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M E M O R A N D U M

February 19, 1981

To: Files

From: Bill Yake

Subject: Permit Conditions for Ammonia, Pullman STP - A Prototype Method for Allocating Ammonia using Ambient Monitoring Data

Introduction

In response to requests from the Municipal Grants Section and the Eastern Regional Office, the following memorandum has been prepared to suggest effluent ammonia limitations for the Pullman wastewater treatment plant (STP). A combination facility and receiving water study (Bernhardt and Yake, 1979) conducted in September 1978, noted excessive un-ionized ammonia concentrations in the South Fork of the Palouse River (SFPR) downstream from the treatment plant and recommended that the planned facility upgrade include nitrification capability to alleviate this condition. Effluent goals must be clearly defined to allow the City of Pullman and their consultants (Parametrix, Inc.) to design the upgraded facility to meet these goals in an efficient and cost-effective manner.

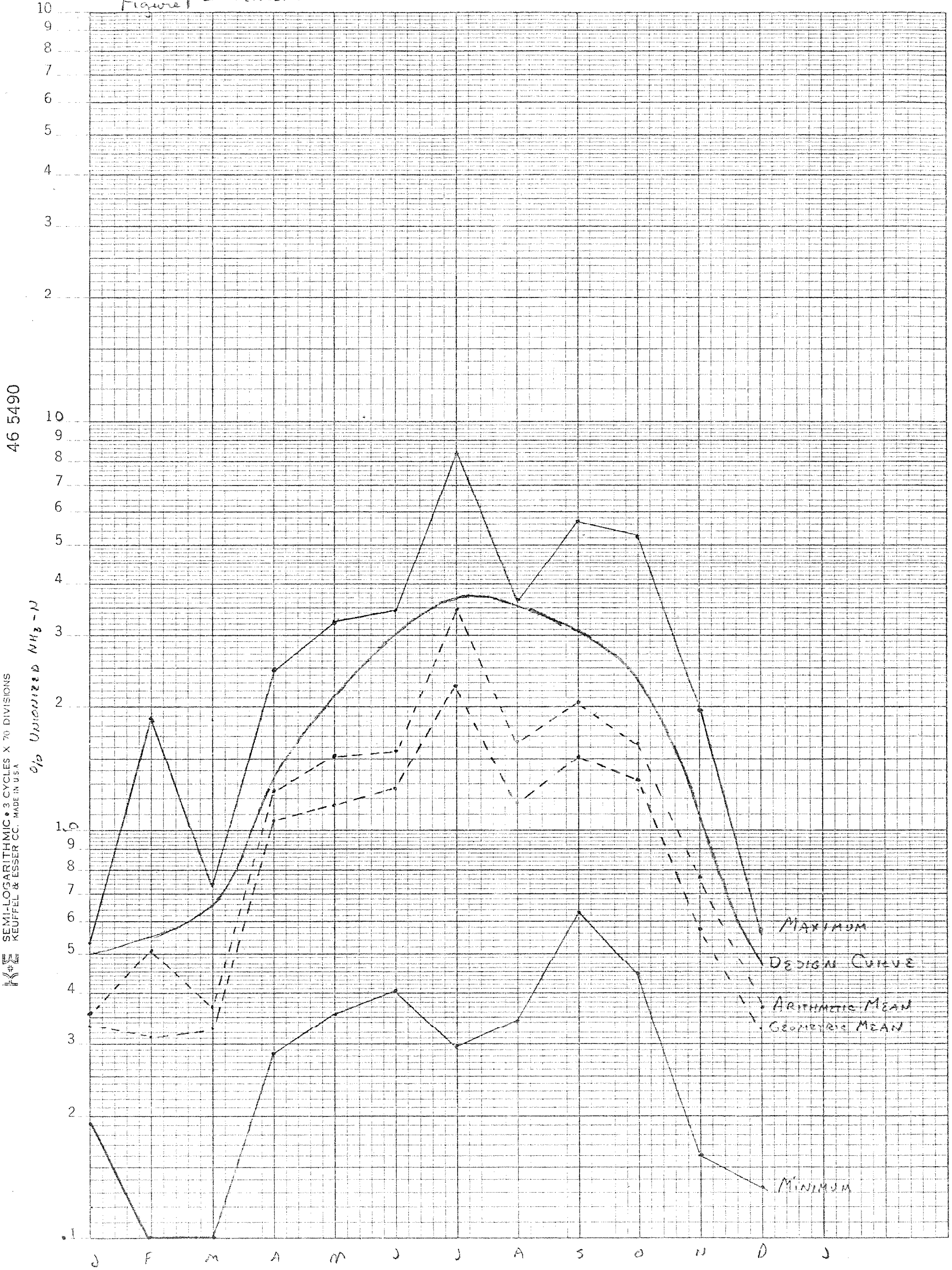
It is hoped that this memorandum may serve as a first-stage prototype for allocating effluent ammonia from point sources in the state. Predicting the in-stream concentrations of un-ionized ammonia nitrogen (NH_3^O-N) which will result from projected total ammonia nitrogen (NH_3+NH_4-N or NH_3^T-N) is complicated by the fact that the percentage of NH_3^T-N which is present as NH_3^O-N is a function of pH and temperature (Willingham, 1976). The method presented here uses the "% un-ionized ammonia" values calculated from temperature and pH data obtained from the Department of Ecology's (DOE) ambient monitoring station (34B110) approximately one mile upstream from the treatment plant discharge. These data are located in the appendix of this report. Monthly values for a "moderate worst-case" percent NH_3^o-N are derived from these data and are used in conjunction with approximate one in ten year low monthly flows to predict NH_3^o-N concentrations downstream of the plant under various effluent loading conditions. In adapting this method for use at other locations in the state, the following points should be noted:

