ESTIMATION OF TIME SERIES SAMPLE SIZES AND SAMPLING FREQUENCIES FOR THE LONG-TERM WATER QUALITY MONITORING NETWORK ON THE NORTH SASKATCHEWAN RIVER IN ALBERTA

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and

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1 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

1.1 Format of This Report

This report is broken into two main sections; "Study One," covering 21 water quality variables over the years 1978-1989, and the three long-term water quality monitoring stations on the North Saskatchewan River (NSR) located at Devon (upstream of Edmonton), Pakan (downstream of Edmonton) and the Alberta-Saskatchewan Border station (Highway 3 bridge, managed by the Prairie Provinces Water Board (PPWB); "Study Two," for 25 water quality variables over the years 1974-1991, located at the PPWB Border station, only.

This format was adopted because data available from the Surface Water Assessment Branch (SWAB) Branch, Alberta Environmental Protection, Edmonton, and those from the PPWB covered different time series and did not contain complete comparable suites of water quality variables. Methods of analysis and statistical protocols in this study were, however, consistent for both studies.

1.2 Objectives and Statistical Protocol

Objectives of this study were:

(i) Descriptive statistics will be computed and combined with graphical analyses of all water quality variables, over space and time;

(ii) Spatial and temporal trends will be estimated: seasonally adjusted, combined with flow adjusted, estimates [data were also detrended for estimating residual, random error];

(iii) Results from (i) and (ii) above, will be used to evaluate and recommend alternative statistical sampling methods which can detect annual changes of at least 10% with probability of 85% or more (Type II error, 15% or less) with a nominal Type I error of 10% or less.

A chart, for quick-reference, is provided in Appendix B-1 which describes the statistical protocol for calculating sampling frequencies and sample sizes.

1.3 Three Stations on the NSR for the Years, 1978-1989

(i) A total of 189 time series (21 variables x 3 locations x 3 monitoring schemes) were fit to an autoregressive, lag-1 model [AR(1)].

(ii) Percentage of all combinations having serial correlation [AR(1)], rather than random 'white noise' (WN), among monthly samples detected among the 21 water quality variables for each station were: Devon, 57%; Pakan, 76% and the Border, 67%, suggesting that monthly serial correlation from factors not removed by adjusting for flow, seasons and trend in the series tends to increase from upstream to downstream with a maximum downstream of Edmonton.

(iii) Similar patterns of time dependent variation over the 3-station network were confirmed by finding that 10 of 21 (48%) water quality variables were concordant, e.g. if a variable's process was AR(1), or WN at Devon, it was also AR(1) or WN at Pakan and the Border.

(iv) While one objective of this study was to determine the number and frequency of monitoring events required to detect an average 10% linear trend (10% of a series mean) with Type I error set at 0.10, Type II at 0.15 and power=0.85, analyses indicated that only about one-third of the 21 variables could be predicted to meet such a goal; for each station, the proportions were: Devon, 6/21; Pakan, 6/21; and the Border, 5/21. The number of years of monitoring to detect such changes varied from 1 to 13. Over the network, about 59% (37/63) of the series indicated that practical lengths of time for monitoring linear changes over time would dictate accepting trend sizes of 30% of the series mean, or greater.

(v) Results are presented from analyses of the historical “monthly” monitoring schedule and data extracted from that series representing two hypothetical "what if?" alternatives (bimonthly1, starting in January, and bimonthly2, starting in February). Results from these 3 schemes suggest that total sampling effort for Devon could decrease by 62% (13/21), Pakan by 67% (14/21) and the Border by 62% (13/21), if our example for changes in monitoring frequency were implemented. Whether these potential savings might be incorporated into a monitoring program would be dependent upon monitoring objectives by an agency and the water quality criterion for each variable.

(vi) This study has treated each water quality variable as though it were independent of all others. While this is not likely the case, multivariate time series analysis exceeds the scope of our objectives.

1.4 PPWB Border Station on the NSR for the Years, 1974-1991

(i) Analyses of 25 water quality variables on the NSR at the PPWB Border station included fitting 125 (25 variables x 5 monitoring schemes) series to an AR(1) process; the number of AR(1) models in each monitoring scheme were:

Monthly(historical data)	19/25
Bimonthly 1 (starting January)	10/25
Bimonthly 2 (starting February)	9/25
Quarterly 1 (staring January)	8/25
Quarterly 2 (starting February)	2/25

(ii) Of the 25 suggested as candidates for reducing monitoring costs (one per water quality variable), only 6 of 25 water quality variables indicated having properties capable of allowing one to detect a linear trend as small as 10% of the series mean; these were: total alkalinity, dissolved calcium, dissolved magnesium, pH (lab and field measurements) and total dissolved solids. Another 5 variables should permit detection of trends between 11 and 30% of the series mean: conductivity (field measurement), dissolved oxygen, dissolved potassium, dissolved sulphates and specific conductivity.

(iii) Monitoring costs might be reduced up to 55% over the suite of 25 water quality variables by applying the statistical properties of each leading to the suggestion that 20 of 25 could be converted from a "monthly" monitoring schedule to one of the other four schemes evaluated, and maintaining the same level of precision as 12 collections per year. The five variables best left on the current "monthly" schedule were dissolved chlorides, dissolved sodium, dissolved copper, $NO_3 + NO_2$ and total zinc.

(iv) See our comments above in section 1.2 (vi).

1.5 Recommendations and Future Needs

(i) We **strongly** recommend that a first priority during this period of re-evaluation of water quality monitoring on the NSR is that the two client agencies agree upon a common suite of variables, or, at least a subset, which is comparable with respect to method (i.e. code), software, and time, thus permitting meaningful periodic evaluations over the network.

(ii) We **strongly** recommend that the Alberta government invest further in a statistical sampling design to detect **step trends** of magnitude compatible with water quality objectives. Our recommendation is prompted by the obvious need to determine whether significant (statistical and/or quality) changes occur in rivers (and lakes, where applicable) following pulp mills, or any point source inputs, commencing operation. Step trend analysis over some pre-set "before" and "after" time series would be most appropriate, rather than testing for long-term linear changes.

(iii) We **strongly** recommend that now is the opportune time for both client agencies to prepare monitoring protocols documenting water quality methods, including statistical design and analyses; New Zealand published such a document in 1989 (cited in this report) which could serve as a model for both rivers and lakes in Alberta. The authors thank Dr. R. Ward for bringing this reference to their attention.

(iv) We have provided step-by-step guidelines in this report (section 6.0) for using the considerable information that is summarized here; we suggest that once users become familiar with the interpretation of this information it can offer considerable opportunities for making comparisons among competing monitoring programs.

(v) This project was designed to have the results apply only to constant linear change with time. We, however, point out in (ii), above, that step trends should be evaluated and here suggest that linearity must not necessarily be assumed in doing future trend analysis. El-Shaarawi and Niculescu (1993) have recently published a test method for detecting non-linear trends in sequentially ordered (e.g., time series), independently distributed data.

(vi) Imaginative, alternative approaches to water quality monitoring need to be examined. We have very preliminary results (not included here) from analyses of a small subset of the water quality variables from this study whereby we attempted to predict the concentration of a variable over time using the data from a small-subset of variable entered into a "neural network" algorithm. The predictor set was composed of variables which are, or can be, monitored electronically (e.g., pH, specific conductivity, dissolved oxygen, flow, temperature). Thus, if the predictions of "variable Y" were within pre-set bounds of precision and accuracy, monitoring schedules could be designed especially for periodic testing of the "neural network" model. Mr. Dennis Yee, formerly of AEC, kindly gave assistance with these preliminary attempts.

2 BACKGROUND

This project grew from discussions during February and March, 1993, among staff of Alberta's Department of Environmental Protection, SWAB Branch (formerly Environmental Quality Monitoring), the Prairie Provinces Water Board (PPWB) and the Department's Applied Statistics and Biometrics Section (ASB) at the Alberta Environmental Centre, Vegreville. A study proposal was developed (Appendix A) and agreed upon the latter part of March 1993.

Because SWAB and PPWB were in the early stages of reviewing the current monthly monitoring program for the North Saskatchewan River (NSR), it was decided to use data extracted from the national water quality database (NAQUADAT) for the three long-term monitoring stations (see map, Fig.1) on the NSR for assessing the frequency of monitoring to determine whether the current program might be revised. Data were to be provided by SWAB and PPWB and statistical analysis provided by the ASB; both SWAB (Shaw et al. 1994) and PPWB (Dunn 1993) have recently produced independent reports on results of trend analyses of NSR long-term monitoring data, collected by SWAB staff and Environment Canada, Water Quality Branch, Western and Northern Region: these data were to form the basis for studying the implications for revising monitoring schedules and frequencies of sample collection within schedules. The PPWB has also received results from long-term trend analyses at the border station done by Dr. A. El-Shaawari's statistics group, National Water Research Institute, Rivers Research Branch, Burlington, Ontario (El-Shaarawi, 1991).

Considerable delay arose during development of a suitable protocol for meeting the study objectives. Factors causing delays included: (i) the iterative process required to define the products wanted by each client agency because each had its own objectives to meet with respect to water quality monitoring; (ii) considerable difficulty was met when attempting to first bring data into the SAS environment, and differences in data structure of files; (iii) merging comparable data among the three stations was very time consuming (NAQUADAT codes for the same water quality variables in each of the two data sets were not strictly compatible); (iv) the senior author accepted an invitation as visiting scientist in the Biostatistics Division, Health Canada, Ottawa, March 1 through May 31, 1994, causing considerable disruption during final report preparation; and (v) time series of the data from SWAB differed in length, and some water quality variables, relative to the PPWB series. It was thus decided by the senior author to separately analyze the data and report results as though originating from two independent studies, yet having principal objectives and statistical methodology in common. This

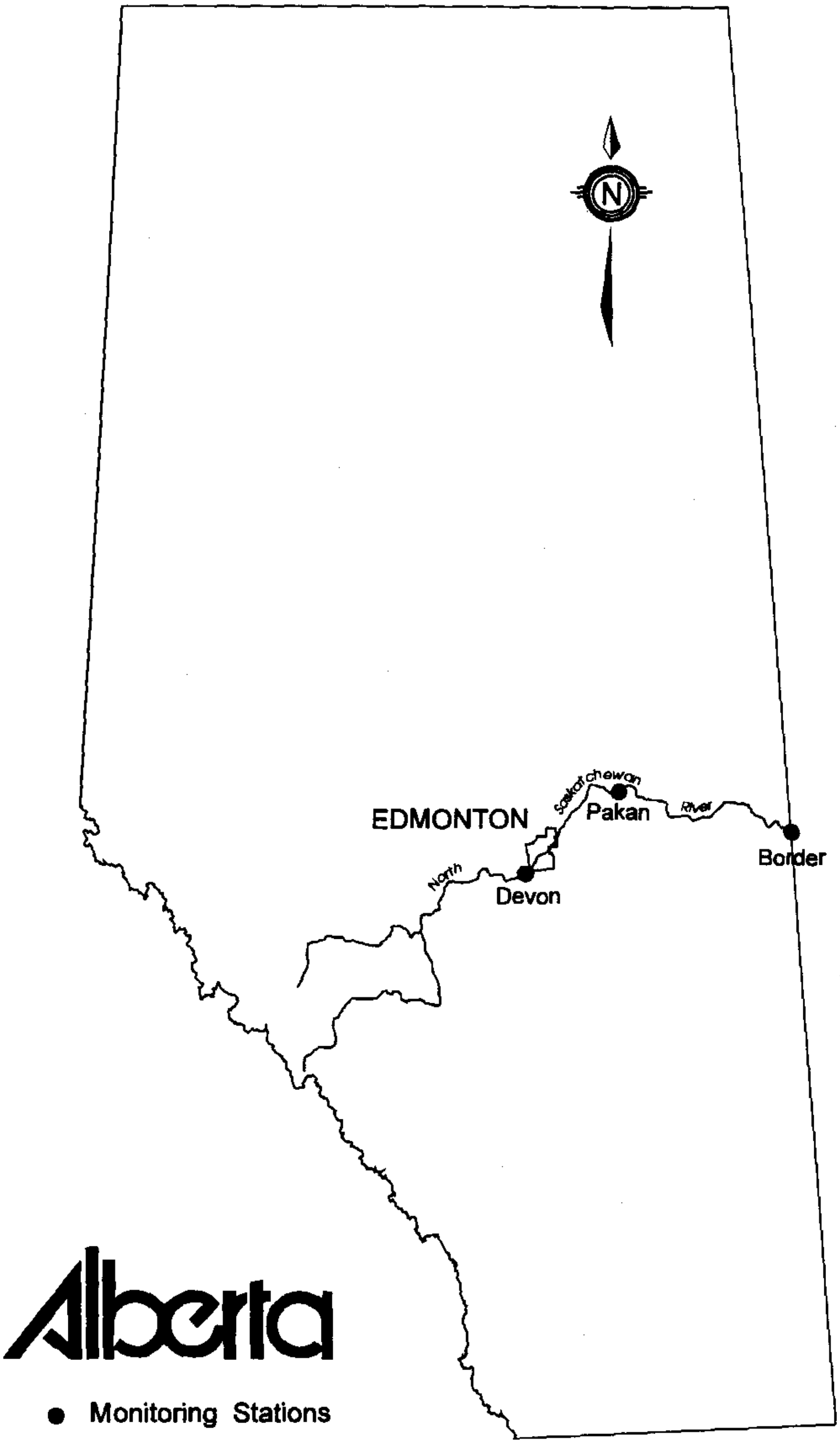

Fig. 1. Three long term water quality monitoring stations on the North Saskatchewan River.

decision, while likely improving the overall quality of the final product and meeting each client's objectives, has added considerable time and expense because of the factorial design: three stations (Study One) and 21 variables (originally 23 but α-BHC [α - benzene hexachloride] and turbidity were not comparable/complete for all three stations) multiplied by three monitoring schemes, and the PPWB station (Study Two) having 25 variables and five schemes. Because the time series was shorter for the common variables at the three stations {1978-1989 (12 yrs) vs. 1974-1991 (18 yrs) at the PPWB border station}, quarterly schemes were omitted from Study One to avoid over extending the data, thus possibly leading to spurious conclusions due to small sample sizes, thus leaving 21 x 3 x 3 = 189 time series to fit among the three stations (Study One) and 25 x 5 = 125, to fit for Study Two, yielding an overall total of 314 fitted models from which to obtain estimates of the parameters in each time series model. Complete listings of water quality variables and their NAQUADAT codes are in Appendices C and F.

3 OBJECTIVES

The project proposal (Appendix A) identified three objectives from the two clients (SWAB, PPWB); ASB was to provide:

(i) statistical and graphical summaries of time series at the three stations;

(ii) estimates of spatial and temporal trends using seasonal and flow adjusted data;

(iii) recommendations for sampling schedules capable of detecting long-term, linear trend changes (increasing or decreasing) of at least 10% the series mean with a power (probability of detecting a trend) of 85% or more, a Type I error (probability of false positives) of 10% or less, and Type II error (probability of false negatives) of 15% or less.

A fourth objective was added during implementation of the analyses:

(iv) comparisons among five monitoring schemes: monthly, bimonthly starting in January, bimonthly starting in February and quarterly, again, starting in either January or February.

Results from graphical summaries (objective (i)) are not contained in the report but can be found in Central Records, Alberta Environmental Centre; see also Shaw et al. (1994). While spatial differences among the three monitoring stations with respect to sampling schemes are discussed in our report, the reader is referred to Shaw et al. (1994) for additional detail. Also, trends (linear and curvilinear) were estimated in our study for the purpose of adjusting for this source of error variation in each series, though we have not included details in our report; results are on file in the Central Records, Alberta Environmental Centre. Note, too that Shaw et al. (1994) addressed this issue in their report. Software developed in SAS, version 6.08 is to be made available, with training, to the clients during 1995-1996.

The principal product was to be a final report, the first draft to be prepared by February 28, 1994, the final draft for internal and external review by March 31, 1994.

N.B. The first draft was distributed in time for the PPWB meeting, mid-April, 1994, and an interim version (three stations, Study One) presented at the International Environmetrics Society Conference, Burlington, Ontario, August 12, 1994 (Florence et al. 1994); L.Z. Florence, at the invitation of PPWB, presented results and provided interpretations on Study Two (PPWB station, years, 1974-1991) at the annual meeting of the Committee on Water Quality, PPWB, Winnipeg, November 16-17, 1994. Final revisions and conclusions from Study One were presented in a public seminar, May 19, 1995, Oxbridge Place, Edmonton. No further comments have been received from clients (September 28, 1995), thus, this final draft constitutes our report.

