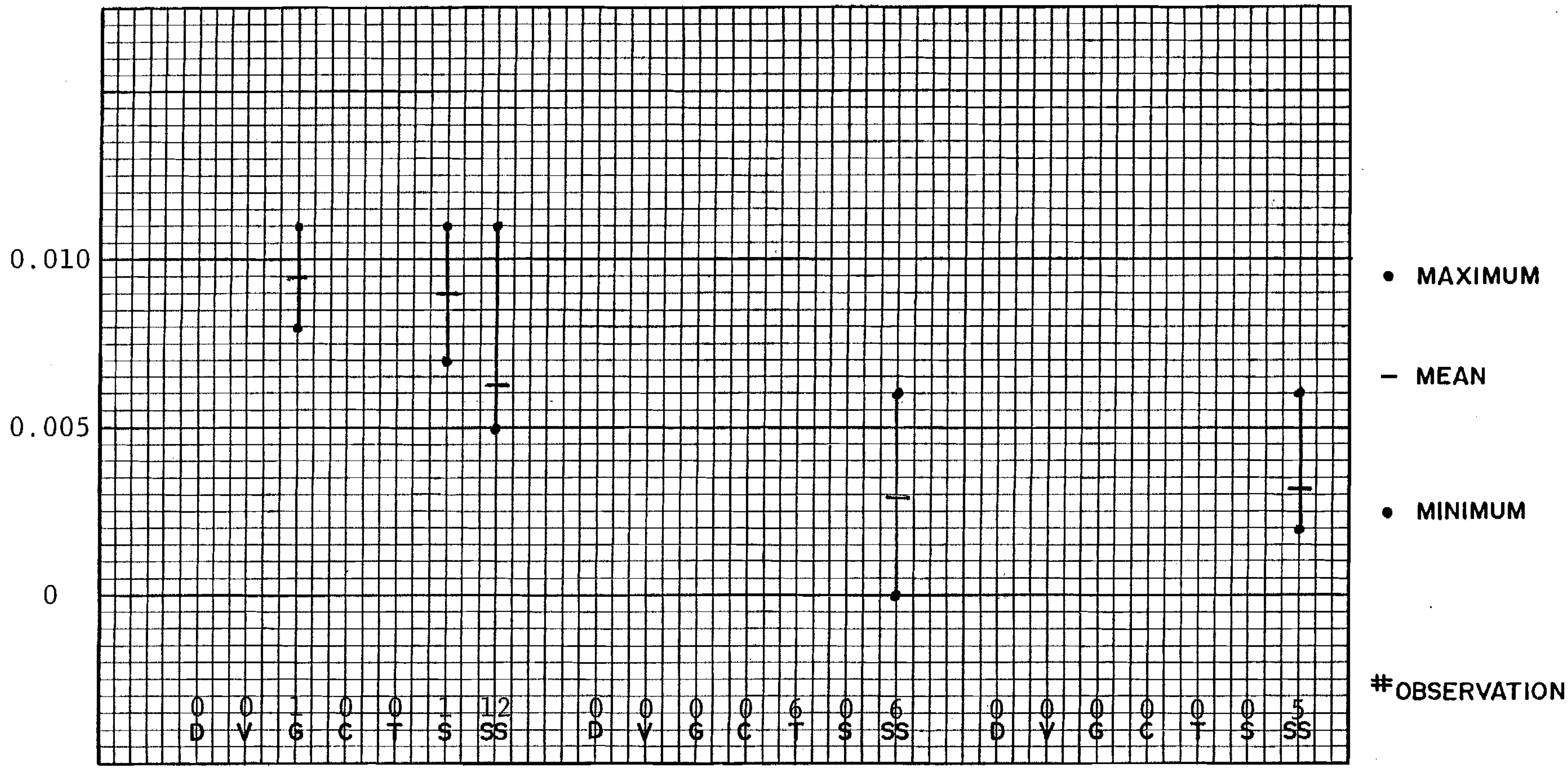
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - COBALT (d)

FIGURE : 39

ACRES

PARAMETER: COBALT (Co) Total Recoverable(mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No Criterion Established

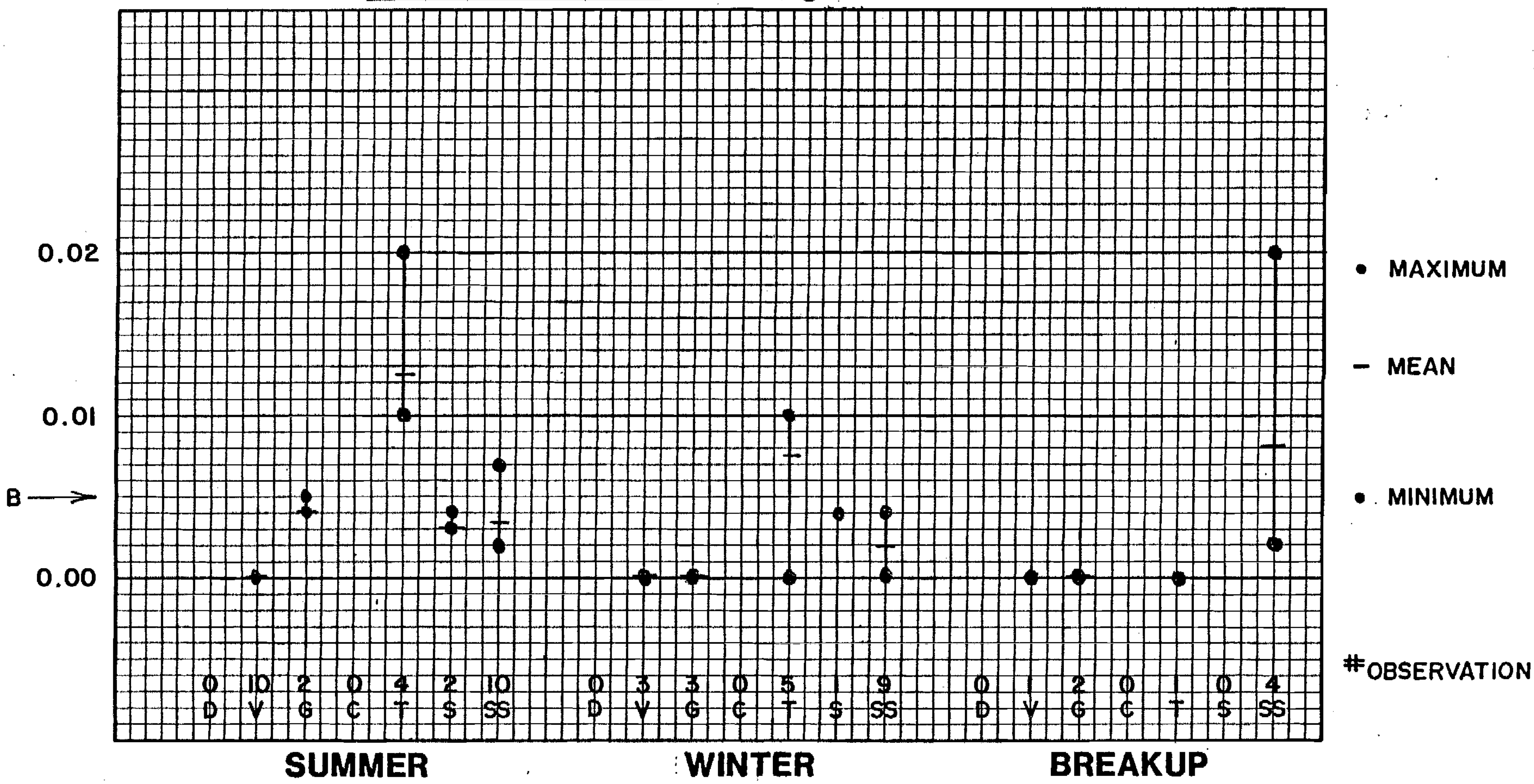
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - COBALT (t)

FIGURE: 40

ACRES

PARAMETER: COPPER (Cu) DISSOLVED (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. 0.01 of the 96-hour LC_{50} determined through bioassay (EPA, 1976).

B. 0.005 mg/l, (McNeely et al, 1979)

Established to protect freshwater aquatic organisms.

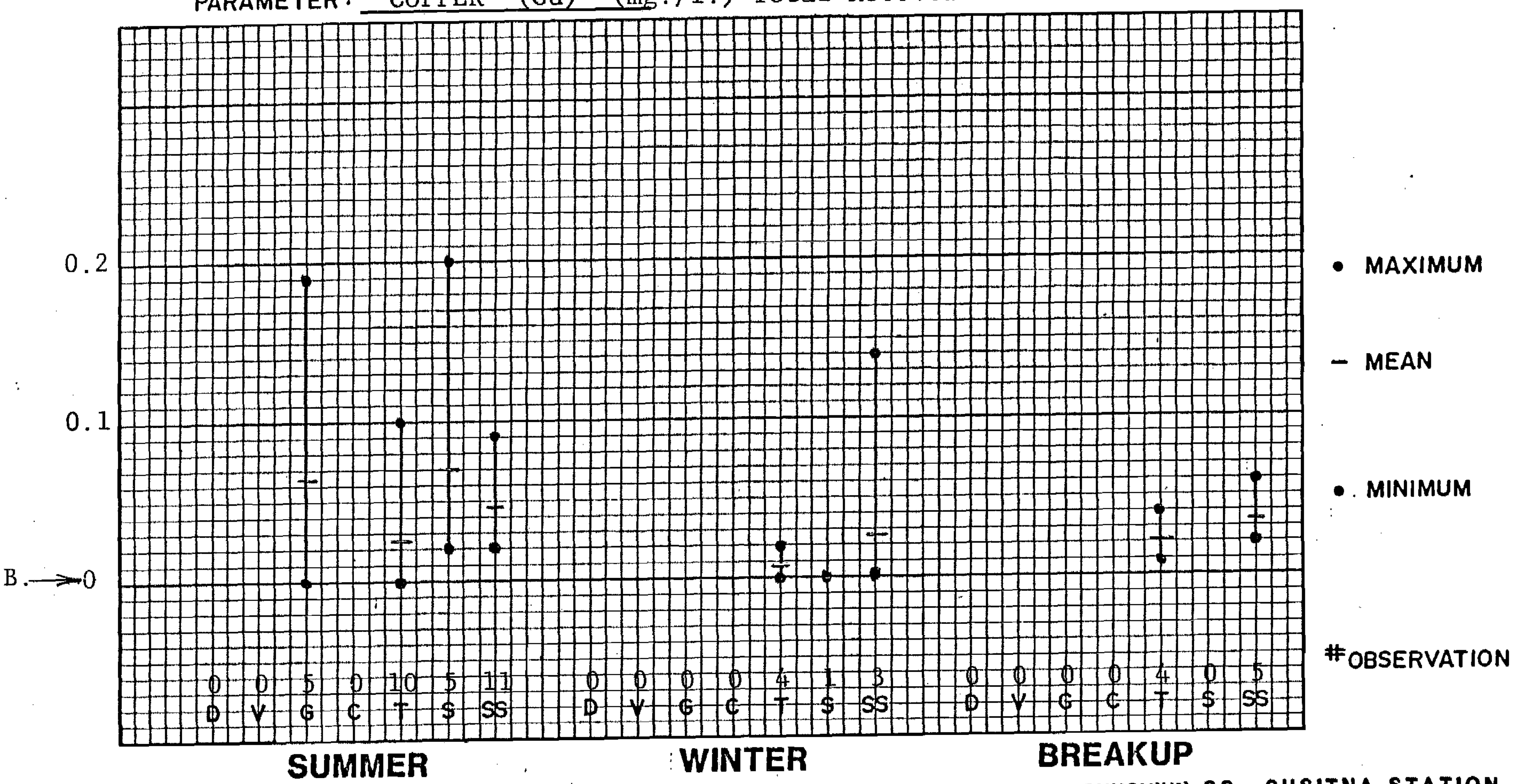
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - COPPER (d)

FIGURE : 41

ACRES

PARAMETER: COPPER (Cu) (mg./1.) Total Recoverable



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. 0.01 of the 96 - hour LC_{50} determined through bioassay (EPA, 1976).

B. 0.005 mg/l (McNeely et al, 1979).

Established to protect freshwater aquatic organisms.

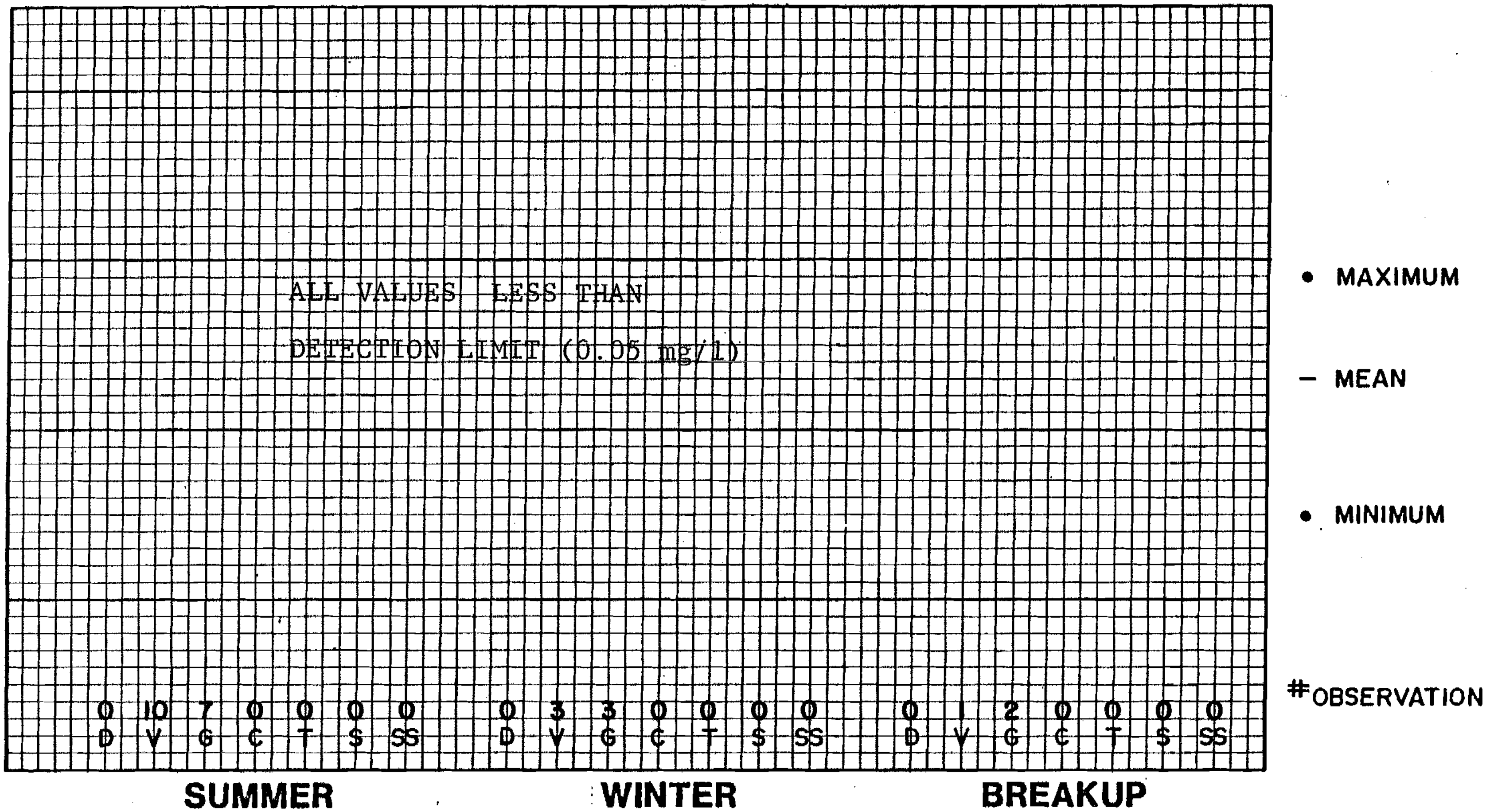
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - COPPER (t)

FIGURE: 42

ACRES

PARAMETER: GOLD (Au) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

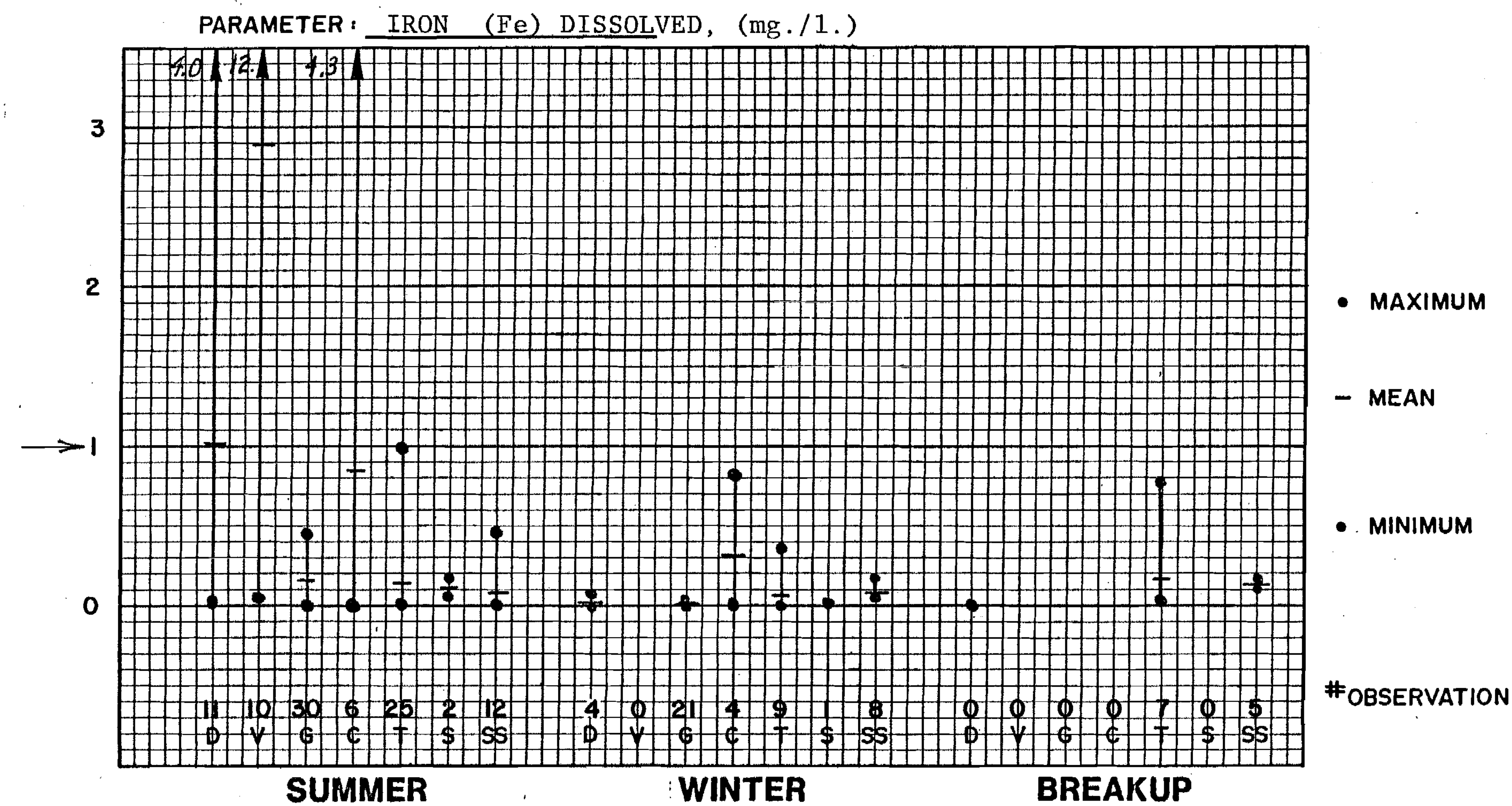
No criterion established.

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - GOLD (d)

FIGURE : 43

ACRES



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S- SUNSHINE SS- SUSITNA STATION

A. Less than 1.0 mg/1 (EPA, 1976; Sittig, 1981).

Established to protect freshwater aquatic organisms.