1. The method does not account for changes in the pH and temperature (and thus percent NH_3^o-N) caused by the addition of the effluent to stream waters. This effect may be substantial in cases of low dilution ratios (such as the present case) but requires detailed information on effluent pH, effluent and receiving water buffering systems, and numerous assumptions to generate "moderate worst-case" conditions.

2. Because of the problems mentioned above, it is preferable to use ambient monitoring data from a station immediately downstream from the plant if such data are available. Even these data, however, will only reflect pH and temperature values under past conditions.

3. The present example allows comparatively liberal ammonia loading because the SFPR is a small warm-water stream with neither a salmonid fish population nor a recognized sport fishery in the vicinity of the plant. This is reflected in the choice of a higher upper limit (criteria) for NH_3^o-N than is recommended by the EPA "Red Book" for protection of salmonid fisheries. In addition, background (upstream) ammonia concentrations are set at the monthly geometric mean of observed values rather than some higher value and no "safety factor" is included to account for the fact that peak discharges from wastewater treatment plants are usually 1.5 to 2.5 times above monthly means. In a stream with a sensitive or sizeable sport or commercial fishery, any or all of the above-mentioned approaches might be altered to provide protection commensurate with the fishery's resource.

Figure 1 - Percent Unionized Ammonia - SFPR @ Pullman



Method for Developing Permit Limitations

A series of conditions or assumptions must be specified to predict the impact of an effluent load on a receiving water. The primary conditions to be specified in the case of un-ionized ammonia are:

1. Receiving water flow;
2. Background or upstream total ammonia concentration;
3. Percent un-ionized ammonia in the receiving water;
4. Effluent flow; and
5. Effluent total ammonia concentration.

Each of the first three factors are derived on a monthly basis from data records for the SFPR at Pullman ambient monitoring station (34B110).

Based on continuous flow records for the station during the WY 1970 to 1979 period, the one in ten year low monthly flows were chosen. The ambient data record shown in the appendix was used to determine background ammonia and percent un-ionized ammonia.

The geometric mean of all NH_3^T-N data for each month was calculated and used for background/upstream NH_3^T-N concentration.

Because the downstream NH_3^O-N concentration is very sensitive to the percent NH_3^O-N value, and because this value is relatively transient, a more conservative approach was employed here.

Figure 1 shows the minimum, maximum, arithmetic mean, and geometric mean monthly percent NH_3^O-N values for the period of record. A "design curve", located between the arithmetic mean and the maximum values, is chosen and used to provide the percent NH_3^O-N values used in succeeding calculations.

The monthly values chosen for these first three conditions are shown in Table 1. These values remain constant in all later calculations. In addition, the background/upstream NH_3^O-N concentration under these conditions is shown for comparisions with downstream concentrations which are calculated later. These background/upstream concentrations are shown graphically in Figure 2 ("Historical Background, geometric mean NH_3^T-N, design percent NH_3^O-N").

Table 1. Flow, Background NH_3^T-N, and Percent NH_3^O-N, SFPR at Pullman.