4 METHODS

4.1 General

Considerable literature exists which addresses the number of samples needed to estimate the adjusted mean (average) and bounds on the adjusted mean of a series e.g. Loftis and Ward 1980, Sanders and Adrian (1978), Ward et al. 1979. This task, however, was not one of our objectives. Literature most relevant to our objectives included two papers by Lettenmaier (1976, 1978), and the one by Bayley and Hammersly (1946, cited by Lettenmaier 1976). References which address designs and general topics for water quality monitoring networks include Smith et al. 1989 and Ward et al. 1990 (neither contain great detail on estimating sample sizes for trend detection in a time series); Helsel and Hirsch (1992) provide widely used statistical methods in water research (but little on sampling theory or modelling time-dependent estimators).

4.2 Software

Software development and analyses were done in SAS, version 6.10 (SAS Institute Inc.,Cary, N.C.) running under Microsoft "Windows," version 3.1.

4.3 Data Transformations

Following exploratory data analysis and time series plots of each water quality variable (see Figs 2, 3 and 4, for examples of NSR time series), the decision was made to transform each variable to its natural log {with exception of the log hydrogen ion concentration (Ph, [F]ield or [L]ab) and temperature, due to negative values}. In general, raw data for most variables tended to be lognormally distributed, and even if not, transformation (Chatfield 1989) would help condition variances (dampen the effects of spatial and temporal extremes), better enable our meeting parametric assumptions, i.e. time series models assume the errors to be independently and normally distributed, and reduce the influence of atypical data upon the estimates of the autocorrelation function. Back-transforming (Bt) means and variances was accomplished by methods described in Gilbert (1987).

Data were first plotted against time and extreme values (averaging about 3 standard deviations and greater) removed; these edited data were considered to be the "best" representative time realization for each water quality variable from which parametric estimates of serial or autocorrelation and standard deviation of residuals could be obtained. The edited data were then log-transformed. Data were further transformed by entering them into the protocol {adapted from Phillips et al. (1990), Montgomery and Reckhow (1984) and Hirsch et al. (1991)} shown in Appendix B, whereby residuals were first adjusted for mean river flow, then seasonal effects, then detrended. Missing data (excluding the two most extreme observations) were estimated using PROC EXPAND in SAS 6.10.

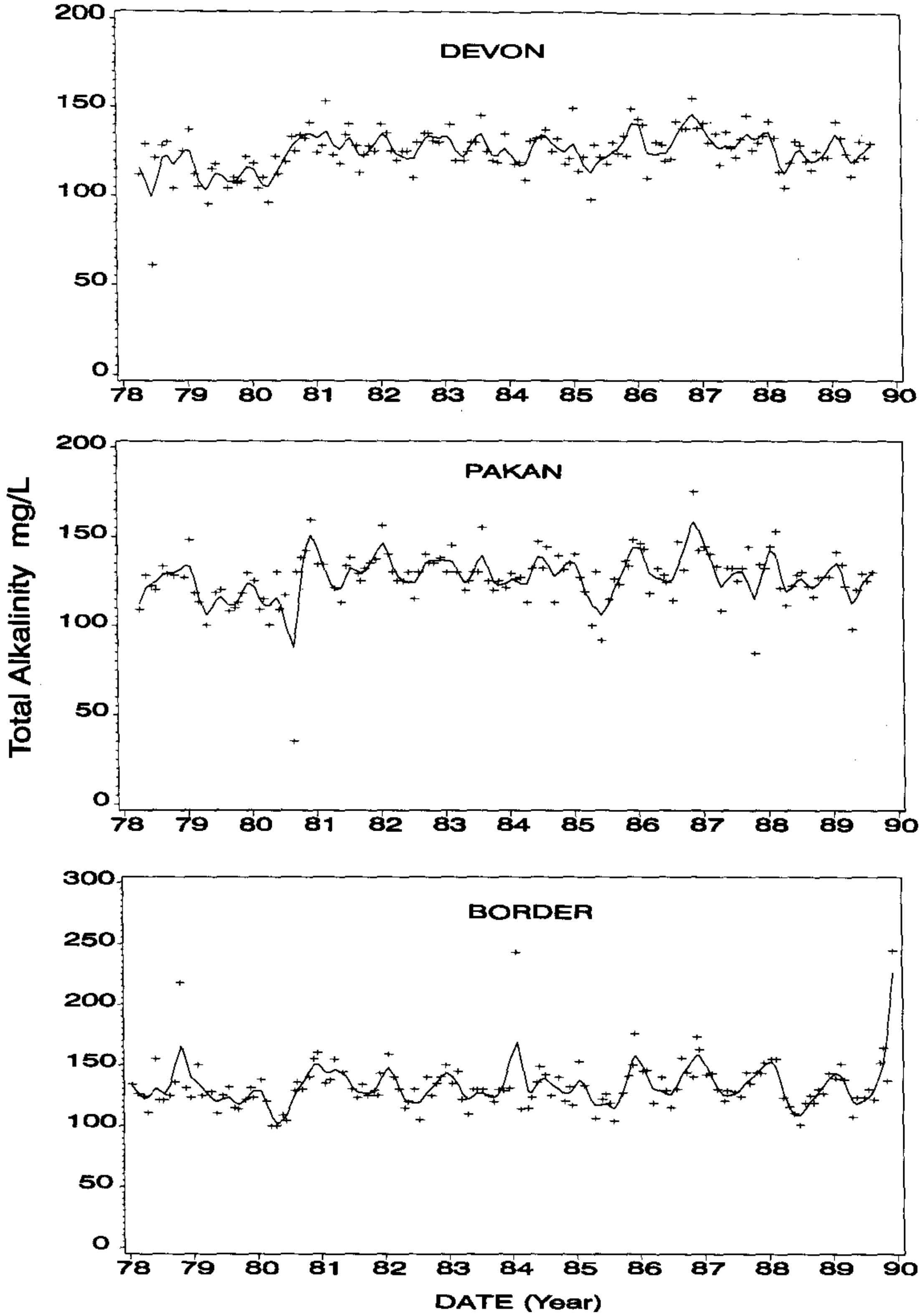

Fig. 2. Time series plots for total alkalinity for three long term water quality monitoring stations in Alberta (cubic spline smoothing).

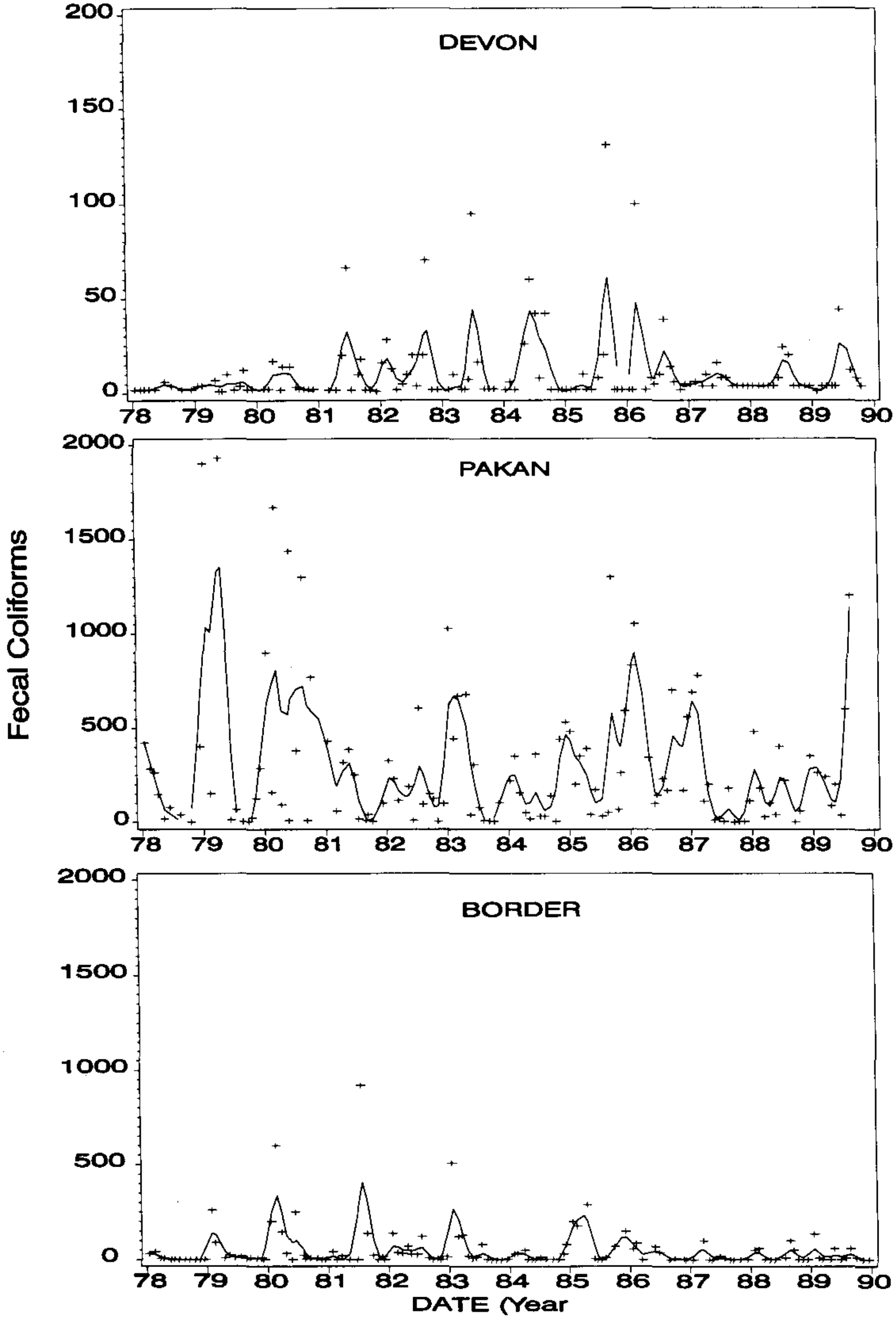

Fig. 3. Time series plots for fecal coliforms for three long term water quality monitoring stations in Alberta (cubic spline smoothing).

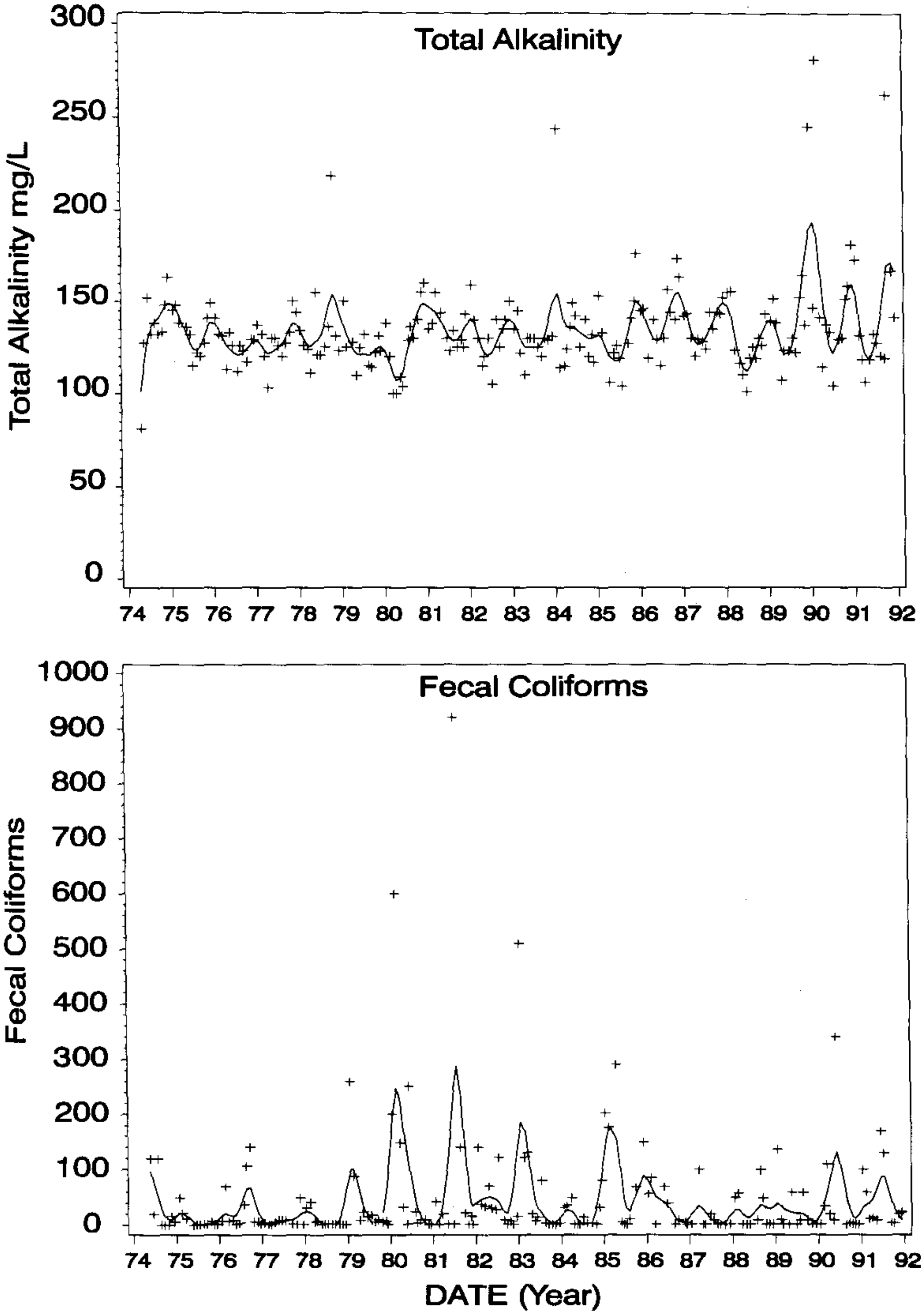

Fig. 4. Time series plots for total alkalinity and fecal coliforms for the PPWB water quality monitoring station at the border (cubic spline smoothing).

4.4 Modelling the Time Series

Adjusted residuals (section 4.3) were entered into the PROC ARIMA analysis using SAS for estimating the autocorrelation function (ACF) and fit to an autoregressive process {AR(1)}. The general form (Box and Jenkins 1970 [revised 1976]; Chatfield 1989) of an AR(1) model is:

$Z_t = \Phi_1 Z_{t-1} + \varepsilon_t$

where,

Z_t = present values of a time series

Z_{t-1} = value of the series at lag-1, i.e. last month, if monthly data.

Φ = autoregression coefficient,

ε_t= random, residual error or, "white noise" term; this term is assumed to be normally distributed with mean zero and variance,σ_ε^2.

For an AR(1) process in a stationary series (i.e.,when there is nonrandom structure remaining in the series), we have:

$\rho_1 = \Phi_1$

$\rho_{(n)} = \Phi_1^n$, n = 1, 2, 3, ...

where, ρ_1 is the autocorrelation function at lag-1.

While we suspected that not all water quality variables would necessarily be limited to only "white noise"(WN) or AR(1) processes, previous literature, e.g. Loftis and Ward (1980b) and Lettenmaier (1976, 1978), suggested that a majority of water quality time series would fit into these two categories, especially for weekly and daily data; fewer AR(1) models might be expected from monthly monitoring schedules because time-dependent autocorrelation is generally weaker as the time lag between sampling events increases. Further, because the sampling distribution for calculating sample sizes to detect linear trends are not clearly defined for ACF beyond lag-1 {see Bayley and Hammersley (1946) and Lettenmaier (1976)}, we opted to restrict our studies to either WN or AR(1) models; if the model was suggestive of forms other than WN or AR(1) we declared it AR(1) if the lag-1 coefficient was significant at the 95% confidence level.

Referring again to the general form for the AR(1) process, above, it is easily seen that if $r_1 \neq 0$ (r_1 is the estimator of ρ_1) the total variation in the process includes both random error and some fraction due to serial correlation with observation at t-1, otherwise, the process is random "white noise" i.e., when $r_1=0$.

For general statistical details regarding analysis of time dependent data, see Chatfield (1989) and, Hipel and McCleod (1994).

4.5 Estimating the Length of, and Sampling Frequency Within, Each Water Quality Time Series

To determine total sample sizes, numbers of years of sampling and effective number of independent samples per year for the three (Study One) or five (Study Two) monitoring schemes {monthly, bimonthly (bimonthly1 for January start date and bimonthly2 for a February start date) and quarterly (quarterly1 and quarterly2 for January and February start dates, respectively)}, a value for ρ_1 must be estimated. This estimator, r_1 (it may vary from -1 to +1, but always 0 or positive with the water quality data analyzed here), is the sample statistic, henceforth referred to as "r", the `autocorrelation coefficient'.

The statistic r is used to calculate the number (n^*) of independent samples (the effective sample size) contained within a series (n) [Montgomery 1984]:

$$n^* = n\{(1+r)/(1-r)-(2/n)(1-r^n)^r/(1-r)^2\}^{-1}$$

where, n^* = number of independent samples, and n = number of samples in the data series being analyzed.

The value n^* is useful for computing the effective frequency for collecting data for a given sampling scheme. For example, if $r>0$ (statistically significant) and samples are to be collected monthly, the effective number, adjusted for the autocorrelation which produces redundant information in the series, will be less than 12.