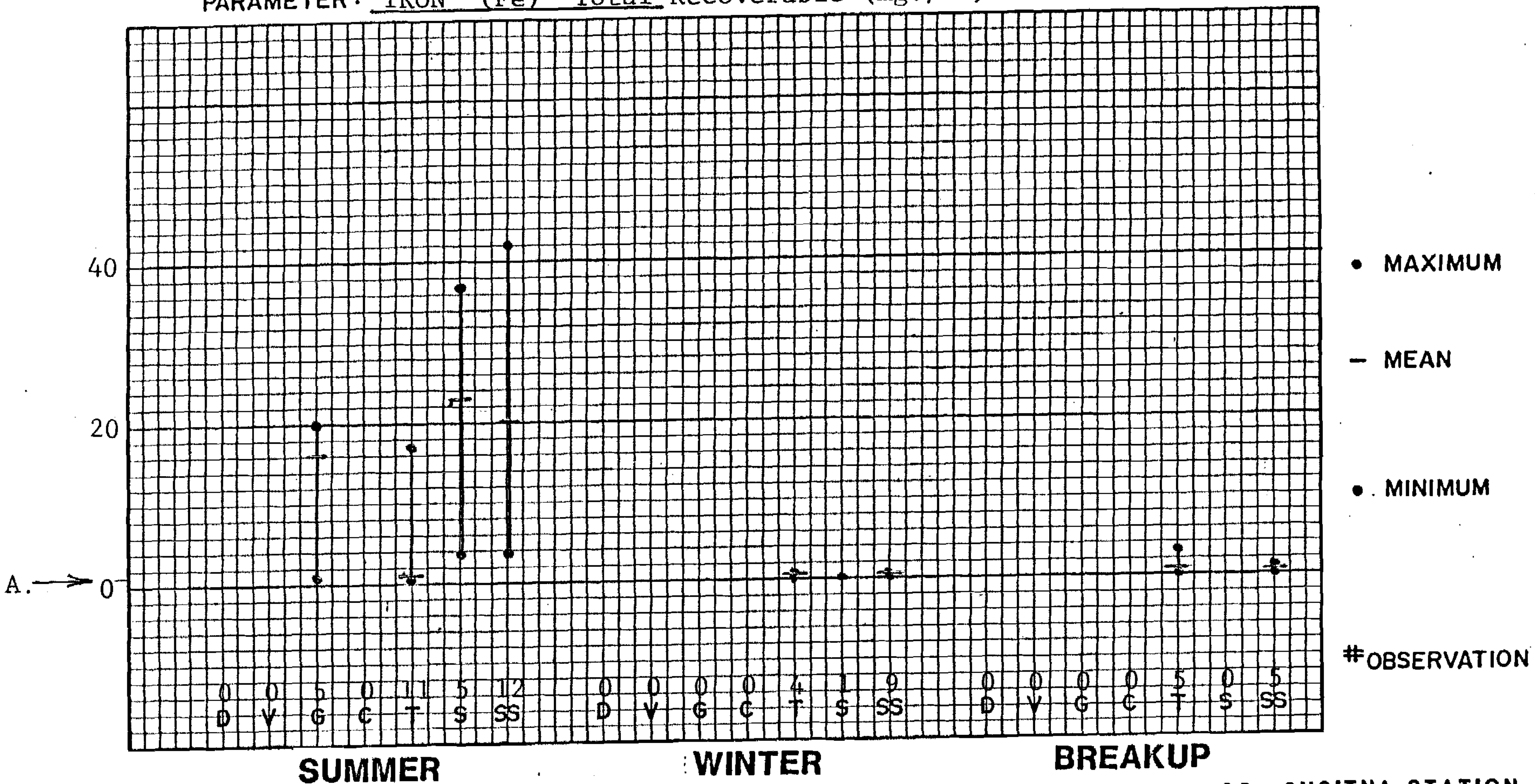
R&M CONSULTANTS, INC.

DATA SUMMARY - IRON (d)

FIGURE : 44

ACRES

PARAMETER: IRON (Fe) Total Recoverable (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 1.0 mg/1 (EPA, 1976; Sittig, 1981)

Established to protect freshwater aquatic organisms.

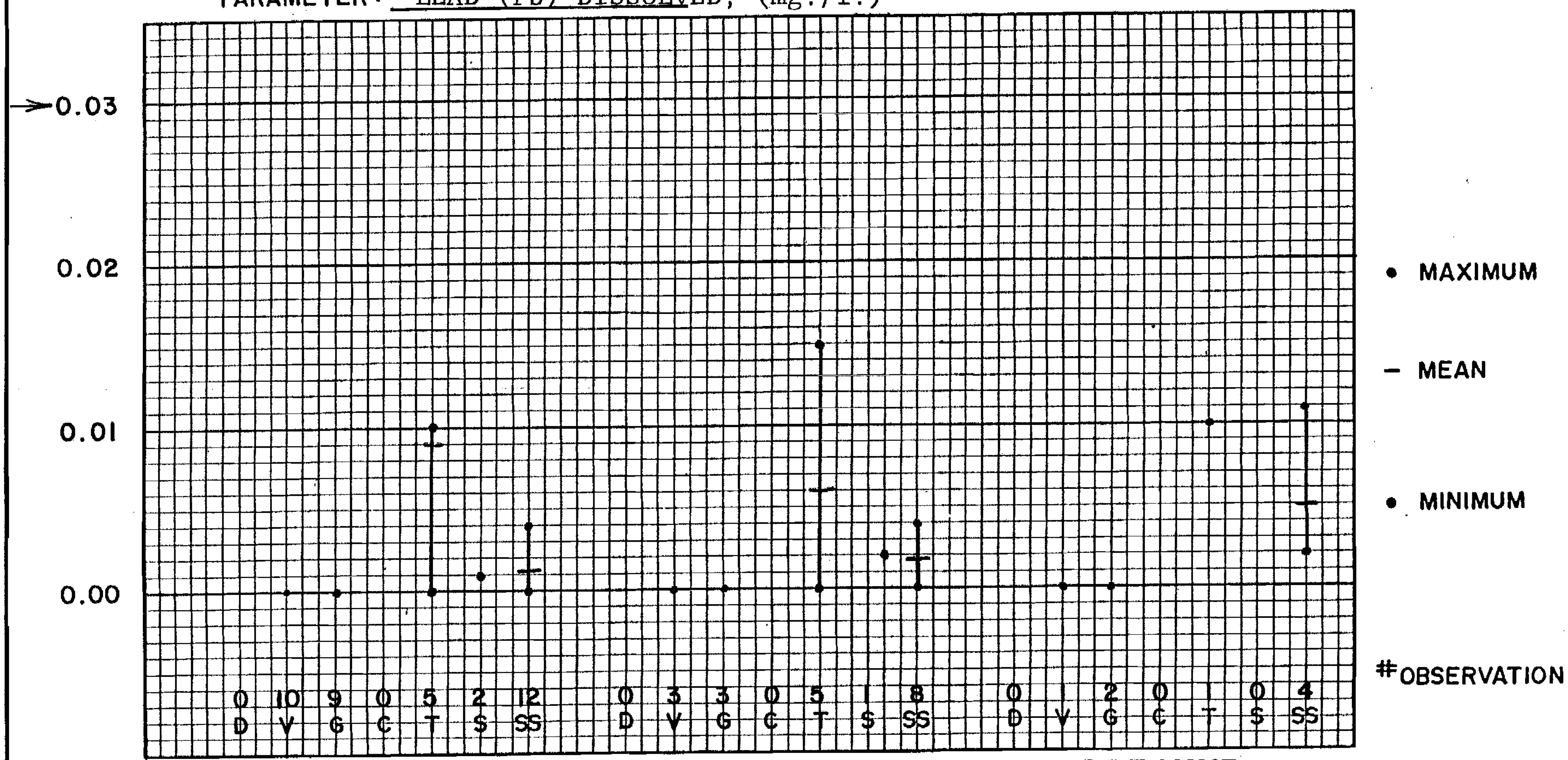
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - IRON (t)

FIGURE: 45

ACRES

PARAMETER: LEAD (Pb) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 0.03 mg/1, (McNeely et al, 1979).

B. 0.01 of the 96-hour LC_{50} determined through bioassay. (EPA, 1976).

Established to protect freshwater aquatic orgqnisms.

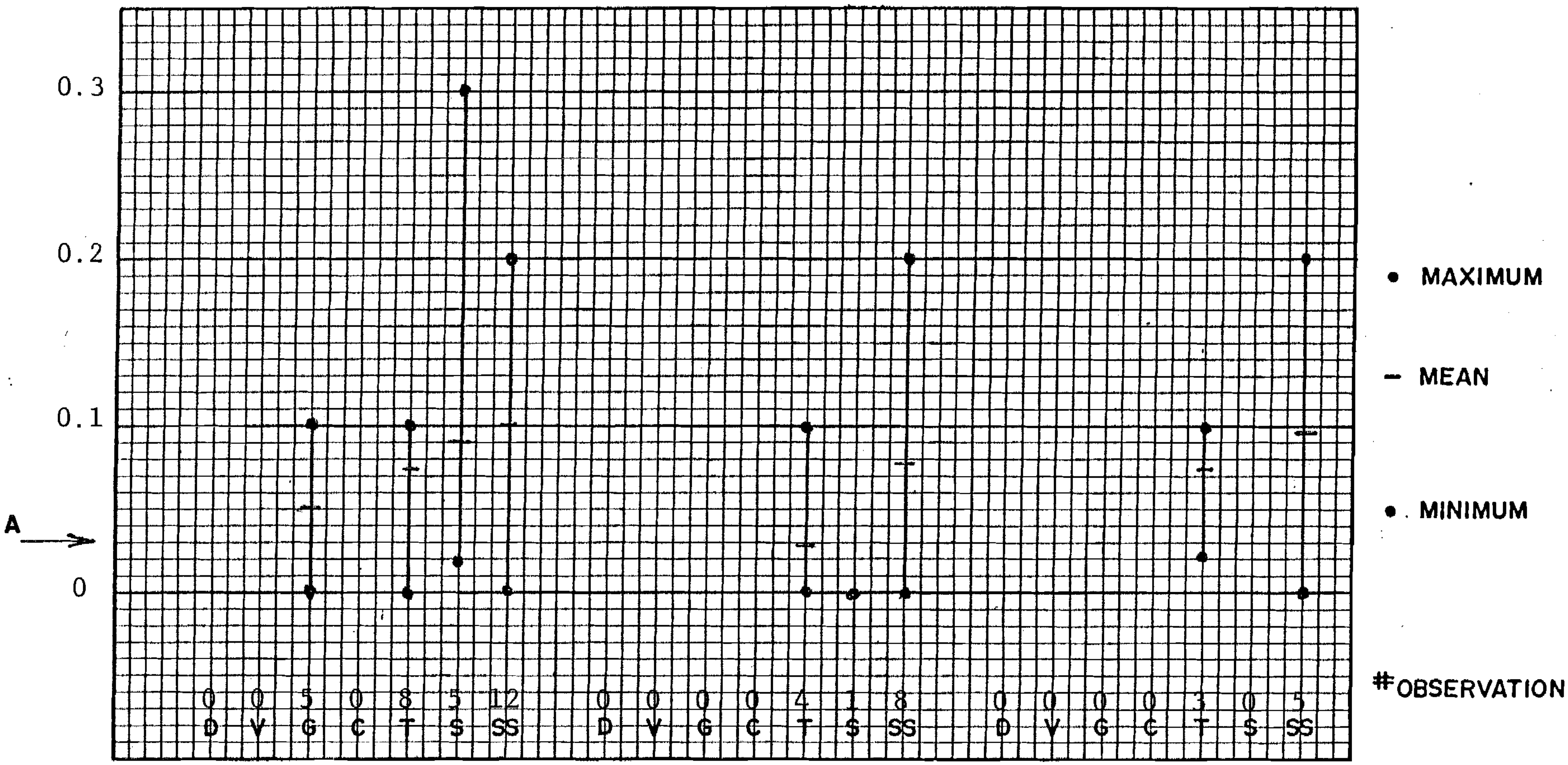
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - LEAD (d)

FIGURE: 46

ACRES

PARAMETER: LEAD (Pb) (mg./1.) Total Recoverable



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 0.03 mg/1 (McNeely et al, 1979).

B. 0.01 of the 96 - hour LC_{50} determined through bioassay (EPA, 1976).

Established to protect freshwater aquatic organisms.

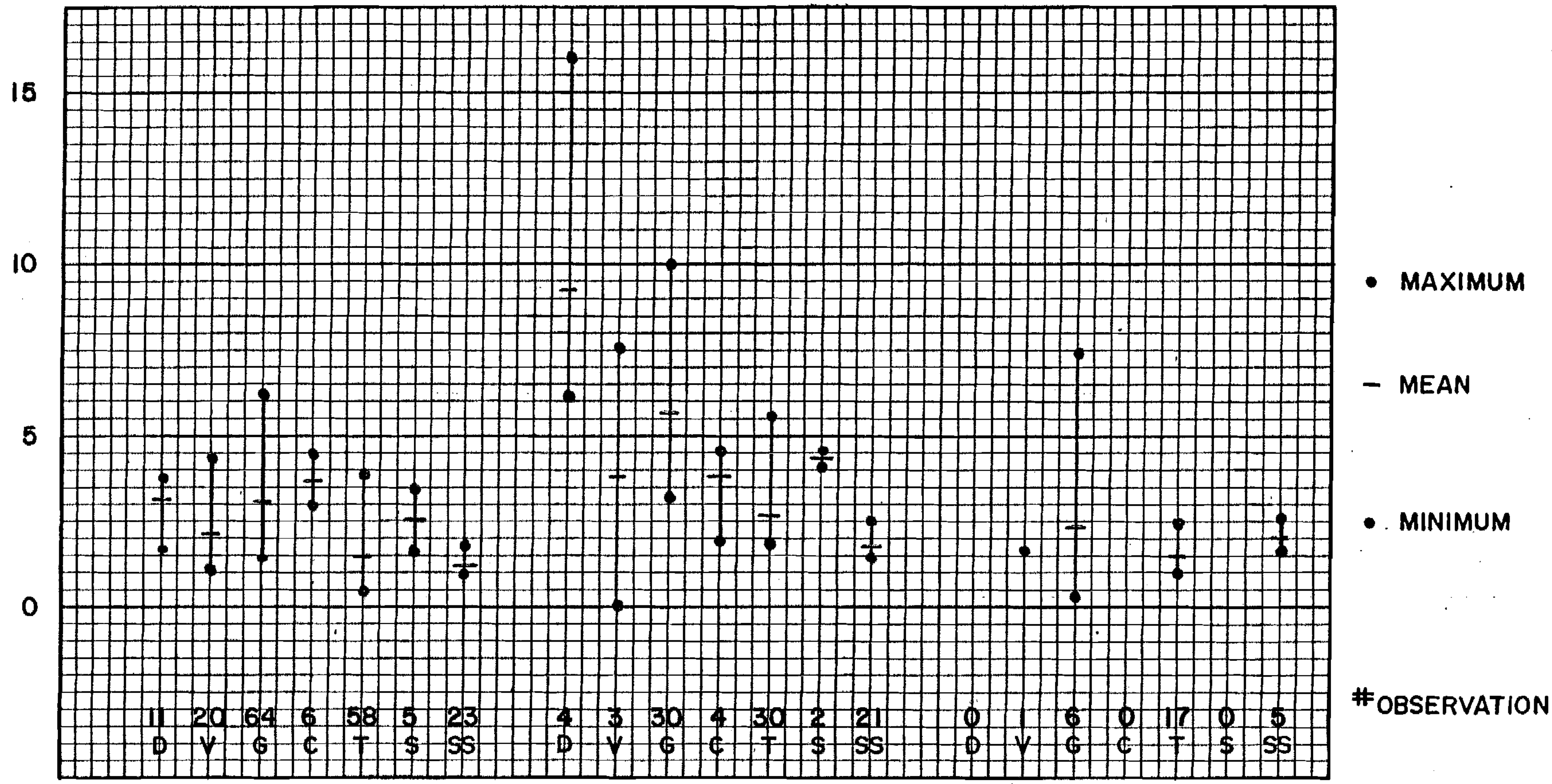
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - LEAD (t)

FIGURE: 47

ACRES

PARAMETER: MAGNESIUM (Mg) DISSOLVED, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established.

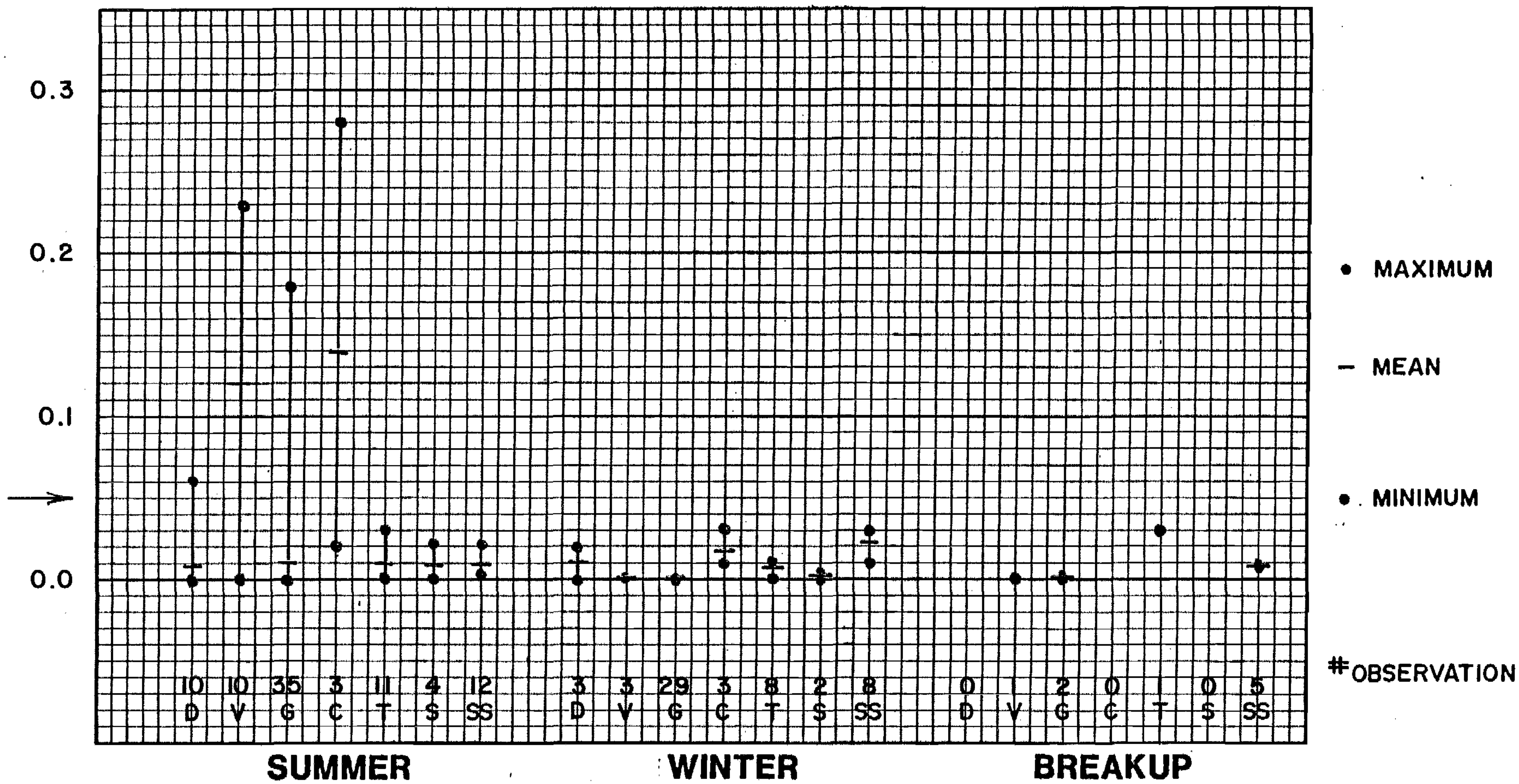
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - MAGNESIUM (d)

FIGURE : 48

ACRES

PARAMETER: MANGANESE (Mn) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 0.05 mg/1 for water supply. (EPA, 1976).

Established to protect water supplies.

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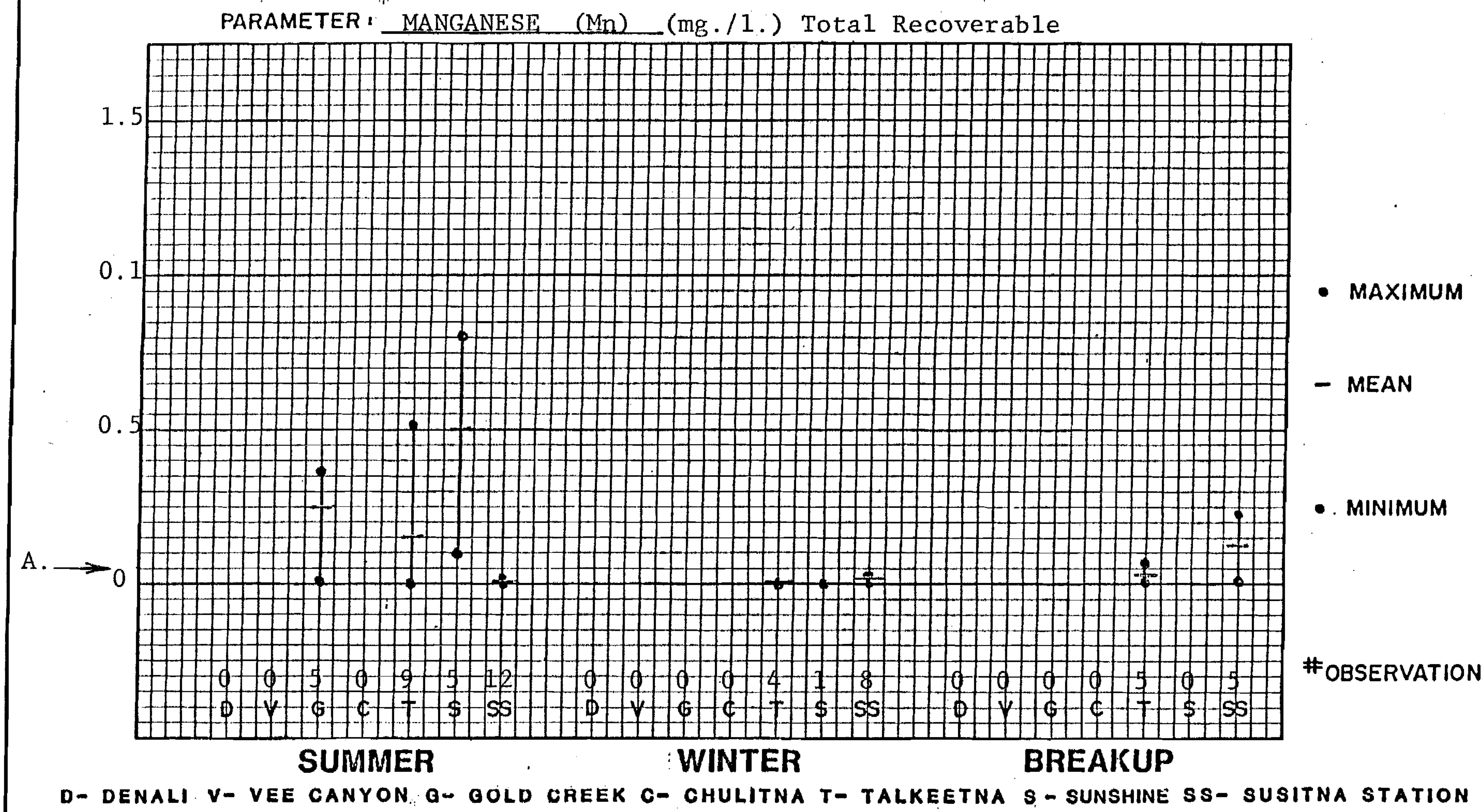
DATA SUMMARY - MANGANESE (d)

FIGURE: 49

ACRES



A. Less than 0.05 mg/l for water supply (EPA, 1976)

Established to protect water supplies.