Month	Flow (cfs)	NH_3^T-N (mg/l)	Percent NH_3^O-N	NH_3^O-N (mg/l)
Jan.	50	.41	.50%	.0021
Feb.	40	.41	.55%	.0023
Mar.	25	.20	.66%	.0013
Apr.	15	.06	1.3%	.0008
May	9	.14	2.1%	.0029
June	4.5	.22	3.0%	.0066
July	3.0	.10	3.7%	.0037
Aug.	2.5	.05	3.5%	.0018
Sept.	4.0	.39	3.1%	.0121
Oct.	4.5	.20	2.3%	.0046
Nov.	5.5	.38	1.1%	.0042
Dec.	12	.29	.48%	.0014

Downstream concentrations of NH_3^O-N were calculated for a variety of treatment plant discharge conditions. The first set of calculations were based on a series of effluent ammonia-N analyses made by treatment plant personnel between August 1979 and July 1980. Generally, four to five analyses were made monthly. Effluent NH_3^T-N concentrations and concurrent flows were averaged for each month and are shown in columns 1 and 2 of Table 2. Effluent NH_3^T-N loadings were calculated from these data, added to upstream NH_3^T-N loadings calculated from Table 1. These loadings were divided by total downstream flow to derive downstream NH_3^T-N concentrations in mg/L (third column, Table 2). Monthly precent NH_3^O-N values determined from Figure 1 and shown in Table 1 were multiplied by these NH_3^T-N concentrations to yield monthly downstream NH_3^O-N concentrations (column 4, Table 2). The resulting NH_3^O-N concentrations are also plotted in Figure 2 ("Current Downstream, Moderate-Worst Case").

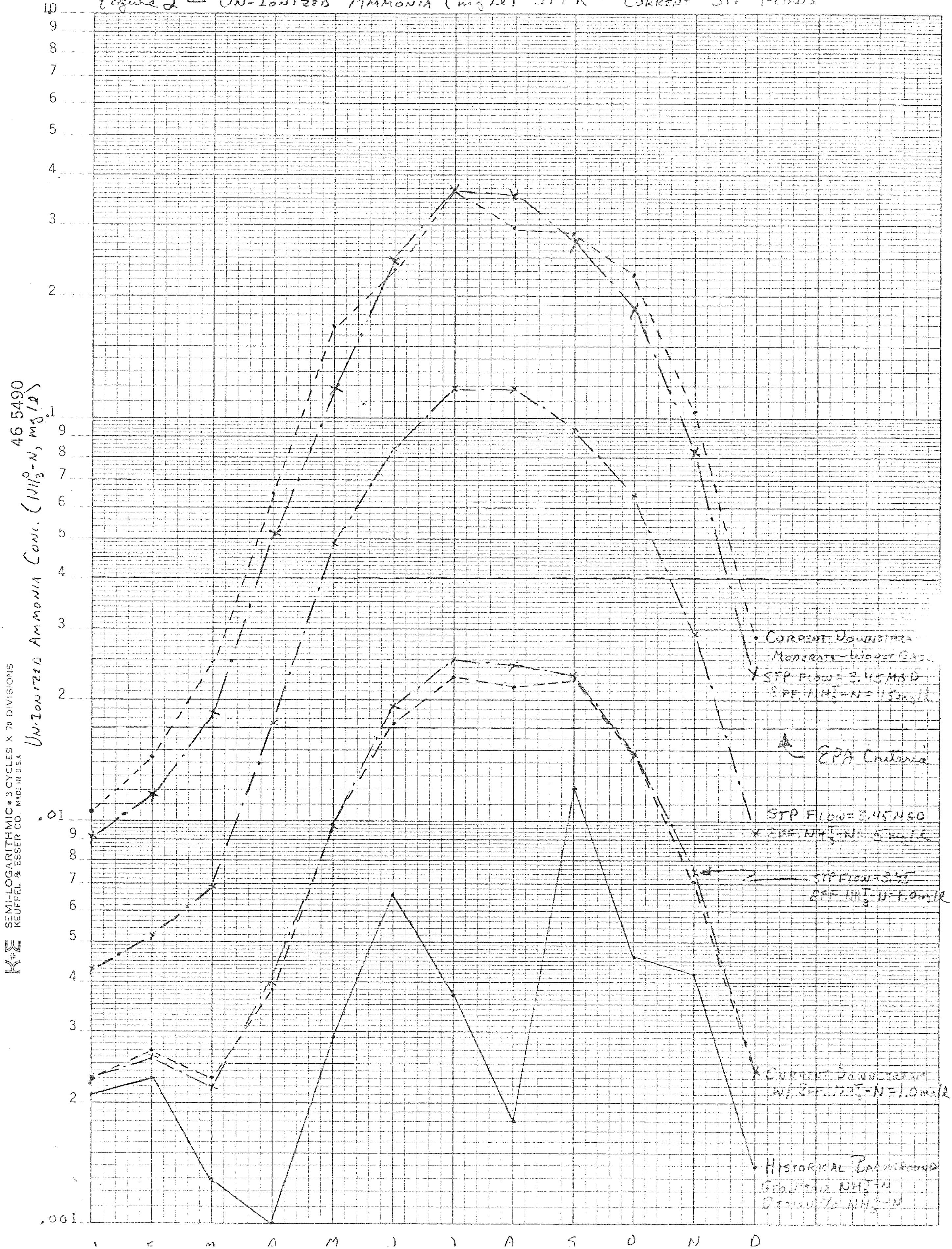
Table 2. Downstream NH_3^o-N Concentrations, Present Flow with and without Nitrification.