To detect a constant, linear trend at a desired level of significance (the predetermined Type I error,α) and power [dependent on the pre-set Type II error(β) because, power = $1-\beta$], the following relation is used (Lettenmaier 1976):

$$1-\beta = F_g(N_t - Z_{1-\alpha/2})$$

where, F_g is the cumulative function of the standardized normal variate, $Z_{1-\alpha/2}$ is the quantile of the normal distribution for a probability of non-exceedance, and $(1-\beta)$ is the power of the test.

In our case, $\alpha=0.10$ and $\beta=0.15$, hence, power=0.85.

The total number of independent samples required to detect a constant linear trend of given size:

$N_T = \{Tr(n^{**})^{1/2}\} / \sigma_\varepsilon(12)^{1/2}$, where

Tr is the magnitude of linear trend over time; it is calculated by the series mean multiplied by the trend expressed as a decimal fraction; σ_ε is the standard deviation of the random component of the series, and n^{**}, the total number of independent samples required to detect the specified magnitude of trend.

Years of monitoring required to detect a specified linear trend for a given sampling scheme can be calculated from n^{**} and the effective frequency of sampling (n^*) for each corresponding sampling scheme under consideration. As an example, for a monthly scheme, the frequency is $12(n^*/n)$ Likewise, to determine the number of years and the size of trend that might be detected within that series, when the trend size equals the background variation, i.e. Ratio= $Tr/\sigma_\varepsilon = 1$ (residual error defined by the σ_ε term, above), terms can be rearranged and algebra used to solve for the needed information.

4.6 Definition of Trend

SWAB and PPWB specified that monitoring schedules be compared when a 10% (positive or negative) change from the series mean was attained. For example, referring to Appendix C-1, the estimate of the series mean for ALKTOT at Devon (after back transforming from ln mean) is 124.647 mg per liter. A 10% change would be approximately 12.5 mg/l (over the total series), based on monthly samples (n=137) from 1978-89. If we were to estimate that a 10% trend should be detected within 10 years of monthly monitoring at $\alpha=0.10$, $\beta=0.15$, then we should expect a slope or rate of change per year to be about 1.25 mg/l; Fig 5 shows this relationship graphically. Likewise, if we decided to set our objective at the level where the residual error and the change over time were equal, then we could determine the number of years until Ratio = Trend Size/error = 1; again, for ALKTOT (Appendix C-1, Monthly, at Devon) we see that the back transformed error (Bt SE) is 8.799 mg/l, which is about 7% of the mean (124.647). Further, it should require approximately, $124.647/8.799 \cong 14$ years, to detect a change of at least 7% of the mean.

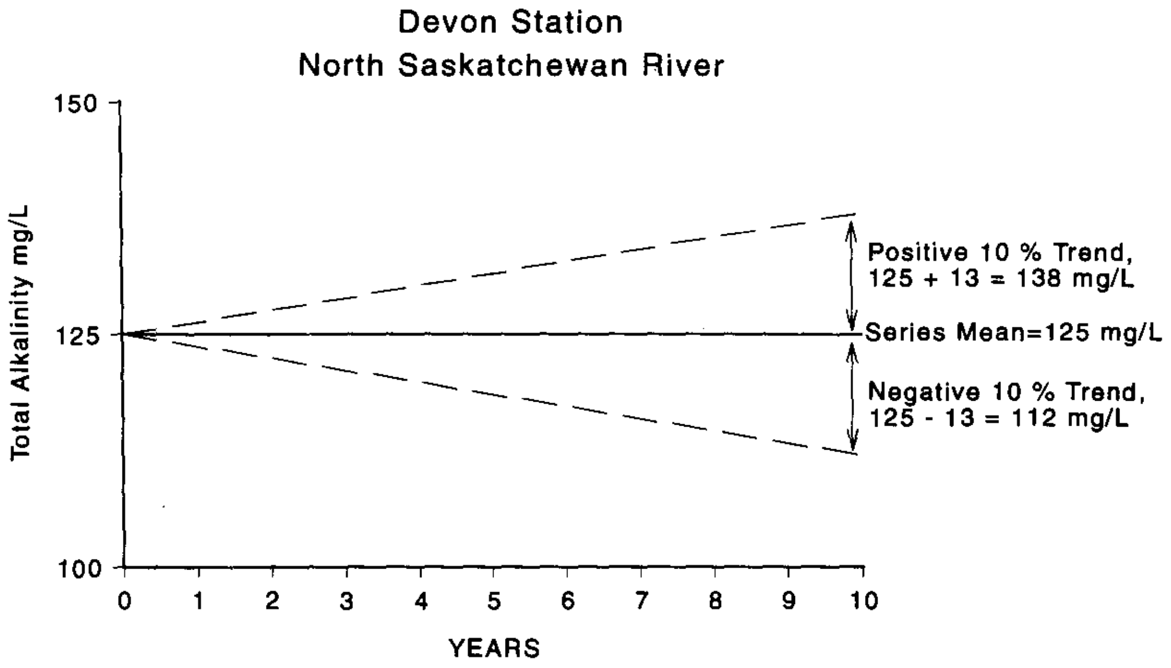

Fig. 5. Graphical presentation of long-term linear trends: positive or negative 10% change from the series mean at the Devon station on the North Saskatchewan River.

5 RESULTS AND DISCUSSION

5.1 Study One: Three Stations for the Years 1978-1989

Results from analyses of the 21 water quality variables at each of the three long-term monitoring stations on the North Saskatchewan River for the years 1978-1989 are summarized in Table 1 (see also Appendices C and D; Appendix D contains the results of estimates of sample sizes and years to detect constant linear trends from 5-30%). Table 1 further condenses those results by reporting the minimum years predicted to detect exactly a 10% linear trend, as defined in Section 4.6 and in the project proposal (Appendix A; note also Appendix C for the series means from which the trend sizes were calculated). Shown also in Table 1 is the estimate of the number of independent samples required to detect a 10% trend by sampling monthly.

Notable conclusions from the summary in Table 1, include:

1. There is wide variation among the water quality variables and among the three stations in regard to the number of years of monthly samples needed to detect a 10% linear trend: for ALKTOT, 9 and 10 years at Devon and Pakan, but 15 years at the Border station to detect changes of 12.46 - 13.02 mg/L. Differences between variables may reach 100-fold or greater, e.g. ALKTOT vs. BDISS.
2. Number of independent samples, following monthly sampling, may help to identify other alternative monitoring schedules. For example, only 5 to 8, out of 12 monthly samples, were independent among ALKTOT series suggesting that the same level of detection could be obtained through bimonthly sampling.
3. If the number of independent monthly samples is 12, then by our criteria, the time series model must be WN (random, "white noise"), otherwise it is an AR(1); see Appendix C for summaries and coefficients. Frequency distributions among the three stations and 21 water quality variables are contained in Table 2.

   One-third (21/63) of the models were determined to be WN and two-thirds AR(1). There is then some suggestion that the water column becomes more structured (i.e. nonrandom) below Edmonton, at Pakan and the Border, with increased number of AR(1) series.
4. Because the NSR water column is being repeatedly sampled in the same month at three locations, but not necessarily the same days, we would expect there to be some concordance among water quality variables and stations based on monthly monitoring, e.g. if a variable is found to be AR(1), or WN, at Devon, is it also AR(1) or WN at the other stations? The four possible states [$0.5(2^3)$] and the variables falling into each (with model, based on the historical "Monthly" monitoring schedule) are below (Table 3):

   Therefore, 10 of 21 (D:P:B column) variables from the "Monthly" series, share the same model structure over the network, though if AR(1), not necessarily the same magnitude of coefficients (see Appendix C), e.g. ALKTOT at Devon had r=0.42, at Pakan, r=0.29 and at the Border, r=0.23. The influence of distance between stations is suggested by there being only one agreement (NADISS) between Devon and the Border station.

Table 1. Summaries of 189 time series models resulting from analyses of **monthly data only** collected among three stations on the North Saskatchewan River, for the years 1978 - 1989 (see Figures 1-21, Appendix D).

Variable	Station	Number of Indep. Samples	Years to Detect 10% Trend	10% Trend Size, Units[1]	Years to Ratio = 1[2]
ALKTOT	Devon	5	9	12.46	14
	Pakan	7	10	12.76	14
	Border	8	15	13.02	14
BDISS	Devon	3	1000	0.004	29
	Pakan	3	1000	0.005	29
	Border	8	200	0.007	10
DO	Devon	12	5	1.08	7
	Pakan	12	6	1.03	7
	Border	12	13	1.02	7
DOC	Devon	12	404	0.28	14
	Pakan	8	252	0.32	10
	Border	7	237	0.33	14
FCOLI	Devon	12	915	0.76	14
	Pakan	6	8000	28.49	14
	Border	5	8000	2.45	14
HCO3	Devon	7	10	15.15	14
	Pakan	5	12	15.48	14
	Border	5	13	15.76	14
KDISS	Devon	12	43	0.08	7
	Pakan	9	117	0.12	10
	Border	8	74	0.14	14
MGDISS	Devon	7	8	1.24	12
	Pakan	9	8	1.28	9
	Border	8	8	1.32	11
NADISS	Devon	12	30	0.04	7
	Pakan	7	55	0.70	12
	Border	12	62	0.86	7
NFR	Devon	7	2000	1.73	14
	Pakan	12	1000	2.25	7
	Border	12	437	1.41	7
NO3NO2	Devon	7	609	0.003	14
	Pakan	7	305	0.03	12
	Border	12	3000	0.04	14
NP	Devon	4	4000	0.008	14
	Pakan	4	3000	0.02	14
	Border	5	628	0.01	17

Variable	Station	Number of Indep. Samples	Years to Detect 10% Trend	10% Trend Size, Units[1]	Years to Ratio = 1[2]
PDISS	Devon	12	142	0.0004	7
	Pakan	12	211	0.007	7
	Border	8	483	0.005	11
PH(F)	Devon	4	2	0.81	14
	Pakan	6	1	0.81	14
	Border	5	3	0.80	17
POC	Devon	6	2000	0.06	14
	Pakan	4	1000	0.09	14
	Border	12	227	0.09	17
PP	Devon	12	1000	0.002	7
	Pakan	7	577	0.005	14
	Border	5	544	0.004	14
PTOT	Devon	12	1000	0.003	7
	Pakan	7	320	0.013	14
	Border	4	324	0.011	19
SO4	Devon	12	9	3.57	7
	Pakan	12	12	4.06	14
	Border	12	14	4.15	7
TCOLI	Devon	3	20,000	5.03	35
	Pakan	6	5000	289.85	14
	Border	5	20,000	16.30	14
TDS	Devon	9	4	17.57	10
	Pakan	12	5	18.92	7
	Border	12	6	19.62	7
TEMP	Devon	5	250	0.81	14
	Pakan	6	221	0.82	14
	Border	8	275	0.81	11

[1] For example, mg per liter.

[2] Ratio = 1, when Trend Size/Residual "background" error = $Tr/\delta_e = 1$.

Table 2. Frequencies of WN and AR(1) models among 21 water quality variables at three monitoring stations on the North Saskatchewan River.

	STATION			
MODEL	**Devon**	**Pakan**	**Border**	**TOTAL**
WN	9	5	7	21
AR(1)	12	16	14	42
Total	21	21	21	63

Table 3. Concordances of time series of water quality variables for all combinations of three monitoring stations on the North Saskatchewan River. For example, NO3NO2 exhibits an AR(1) process at Devon, and also at Pakan but not at the Border station; AKTOT and nine other variables are consistently AR(1) at all three stations.

Devon:Pakan	Devon:Border	Pakan:Border	D:P:B
NO3NO2 [AR(1)]	NADISS [WN]	DOC [AR(1)]	ALKTOT [AR(1)]
PDISS [WN]		FCOLI [AR(1)]	BDISS [AR(1)]
POC [AR(1)]		KDISS [AR(1)]	DO [WN]
		NFR [WN]	HCO3 [AR(1)]
		PP [AR(1)]	MGDISS [AR(1)]
		PTOT [AR(1)]	NP [AR(1)]
		TDS [WN]	PH [AR(1)]
			SO4 [WN]
			TCOLI [AR(1)]
			TEMP [AR(1)]

5. When the time to detection is targetted, allowing for trend size to vary (Table 4), results indicate that 42/63 (67%) variable-location combinations could be assigned a schedule shorter than monthly intervals, i.e. bimonthly or quarterly. Therefore the average annual sampling effort would be reduced by more than 50% and maintain the same level of precision for detecting change in water quality. One such possible alternative schedule for all combinations is shown in Table 4, last column.

Table 4. Trend size, years to detect the given trend and one possible monitoring schedule to detect each trend size for 21 water quality variables at the three long-term monitoring stations on the North Saskatchewan River.

Variable	Station	Num. Indep. Samples / Yr	Trend Size (%)	Tr. Size Units	Years to Detect	Possible Schedule
ALKTOT	Devon	5	7	8.841	14	Bimonthly 1
	Pakan	7	7	9.015	14	Bimonthly 1
	Border	8	10	13.171	14	Bimonthly 1
BDISS	Devon	3	68	0.025	29	Quarterly
	Pakan	3	69	0.034	29	Quarterly
	Border	8	39	0.025	14	Bimonthly 2
DO	Devon	12	9	0.971	7	Monthly
	Pakan	12	9	0.929	7	Monthly
	Border	12	14	1.423	7	Monthly
DOC	Devon	12	53	1.366	14	Bimonthly 2
	Pakan	8	49	1.548	10	Monthly
	Border	7	36	1.202	14	Bimonthly 2
FCOLI	Devon	12	79	4.475	14	Bimonthly 2
	Pakan	6	264	770.811	14	Bimonthly 1
	Border	5	232	78.086	14	Bimonthly 1
HCO3	Devon	7	7	10.735	14	Bimonthly 1
	Pakan	5	7	10.926	14	Bimonthly 1
	Border	5	9	14.319	14	Bimonthly 1
KDISS	Devon	12	25	0.188	7	Monthly
	Pakan	9	33	0.412	14	Bimonthly 2
	Border	8	23	0.305	14	Bimonthly 2
MGDISS	Devon	7	8	0.997	14	Bimonthly 1
	Pakan	9	9	1.198	9	Monthly
	Border	8	8	1.060	14	Bimonthly 1
NADISS	Devon	12	20	0.786	7	Monthly
	Pakan	7	20	1.390	14	Bimonthly 2
	Border	12	29	2.491	7	Monthly
NFR	Devon	7	128	19.519	14	Bimonthly 1
	Pakan	12	126	28.366	7	Monthly
	Border	12	78	10.998	7	Monthly
NO3NO2	Devon	7	60	0.014	14	Bimonthly 2
	Pakan	7	57	0.175	14	Bimonthly 2
	Border	12	117	0.317	14	Bimonthly 2

Variable	Station	Num. Indep. Samples / Yr	Trend Size (%)	Tr. Size Units	Years to Detect	Possible Schedule
NP	Devon	4	112	0.080	14	Bimonthly 2
	Pakan	4	89	11.020	14	Bimonthly 2
	Border	5	73	0.093	14	Bimonthly 1
PDISS	Devon	12	44	0.002	7	Monthly
	Pakan	12	54	0.038	7	Monthly
	Border	8	66	0.032	11	Monthly
PH(F)	Devon	4	3	0.245	14	Bimonthly 1
	Pakan	6	3	0.242	14	Bimonthly 1
	Border	5	4	0.320	24	Bimonthly 2
POC	Devon	6	98	0.491	14	Bimonthly 1
	Pakan	4	84	0.759	14	Bimonthly 2
	Border	12	56	0.502	7	Monthly
PP	Devon	12	144	0.031	7	Monthly
	Pakan	7	58	0.027	14	Bimonthly 2
	Border	5	60	0.023	14	Bimonthly 2
PTOT	Devon	12	127	0.032	7	Monthly
	Pakan	7	47	0.062	14	Bimonthly 1
	Border	4	49	0.054	14	Bimonthly 1
SO4	Devon	12	11	3.923	7	Monthly
	Pakan	12	13	5.273	7	Monthly
	Border	12	14	5.810	7	Monthly
TCOLI	Devon	3	235	123.137	35	Bimonthly 1
	Pakan	6	139	3638.436	14	Bimonthly 1
	Border	5	234	266.306	14	Bimonthly 2
TDS	Devon	9	6	10.544	10	Monthly
	Pakan	12	9	17.032	7	Monthly
	Border	12	9	17.659	7	Monthly
TEMP	Devon	5	41	3.258	14	Bimonthly 1
	Pakan	6	50	4.091	14	Bimonthly 1
	Border	8	50	4.036	11	Monthly

6. These trials have highlighted the fact that setting 10% limits on the size of trend is not practical for possibly 14 of the 21 water quality variables, i.e. all those in Table 1 requiring 30 or more years to detect a 10% linear trend. This obstacle to effectively monitoring for long-term trends leads to another option, namely, determine (i) how many years would be required to detect a linear trend equal to or greater than the magnitude of the residual error (i.e. background noise) in the series

(Table 1) and (ii) how large might be the corresponding trend when these two are equal, i.e. Ratio = Trend size/residual error =1? With exception of TCOLI (Table 4), all variables could enter into a monitoring schedule whereby a trend should be detected within 29 years (with 85% chance [power], and if detected, 90% confidence [1-α] that it is real). The obvious disadvantage is that the size of linear trend predicted to be detected may be quite large, relative to the mean over the series: rather than ca. 1000 yrs to detect a 10% trend in BDISS at Devon and Pakan, we may expect to detect a change of almost 70% within 29 yrs. Again, this may not be a desirable option with respect to "risk" attributable to water quality but it may assist in making decisions regarding priorities and budgeting costs.