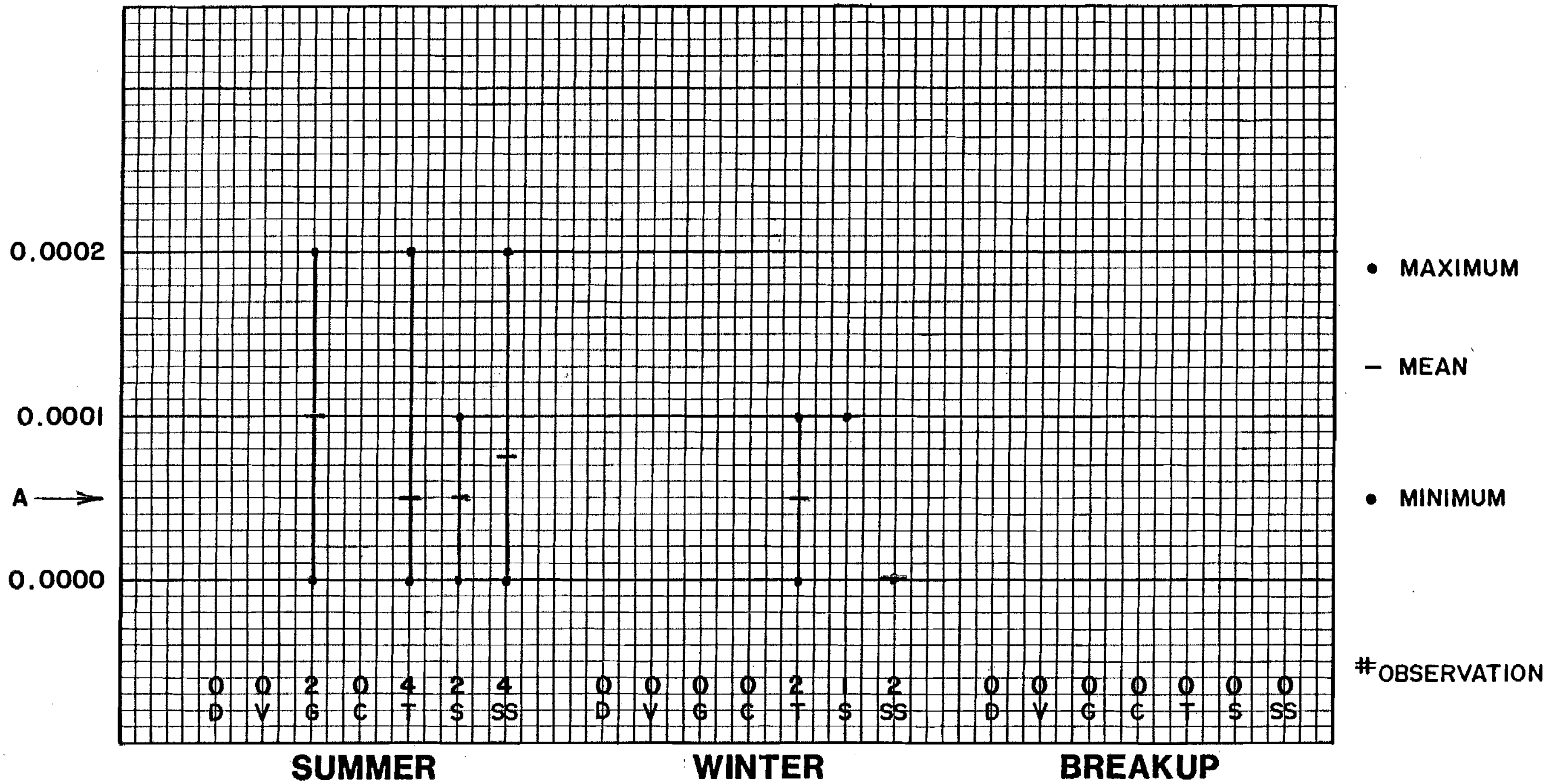
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - MANGANESE (t)

FIGURE: 50

ACRES

PARAMETER: MERCURY (Hg) DISSOLVED, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 0.00005 mg/l. (EPA, 1976).

Established to protect freshwater aquatic organisms.

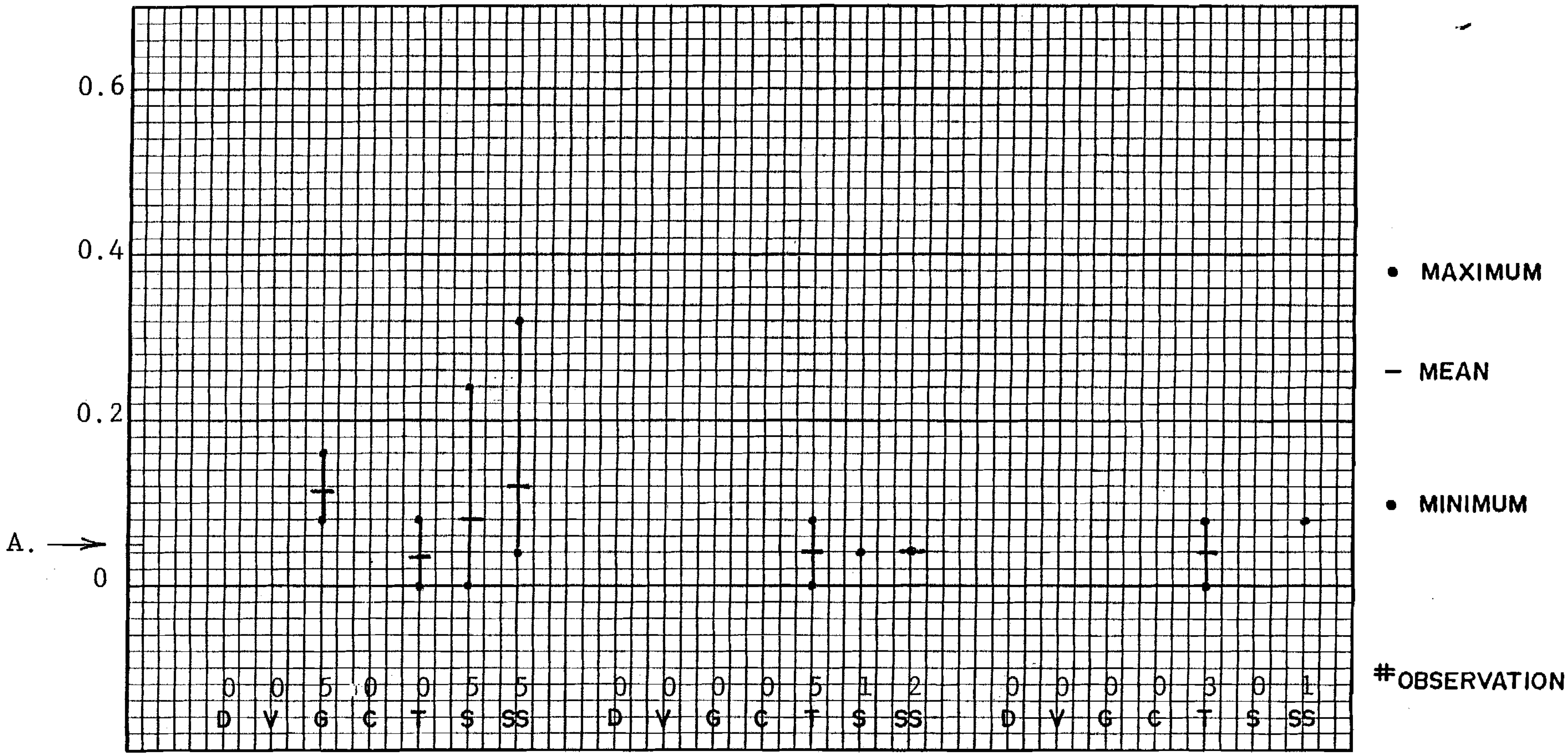
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - MERCURY (d)

FIGURE : 51

ACRES

PARAMETER: MERCURY (Hg) Total Recoverable (μg/1)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 0.05 μg/1 (EPA, 1976)

Established to protect freshwater aquatic organisms.

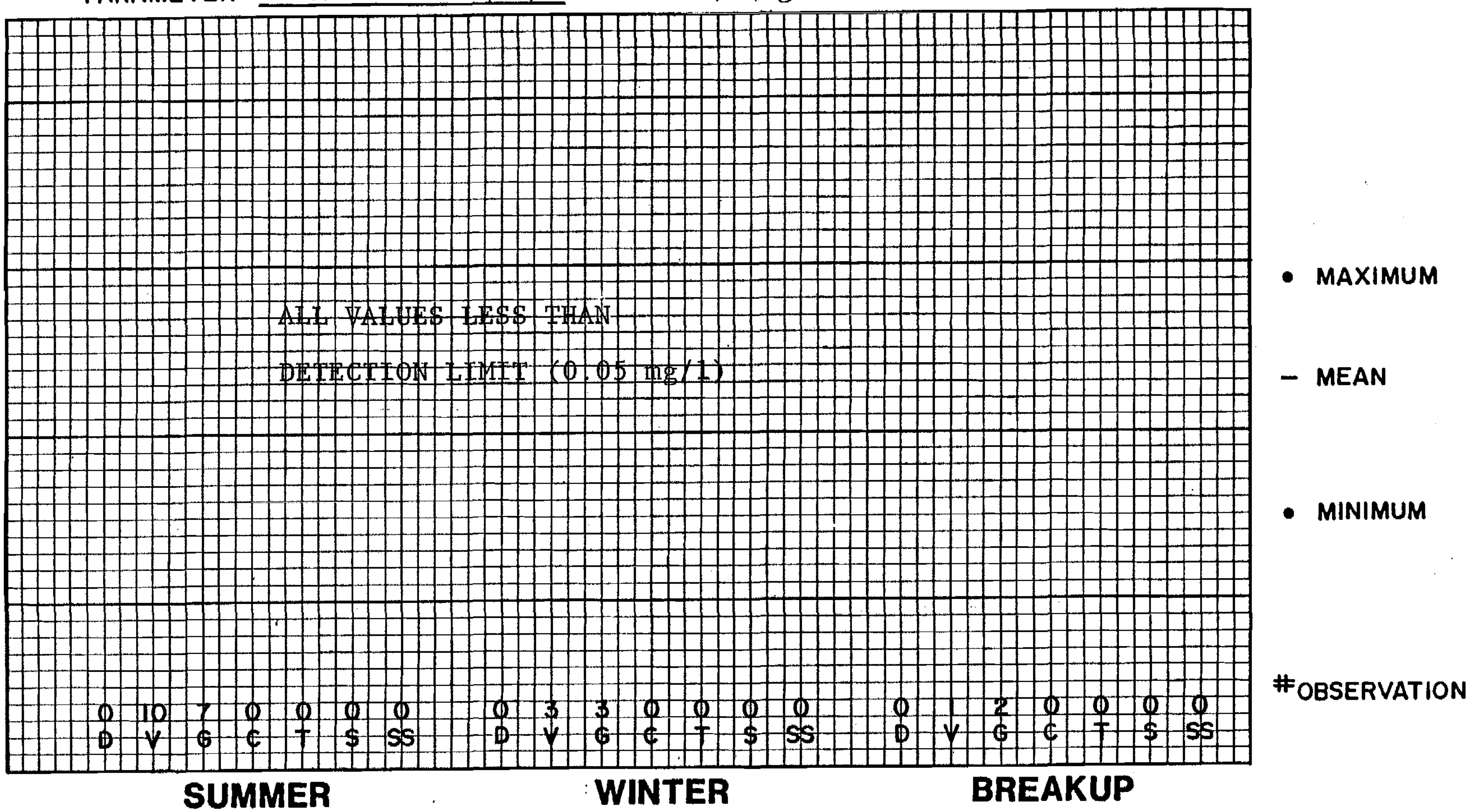
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - MERCURY (t)

FIGURE: 52

ACRES

PARAMETER: MOLYBDENUM (Mo) DISSOLVED, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

Less than 0.07 mg/l. (Sittig, 1981).

Established on the basis of human health effects.

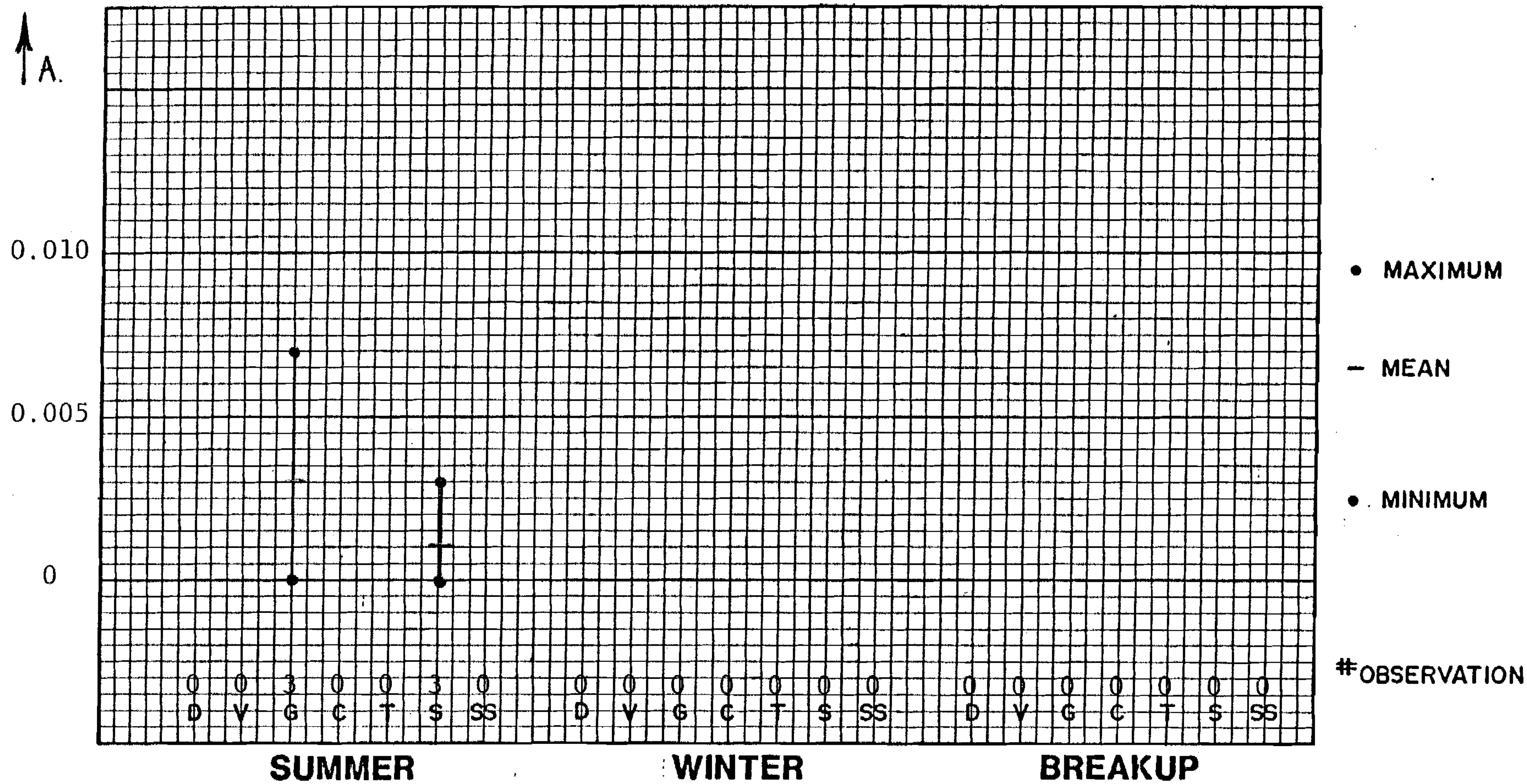
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - MOLYBDENUM (d)

FIGURE: 53

ACRES

PARAMETER: MOLYBENUM (Mo) Total Recoverable (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 0.07 mg/1 (Sittig, 1981).

Established on the basis of human health effects.

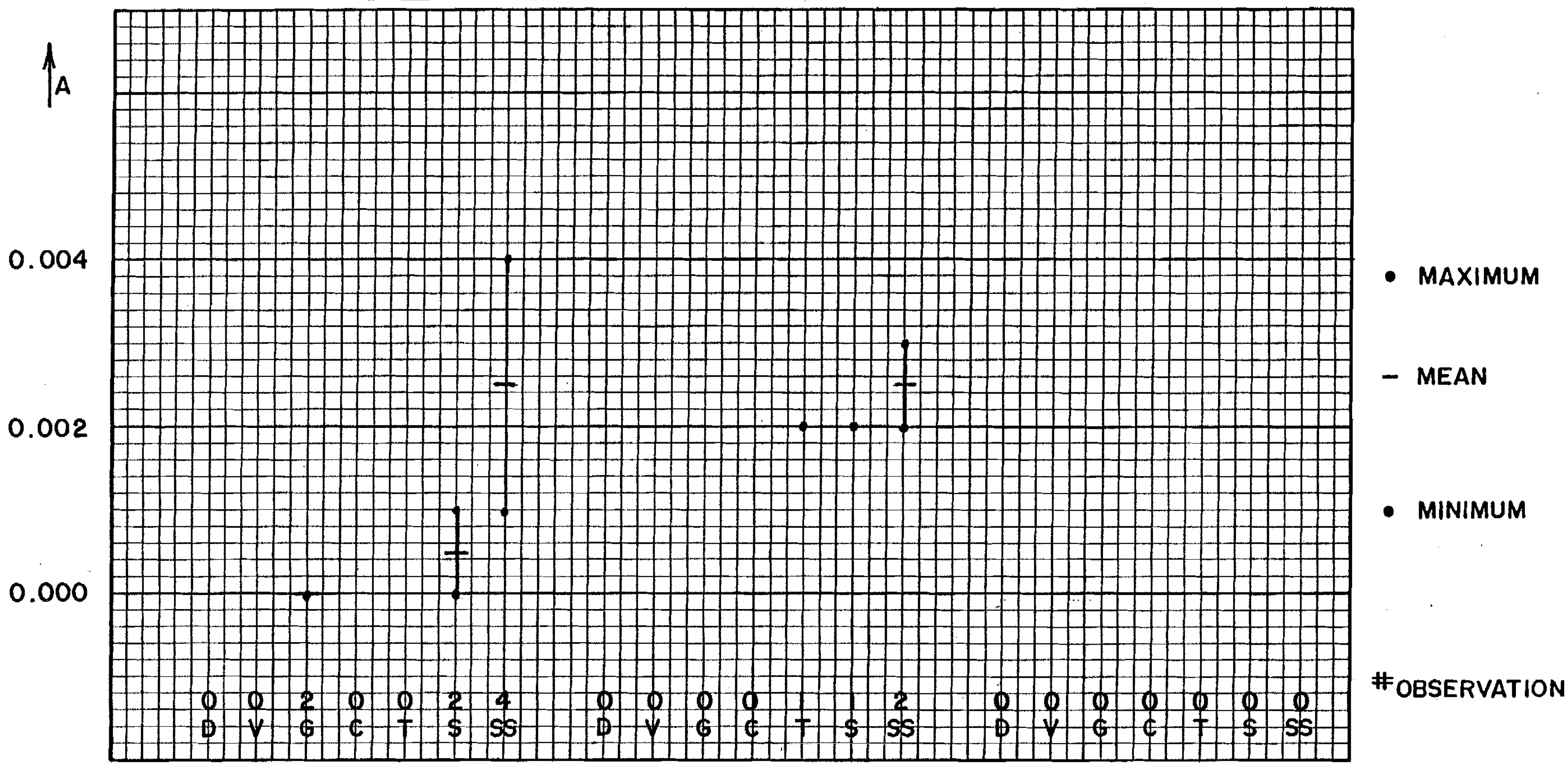
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - MOLYBENUM (t)

FIGURE: 54

ACRES

PARAMETER: NICKEL (Ni) DISSOLVED, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 0.025 mg/l. (McNeely et al, 1979).

B. 0.01 of the 96-hour LC_{50} determined through bioassay. (EPA, 1976).

Established to protect freshwater aquatic organisms.