Month	Present Plant Flow & Effluent Ammonia				Present Plant Flow, Nitrified Eff.		
	Present Flow MGD	Current Effluent NH_3-N (mg/L)	River NH_3^T-N (mg/L)	River NH_3^o-N (mg/L)	Nitrified Effluent NH_3-N (mg/L)	River NH_3^T-N (mg/L)	River NH_3^o-N (mg/L)
January	3.25	18.8	2.09	.0105	1.0	.46	.0023
February	3.56	18.6	2.61	.0144	1.0	.48	.0027
March	3.79	19.0	3.77	.0249	1.0	.35	.0023
April	3.13	20.2	4.98	.0647	1.0	.29	.0038
May	3.57	21.0	8.08	.1696	1.0	.47	.0098
June	2.55	16.2	7.69	.2306	1.0	.58	.0175
July	2.62	17.0	9.81	.3631	1.0	.62	.0228
August	2.40	14.0	8.39	.2936	1.0	.62	.0216
September	3.22	16.5	9.33	.2892	1.0	.73	.0226
October	3.44	18.0	9.85	.2263	1.0	.63	.0146
November	2.74	21.0	9.36	.1030	1.0	.65	.0071
December	3.41	19.0	6.01	.0288	1.0	.51	.0024

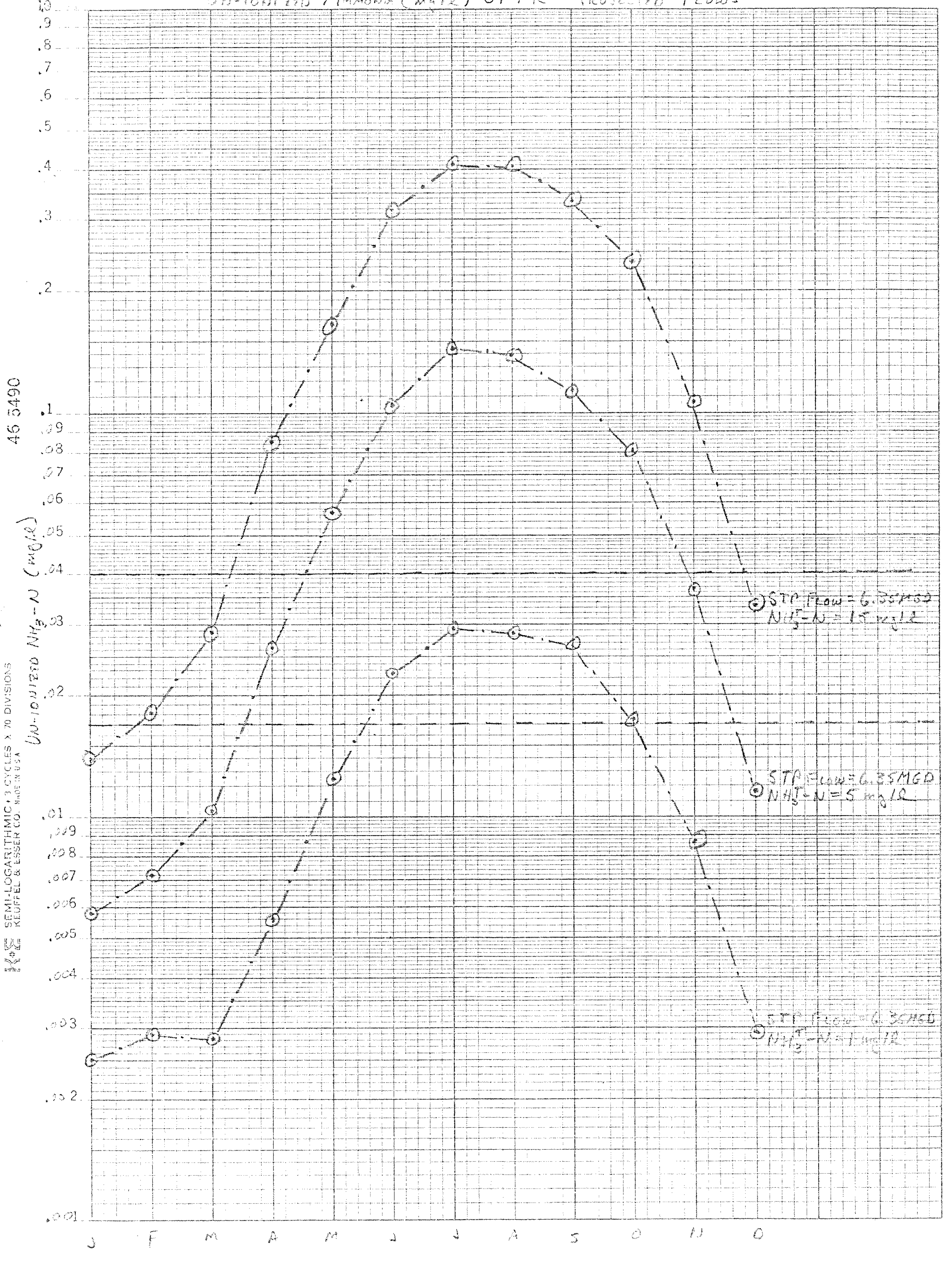
Table 3. Downriver Ammonia Concentrations at Initial (3.45 MGD) and Projected (6.35 MGD) STP Flows.