5.2 Study Two: PPWB Border Station for the Years, 1974-1991

Tables 5 and 6 present the summaries for the 25 sets of historical monthly data at the PPWB station, years 1974-1991. Conclusions from these results include:

1. The number of independent samples ranged from 1 to 12 (Table 5), while years until a 10% linear trend would be detected varied from 1 to 8815. These extremes emphasize the large amounts of variation among the 25 water quality variables. Fourteen of 25 variables would permit our detecting a 10% change within 22 years, or less, of monthly sampling even though such a schedule would be inefficient for several due to the number of independent samples less than 12, i.e. if $n_e < 12$, observations share redundant information, causing inefficient sampling effort.
2. Table 6 shows the change in years to detection and trend size when we calculate the years to detection when the ratio of trend (T_r) to residual, background error (σ_e) in the time series equals 1, i.e. Ratio = 1. The obvious tradeoff between lengths of monitoring when the trend size is limited to a fixed level, such as 10%, is that monitoring periods become shorter on average. Refer to BDISS (Table 5), and note that 328 years of monthly monitoring is required to detect a 10% change but if we can accept a change in water quality up to about 45% in BDISS (Table 6), we should expect to detect this in approximately 16 years of monthly sampling. However, due to autocorrelation (refer to Appendix F) the number of independent samples, when monthly, are only 5 for BDISS, not 12, if all monitoring events were uncorrelated, i.e. independent. These observations suggest alternative monitoring schedules may be more efficient.

Table 5. Summaries of 125 time series models resulting from analyses of **data collected monthly** at the PPWB Border station, North Saskatchewan River, for the years 1974-1991 (see appendix G, Figures 1-25). Shown are the number of years of monthly sampling to detect a 10% linear trend (from overall mean) and size of 10% trend expressed in measurement units, e.g. mg/l.

Variable	**Number of Independent Samples/Yr.**	**Years to Detect 10% Trend**	**Trend Size, Units**
ALKTOT	8	17	13.38
BDISS	5	328	0.007
CADISS	8	8	4.41
CLDISS	12	180	0.47
COND(F)	6	19	34.43
CUDISS	12	403	0.0003
DO	9	16	1.02
FCOLI	4	6588	1.88
KDISS	9	88	0.15
MGDISS	12	19	1.33
NADISS	11	126	0.94
NFR	7	783	1.43
NO3NO2	12	177	0.03
PDISS	6	676	0.005
PH(L)	7	1	0.81
PH(F)	5	3	0.80
PTOT	4	320	0.01
SO4DISS	12	22	0.41
SPCOND	5	12	35.38
TDS	7	10	19.83
TEMP(F)	6	311	0.81
TN	8	162	0.08
TURB(F)	1	8815	1.29
TURB(L)	6	807	0.98
ZNTOT	12	250	0.0005

Table 6. Years of **monthly sampling** to detect linear trend size when Ratio = $Tr/\sigma_e = 1$, for 25 water quality variables analyzed at the PPWB border station on the North Saskatchewan River.

Variable	Number of Independent Samples/ Yr.	Trend Size, Percent of Mean	Trend Size Units	Years to Ratio=1
ALKTOT	8	12.4	16.59	11
BDISS	5	45.4	0.03	16
CADISS	8	8.5	3.75	11
CLDISS	12	50.0	2.34	7
COND(F)	6	11.0	37.87	16
CUDISS	12	74.9	0.002	7
DO	9	12.8	1.30	10
FÇOLI	4	177.6	33.33	21
KDISS	9	30.7	0.45	9
MGDISS	12	16.1	2.14	7
NADISS	11	32.1	3.01	12
NFR	7	79.2	11.29	12
NO3NO2	12	156.9	0.52	7
PDISS	6	71.3	.03	13
PH(L)	7	2.9	0.23	13
PH(F)	5	3.9	0.31	19
PTOT	4	37.6	0.04	23
SO4DIS	12	17.5	7.23	7
SPCOND	5	8.8	31.14	16
TDS	7	9.1	18.05	12
TEMP(F)	6	47.8	3.87	14
TN	8	37.6	0.28	11
TURB(F)	1	82.6	10.69	129
TURB(L)	6	72.0	7.07	16
ZNTOT	12	59.0	0.003	7

3. In addition to fitting monthly data for these 25 variables, recall that four other possible schemes were evaluated, based on subsets representing: bimonthly 1 (January), bimonthly 2 (February) and Quarterly, 1 and 2, beginning in January and February, respectively (see Appendix F for summary statistics). One set of possible alternative monitoring schedules are listed in Table 7. Referring again, for example, to BDISS (see also Figure 2, Appendix G), note that when we account for the autocorrelation in the series, and thus the reduction in independent samples, a quarterly schedule

beginning in January should permit detecting a linear trend of 44% of the mean within 22 years (when Ratio = 1). Similar options can be determined for the remaining 24 variables: note that 5 of 25 variables could continue to be on a monthly schedule and a reasonable number of years to detection, but possibly, unacceptable levels of departure from the long-term mean, e.g. NO3NO2, 157% trend size, 7 years to detection. Note that while NFR exhibits only 7 independent samples/yr, reducing the sampling frequency would result in time to detection of ≥22 years vs. 12 yr.

4. Further observations (Table 8) suggest that implementing this one possible monitoring schedule could result in an average, annual reduction in sampling effort of approximately 47%.
5. If annual monitoring budgets were reviewed with these results, we can conclude that reductions are possible while maintaining the same or greater precision for detecting long-term trends in water quality of the North Saskatchewan River. Reductions in sampling efforts must be weighed by the importance of individual analytes and their analytical costs. Smith, et al. (1989), in designing monitoring programs for rivers and lakes in New Zealand, describe one agency's philosophy for choosing a limited number of analytes representing likely changes among correlated surrogates. Efforts are now underway to study the multivariate associations among the variables analyzed for the North Saskatchewan River.
6. Twenty of twenty-five (80%) of the variables at the PPWB station (Table 8) could be possibly sampled less frequently than monthly: 10 bimonthly, 10 quarterly. Because our analyses adjusted for major sources of error, i.e. flow, season and trend, there are likely other exogenous factors unaccounted for because we have revealed two-fold disparities between the two forms of bimonthly and quarterly sampling schedules. We presently have no explanation for why sampling schedules beginning in January or February should produce such large differences in numbers. There is obviously time dependent structure in the water column, independent of flow, seasons and trend, which affects the strength of autocorrelation and levels of residual error upon which sample sizes are strongly influenced.

Table 7. **One possible alternative sampling schedule** at the PPWB border station on the North Saskatchewan River.

Variable	Number Independent Samples/Yr	Trend Size, Percent Mean	Trend Size, Units	Years to Detect Trend	Possible Sampling Schedule
ALKTOT	6	10	13.21	10	Bimonthly1
BDISS	4	44	0.03	22	Quarterly1
CADISS	6	11	4.86	8	Bimonthly1
CLDISS	12	50	2.34	7	Monthly
COND(F)	2	13	44.70	16	Quarterly2
CUDISS	12	75	0.002	7	Monthly
DO	6	11	1.11	14	Bimonthly2
FCOLI	4	160	7.38	22	Quarterly1
KDISS	6	29	0.42	14	Bimonthly2
MGDISS	4	11	1.48	12	Quarterly2
NADISS	7	31	2.86	14	Bimonthly1
NFR	7	79	11.26	12	Monthly
NO3NO2	12	157	0.52	7	Monthly
PDISS	6	73	0.04	14	Bimonthly1
PH(L)	4	10	0.80	1	Quarterly1
PH(F)	4	10	0.81	3	Quarterly2
PTOT	6	46	0.04	14	Bimonthly1
SO4DIS	4	11	4.66	21	Quarterly2
SPCOND	4	12	43.03	12	Quarterly2
TDS	6	11	21.77	8	Bimonthly1
TEMP(F)	4	52	4.19	22	Quarterly2
TN	6	34	0.26	14	Bimonthly2
TURB(F)	4	63	6.75	22	Quarterly2
TURB(L)	4	69	6.51	21	Bimonthly1
ZNTOT	12	59	0.003	7	Monthly

Table 8. Summary of one possible alternative sampling schedule at the PPWB border station on the North Saskatchewan River **grouped by change in sampling effort per year** using the current "Monthly" schedule as basis for comparison.

Variable	**Possible Sampling Schedule**	**Change in Sampling Effort (%)**
CLDISS	Monthly	0
CUDISS	Monthly	0
NFR	Monthly	0
NO3NO2	Monthly	0
ZNTOT	Monthly	0
ALKTOT	Bimonthly1	-50
CADISS	Bimonthly1	-50
NADISS	Bimonthly1	-50
PDISS	Bimonthly1	-50
PTOT	Bimonthly1	-50
TDS	Bimonthly1	-50
TRUB(L)	Bimonthly1	-50
DO	Bimonthly2	-50
KDISS	Bimonthly2	-50
TN	Bimonthly2	-50
BDISS	Quarterly1	-67
FCOLI	Quarterly1	-67
PH(L)	Quarterly1	-67
COND(F)	Quarterly2	-67
MGDISS	Quarterly2	-67
PH(F)	Quarterly2	-67
SO4DIS	Quarterly2	-67
SPCOND	Quarterly2	-67
TEMP(F)	Quarterly2	-67
TURB(F)	Quarterly2	-67
Overall	**Monthly=5** **Bimonthly1=7** **Bimonthly2=3** **Quarterly1=3** **Quarterly2=7**	**Average Yearly Reduction in Sampling Effort over 25 Variables: (160-300/300)100=47%**

6 POSSIBLE ALTERNATIVE MONITORING SCHEDULES: APPLYING THE INFORMATION CONTAINED IN THIS REPORT

We have presented in Tables 4 and 7 alternative monitoring programs which represent only one possible scheme for each water quality variable. Here we describe to the clients ways which they might further use and evaluate the information contained in this report; we do not present this discussion for each "Study" because the approach is applicable to each.

For illustrative purposes, we will refer to Appendix D (Figs 1a - 21a) and Appendix E, containing the number of years to detect a linear trend when the trend size is equal to or greater than the background variation, i.e. Ratio=1. Here we discuss two alternative approaches which depend on how an agency might set water quality objectives.

Alternative 1. Set the desired trend size (as percent of the overall series mean, Appendix C) and let the years of monitoring vary for each water quality variable. We use total alkalinity (ALTOT) and dissolved boron (BDISS) at Devon for examples (see Appendix D, Figs 1a, 2a), and we will **assume that the objective is to detect a 20% linear trend.**

(i) The table underneath Fig 1a, shows the number of years to detection plotted for trend sizes varying from 5-30%. For a pre-set trend size of 20%, and "monthly" monitoring, we should detect a trend of ≥20% within 2 years.

(ii) However, now refer to the box in the upper right corner of the graph and see that "monthly" sampling has only 5 independent samples per year, not 12, owing to the fact there is serial correlation among months. This suggests we could switch to bimonthly monitoring, or 6 samples per year.

(iii) Again, in the box, we note "bimonthly1" has 6 independent samples per year, meaning no serial correlation among samples collected every other month, beginning in January. We should be able to detect a 20% trend within 2 years, at the same level of precision, with α=0.10 and power=0.85, and thus, 90% confidence that the trend is "real," if detected. We should achieve our objective of 20% trend detection with half the sampling effort per year, compared to the usual monthly scheme, <u>and also</u> have accounted for the serial correlation in the water column by making the decision to convert to bimonthly sampling.

We go now to the BDISS at Devon (Fig 2a Appendix D) and find that "monthly" sampling to detect a 20% trend would require up to 337 years [**note:**(0.337)*(1000)=337 years] and further, serial correlation is present for all three of the schemes evaluated, i.e. monthly (3 of 12), bimonthly1 (2 of 6) and bimonthly2 (2 of 6). Our **objective is not compatible** with the statistical properties associated with the process in BDISS.

(iv) Refer to Appendix E, showing the number of years to detect a trend when Ratio=$TR/\sigma_\varepsilon=1$. From (iii), above, we know that due to serial correlation for the three schemes evaluated, we might as well consider a scheme at Devon which approaches "quarterly" monitoring or even fewer because monthly and bimonthly schemes exhibit only 3 of 12 or 2 of 6 independent observations, respectively.

(v) Because the "monthly" outcome (Fig. 2a) indicates to be nearest to a "quarterly" schedule, i.e. 3 independent observations per year, we will choose a "QuarterlyX" schedule (the X indicates we don't have information from these analyses to choose between January and February start dates).

(vi) In Appendix E, Table 1, for Devon, "monthly" monitoring, we would expect to detect a trend of at least 68% of the series mean of BDISS, by monitoring on a quarterly schedule for 29 years. This outcome would have to be compared with water quality objectives.

(vii) Alternatively, we might choose to review the long-term record for BDISS and select two (2) months of the year (recall, both "bimonthly" schemes, in Fig 2a) which represent critical levels of boron. In this case, refer again to Appendix E, and evaluate the two bimonthly schemes. Starting in January, we could take two samples for 47 years and expect to detect a 71% trend or 48 years and detect a 69% change.

Therefore, the "best" of these alternatives would apparently be to monitor quarterly (vi, above) for 29 years to detect a trend size of at least 68% of the mean.

Alternative 2. Set the desired number of years over all water quality variables and let the trend size vary for each.

(i) Choosing among alternatives for this objective would require the same line of reasoning, as put forth above.

(ii) Let us assume we want to do a complete evaluation of the NSR network every 5 years.

(iii) Refer to ALKTOT, Fig. 1a (Appendix D); look for "5 years" in the table below the graph. For "monthly" we should expect to detect 13% trend within 5 years (5 samples/year), the same for a bimonthly schedule beginning in January, but for bimonthly starting in February, the trend size would increase to 20%: however, only 2 samples per year would be required to achieve this.

Therefore, bimonthly sampling for 5 years beginning in January (total of 6*5=30 samples) would be more efficient than monthly sampling (12*5=60 samples) because only about 6 samples per year are independent. Choosing two (2) months per year for 5 years (2*5=10 samples) would considerably reduce total costs but reduce one's ability to detect smaller sized trends.

(iv) Moving to BDISS at Devon (Fig. 2a), we find we are unable to detect any trend 30% or less within 5 years. Therefore, we may alternatively choose to determine the monitoring schedule allowing us to detect a trend size equal to the background variation.

(v) Refer to Table 1, Appendix E. We could settle for detecting a 68% trend within 29 years of quarterly sampling (referring to "monthly" and recalling that monthly monitoring for BDISS contains only 3 independent samples). Note here that the same outcomes will result as discussed above: the "best" monitoring schedule we could hope to attain for BDISS in the fewest number of years would be some form of quarterly sampling for 29 years. Hence, while we would continue monitoring for BDISS, and assuming the serial correlation and error variance in the NSR water column remained constant over time, we would not anticipate detecting trends smaller than about 68% of the mean until we had gone through about 6 cycles of our monitoring program, i.e. 29 years divided by 5 years per cycle.

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APPENDIX A: STUDY PROPOSAL

APPENDIX A - 2

PROPOSAL FOR REVIEWING SURFACE WATER MONITORING AND SAMPLING FREQUENCY STRATEGIES IN ALBERTA

1 INTRODUCTION

Alberta Environmental Protection (Environmental Quality Monitoring Branch [EQMB]) and the Prairie Provinces Water Board (PPWB) have accumulated monthly monitoring data for 25 water quality parameters over a period of 18 or more years from three or more sampling stations on the North Saskatchewan River (NSR), within Alberta and at the Alberta-Saskatchewan border. Because monitoring costs have continued to increase with small likelihood of increased funding support, together with changes in land use patterns, i.e. point and non-point sources of input, and assay methods, it is important to evaluate this database for purposes of studying revisions to the sampling strategy for the NSR. This evaluation may serve as a model for applying similar strategic, sampling changes to river systems across the province for trend detection and monitoring for compliance to water quality standards.

1.1 Objectives

1.1.1 Descriptive statistics will be computed and combined with graphical analyses of all water quality variables, over space and time.

1.1.2 Spatial and temporal trends will be estimated: (i) seasonally adjusted and (ii) seasonal, combined with flow adjusted, estimates.

1.1.3 Results from numbers 1 and 2, above, will be used to evaluate and recommend alternative statistical sampling methods which can detect annual changes of at least 10% with probability of 85% or more (Type II error, 15% or less) with a nominal Type I error of 10% or less.