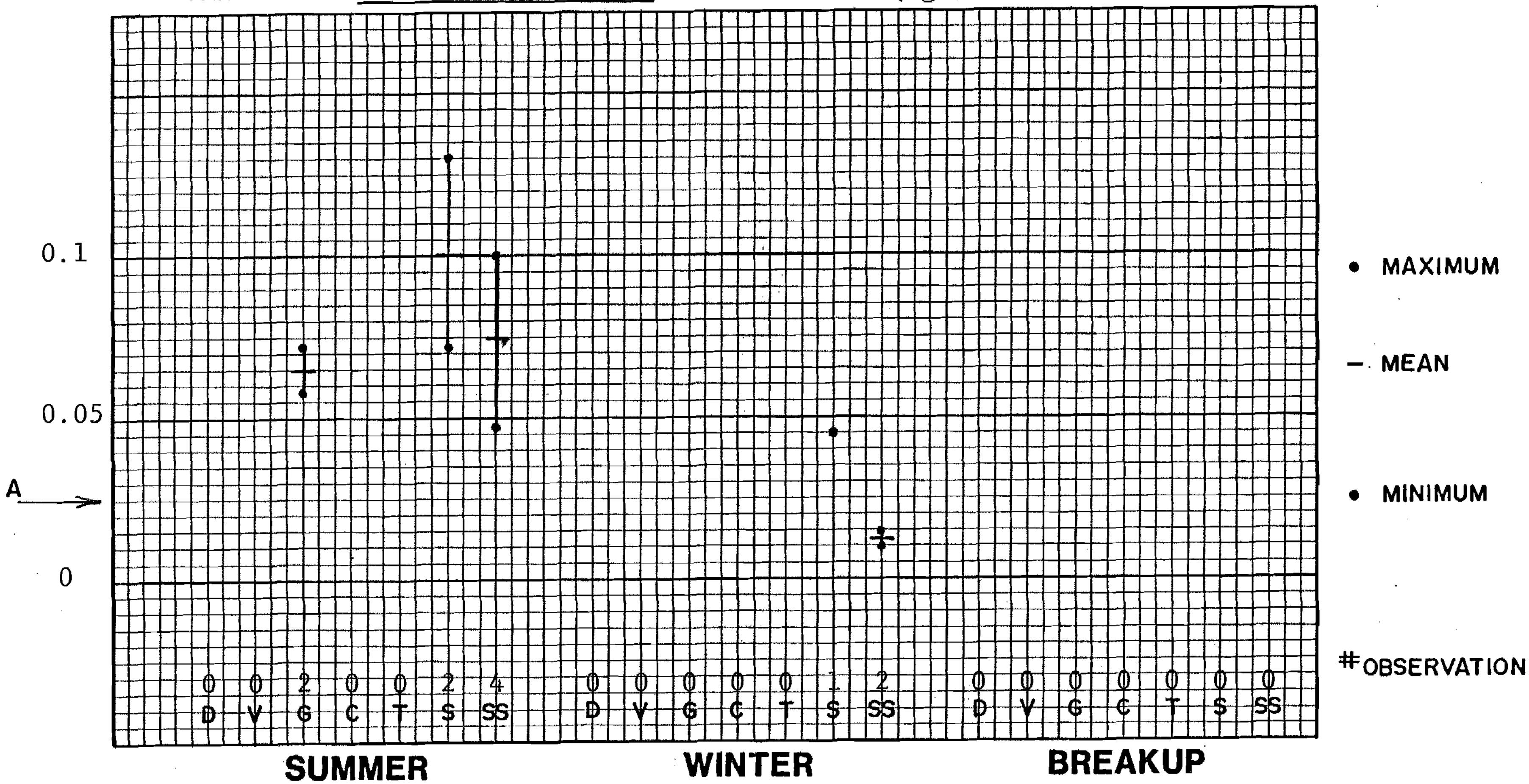
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - NICKEL (d)

FIGURE: 55

ACRES

PARAMETER: NICKEL (Ni) Total Recoverable (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S- SUNSHINE SS- SUSITNA STATION

A. Less than 0.025 mg/1 (McNeely et al, 1979).

B. 0.01 of the 96 - hour LC_{50} determined through bioassay (EPA, 1976)

Established to protect freshwater aquatic organisms.

R&M CONSULTANTS, INC.
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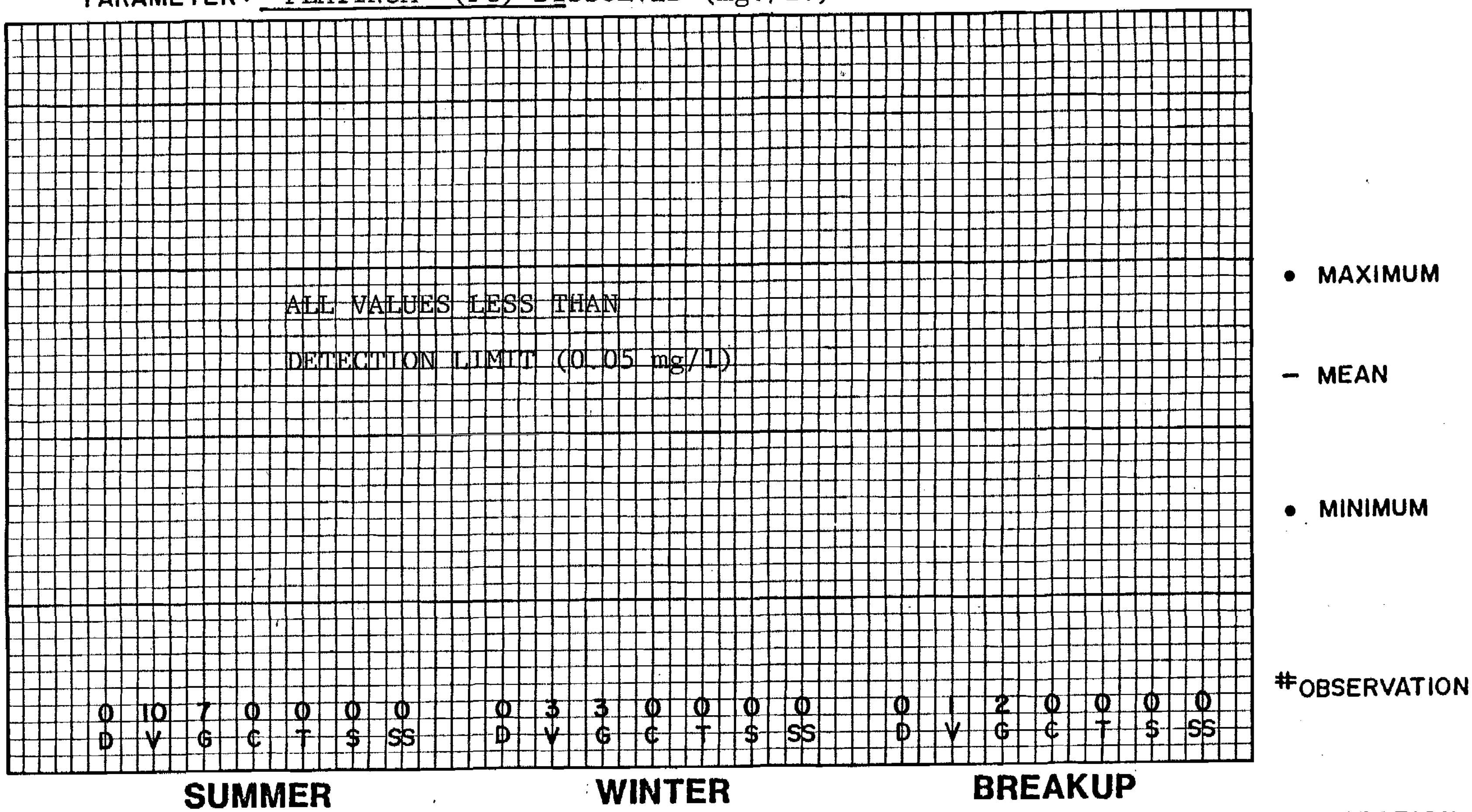
DATA SUMMARY - NICKEL (t)

FIGURE: 56

ACRES

PARAMETER: PLATINUM (Pt) DISSOLVED (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established.

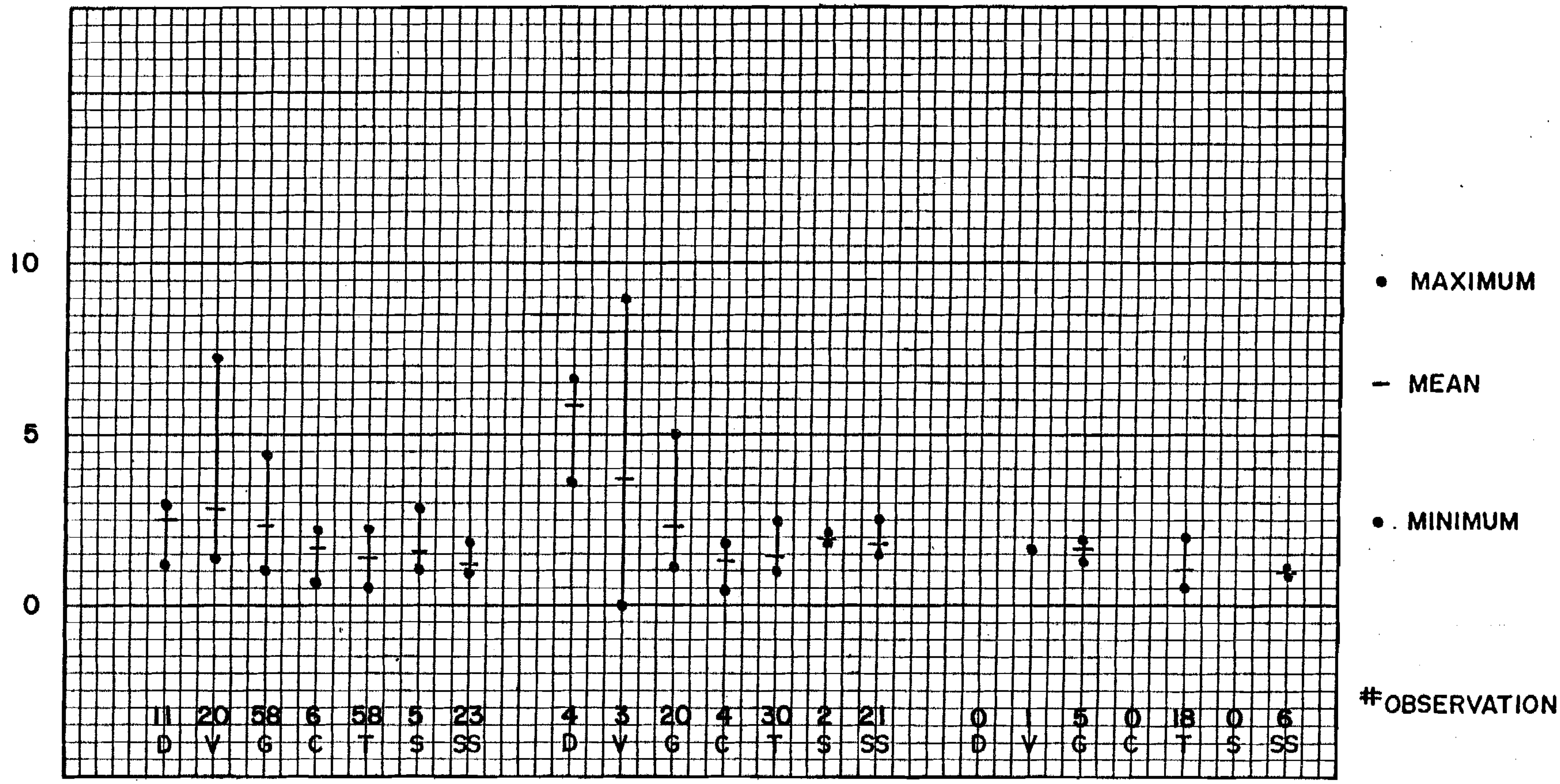
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - PLATINUM (d)

FIGURE : 57

ACRES

PARAMETER: POTASSIUM (K) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established.

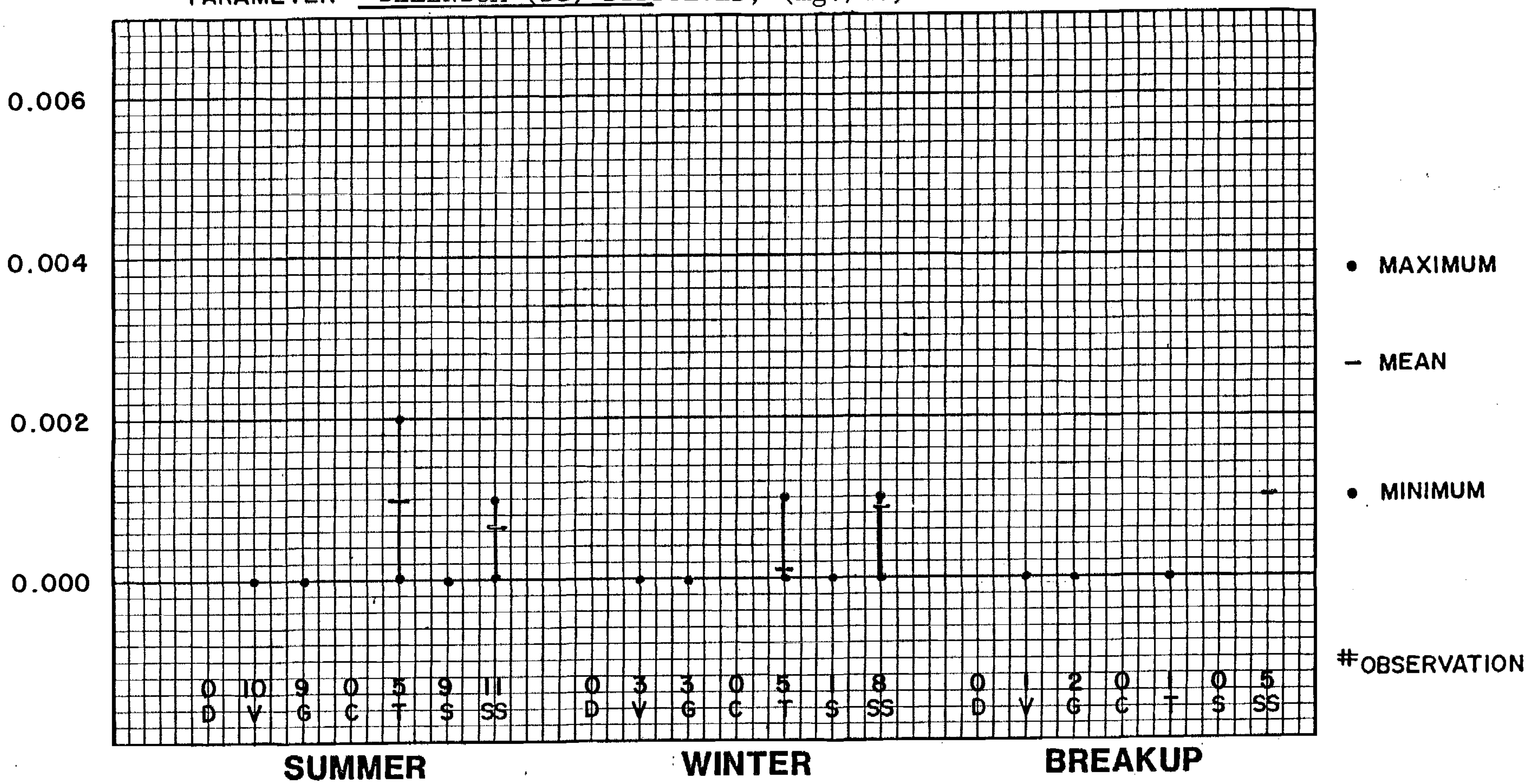
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY POTASSIUM (d)

FIGURE: 58

ACRES

PARAMETER: SELENIUM (Se) DISSOLVED, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 0.01 mg/l, (McNeely et al, 1979).

B. 0.01 of the 96-hour LC_{50} determined through bioassay (EPA, 1976).

Established to protect freshwater aquatic organisms.

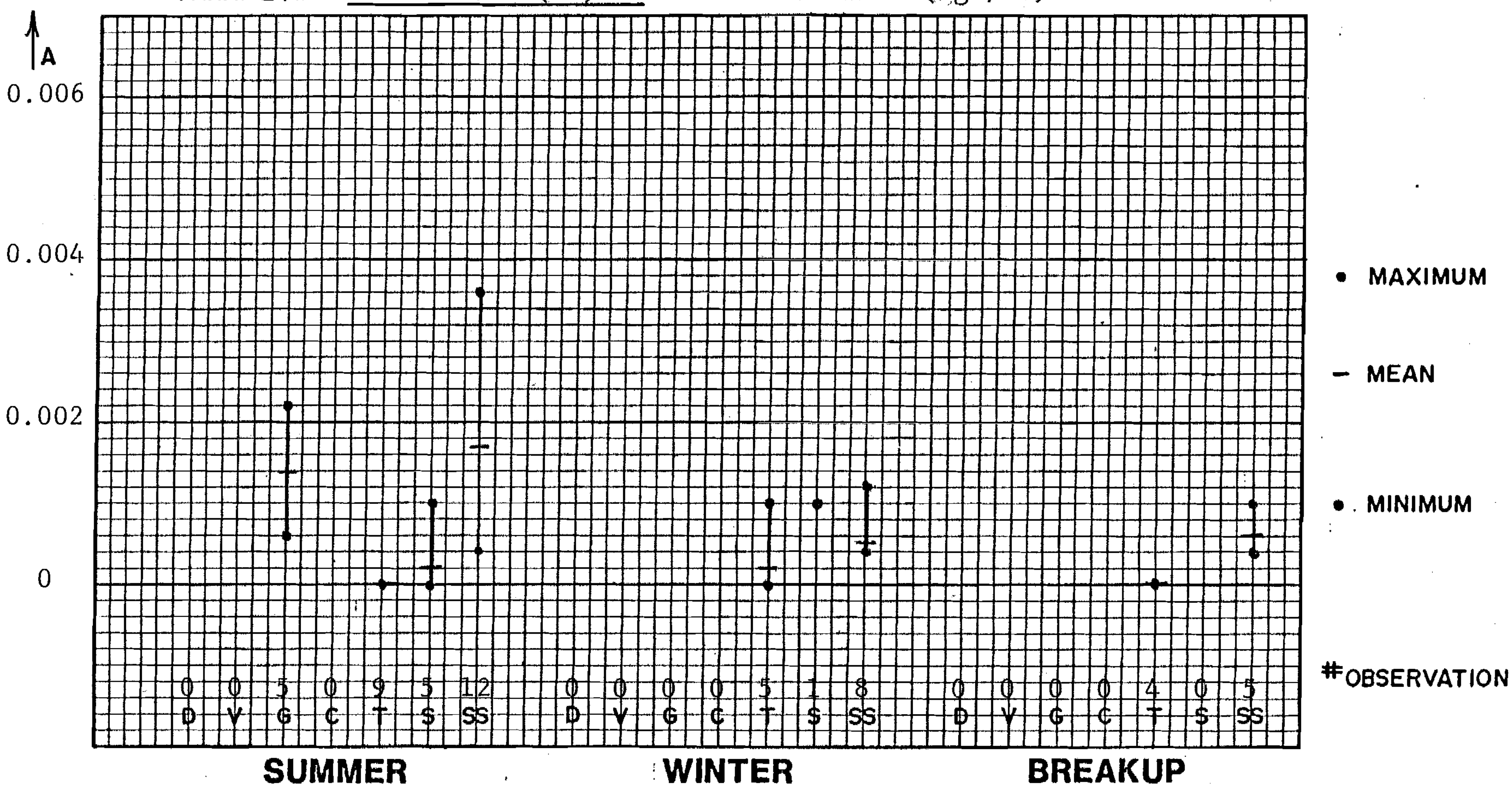
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - SELENIUM (d)

FIGURE : 59

ACRES

PARAMETER: SELENIUM (Se) Total Recoverable (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 0.01 mg/l (McNeely et al, 1979).