	STP Flow = 3.45 MGD						STP Flow = 6.35 MGD					
Eff.	NH_3^T-N = 15 mg/L		NH_3^T-N = 5 mg/L		NH_3^T = 1 mg/L		NH_3^T-N = 15 mg/L		NH_3^T = 5 mg/L		NH_3^T = 1 mg/L	
River	NH_3^T-N	NH_3^O-N	NH_3^T-N	NH_3^O-N	NH_3^--N	NH_3^O-N	NH_3^T-N	NH_3^O-N	NH_3^T-N	NH_3^O-N	NH_3^T-N	NH_3^O-N
Jan.	1.82											
Jan.	1.82	.0091	.853	.0043	.447	.0023	2.81	.0140	1.16	.0058	.51	.0025
Feb.	2.13	.0117	.951	.0052	.480	.0026	3.29	.0181	1.32	.0072	.53	.0029
Mar.	2.81	.0185	1.04	.0069	.339	.0022	4.38	.0289	1.55	.0103	.43	.0028
Apr.	3.98	.0518	1.34	.0175	.307	.0040	6.54	.0850	2.02	.0262	.43	.0056
May	5.67	.1192	1.95	.0409	.460	.0097	7.90	.1658	2.68	.0562	.59	.0124
June	8.24	.2473	2.81	.0844	.643	.0193	10.36	.3108	3.50	.1050	.76	.0227
July	9.64	.3557	3.24	.1198	.676	.0250	11.52	.4261	3.85	.1426	.79	.0292
Aug.	10.23	.3582	3.42	.1198	.697	.0244	11.97	.4189	4.00	.1399	.81	.0283
Sept.	8.74	.2711	3.03	.0938	.739	.0229	10.77	.3340	3.67	.1137	.83	.0255
Oct.	8.23	.1893	2.81	.0645	.634	.0146	10.35	.2381	3.49	.0803	.75	.0172
Nov.	7.58	.0834	2.66	.0292	.686	.0075	9.75	.1073	3.34	.0368	.78	.0086
Dec.	4.82	.0231	1.74	.0084	.509	.0024	6.91	.0332	2.41	.0116	.61	.0029

Figure 2 — Un-ionized Ammonia (mg/l) SFPR - Current STP Flows



UN-IONIZED AMMONIA (mg/l) SFPR - PROJECTED FLOWS



Also tabulated in Table 2 and displayed in Figure 2 ("Current Downstream w/eff. NH_3^T-N = 1.0 mg/L") are downstream NH_3^O-N concentrations for the same effluent flows, but assuming a nitrified effluent with an NH_3^O-N concentration of 1 mg/L.

Design of the upgraded Pullman treatment plant has been based on a "present" flow of 3.45 MGD and a "projected" effluent flow of 6.35 MGD. Table 3, therefore, shows downstream NH_3^O-N concentrations for effluent NH_3^T-N of 15, 5, and 1 mg/L. Resulting downstream NH_3^O-N concentrations for the "present" discharge of 3.45 MGD are shown in Figure 2; those for the "projected" flow of 6.35 MGD are shown in Figure 3.

Also shown in Figures 2 and 3 are two NH_3^O-N concentrations which can be used as criteria. The first is the EPA Red Book criterion (EPA, 1976) of 0.02 mg NH_3^O/L (0.017 mg NH_3^O-N/L). This criterion is set for the protection of salmonid fishes. The American Fisheries Society in "A Review of the EPA Red Book: Quality Criteria for Water" note that while the criterion of .02 mg NH_3-N is reasonable for salmonids "the appropriateness of the Red Book criterion for non-salmonid freshwater fishes and for other freshwater organisms has not been demonstrated." Szumski, et al., in a re-evaluation of the un-ionized ammonia criteria suggest criteria of .04 mg NH_3^O-N/l for salmonids and .08 mg NH_3^O-N/L for warm-water fishes at the gill surface. These authors note that CO_2 excretion lowers the pH and thus the percent un-ionized ammonia to which the fish is exposed. The degree of this effect is a function of receiving water alkalinity. In the absence of good receiving water alkalinity data and the relatively high (0.2) application factor used by Szumski, et al (vs. factors of .05 and .1 suggested by American Fisheries Society and EPA, respectively), we feel that a criterion of 0.04 mg NH_3-N/L is reasonable and conservative in the case of the SFPR. This value is shown in Figures 2, 3, and 4 and is used as the basis for setting permit limits.