2 MATERIALS AND METHODS

2.1 Data files will be supplied by the EQMB and PPWB. Statistical analyses will be done at the Alberta Environmental Centre (AEC), Applied Statistics and Biometrics Section, Vegreville, Alberta, under direction of L.Z. Florence in collaboration with members of the EQMB and PPWB.

2.2 The study will begin April 1, 1993 and final written report completed by September 30, 1993.

2.3 Microcomputer software, for trend analysis, and a 386/25 Mhz IBM-compatible desktop microcomputer, will be supplied by PPWB.

2.4 All statistical analyses, except trend and regression tree analyses, will be done using software available at AEC. Trend analysis software will be supplied by PPWB and regression tree analysis for selecting important subsets of water quality variables (PC-GROUP) will be purchased from Austin Data Management Associates, P.O. Box 4358, Austin, Texas, 78765-9946, USA. The latter is important in order to evaluate the possibility of reducing monitoring costs by sampling only key water quality parameters or homogeneous subsets, based on spatial and/or temporal variation; covariances among a group of 25 variables likely contain structure which can be used to identify subgroups sharing similar amounts of information within but differing between subgroups.

2.5 Current complete databases for the NSR contain data for at least 25 water quality variables sampled on a monthly basis over 18 or more years; these form the core of this study.

2.5.1 Alternative monitoring scenarios will be evaluated for each variable by "systematic sampling" from these data at varying intervals, e.g. bimonthly, quarterly, by season and at varying flow rates over intervals of 5, 10 and 15 years. These results will then be compared to those using the entire core database as "standard" to which alternatives will be compared. Intent will be to identify for each variable a sampling method capable of detecting changes in trend and compliance patterns, at a given location, equal to or greater than 10%. Type I error rate will be set at 0.10 or less, the Type II rate at 0.15 or less and the power (probability of detecting a real change if it is present) at 85% or more.

2.5.2 Simple random and stratified random sampling (spatial and/or temporal) will be evaluated as candidate methods for effectively allocating fixed sampling costs while optimizing information per unit cost (Cochran 1977; Scheaffer et al. 1990).

2.5.3 Time permitting, an attempt will be made to define a method whereby sampling frequency and location(s) may be weighted according to the potential public or biotic "risk" associated with <u>not</u> having obtained data for a particular variable(s): "risk" being conditioned by historical trends and land uses within a sampling unit.

2.6 Statistical methods will largely follow those described in Gilbert (1987) and Helsel and Hirsch (1992). Preliminary analyses of trends for PPWB databases (El-Shaarawi et al. 1991) are available and will complement these sources with respect to methods and presentation of results.

3 PRODUCTS

3.1 A final written report will be prepared for delivery to EQMB and PPWB on or before September 30, 1993. This report will include evaluations and summaries of the methods described in this proposal and recommendations for revising current sampling methods with intent of reducing monitoring costs. Of utmost importance will be to maintain comparable levels of information and detection sensitivity as that contained in the core database which have resulted from the current monthly monitoring program.

4 BUDGET

Item	Cost	Agency
4.1 Manpower: wages, 0.2 myr statistical analyst	$6000	EQMB
4.2 Statistical Software (incl. exchange at 1.25)	625	EQMB
4.3 Report materials and courier costs	NIL	AEC
4.4 Wordprocessing	NIL	AEC
4.5 Statistical supervision and report writing	NIL	AEC
4.6 Travel to conference to present results	2000	AEC
4.7 Travel to PPWB, Regina	700	PPWB
4.8 Loan of 386/25 microcomputer and trend analysis software	NIL	PPWB
TOTAL	$9325	

5 REFERENCES

Cochran, W.G. 1977. Sampling Techniques. John Wiley & Sons, New York.

El-Shaarawi, A.H., S.R. Esterby and J. Yip. 1991. Trend assessment techniques: application to Prairie Provinces Water Board quality data. National Water Research Institute. Burlington, Ontario.

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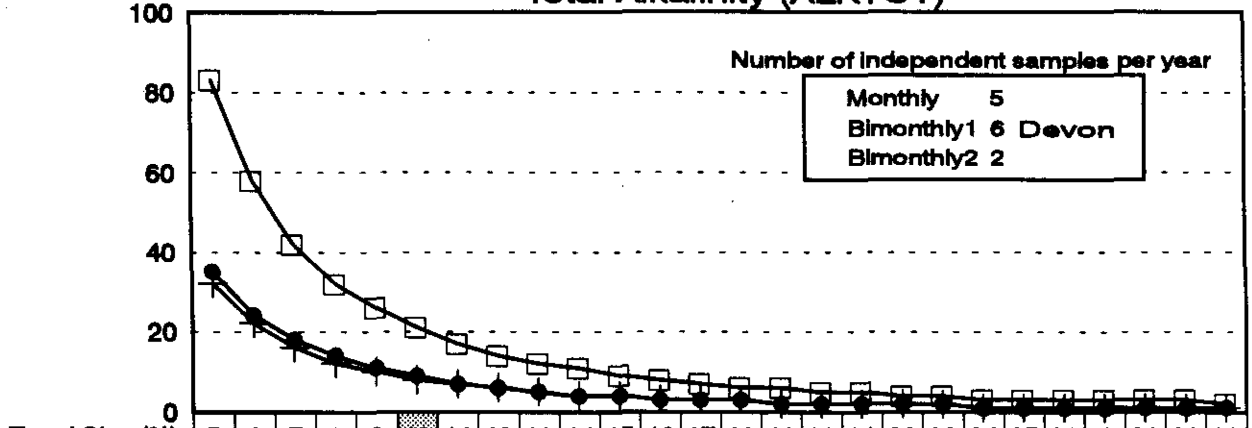
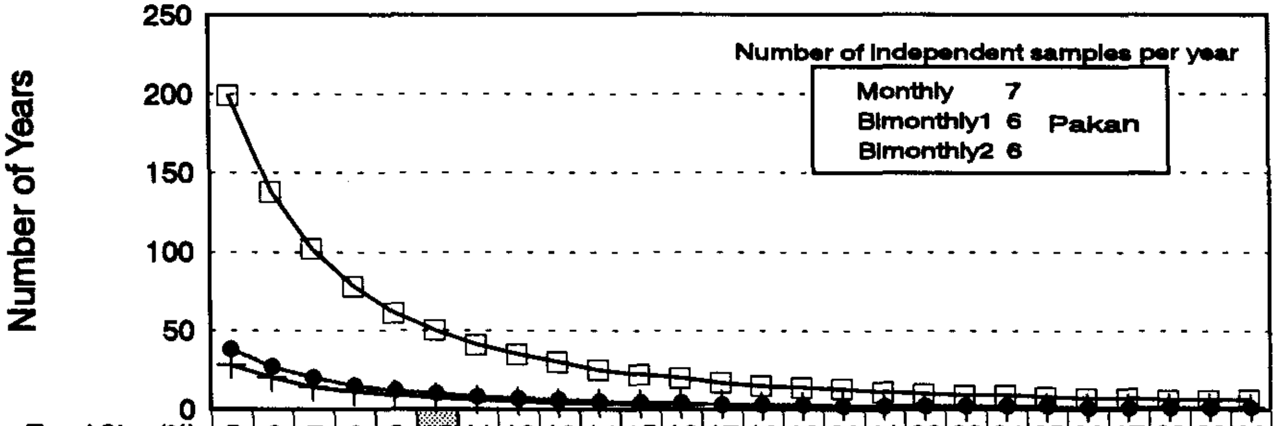
Fig. 1a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

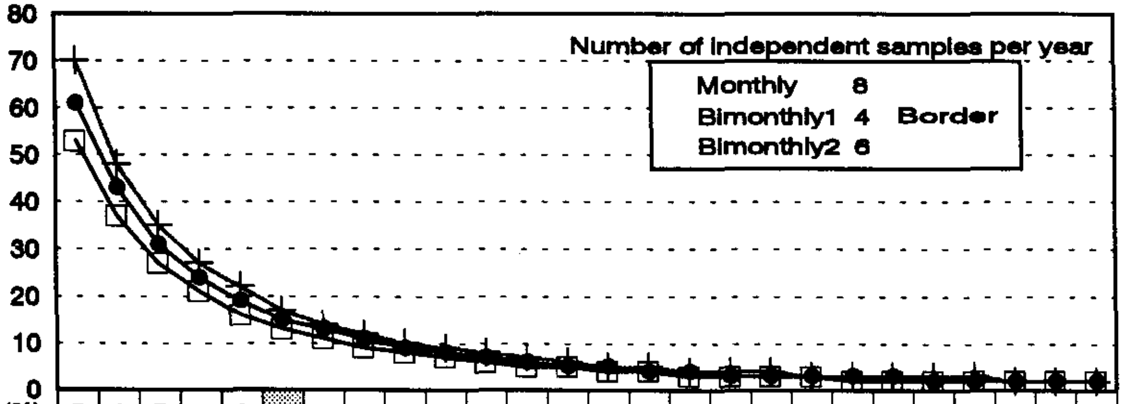
Total Alkalinity (ALKTOT)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	35	24	18	14	11	9	7	6	5	4	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	Years
Bimonthly1 +	32	22	16	12	10	8	7	6	5	4	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	
Bimonthly2 ⊟	83	58	42	32	26	21	17	14	12	11	9	8	7	6	6	5	5	4	4	3	3	3	3	3	3	2	

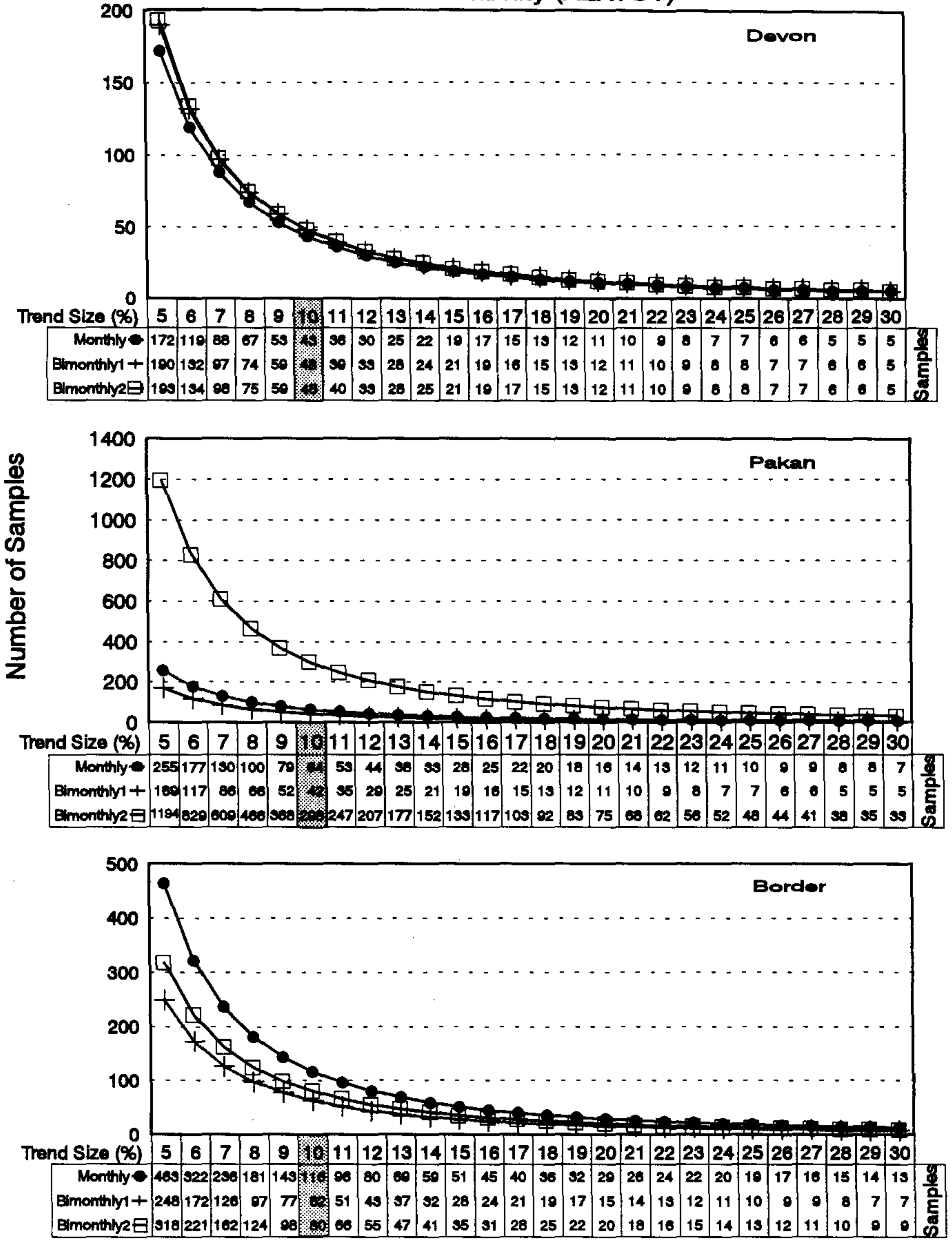


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	38	27	20	15	12	10	8	7	6	5	4	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	Years
Bimonthly1 +	28	20	14	11	9	7	6	5	4	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	
Bimonthly2 ⊟	199	138	102	78	61	50	41	35	30	25	22	20	17	15	14	13	11	10	9	9	8	7	7	6	6	6	



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	61	43	31	24	19	15	13	11	9	8	7	6	5	5	4	4	3	3	3	3	3	2	2	2	2	2	Years
Bimonthly1 +	70	48	35	27	22	17	14	12	10	9	8	7	6	5	5	4	4	4	3	3	3	3	3	2	2	2	
Bimonthly2 ⊟	53	37	27	21	16	13	11	9	8	7	6	5	5	4	4	3	3	3	3	2	2	2	2	2	2	2	

Fig. 1b. Number of Independent Samples to Detect a Linear Trend (%)
For Three Monitoring Schemes
Total Alkalinity (ALKTOT)



Devon

Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	172	119	88	67	53	43	36	30	25	22	19	17	15	13	12	11	10	9	8	7	7	6	6	5	5	5
Bimonthly1 +	190	132	97	74	59	48	39	33	28	24	21	19	16	15	13	12	11	10	9	8	8	7	7	6	6	5
Bimonthly2 ⊟	193	134	98	75	59	48	40	33	28	25	21	19	17	15	13	12	11	10	9	8	8	7	7	6	6	5

Samples

Pakan

Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	255	177	130	100	79	64	53	44	38	33	28	25	22	20	18	16	14	13	12	11	10	9	9	8	8	7
Bimonthly1 +	169	117	86	66	52	42	35	29	25	21	19	16	15	13	12	11	10	9	8	7	7	6	6	5	5	5
Bimonthly2 ⊟	1194	829	609	466	368	298	247	207	177	152	133	117	103	92	83	75	68	62	56	52	48	44	41	38	35	33

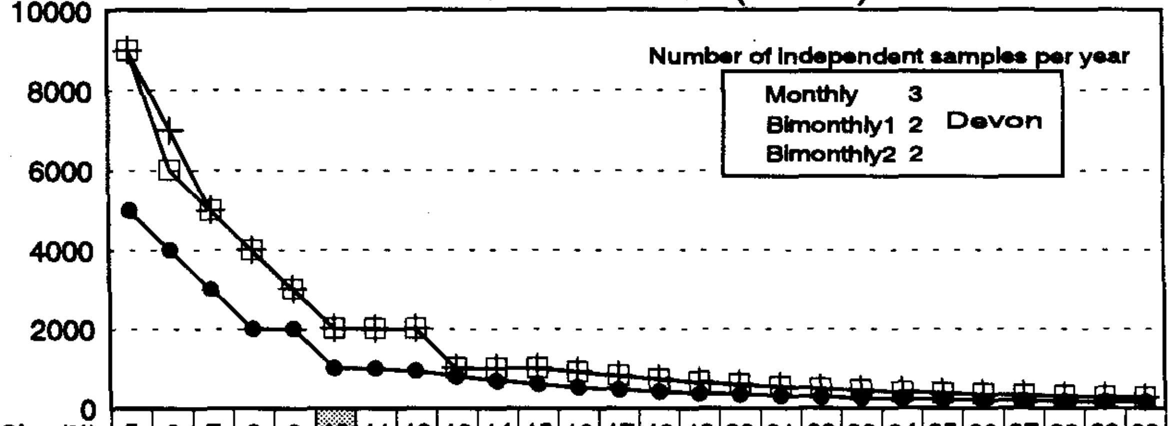
Samples

Border

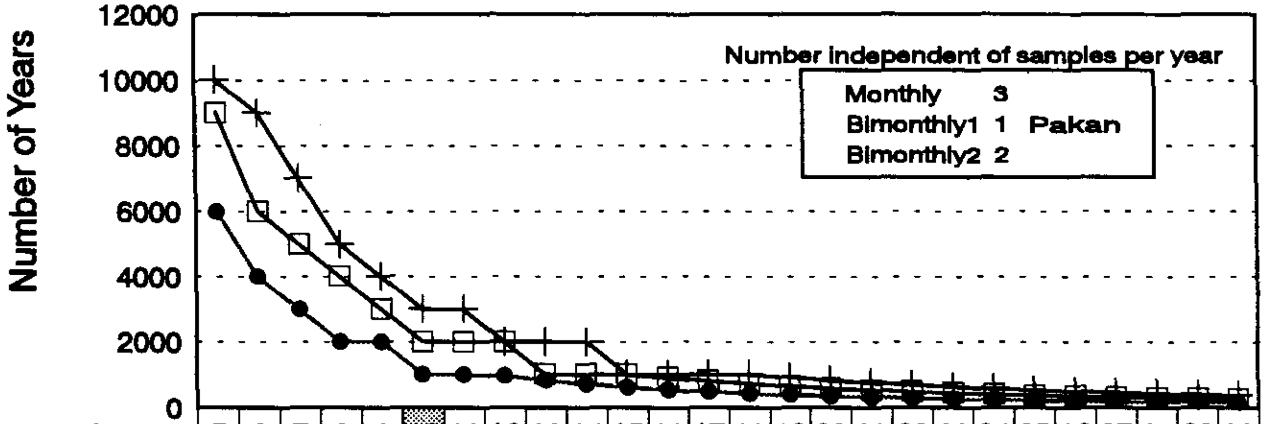
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	463	322	236	181	143	116	96	80	69	59	51	45	40	36	32	29	26	24	22	20	19	17	16	15	14	13
Bimonthly1 +	248	172	126	97	77	82	51	43	37	32	28	24	21	19	17	15	14	13	12	11	10	9	9	8	7	7
Bimonthly2 ⊟	318	221	162	124	98	80	66	55	47	41	35	31	28	25	22	20	18	16	15	14	13	12	11	10	9	9