B. 0.01 of the 96 - hour LC_{50} determined through bioassay (EPA, 1976).

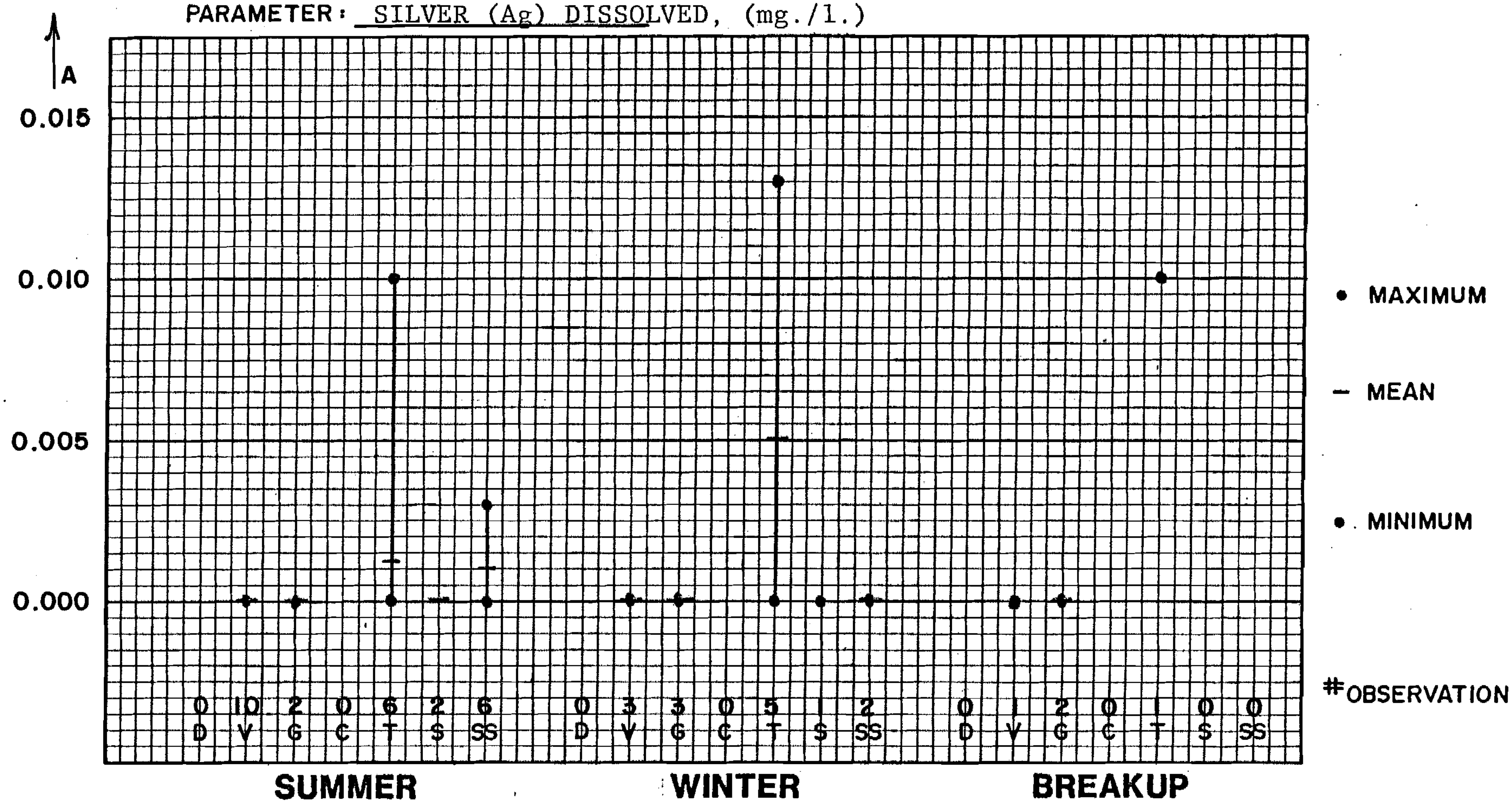
Established to protect freshwater aquatic organisms.

R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - SELENIUM (t)

FIGURE: 60

ACRES



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than .050 mg/l for drinking water. (EPA, 1976)

B. 0.01 of the 96-hour LC_{50} determined through bioassay, (EPA, 1976).

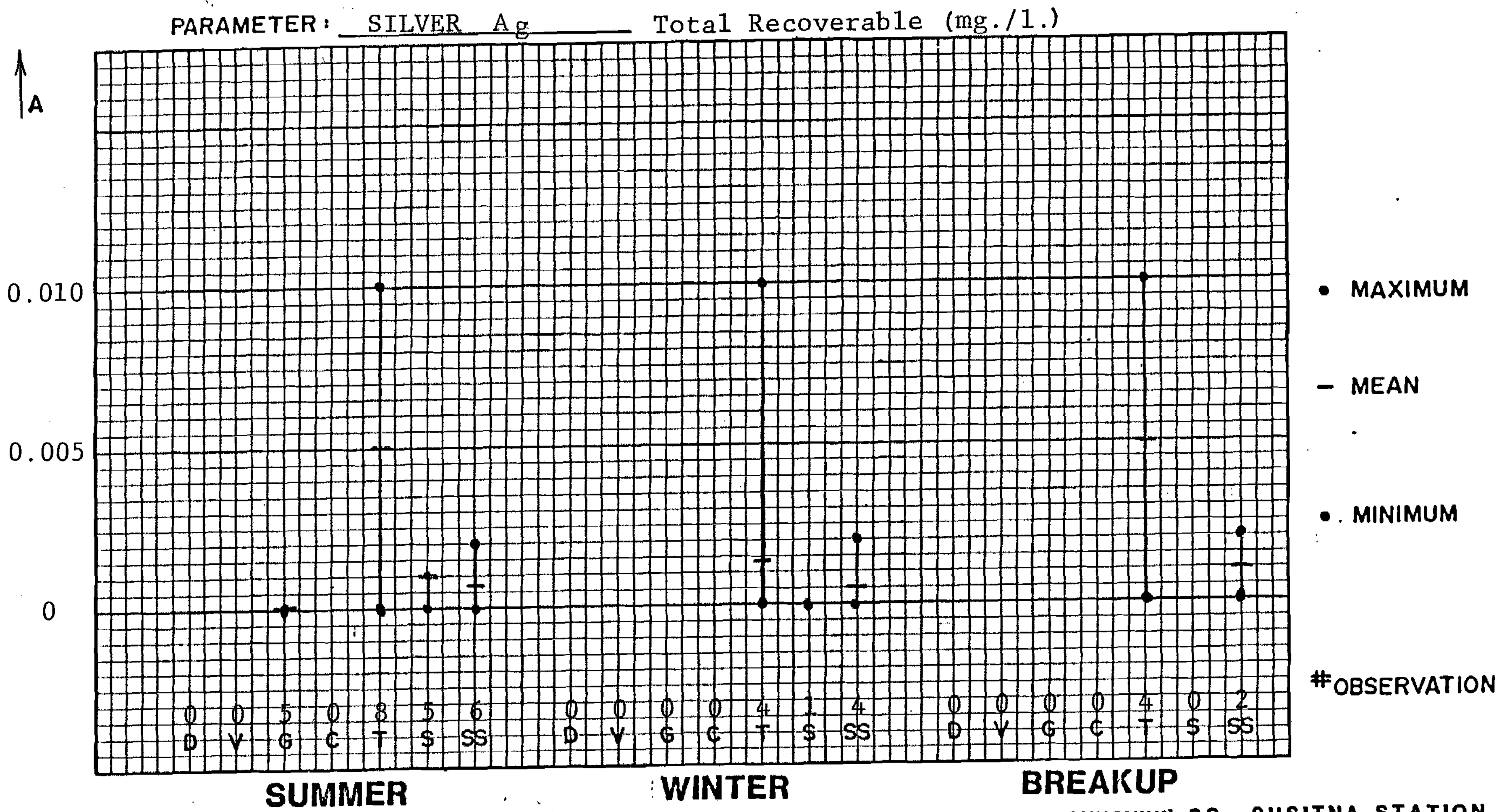
Established to protect water supplies.

R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - SILVER (d)

FIGURE: 61

ACRES



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 0.05 mg/l for drinking water (EPA,1976)

B. 0.01 of the 96-hour LC_{50} determined through bioassay (EPA,1976)

Established to protect water supplies.

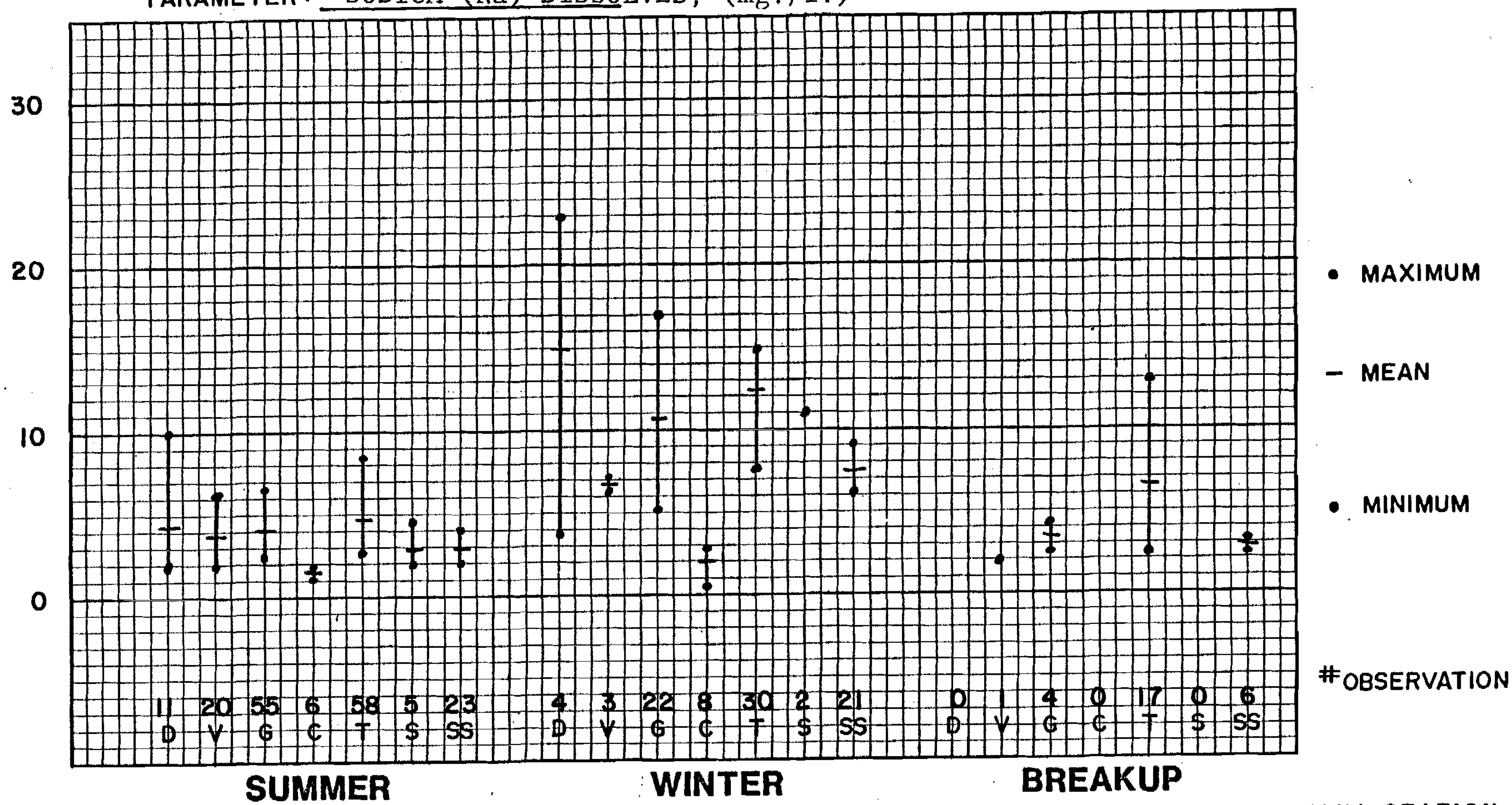
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - SILVER (t)

FIGURE: 62

ACRES

PARAMETER: SODIUM (Na) DISSOLVED, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S- SUNSHINE SS- SUSITNA STATION

No criterion established.

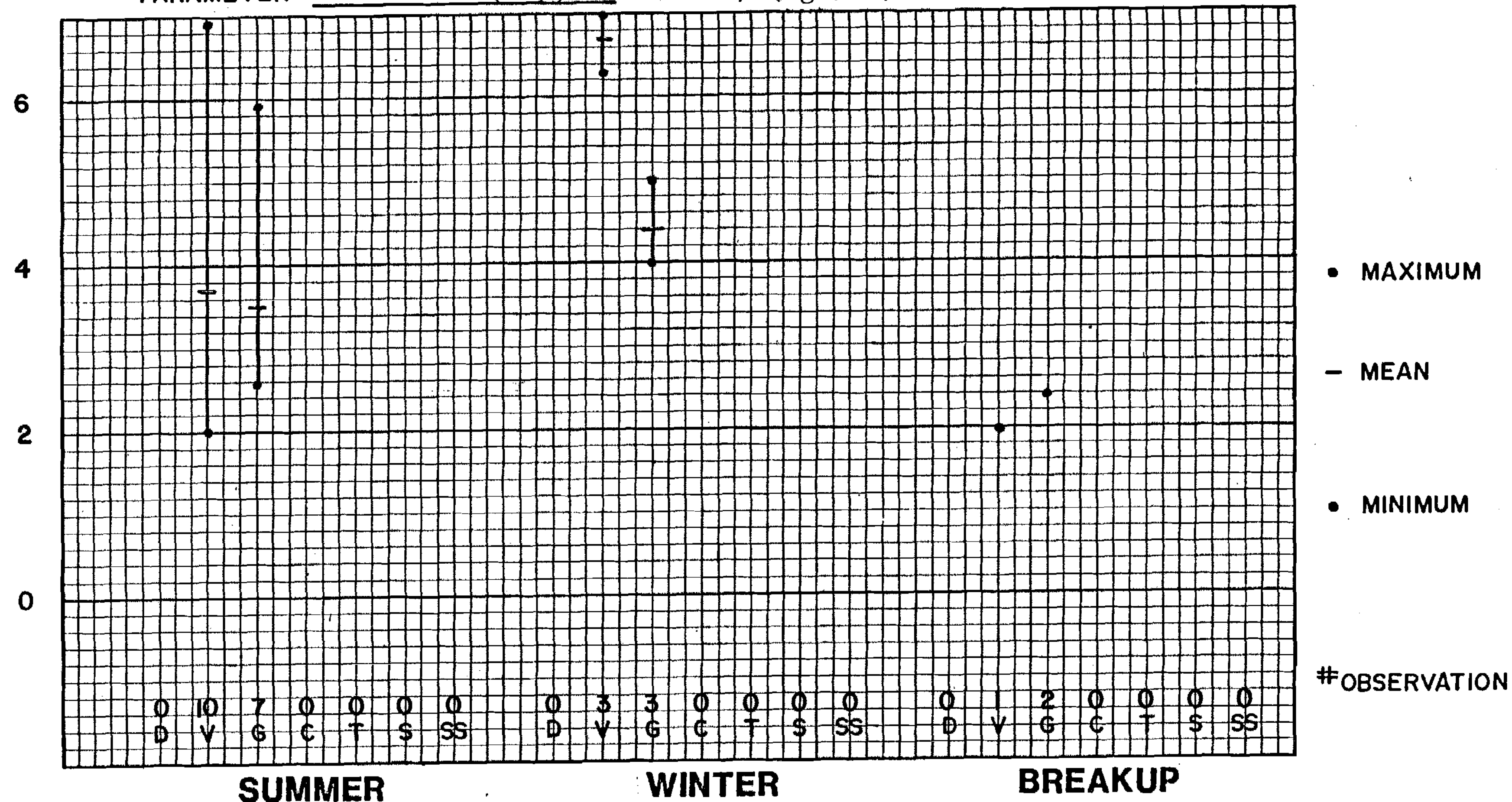
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - SODIUM (d)

FIGURE: 63

ACRES

PARAMETER: SILICON (Si), DISSOLVED, (mg./1.)



D– DENALI V– VEE CANYON G– GOLD CREEK C– CHULITNA T– TALKEETNA S – SUNSHINE SS– SUSITNA STATION

No criterion established.

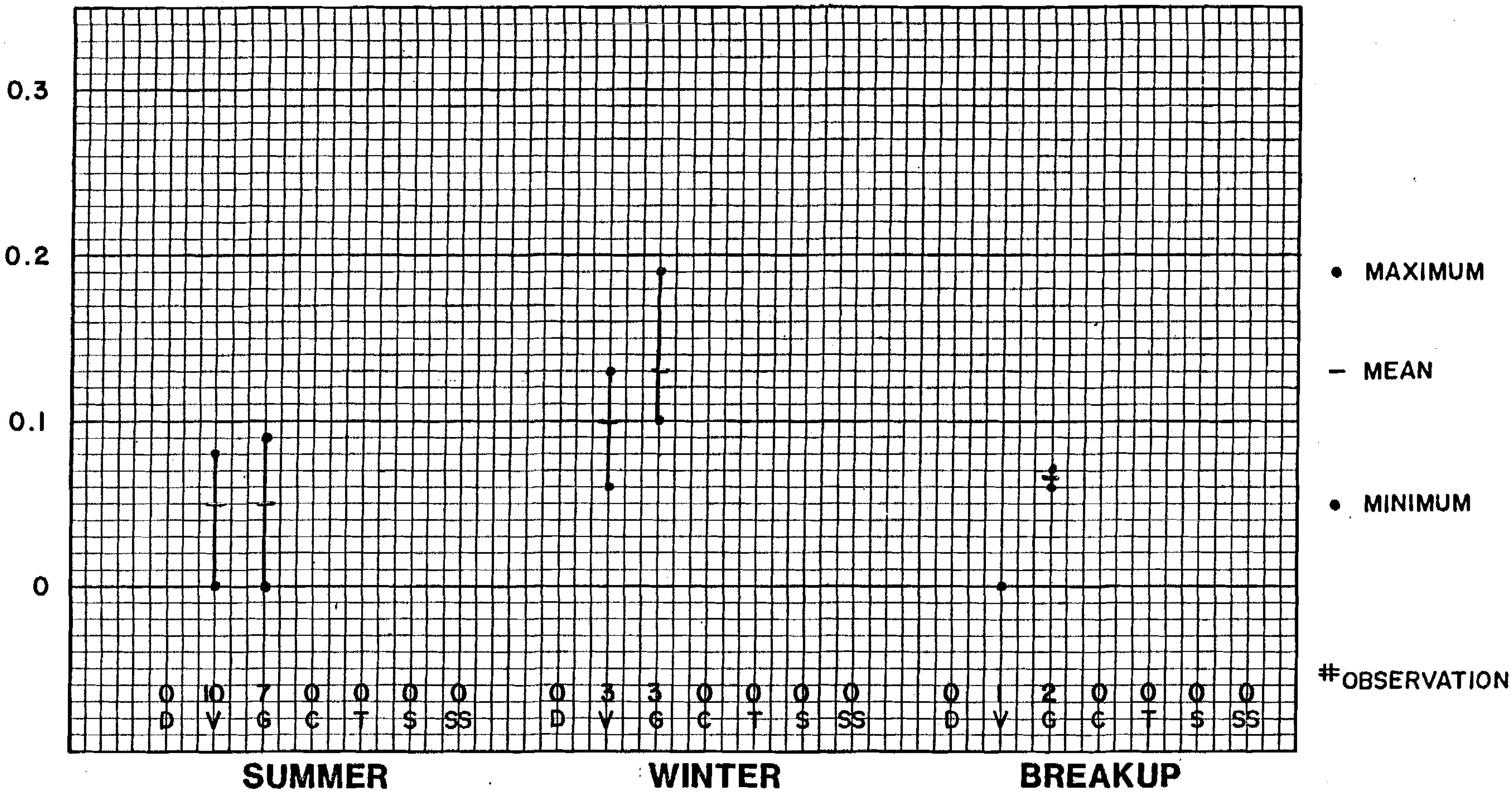
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - SILICON (d)

FIGURE: 64

ACRES

PARAMETER: STRONTIUM (Sr) DISSOLVED (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established.

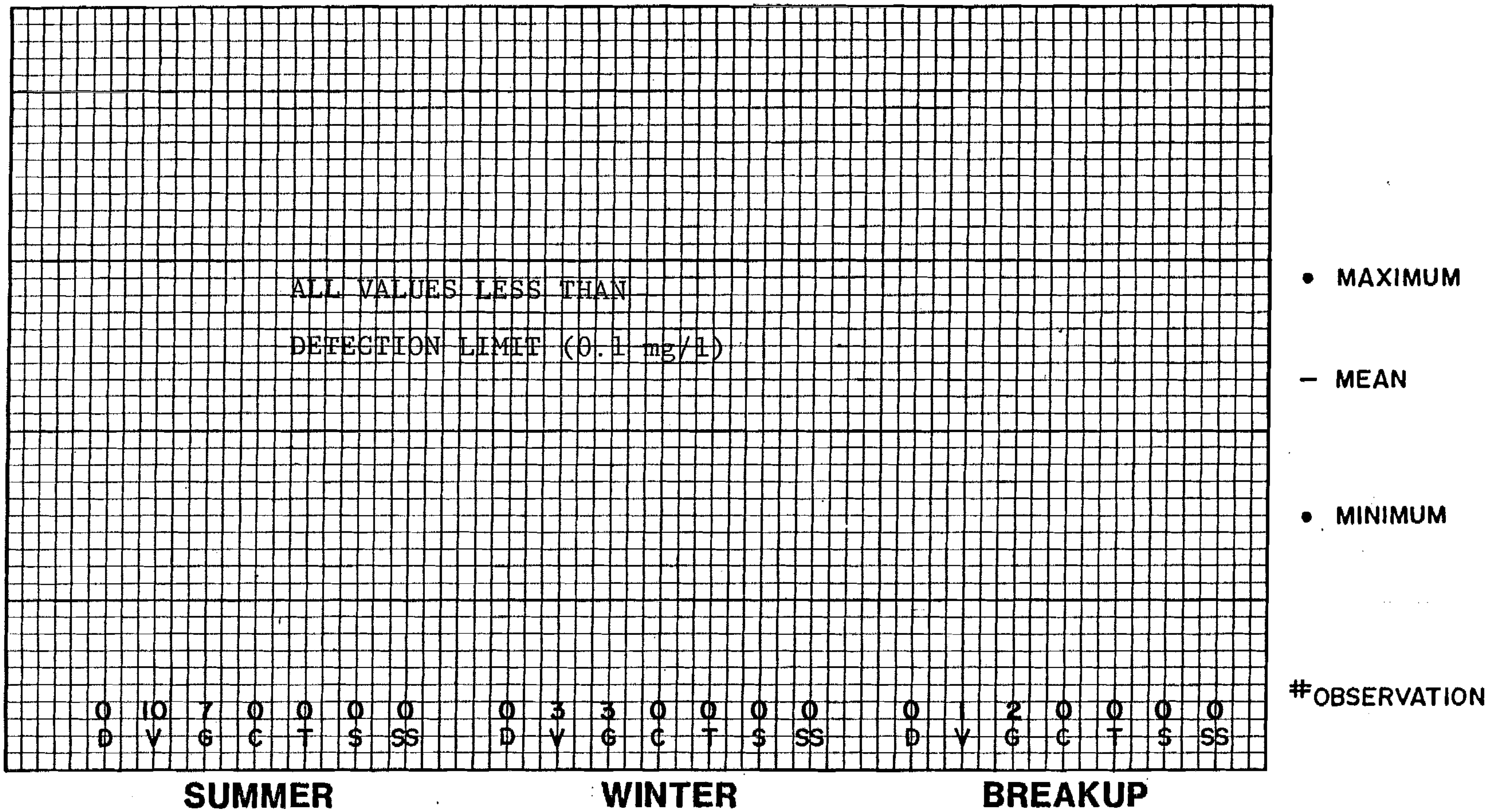
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - STRONTIUM (d)

FIGURE : 65

ACRES

PARAMETER: TIN (Sn) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established.