The goal in the setting of permit limitations is to provide for protection of in-stream resources while simultaneously minimizing treatment costs in terms of capital costs, maintenance, and energy usage. To this end, the following permit limitations are recommended:

Time Period	Limitation (Monthly Average)
December 1 to March 30	No limitation
April 1 to April 30	5 mg NH_3^T-N/L
May 1 to October 30	1 mg NH_3^T-N/L
November 1 to November 30	5 mg NH_3^T-N/L

Using these permit limitations, the resulting downstream NH_3^O-N concentrations are shown in Figure 4.

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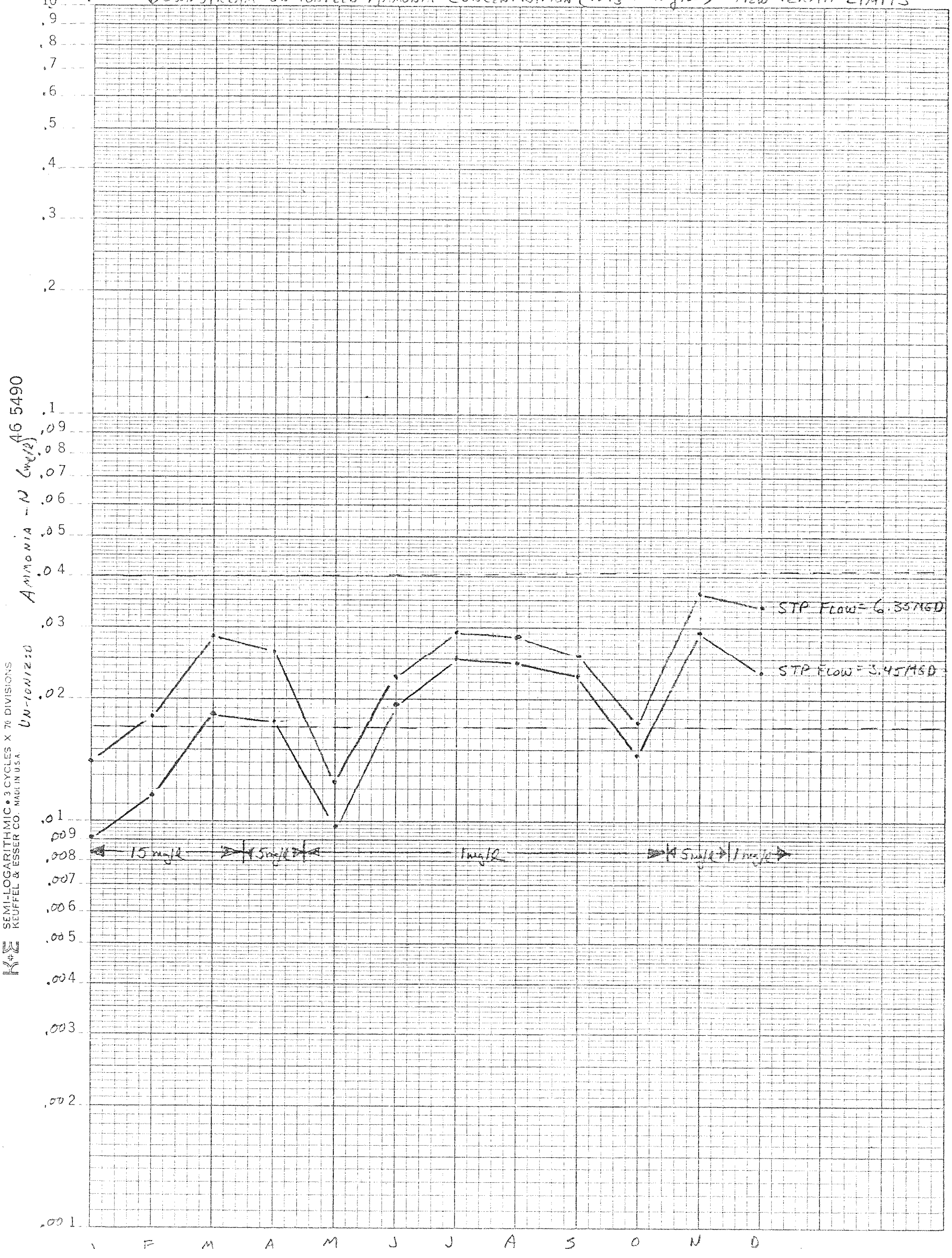
Fig. 4 — Downstream Un-ionized Ammonia Concentration (NH_3^0-N mg/l) - New Permit Limits