Samples

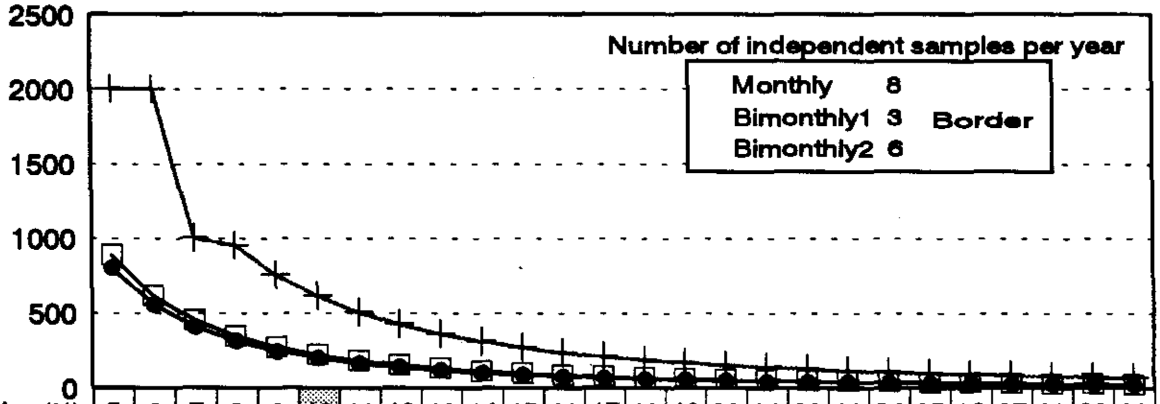
Fig. 2a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes Boron Dissolved (BDISS)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	5000	4000	3000	2000	2000	1000	1000	936	798	688	599	527	466	416	373	337	306	276	255	234	216	199	185	172	160	150	Years
Bimonthly1 +	9000	7000	5000	4000	3000	2000	2000	2000	1000	1000	1000	917	812	724	650	587	532	485	443	407	375	347	322	299	279	261	
Bimonthly2 ⊟	9000	6000	5000	4000	3000	2000	2000	2000	1000	1000	1000	910	806	719	645	583	528	481	440	404	372	344	319	297	277	259	



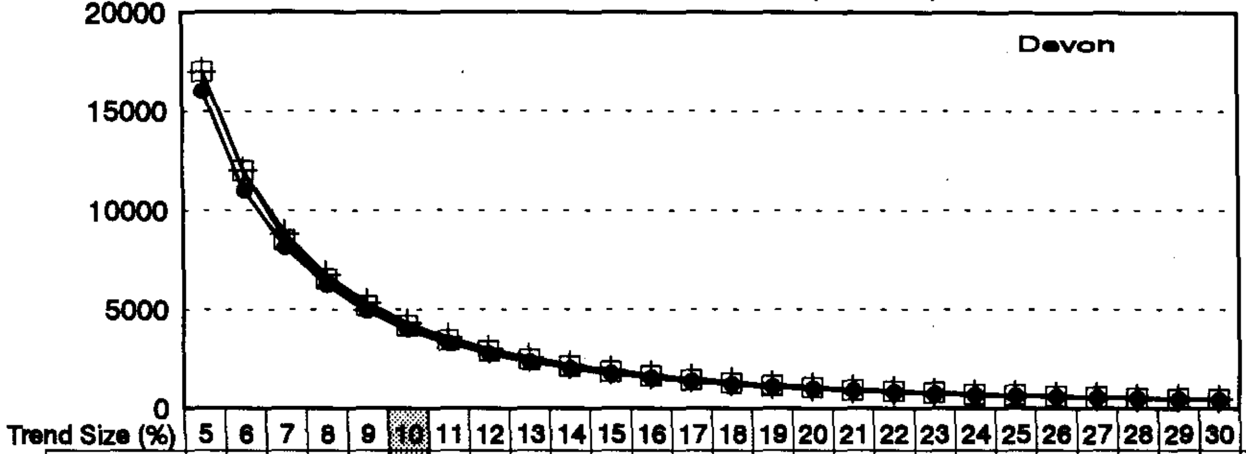
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	6000	4000	3000	2000	2000	1000	1000	964	822	708	617	542	481	429	385	347	315	287	262	241	222	205	191	177	165	154	Years
Bimonthly1 +	10000	9000	7000	5000	4000	3000	3000	2000	2000	2000	1000	1000	1000	1000	918	828	752	685	626	576	531	490	454	423	394	368	
Bimonthly2 ⊟	9000	6000	5000	4000	3000	2000	2000	2000	1000	1000	1000	913	809	722	648	584	530	483	442	406	374	346	321	298	278	260	



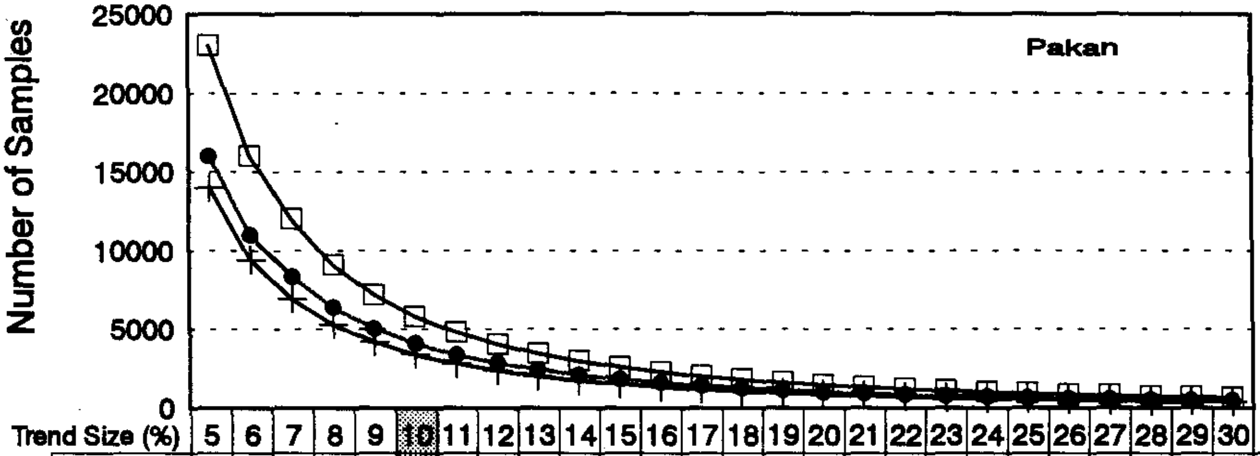
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	801	556	409	313	247	200	165	139	118	102	89	78	69	62	55	50	45	41	38	35	32	30	28	25	24	22	Years
Bimonthly1 +	2000	2000	1000	951	752	609	503	423	360	311	271	236	211	188	169	152	136	126	115	106	97	90	84	78	72	68	
Bimonthly2 ⊟	885	615	452	346	273	221	183	154	131	113	98	87	77	68	61	55	50	46	42	39	35	33	30	28	26	25	

Fig. 2b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

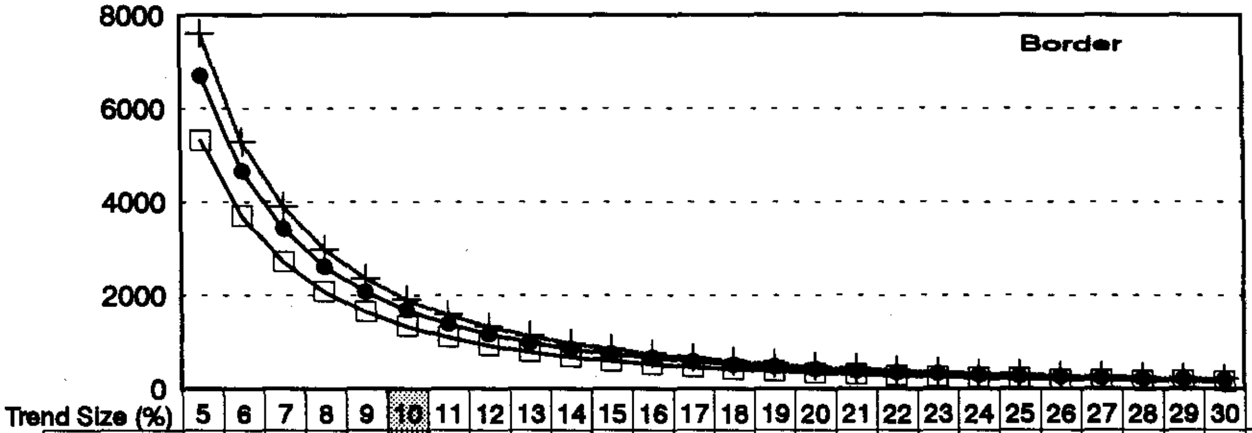
Boron Dissolved (BDISS)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	16000	11000	8113	6211	4906	[illegible]	3265	2761	2352	2028	1767	1553	1375	1227	1101	994	901	821	751	690	636	588	545	507	473	442	Samples
Bimonthly1 +	17000	12000	8761	6723	5312	[illegible]	3558	2988	2546	2195	1912	1681	1489	1328	1192	1076	976	889	813	747	688	636	590	549	512	478	
Bimonthly2 ⊟	17000	12000	8466	6497	5133	[illegible]	3436	2888	2460	2121	1848	1624	1439	1283	1152	1040	943	859	786	722	665	615	570	530	494	462	



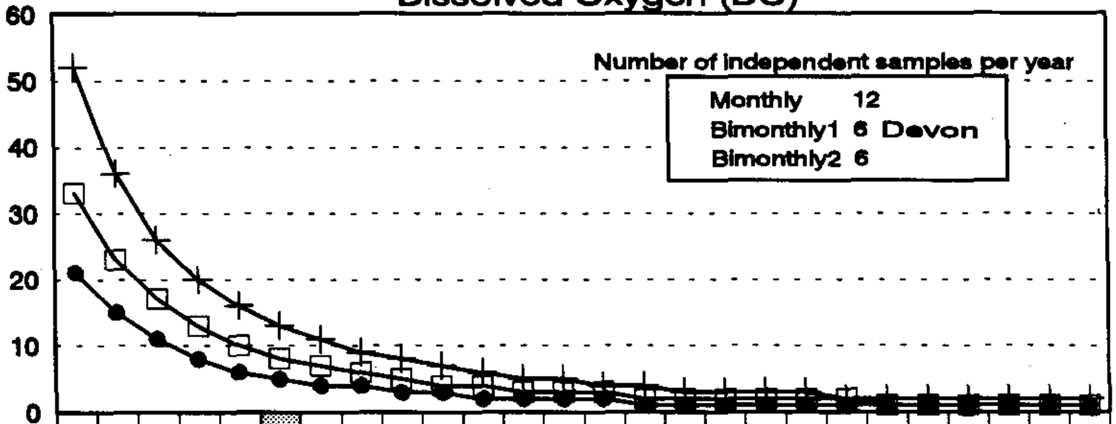
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	16000	11000	8356	6397	5055	[illegible]	3384	2843	2423	2089	1820	1599	1417	1264	1134	1024	928	846	774	711	655	606	562	522	487	455	Samples
Bimonthly1 +	14000	9405	6910	5291	4180	[illegible]	2798	2351	2004	1728	1505	1323	1172	1045	938	846	768	700	640	588	542	501	464	432	403	376	
Bimonthly2 ⊟	23000	16000	12000	9096	7187	[illegible]	4811	4043	3445	2970	2587	2274	2014	1797	1613	1455	1320	1203	1100	1011	931	861	799	743	692	647	



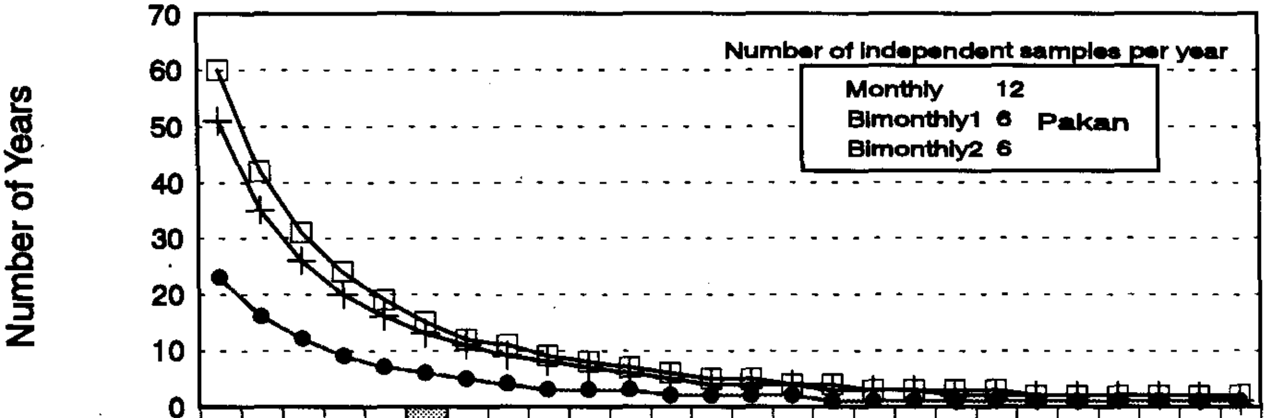
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	6695	4650	3416	2615	2066	1674	1383	1162	990	854	744	654	579	517	464	418	380	346	316	291	268	248	230	213	199	186	Samples
Bimonthly1 +	7606	5282	3881	2971	2348	[illegible]	1571	1320	1125	970	845	743	658	587	527	475	431	393	359	330	304	281	261	243	226	211	
Bimonthly2 ⊟	5312	3689	2710	2075	1640	[illegible]	1098	922	786	678	590	519	460	410	368	332	301	274	251	231	212	196	182	169	158	148	

Fig. 3a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

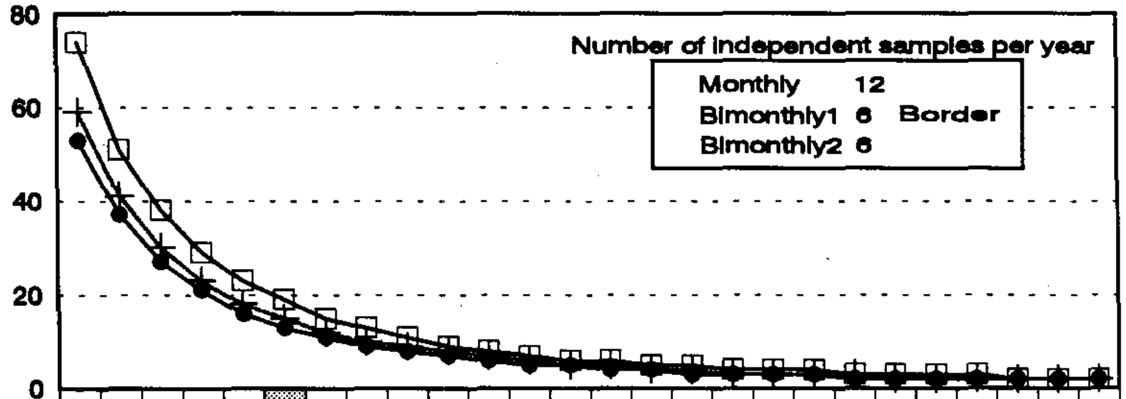
Dissolved Oxygen (DO)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	21	15	11	8	6	5	4	4	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	Years
Bimonthly1 +	52	36	26	20	16	13	11	9	8	7	6	5	5	4	4	3	3	3	3	2	2	2	2	2	2	2	
Bimonthly2 ⊟	33	23	17	13	10	8	7	6	5	4	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1	