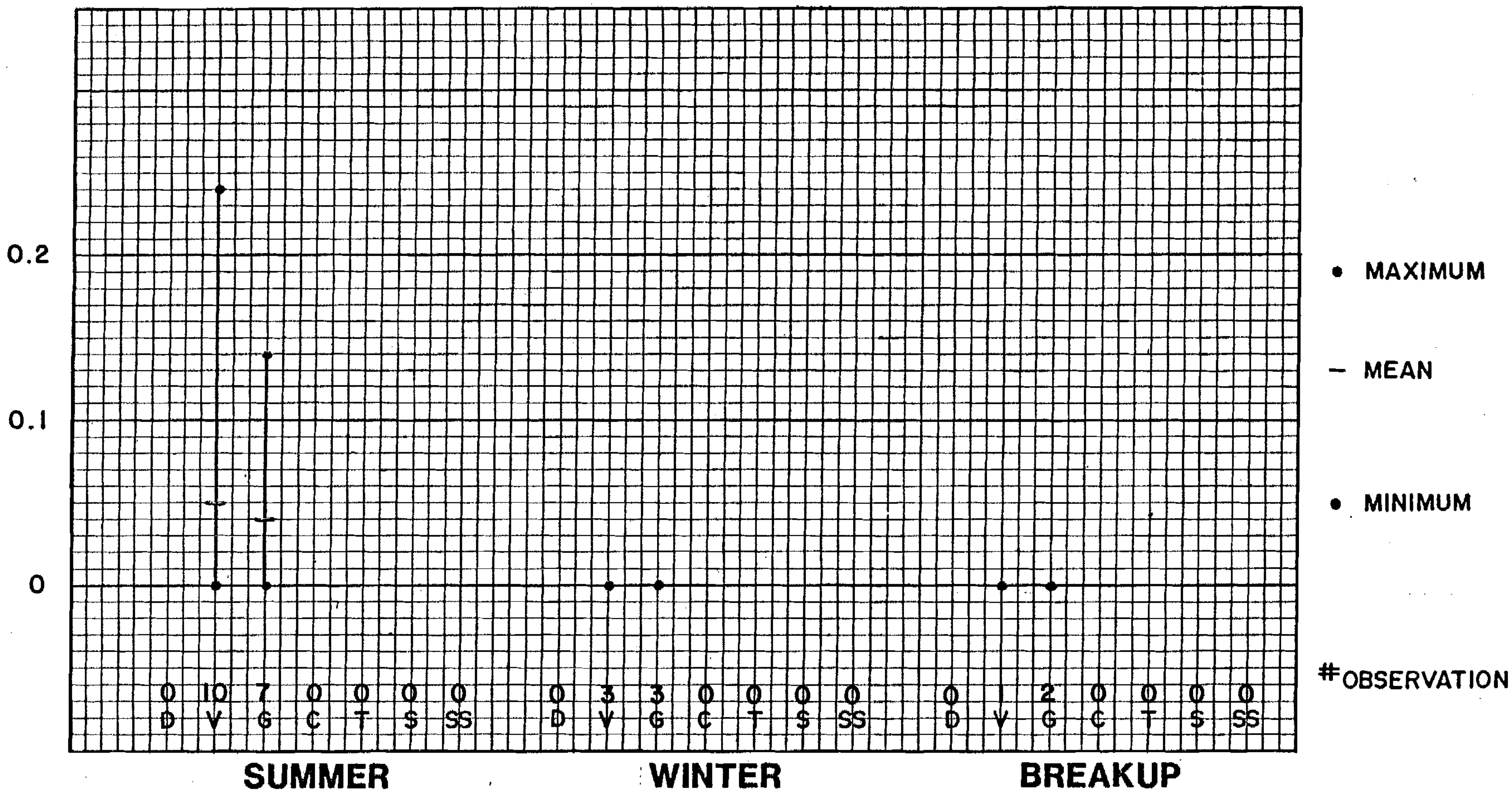
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - TIN (d)

FIGURE : 66

ACRES

PARAMETER: TITANIUM (Ti) DISSOLVED, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established.

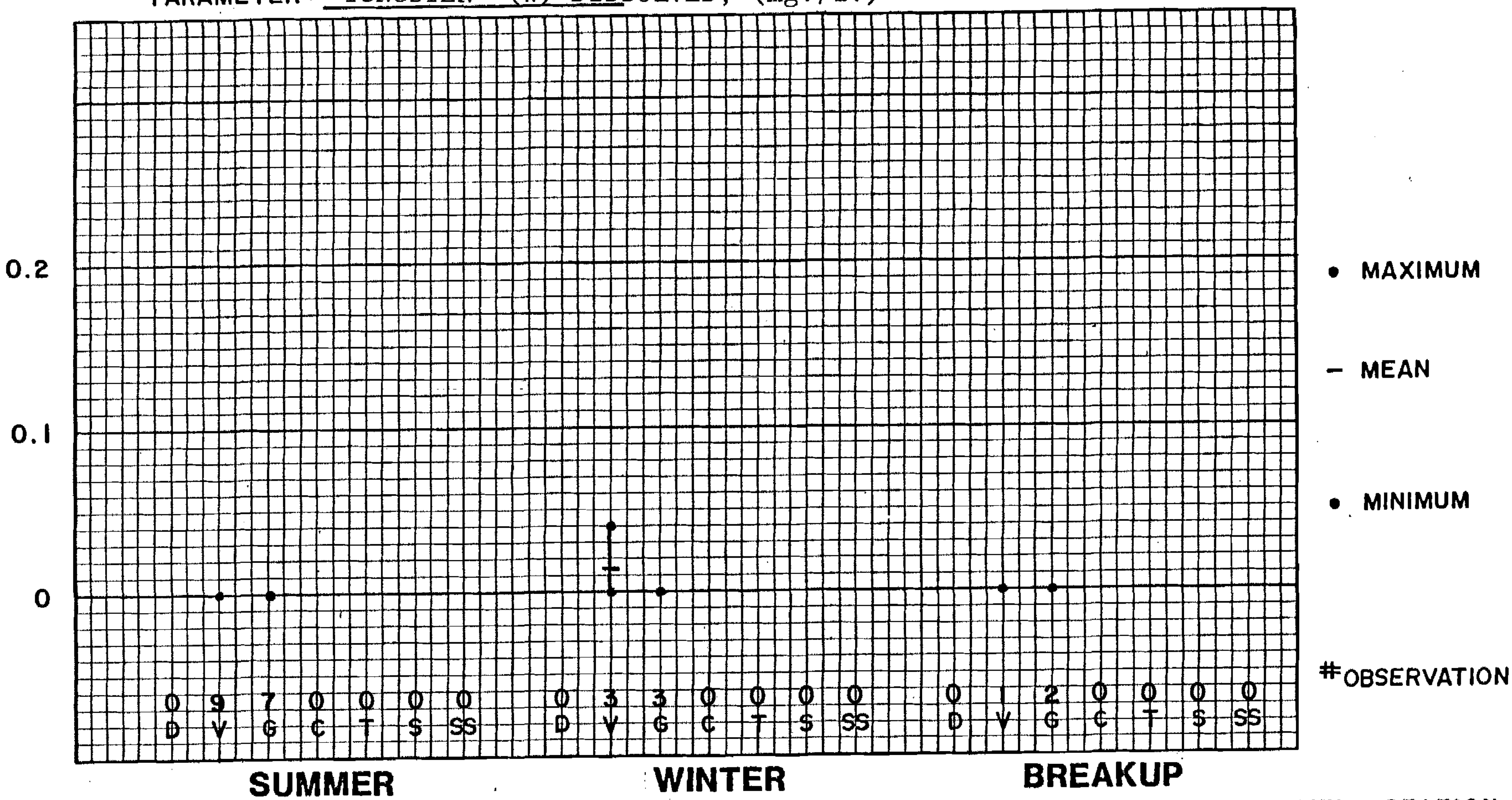
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - TITANIUM (d)

FIGURE : 67

ACRES

PARAMETER: TUNGSTEN (W) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established.

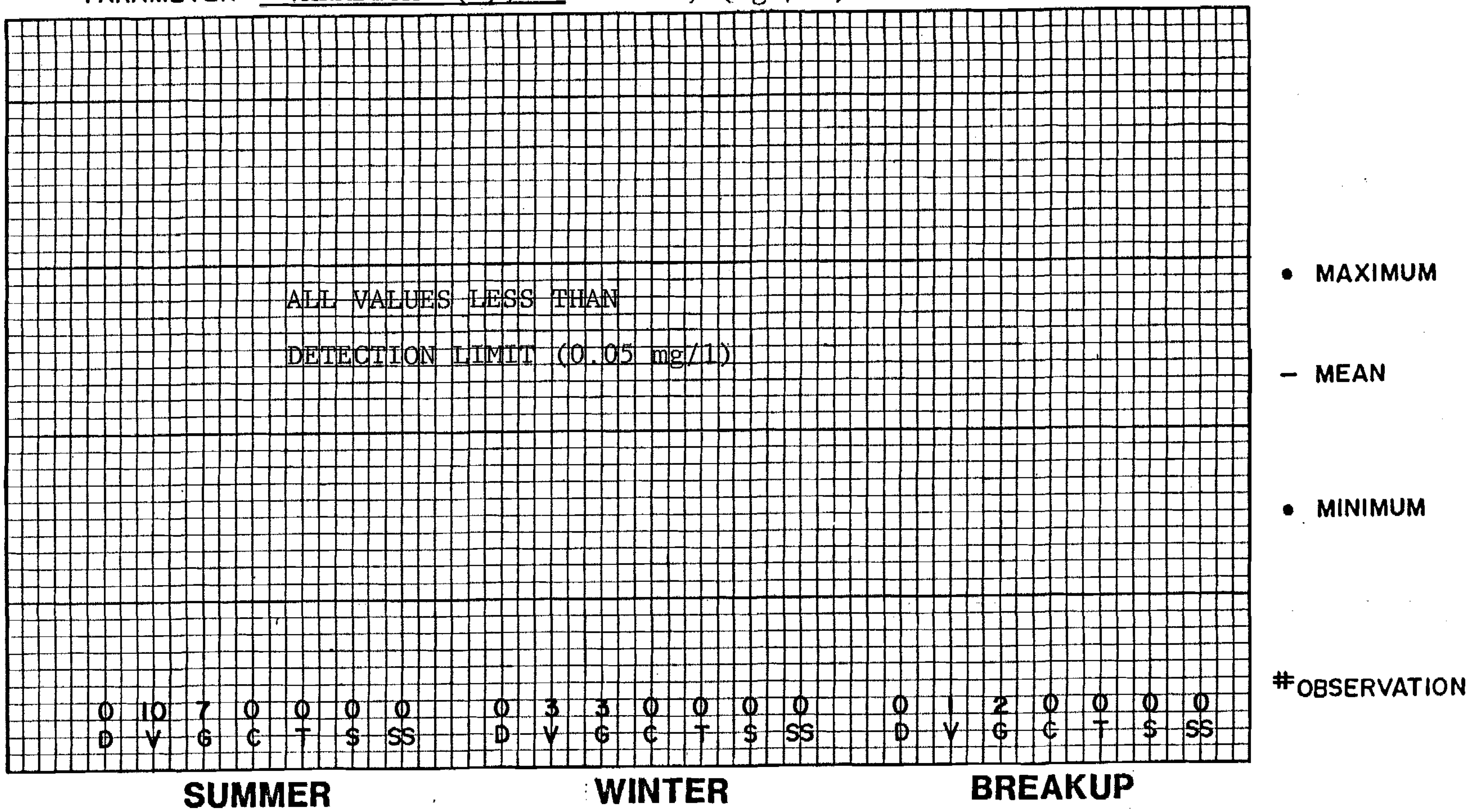
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - TUNGSTEN (d)

FIGURE : 68

ACRES

PARAMETER: VANADIUM (V), DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established, however, EPA has suggested 0.007 mg/l. (Sittig, 1981).

The suggested limit is based on human health effects.

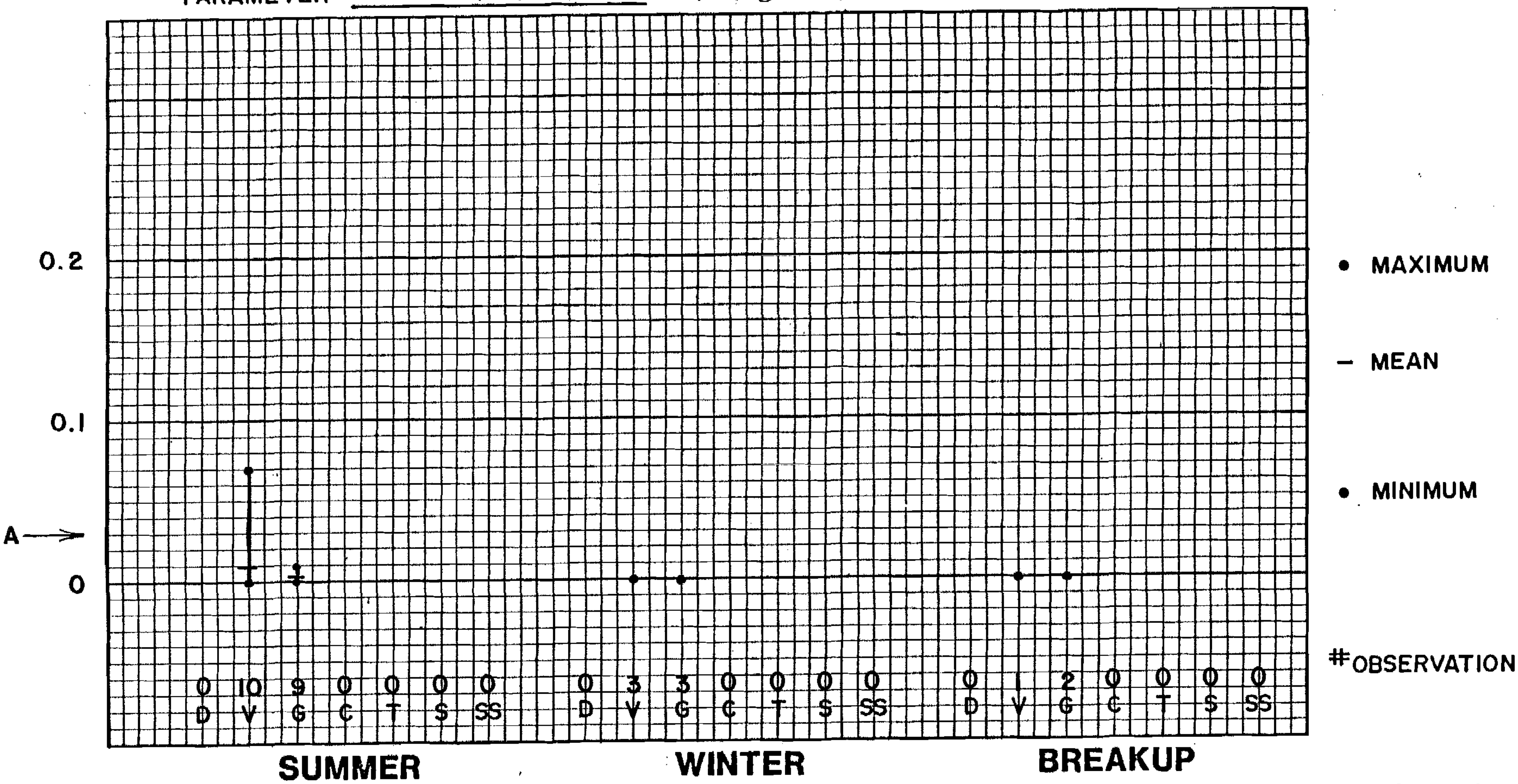
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - VANADIUM (d)

FIGURE : 69

ACRES

PARAMETER: ZINC (Zn) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 0.03 mg/1 (McNeely, 1979)

B. 0.01 of the 96-hour LC_{50} determined through bioassay (EPA, 1976).

The suggested limit is based on human health effects.

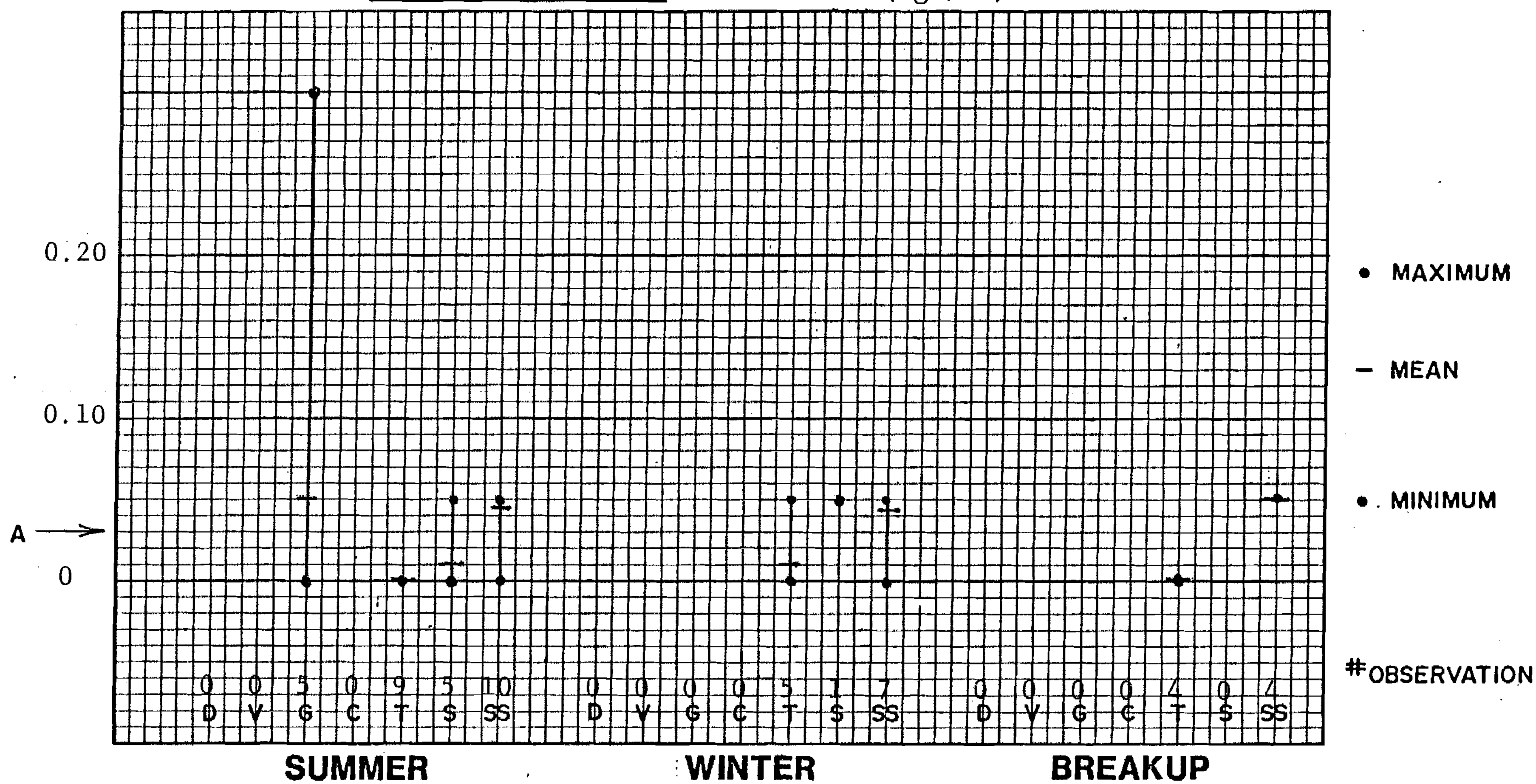
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - ZINC (d)

FIGURE: 70

ACRES

PARAMETER: ZINC (Zn) Total Recoverable (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 0.03 mg/1 (McNeely, 1979).

B. 0.01 of the 96 - hour LC_{50} determined through bioassay (EPA, 1976).
Established to protect freshwater aquatic organisms.