DEPARTMENT OF ECOLOGY

RETRIEVAL --- 06 FEBRUARY 1981

OFFICE OF WATER PROGRAMS
WATER QUALITY MANAGEMENT DIVISION
WATER & WASTEWATER MONITORING SECTION

34B110 SF PALOUSE RIVER AT PULLMAN 13348000

DATES: 00/00/00 TO 99/99/99

STORET MINOR BASIN: LOWER SNAKE STORET SUB BASIN: PALOUSE

LATITUDE: 46 43 58.0 ELEVATION (FEET): 2320 WATER CLASS: A
LONGITUDE: 117 10 48.0 COUNTY: WHITMAN SEGMENT: 16-34-02

AGENCY: 21540000 STATE: WASHINGTON STA TYPE: RMP

TERMINAL STREAM	1ST LEV MILES	2ND LEV MILES	3RD LEV MILES	4TH LEV MILES	5TH LEV MILES	6TH LEV MILES
1310001	324.30	059.50	089.60	022.20		

DATE FROM TO	TIME	DEPTH FEET	00060 STREAM FLOW CFS-AVG	00010 WATER TEMP DEG-C	00400 pH STANDARD UNITS	00610 AMMONIA T NH3-N mg/l	00617 UN-IONZD AMMONIA PERCENT	00619 UN-IONZD AMMONIA mg/l
70/12/09	0830			2.0	7.7	0.19	0.487	0.001
71/01/26	0815			3.6	7.2			
71/02/09	0810			0.4	7.5	0.20	0.270	0.001
71/02/23	0835			3.3	7.6	0.28	0.431	0.001
71/03/09	0900			2.5	7.8	0.39	0.639	0.002
71/03/23	0800			4.0	7.6	0.08	0.457	0.000
71/04/06	0850			9.6	7.7	0.00	0.897	0.000
71/04/20	0750			8.8	7.8	0.01	1.058	0.000
71/05/04	0745			14.2	7.8	0.08	1.600	0.001
71/05/18	0830			8.4	7.9	0.12	1.288	0.002
71/06/02	0830			9.6	7.3	0.43	0.359	0.002
71/06/15	0800			13.0	7.9	0.10	1.833	0.002
71/07/06	0740		9.0	13.6	8.0	0.00	2.403	0.000
71/07/20	0800		6.0	21.5	8.1	0.12	5.283	0.006
71/08/03	0815		6.0	20.4	7.5	0.10	1.277	0.001
71/08/17	0855		4.0	15.0	7.1	0.02	0.344	0.000
71/09/07	0755		6.0	11.7	7.7	0.14	1.055	0.001
71/09/21	0745		5.0	8.0	7.6	8.00	0.629	0.050
73/10/17	0815		4.5	8.6	8.0	0.25	1.641	0.004
73/10/29	1605		4.3	9.4	8.5	0.29	5.322	0.015
73/11/13	0645		52.0	5.0	7.6	1.20	0.495	0.006
73/11/27	0645		25.0	1.8	7.9	0.40	0.758	0.003
73/12/11	0700		93.0	2.5	7.7	0.48	0.508	0.002
73/12/18	0645		293.0	5.3	7.5	0.77	0.403	0.003
74/01/08	0715		66.0	0.0	7.5	0.31	0.261	0.001
74/01/22	0700		215.0	1.0	7.7	0.39	0.449	0.002
74/02/05	0715		373.0	0.9	7.5	0.70	0.281	0.002
74/02/20	0715		200.0	1.2	7.6	0.56	0.363	0.002
74/03/05	0715		262.0	2.6	7.6	0.22	0.407	0.001
74/03/19	0745		165.0	4.3	7.8	0.32	0.740	0.002
74/04/02	0750		289.0	3.8	7.4	0.38	0.284	0.001
74/04/16	0730		93.0	7.5	7.7	0.28	0.761	0.002
74/05/07	0745		44.0	13.6	8.0	0.29	2.403	0.007
74/05/21	0735		48.0	10.4	7.8	1.00	1.138	0.017
74/06/04	0735		22.0	13.1	7.8	0.27	1.473	0.00