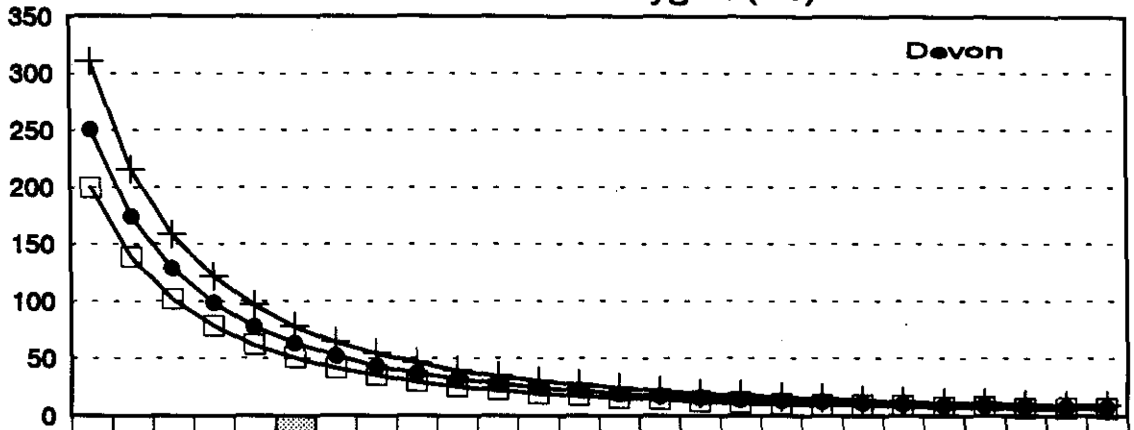
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	23	16	12	9	7	6	5	4	3	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	Years
Bimonthly1 +	51	35	26	20	16	13	11	9	8	7	6	5	4	4	4	3	3	3	2	2	2	2	2	2	2	1	
Bimonthly2 ⊟	60	42	31	24	19	15	12	11	9	8	7	6	5	5	4	4	3	3	3	3	2	2	2	2	2	2	



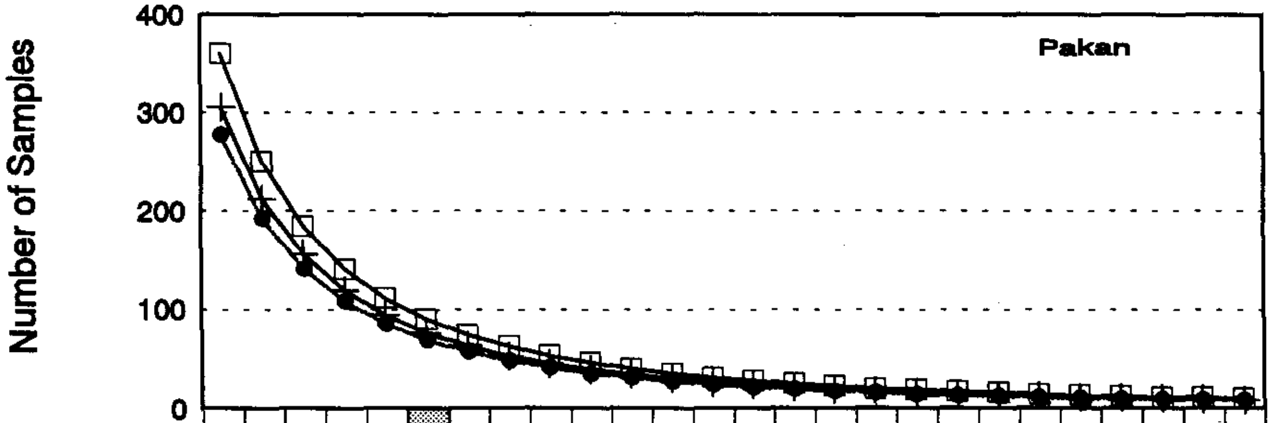
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	53	37	27	21	16	13	11	9	8	7	6	5	5	4	4	3	3	3	3	2	2	2	2	2	2	2	Years
Bimonthly1 +	59	41	30	23	18	15	12	10	9	8	7	6	5	5	4	4	3	3	3	3	2	2	2	2	2	2	
Bimonthly2 ⊟	74	51	36	29	23	19	15	13	11	9	8	7	6	6	5	5	4	4	4	3	3	3	3	2	2	2	

Fig. 3b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

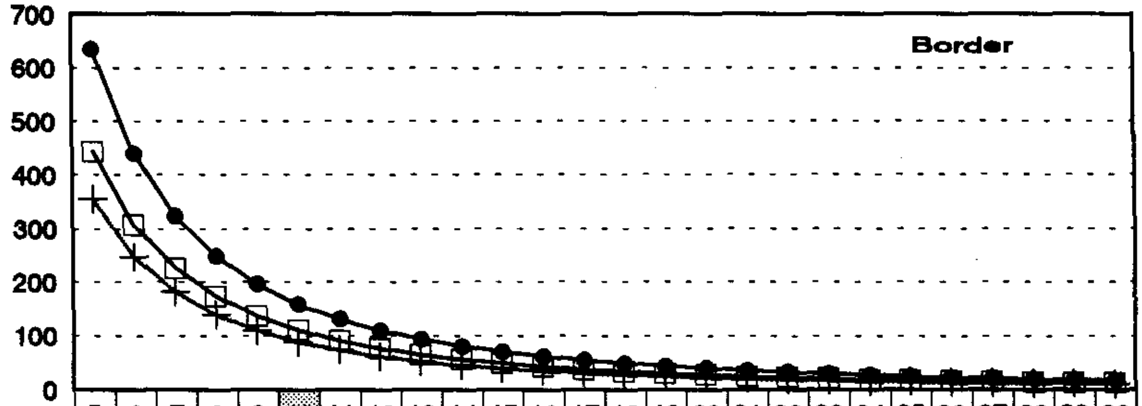
Dissolved Oxygen (D0)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	250	174	128	98	77	63	52	43	37	32	28	24	22	19	17	16	14	13	12	11	10	9	9	8	7	7	Samples
Bimonthly1 +	310	215	158	121	96	77	64	54	46	39	34	30	27	24	21	19	18	16	15	13	12	11	11	10	9	9	
Bimonthly2 ⊟	199	138	101	78	61	50	41	35	29	25	22	19	17	15	14	12	11	10	9	9	8	7	7	6	6	6	

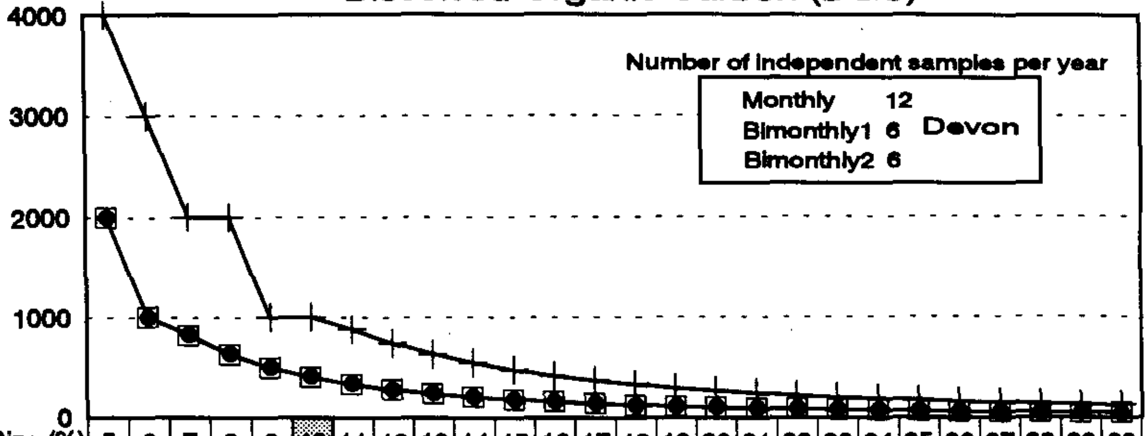


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	277	192	141	108	85	69	57	48	41	35	31	27	24	21	19	17	16	14	13	12	11	10	9	9	8	8	Samples
Bimonthly1 +	305	212	156	119	94	76	63	53	45	39	34	30	26	24	21	19	17	16	14	13	12	11	10	10	9	8	
Bimonthly2 ⊟	360	250	184	141	111	90	74	63	53	46	40	35	31	28	25	23	20	19	17	16	14	13	12	11	11	10	

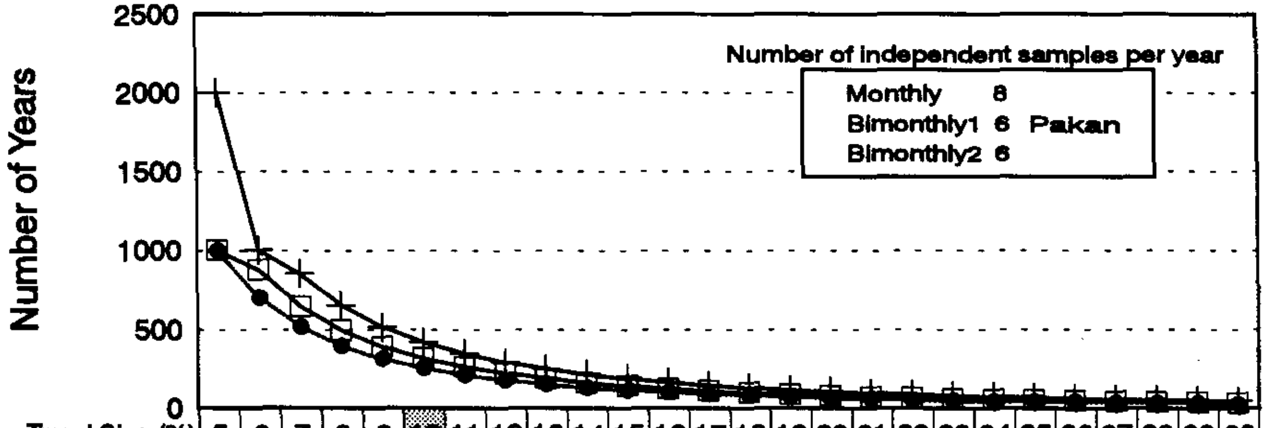


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	634	440	323	248	196	158	131	110	94	81	70	62	55	49	44	40	36	33	30	28	25	23	22	20	19	18	Samples
Bimonthly1 +	354	246	181	138	109	88	73	61	52	45	39	35	31	27	25	22	20	18	17	15	14	13	12	11	11	10	
Bimonthly2 ⊟	443	307	226	173	137	111	91	77	65	56	49	43	38	34	31	28	25	23	21	19	18	16	15	14	13	12	

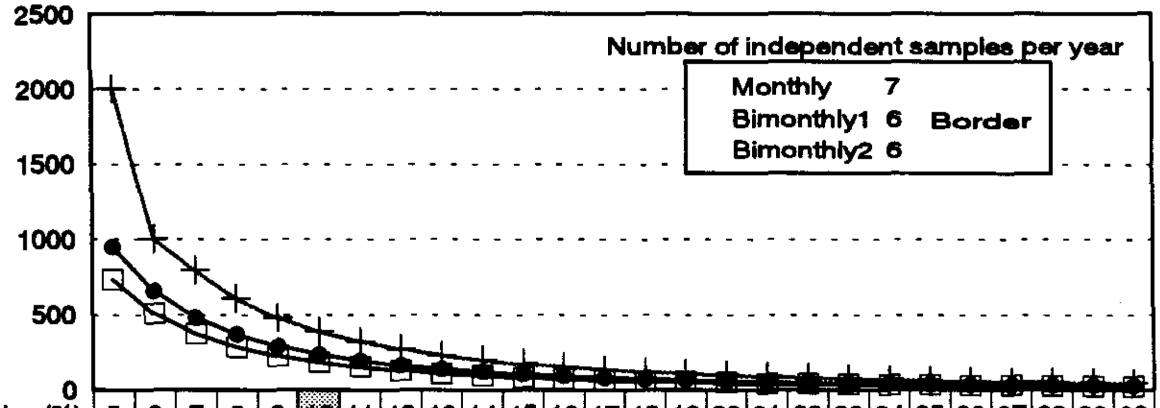
Fig. 4a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes Dissolved Organic Carbon (DOC)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	2000	1000	825	632	499	406	334	281	239	208	180	158	140	125	112	101	92	84	76	70	65	60	55	52	48	45	Years
Bimonthly1 +	4000	3000	2000	2000	1000	1000	883	742	632	545	475	417	370	330	296	267	242	221	202	185	171	158	147	136	127	119	
Bimonthly2 ⊟	2000	1000	818	626	495	401	331	278	237	205	178	157	139	124	111	100	91	83	76	70	64	59	55	51	48	45	



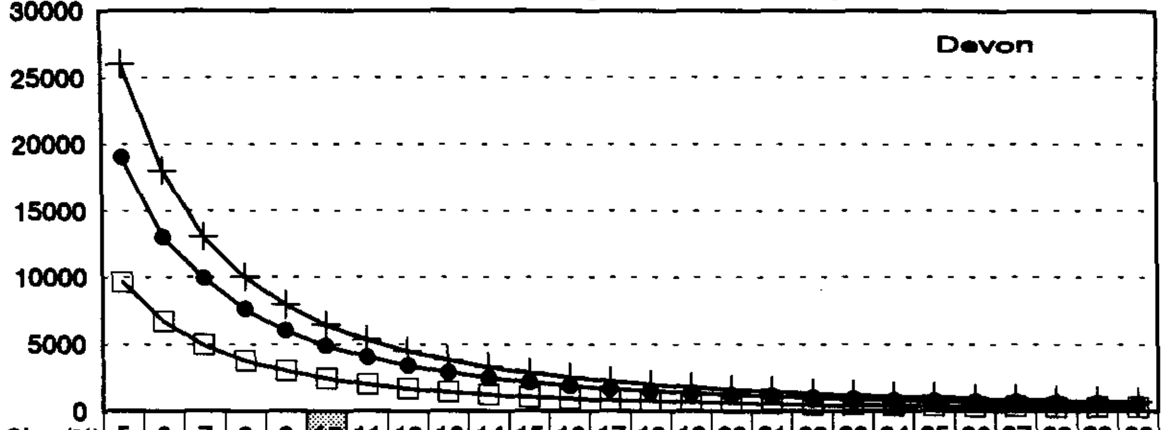
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	1000	699	514	393	311	252	206	175	149	126	112	98	87	78	70	63	57	52	48	44	40	37	35	32	30	28	Years
Bimonthly1 +	2000	1000	850	651	514	417	344	289	247	213	185	163	144	129	115	104	95	86	79	72	67	62	57	53	50	46	
Bimonthly2 ⊟	1000	876	644	493	389	315	261	219	187	161	140	123	109	97	87	79	72	65	60	55	51	47	43	40	38	35	



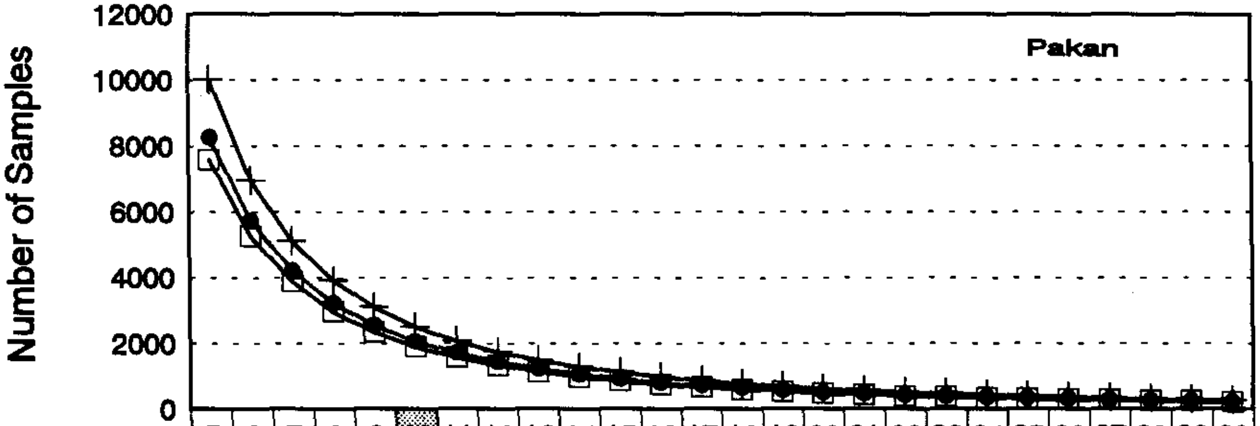
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	947	658	469	370	292	237	196	164	140	121	105	93	82	73	66	59	54	49	45	41	38	35	32	30	28	26	Years
Bimonthly1 +	2000	1000	792	607	479	386	321	270	230	198	173	152	134	120	108	97	88	80	73	67	62	58	53	50	46	43	
Bimonthly2 ⊟	730	507	373	285	225	183	151	127	108	93	81	71	63	56	51	46	41	38	35	32	29	27	25	23	22	20	