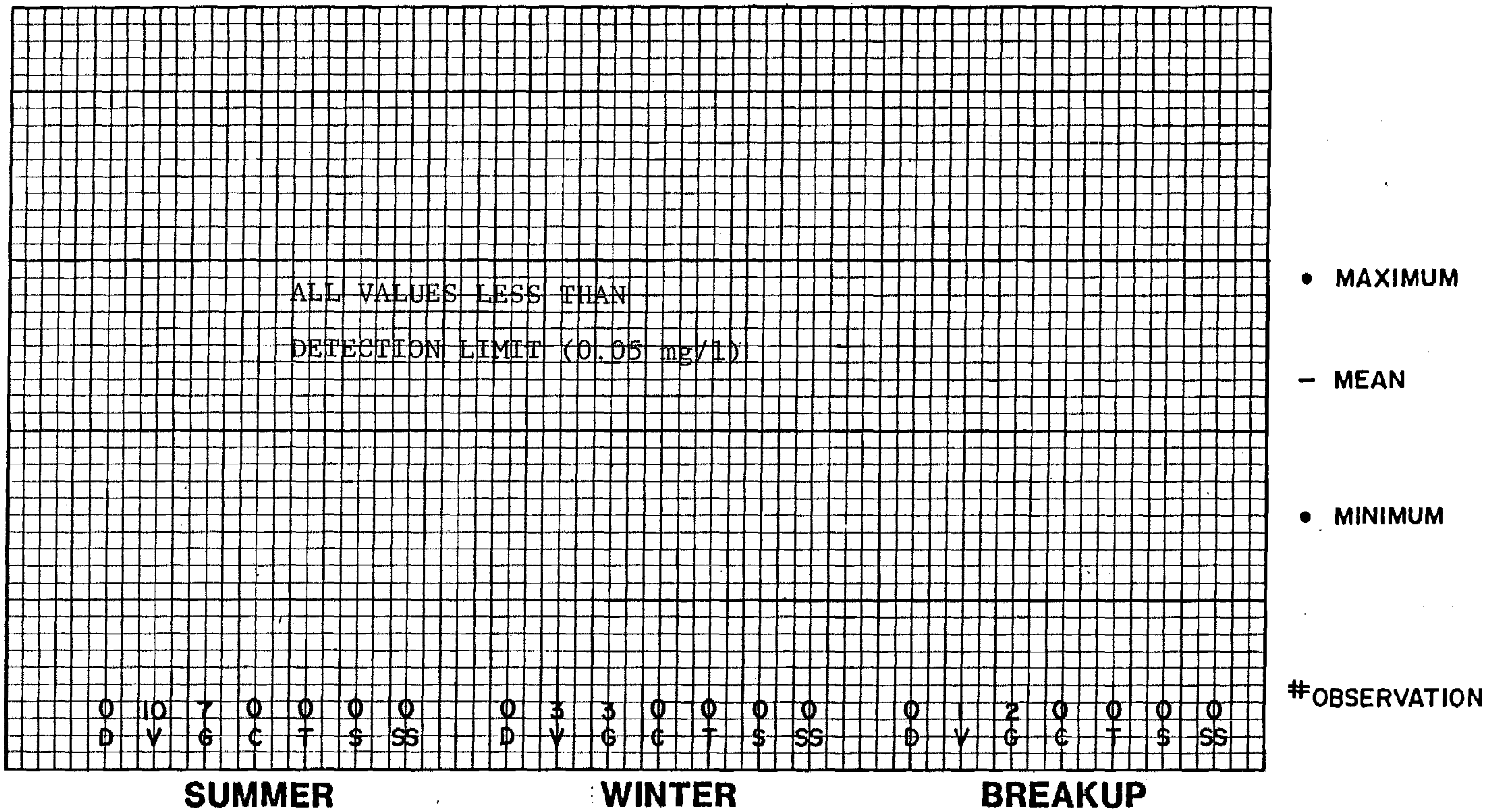
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - ZINC (t)

FIGURE: 71

ACRES

PARAMETER: ZIRCONIUM (Zr) DISSOLVED, (mg./1.)



D– DENALI V– VEE CANYON G– GOLD CREEK C– CHULITNA T– TALKEETNA S – SUNSHINE SS– SUSITNA STATION

No criterion Established.

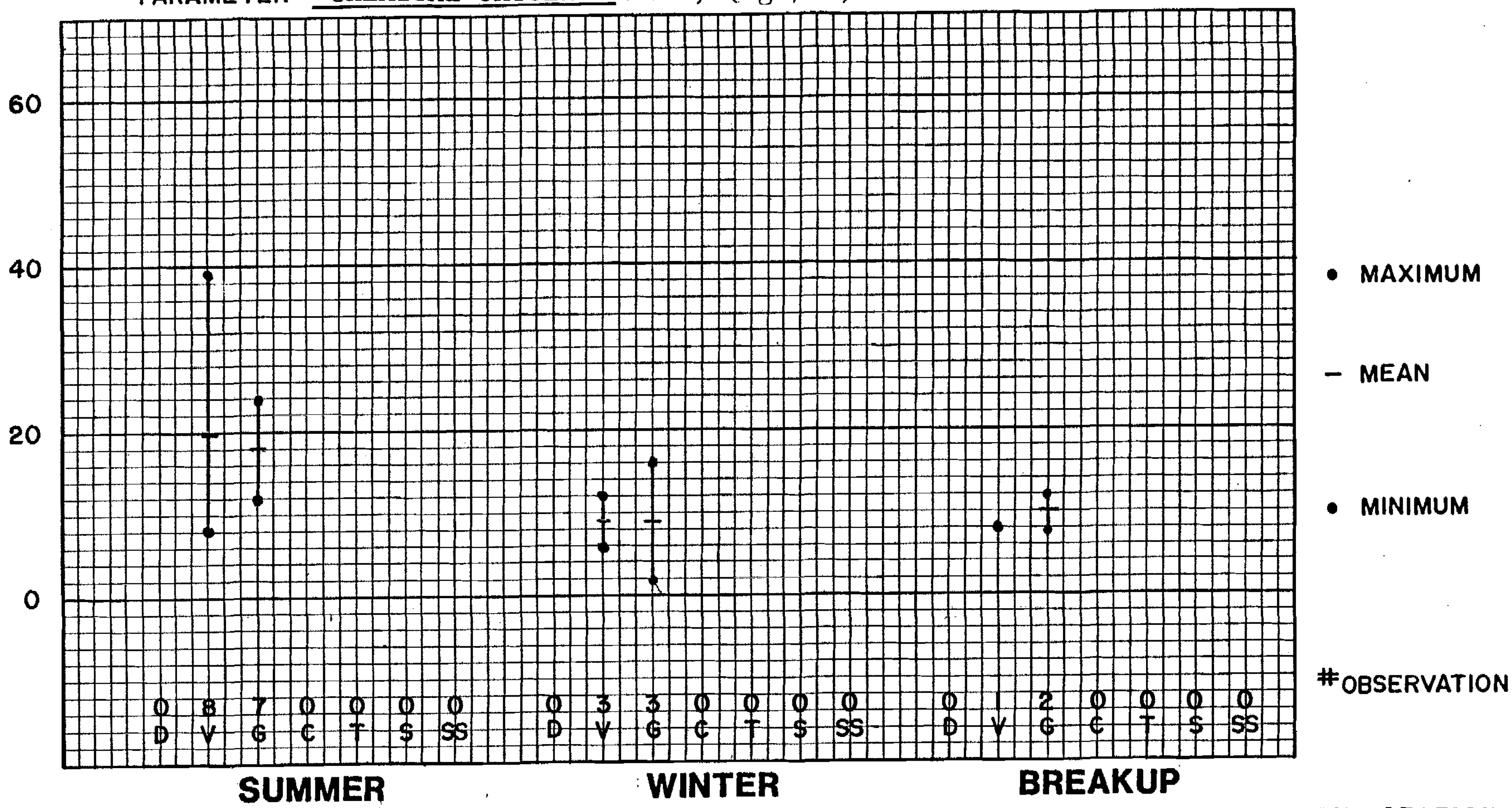
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY – ZIRCONIUM (d)

FIGURE : 72

ACRES

PARAMETER: CHEMICAL OXYGEN DEMAND, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established

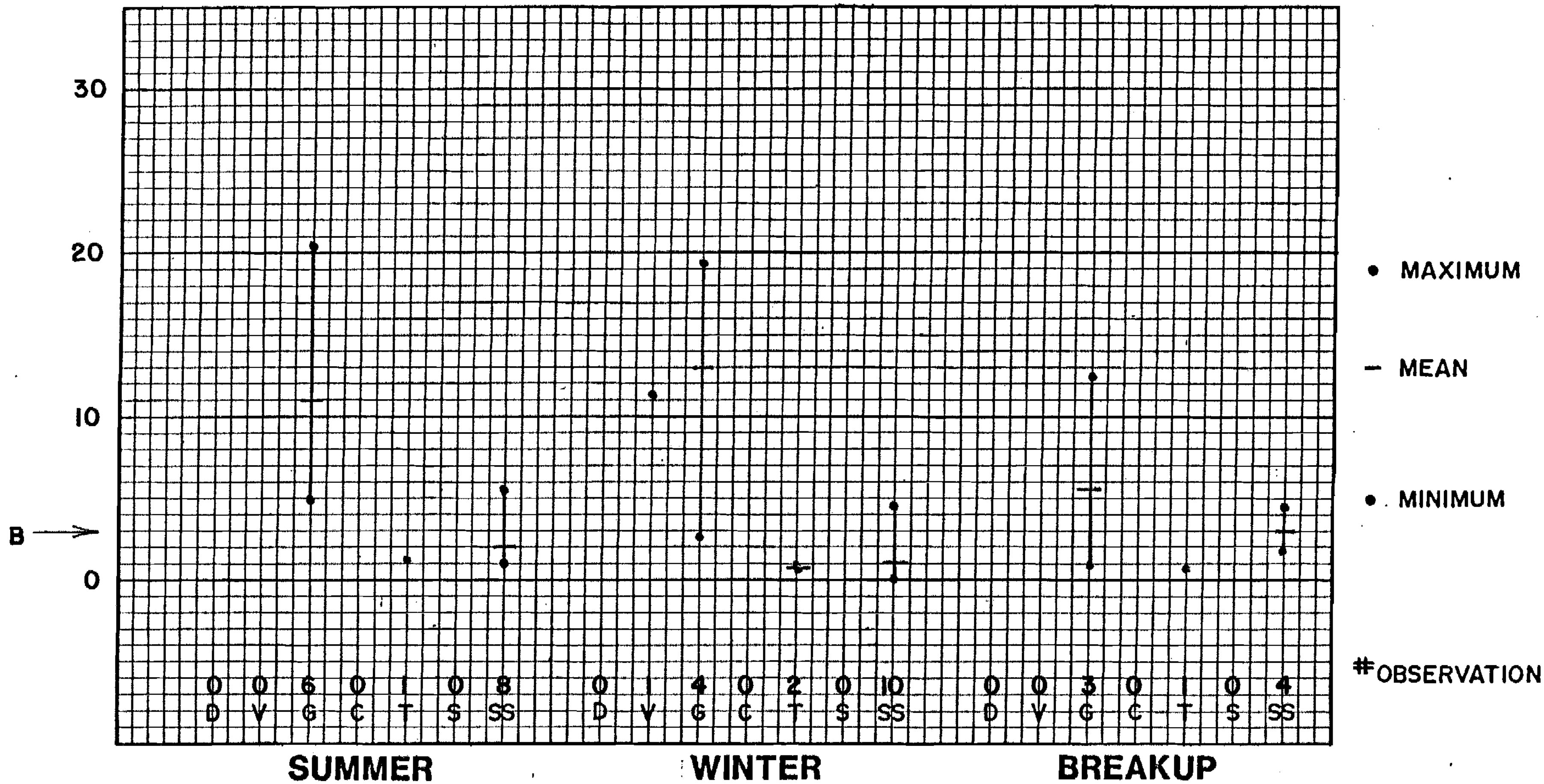
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - CHEMICAL OXYGEN DEMAND

FIGURE : 73

ACRES

PARAMETER: TOTAL ORGANIC CARBON, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. No criterion established

B. Waters containing less than 3.0 mg/l have been observed to be relatively clean, (McNeely et al, 1979).

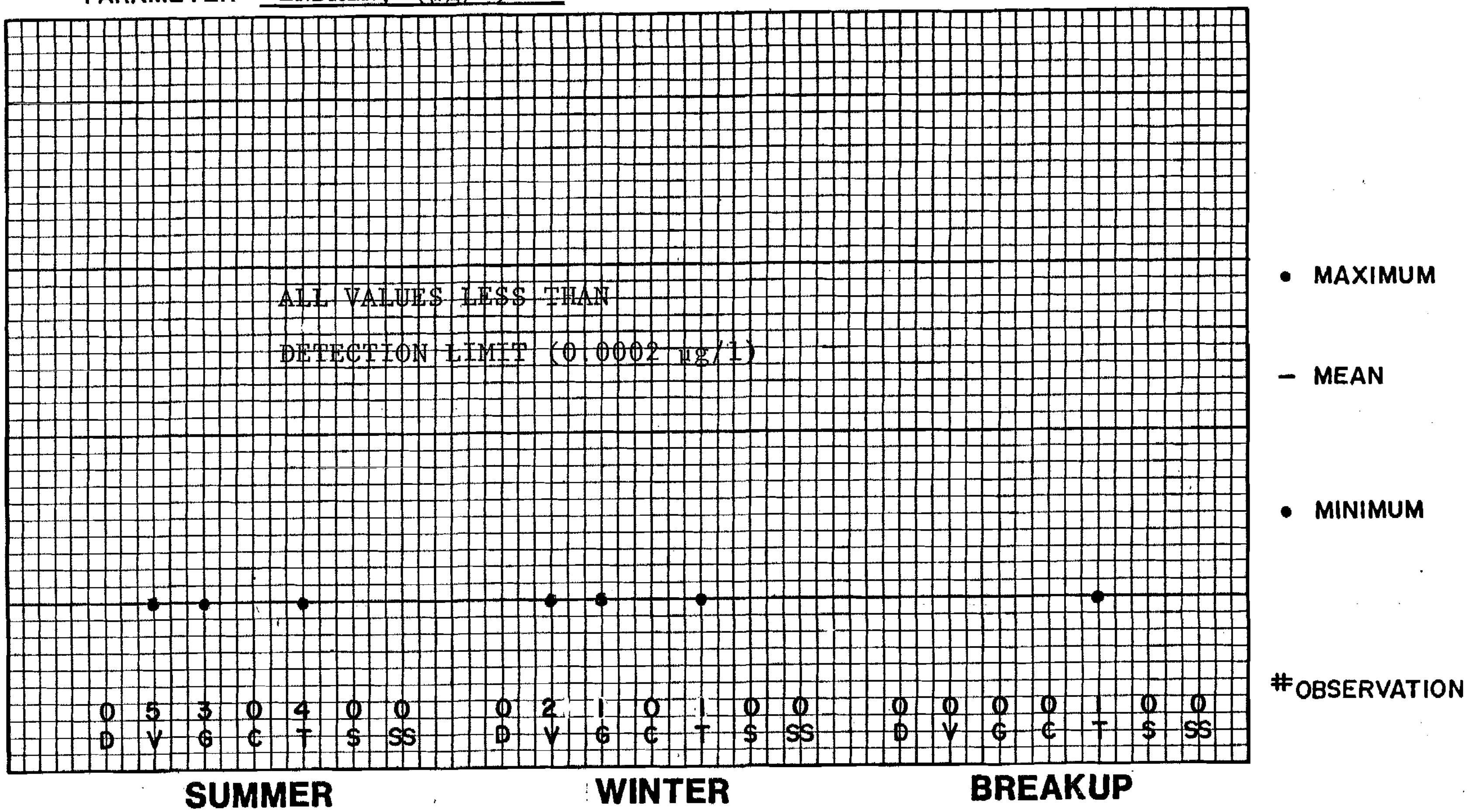
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY TOTAL ORGANIC CARBON

FIGURE : 74

ACRES

PARAMETER: ENDRIN, (µg/1)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

Less than 0.004 µg/l. (EPA, 1976; McNeely, 1979)

Established to protect freshwater aquatic organisms.

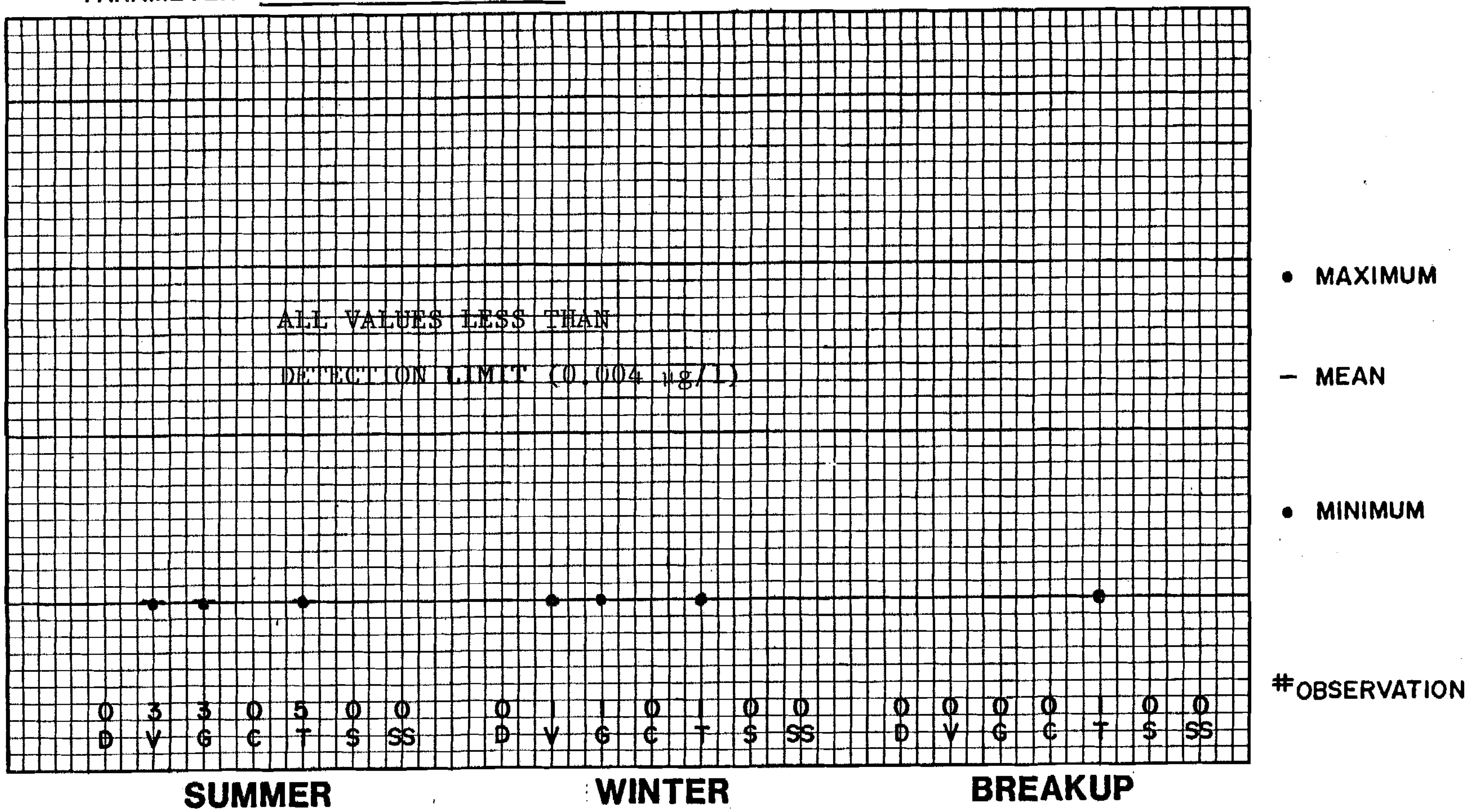
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - ENDRIN

FIGURE : 75

ACRES

PARAMETER: LINDANE, (µg/l)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

Less than 0.01 µg/l. (EPA, 1976; Sittig, 1979).

Established to protect freshwater aquatic organisms.

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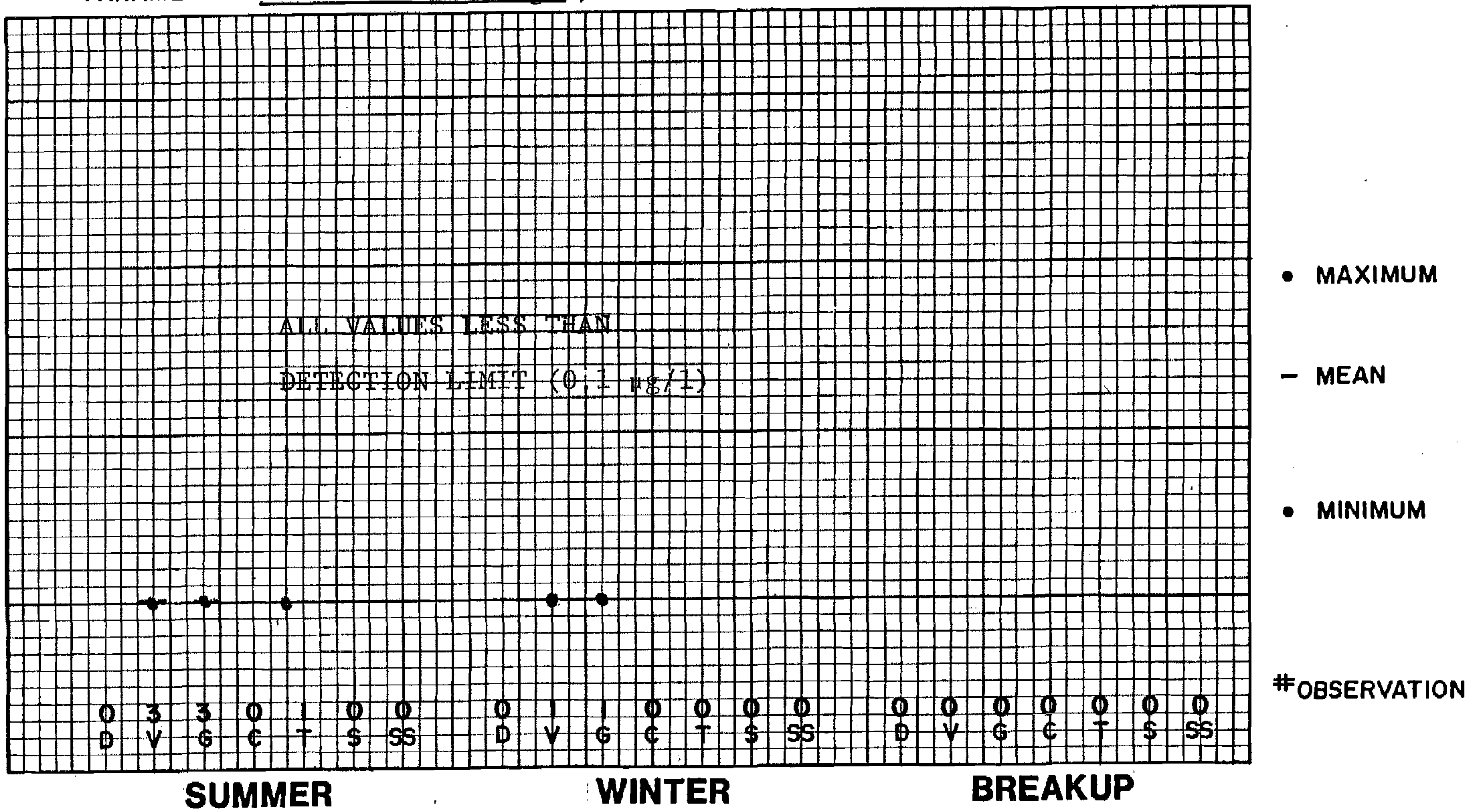
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - LINDANE

FIGURE: 76

ACRES

PARAMETER: METHOXYCHLOR (µg/l)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

Less than 0.03 µg/l. (EPA, 1976; Sittig, 1981).