74/06/19 0740	15.0	20.2	8.0	0.11	3.875	0.004
74/07/09 0830	10.0	16.5	7.9	0.34	2.377	0.008
74/07/23 0750	4.5	17.1	8.1	0.76	3.889	0.072
74/08/06 0815	4.8	16.2	8.1	0.14	3.637	0.005
74/08/20 0805	5.1	13.5	8.2			
74/09/04 0805	5.3	14.6	8.2			
74/09/17 0800	5.5	19.9	7.9	0.13	3.037	0.004
77/10/26 0830	9.2	8.3	6.5	1.60	0.052	0.001
77/11/29 1115	19.0	7.0	6.3	0.68	0.029	0.000
77/12/20 0800	21.0	0.2	7.2	0.60	0.133	0.001
78/01/24 0730	46.0	1.5	6.8	0.39	0.059	0.000
78/02/14 0815	68.0	2.2	7.0	0.43	0.098	0.000
78/03/28 0815	40.0	11.4	7.2	0.10	0.323	0.000
78/04/25 0930	30.0	14.0	8.0	0.13	2.475	0.003
78/05/23 0815	22.0	11.6	8.2	0.19	3.237	0.006
78/06/20 0800	5.7	14.2	8.0	0.30	2.512	0.008
78/07/25 0815	3.9	18.8	8.4	0.13	8.372	0.011
78/08/22 0820	6.7	14.4	8.1	0.02	3.183	0.001
78/09/26 0845	4.7	13.1	8.4	0.14	5.617	0.008
78/10/24 0745	6.9	9.7	8.2	0.06	2.803	0.002
78/11/29 0930	9.6	7.7	8.1	0.54	1.918	0.010
78/12/20 0845	8.2	1.0	7.8	0.38	0.564	0.002
79/01/25 0930	7.7	0.4	7.8	0.60	0.537	0.003
79/02/28 0950	76.0	1.8	8.3	0.47	1.882	0.009
79/03/20 0905	81.0	5.7	7.3	0.17	0.263	0.000
79/04/25 0915	79.0	11.6	7.9	0.26	1.649	0.004
79/05/22 1000	24.0	18.6	7.0	0.17	0.357	0.001
79/06/19 0930	13.0	14.2	7.2	1.80	0.407	0.007
79/07/24 0915	4.7	17.0	7.1	0.11	0.399	0.000
79/08/28 0900	5.2	15.4	7.3	0.04	0.560	0.000
79/09/25 0915	5.5	12.2	7.7	0.05	1.026	0.001
79/10/23 0845		9.5	7.4	0.02	0.448	0.000
79/11/27 0930		2.4	7.2	0.12	0.160	0.000
79/12/18 0900		5.2	7.4	0.23	0.318	0.001
80/01/22 0900		1.8	7.3	0.42	0.191	0.001
80/02/27 0910		6.6	7.2	0.43	0.225	0.001
80/03/25 0920		5.1	6.9	0.40	0.100	0.000
80/04/22 0930		12.4	7.9	0.02	1.752	0.000
80/05/20 0750		12.0	7.3	0.01	0.433	0.000
80/06/24 0750		13.7	7.8	0.04	1.541	0.001
80/07/22 1020		21.5	7.6	0.06	1.733	0.001
80/08/26 0800		10.0	7.7	0.06	0.925	0.001
80/09/23 0800		10.0	7.7	3.60	0.925	0.033
80/10/21 0940		9.8	7.3	0.18	0.365	0.001
80/11/18 0745		6.1	7.6	0.14	0.541	0.001
80/12/16 0745		3.4	7.2	0.05	0.174	0.000
NUMBER OF SAMPLES	61	100	100	96	96	96
MAXIMUM VALUE	373.00	21.50	8.50	8.00	8.372	0.050
MINIMUM VALUE	3.90	0.00	6.30	0.00	0.029	0.000
ARITHMETIC MEAN	48.74	9.18	7.65	0.47	1.304	0.004
GEOMETRIC MEAN	17.23	6.14	7.64	0.17	0.758	0.002
LOG/GEOMETRIC MEAN	2.85	1.81	2.03	-1.78	-0.277	-6.350
MEDIAN	9.20	9.45	7.70	0.19	0.690	0.001
STANDARD DEV OF LOGS	1.38	1.23	0.05	1.45	1.103	1.147
STANDARD DEVIATION	82.34	5.94	0.40	1.19	1.462	0.008
VARIANCE	6779.55	35.32	0.16	1.43	2.137	0.000
COEFF OF VARIATION	168.94	64.72	5.18	251.95	112.110	212.054
SUM OF VALUES	2973.00	918.30	764.90	45.50	125.182	0.382
MEAN +2 STD DEV	213.41	21.07	8.44	2.86	4.228	0.021
MEAN -2 STD DEV	-115.94	-2.70	6.86	-1.91	-1.620	-0.013
GEO MEAN +2 STD DEV	269.63	72.52	8.49	3.05	6.887	0.017
GEO MEAN -2 STD DEV	1.10	0.52	6.87	0.01	0.083	0.000
SUM OF SQUARES	551670.18	11929.69	5866.29	157.03	366.261	0.008