Established to protect freshwater aquatic organisms.

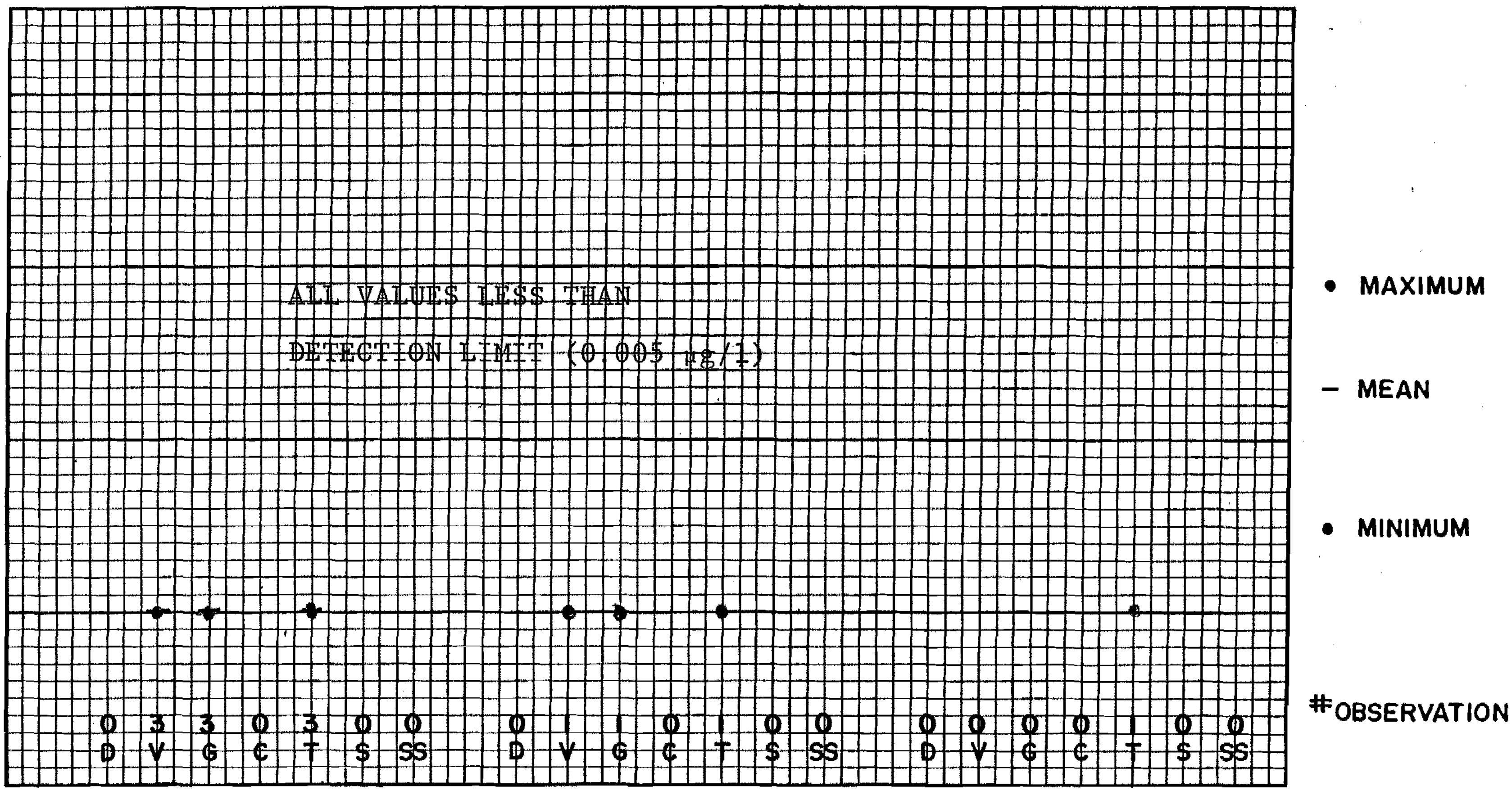
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - METHOXYCHLOR

FIGURE : 77

ACRES

PARAMETER: TOXAPHENE, (μg/1)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S- SUNSHINE SS- SUSITNA STATION

Less than 0.013 as a 24-hour average, never to exceed 1.6 μg/1. (EPA, 1980; Sittig, 1981).

Established to protect freshwater aquatic organisms.

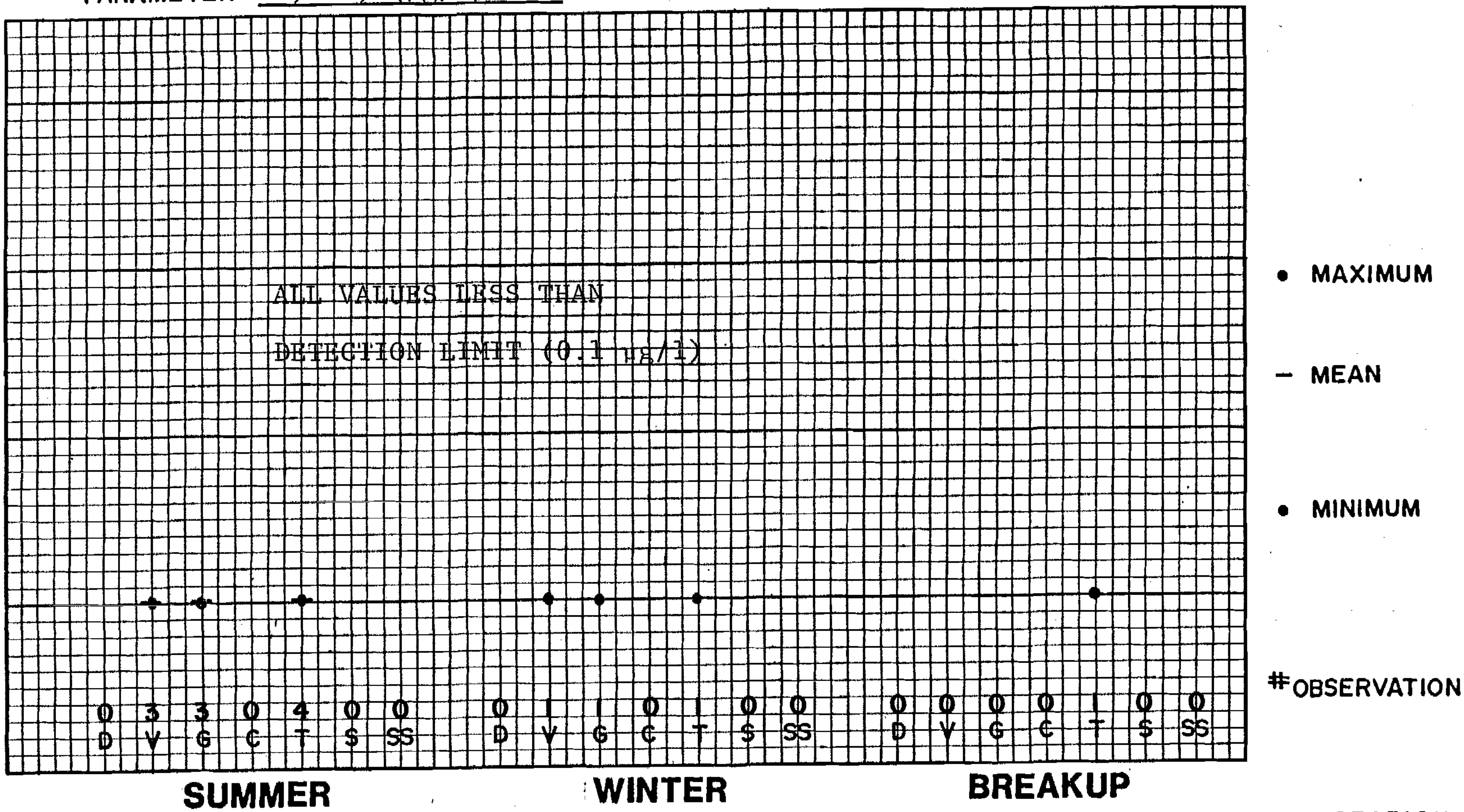
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - TOXAPHENE

FIGURE: 78

ACRES

PARAMETER: 2,4-D, (µg/l)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

Less than 100 µg/l (water supply) (EPA, 1976; Sittig, 1981).

Established to protect water supplies.

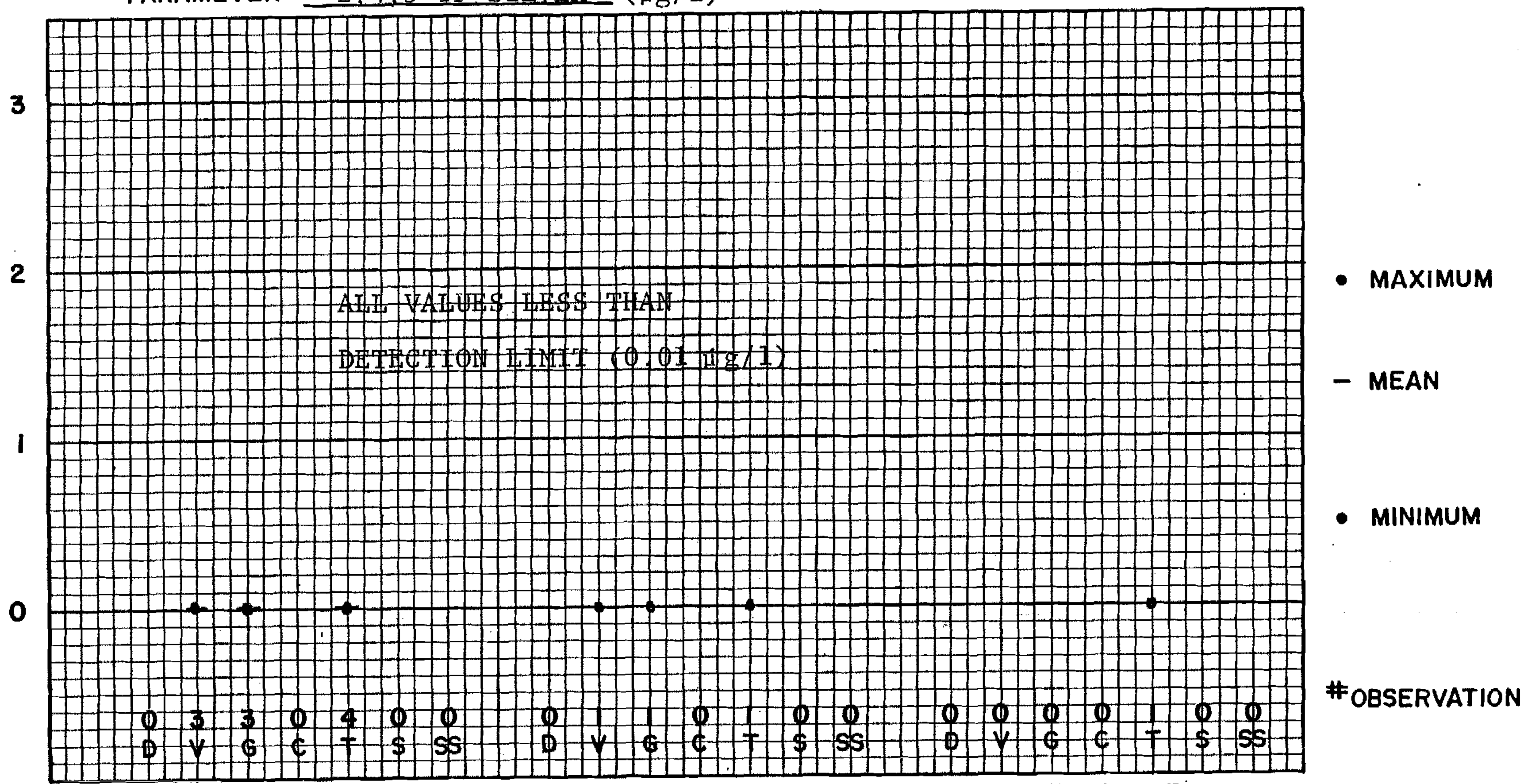
R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - 2,4-D

FIGURE: 79

ACRES

PARAMETER: 2,4,5-TP SILVEX (µg/1)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

Less than 10 µg/1 (water supply). (EPA, 1976)

Established to protect water supplies.

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DATA SUMMARY - 2,4,5-TP SILVEX

FIGURE : 80

ACRES

ATTACHMENT B

A REVIEW OF A METHOD FOR PREDICTING THE POTENTIAL FOR EUTROPHICATION IN IMPOUNDMENTS

The information contained herein was synthesized from the following reports: Dillon and Rigler (1975), Dillon and Kirchner (1975), Kirchner and Dillon (1975), Reckhow (1979), and Utturmark and Hutchins (1978).

All of these authors cite the work of R.A. Vollenweider, who, in 1968, authored, "Scientific Fundamentals of the Eutrophication of Lakes and Flowing Waters, with Particular Reference to Nitrogen and Phosphorus as Factors in Eutrophication." Vollenweider's work appears to be the basis for the techniques for predicting eutrophication presented in the following pages.

Phosphorus is usually considered to be the important nutrient controlling algal growth in lakes. Phosphorus loading, the amount of phosphorus added to a lake per unit area per unit time, is recognized as the best measure of the degree of eutrophication that may be predicted in a lake. A technique for predicting the spring total phosphorus concentration in a lake appears below.

The phosphorus imported to a lake in runoff, when combined with input directly to the lake's surface through precipitation and dry fallout, gives a measure of the natural total phosphorus load. The total natural phosphorus load can be combined with the total artificial phosphorus load, the mean depth of the lake, the lake's water budget expressed as the flushing rate, and the phosphorus retention coefficient of the lake, to predict spring total phosphorus concentration in the lake. The predicted spring total phosphorus concentration can then be used to predict trophic status expressed as a summer chlorophyll "a" concentration, and this, in turn, can be used to estimate the secchi disc transparency. The equation to predict the total, steady-state phosphorus concentration is expressed by:

$$[P] = \frac{L(1-R)}{\bar{z}\, p}$$

where: $[P]$ = steady-state phosphorus concentration,

L = total loading (natural and artificial),

$\bar{z}$ = mean depth of the lake (lake morphometry), p = flushing rate (water budget of the lake),

R = retention coefficient (the fraction of the loading that is not lost via the outflow).

The total phosphorus concentration is equal to phosphorus loading (phosphorus from each drainage basin multiplied by the phosphorus coefficient) multiplied by (1 - the phosphorus retention coefficient); divided by [the mean depth multiplied by the flushing rate (the total outflow divided by the lake volume)].

According to the predictive model, the total concentration of phosphorus may be predicted for a lake. Theoretically, this may be used to predict the trophic status of a reservoir following the impoundment of a stream or river.

Loading. Total phosphorus loading is calculated by totalling the phosphorus load from the land (runoff), the phosphorus load from precipitation, and the artifical phosphorus load (from human development). Total phosphorus load from the land is equal to the total area of each watershed or drainage basin contributing runoff to the lake. Multiplied by the phosphorus export coefficient, this coefficient is the phosphorus exported from soil in g/m^2 of the land drainage per year. Dillon and Kirchner (1975) measured the total phosphorus export for 34 southern Ontario watersheds. The annual total phosphorus export for each watershed was obtained by dividing the total phosphorus carried by each stream (kg/yr) by the areas of the watershed. The total phosphorus export for all watersheds was tabulated along with additional information on the geology, land use, and population density of each watershed. Upon inspection of these data, it was apparent that the watersheds could be grouped according to whether they were forested or consisted of pasture as well as forest, and according to whether they were on igneous or sedimentary formations. The range and mean phosphorus export values ($mg/m^2/yr$) obtained for each two-way (land use-geology) classification were:

Land Use	Igneous	Sedimentary
Forest		
Range	2.5 - 7.7	6.7 - 14.5
Mean	4.8	10.7
Forest & Pasture		
Range	8.1 - 16.0	20.5 - 37.0
Mean	11.7	28.8

Changing land use from "forest" to "forest and pasture" in watersheds on igneous rock apparently doubles the phosphorus export. Similarly, the export from a sedimentary forested watershed is about double that from an igneous forested watershed. The total phosphorus load from the land is combined with the total phosphorus load from precipitation to calculate the total phosphorus load. The total phosphorus load from precipitation applicable to southern Ontario is 75 mg/m^2/year (Dillion and Rigler, 1975). This value may be expected to vary according to geographical location.

Mean Depth. The mean depth of a lake or a measure of the lake's morphometry is required in using the predictive model for phosphorus concentrations.

Flushing Rate. The flushing rate is equivalent to the lake's annual water budget and is expressed as the total outflow volume per year divided by the lake volume.

Retention Coefficient. Successful use of this equation is dependent on an accurate estimate of the phosphorus retention in the lake in question. Phosphorus retention in the lake is a function of sedimentation - specifically, the amount of phosphorous that is retained by sedimentation. This amount is difficult to calculate, but a model was used relating the areal water load (qs) to phosphorus retention. The phosphorus retention coefficient is: Rp = 0.426 exp (-0.271 qs) + 0.574 exp (-0.00949qs). Areal loading (qs) in m/yr is the surface overflow rate and is calculated as the lake outflow volume divided by the lake surface area. Values for phosphorus retention in 15 Ontario lakes, using the measurement model and the values derived from the theoretical model were in close agreement (r = 0.94). "The fact that the retention coefficient of phosphorus is more closely related to the areal water load (qs) than the volumetric water load (ie. water renewal time) is not readily explainable, but in light of the above advantages we feel that this model warrants acceptance on purely empirical grounds," (Dillon and Rigler, 1975).

Application of Method to Susitna Project.

Application of the equation,

$$[P] = \frac{L(1-R)}{\bar{z}\ p}$$

to the Susitna Hydroelectric Project was made using the following rationale.

Natural Land Loading. The annual average phosphorus loading in runoff was assumed to equal 0.01 mg/l (the mean level measured at Vee Canyon). This concentration was converted to mg/m^3 and multiplied by the average annual flow (m^3/yr) at each dam site and the product divided by the drainage area in m^2. Natural land loading at Watana is 5.2 $mg/m^2/yr$ and at Devil Canyon it is 4.7 $mg/m^2/yr$. These levels appear reasonable and in the same range as the Ontario study discussed earlier. Comparable values were seen in Ontario in the forest (undeveloped) areas.

Natural Precipitation Loading. The phosphorus concentration in precipitation was taken as 0.03 mg/l -- the maximum phosphorus concentration reported in snow and rain samples collected at Fairbanks, Alaska by Peterson (1973). Conversion of the area used to collect samples and the volume of sample collected, and using the normal annual precipitation at Talkeetna indicates that natural precipitation loading will be 22 $mg/m^2/yr$.

Artificial Loading. This is assumed to be zero since there are no man-induced sources of phosphorus in the study area.

R, Retention Coefficient. R was assumed to be zero, a worst case situation.

$\bar{z}$, Mean Depth. The mean depth at Watana is 34 m, and at Devil Canyon it is 25 m. The mean depth was assumed to be 1/8 the dam height. The mean depth at the dam would be ¼ the dam height if the side slopes were 45 degrees and the depth is zero at the upper end of the reservoir. Therefore, the mean depth should not be less than 1/8 the dam height. This assumption is expected to be conservative and increases the value of [P].

p, Flushing Rate. The flushing rate at Watana is 1.64 yr, and at Devil Canyon it is 0.16 yr (R&M Consultants, 1982).

Use of the above values indicates that the spring phosphorus concentration [P] is 0.5 mg/m^3 at Watana and 3.7 mg/m^3 at Devil Canyon if only one reservoir is in place. The concentration at Devil Canyon will be reduced if the Watana Reservoir is in place because it will act as a nutrient trap, thereby reducing the natural land loading. These values of [P] indicate the reservoirs will be oligotrophic. Levels between 10 and 20 mg/m^3 are indicative of mesotrophic conditions, and eutrophic conditions appear above 20 mg/m^3.

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