Fig. 4b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

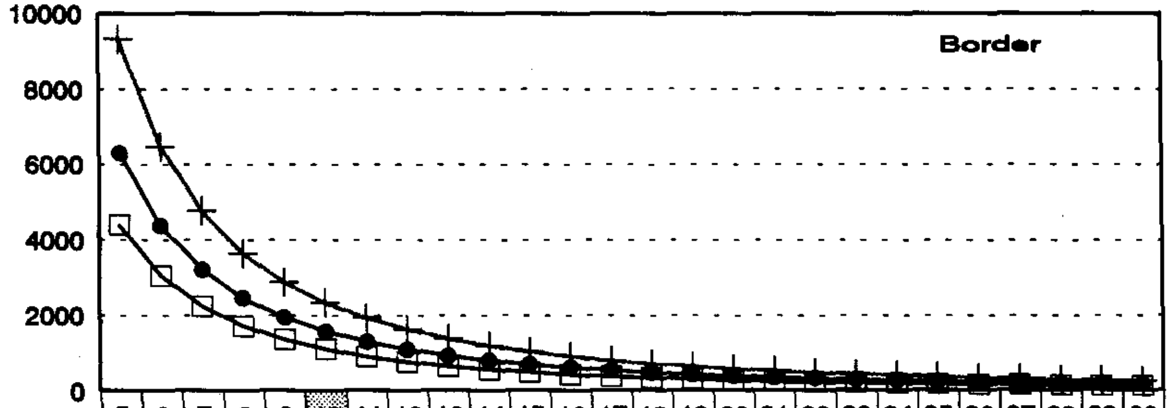
Dissolved Organic Carbon (DOC)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly ●	19000	13000	9896	7576	5988	[illegible]	4008	3366	2870	2475	2156	1895	1676	1467	1344	1213	1100	1002	917	842	776	717	666	619	577	539	
Bimonthly1 +	26000	18000	13000	10000	7911	[illegible]	5296	4450	3792	3269	2846	2503	2217	1976	1775	1602	1453	1324	1211	1112	1025	948	879	817	762	712	
Bimonthly2 ⊟	9616	6676	4906	3756	2968	[illegible]	1987	1670	1423	1227	1068	939	832	742	666	601	545	497	454	417	385	356	330	307	286	267	



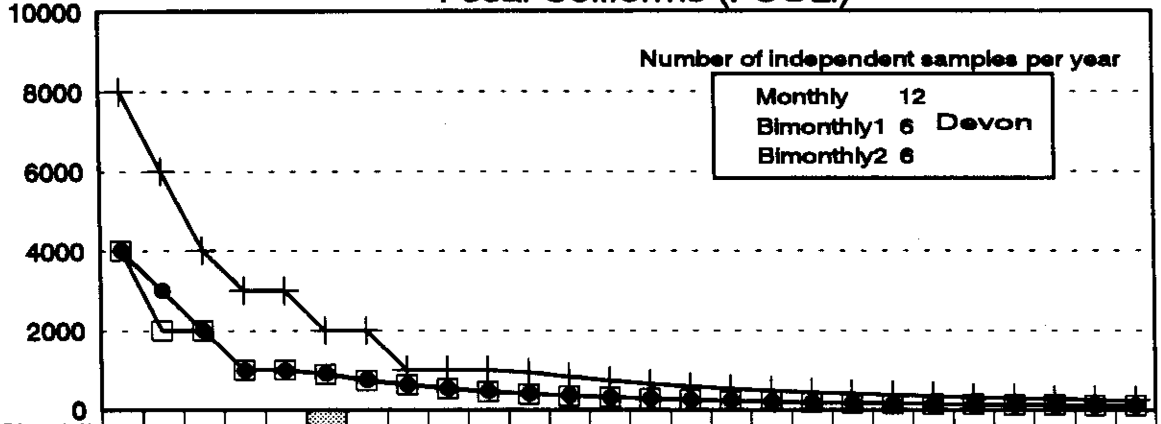
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly ●	8246	5727	4207	3221	2546	[illegible]	1704	1432	1220	1052	916	805	713	636	571	515	467	428	390	358	330	305	283	263	245	229	
Bimonthly1 +	9996	6943	5101	3905	3086	[illegible]	2066	1736	1479	1275	1111	976	865	771	692	625	567	516	472	434	400	370	343	319	297	278	
Bimonthly2 ⊟	7566	5256	3861	2956	2336	[illegible]	1584	1314	1120	966	841	739	655	584	524	473	429	391	358	328	303	280	260	241	225	210	



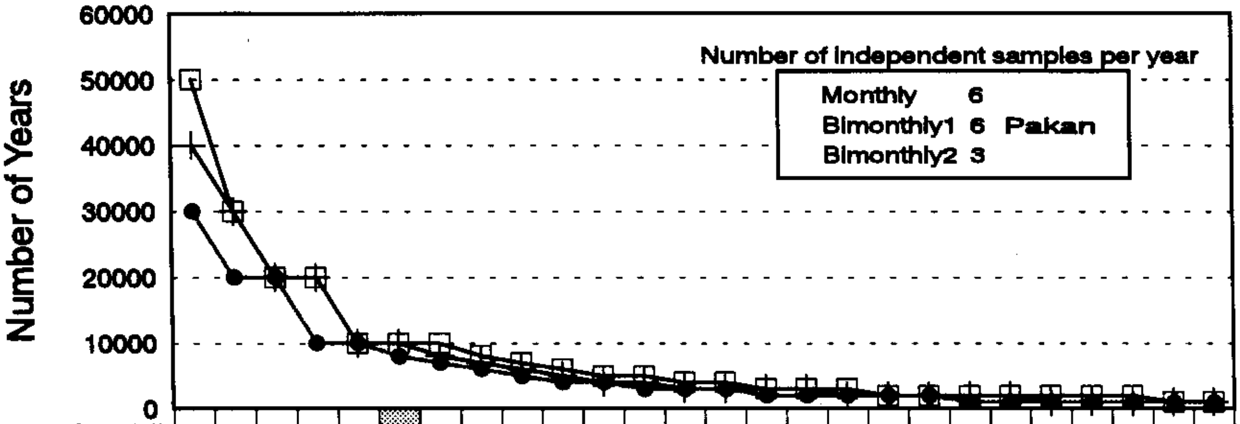
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly ●	6264	4364	3206	2455	1939	1571	1296	1091	930	801	698	614	544	485	435	393	356	325	297	273	251	232	215	200	187	175	
Bimonthly1 +	9316	6471	4754	3640	2876	[illegible]	1925	1618	1376	1186	1035	910	806	719	645	582	526	481	440	404	373	345	320	297	277	259	
Bimonthly2 ⊟	4361	3042	2235	1711	1352	[illegible]	905	761	646	559	487	426	379	336	303	274	248	226	207	190	175	162	150	140	130	122	

Fig. 5a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

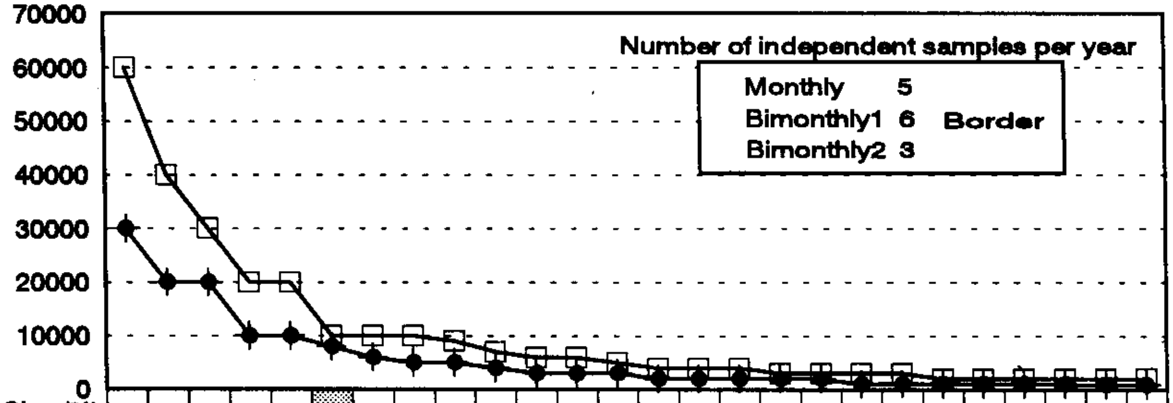
Fecal Coliforms (FCOLI)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	4000	3000	2000	1000	1000	915	766	636	541	467	407	357	317	282	254	229	208	189	173	159	146	135	126	117	109	102	Years
Bimonthly1 +	6000	6000	4000	3000	3000	2000	2000	1000	1000	1000	940	826	732	653	586	529	460	437	400	367	336	313	290	270	252	235	
Bimonthly2 ⊟	4000	2000	2000	1000	1000	[illegible]	739	621	529	456	397	349	309	276	248	224	203	185	169	155	143	132	123	114	106	99	



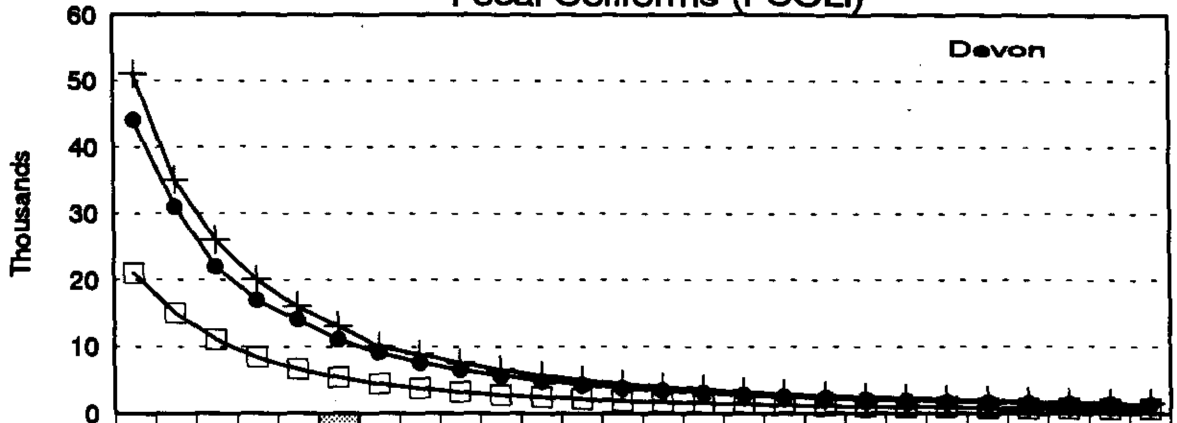
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	30000	20000	20000	10000	10000	8000	7000	6000	5000	4000	4000	3000	3000	3000	2000	2000	2000	2000	2000	1000	1000	1000	1000	1000	970	906	Years
Bimonthly1 +	40000	30000	20000	20000	10000	10000	8000	7000	6000	5000	4000	4000	3000	3000	3000	3000	2000	2000	2000	2000	2000	1000	1000	1000	1000	1000	
Bimonthly2 ⊟	50000	30000	20000	20000	10000	10000	10000	8000	7000	6000	5000	5000	4000	4000	3000	3000	3000	2000	2000	2000	2000	2000	2000	2000	1000	1000	



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	30000	20000	20000	10000	10000	8000	6000	5000	5000	4000	3000	3000	3000	2000	2000	2000	2000	2000	1000	1000	1000	1000	1000	983	917	856	Years
Bimonthly1 +	30000	20000	20000	10000	10000	8000	6000	5000	5000	4000	3000	3000	3000	2000	2000	2000	2000	2000	1000	1000	1000	1000	1000	984	917	857	
Bimonthly2 ⊟	60000	40000	30000	20000	20000	10000	10000	10000	9000	7000	6000	6000	5000	4000	4000	4000	3000	3000	3000	3000	2000	2000	2000	2000	2000	2000	

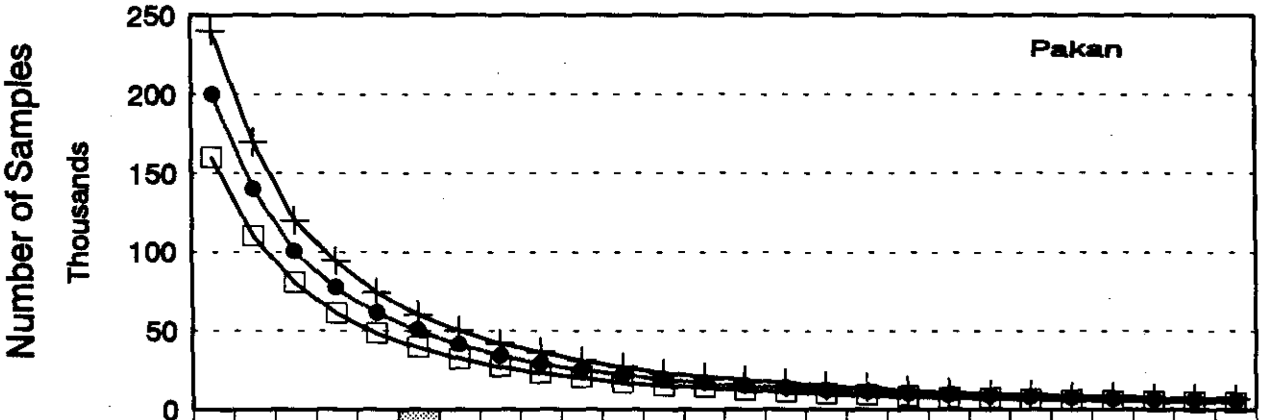
Fig. 5b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

Fecal Coliforms (FCOLI)



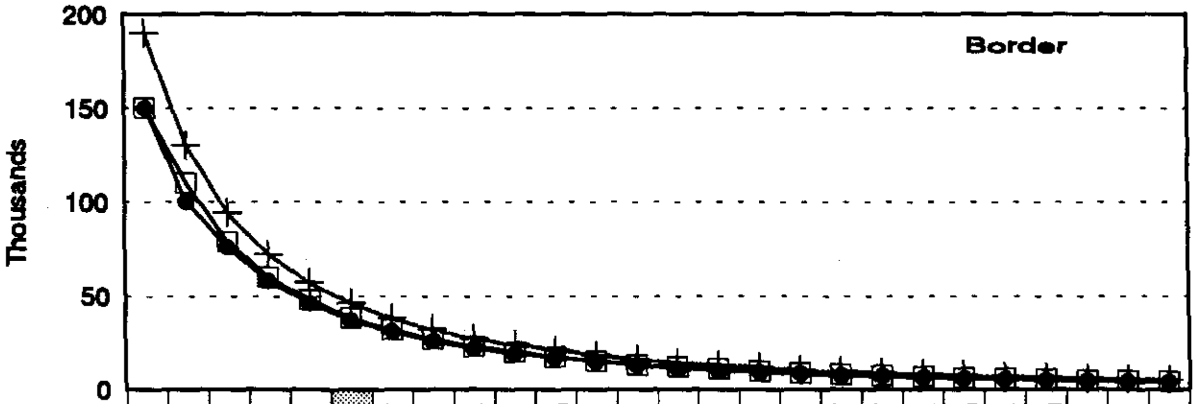
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	44	31	22	17	14	[illegible]	9.075	7.626	6.497	5.602	4.88	4.289	3.8	3.389	3.042	2.745	2.49	2.269	2.076	1.906	1.757	1.624	1.506	1.401	1.306	1.22
Bimonthly1 +	51	35	26	20	16	13	10	8.812	7.509	6.474	5.64	4.957	4.391	3.917	3.515	3.172	2.878	2.622	2.399	2.205	2.03	1.877	1.741	1.619	1.509	1.41
Bimonthly2 ⊟	21	15	11	8.35	6.621	[illegible]	4.432	3.724	3.179	2.739	2.364	2.095	1.866	1.655	1.486	1.341	1.216	1.108	1.014	0.931	0.856	0.793	0.736	0.684	0.636	0.596

Samples



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	200	140	100	77	61	[illegible]	41	34	29	25	22	19	17	15	14	12	11	10	9.386	8.602	7.928	7.33	6.797	6.32	5.892	5.505
Bimonthly1 +	240	170	120	94	74	[illegible]	50	42	36	31	27	23	21	19	17	15	14	12	11	10	9.617	8.892	8.245	7.667	7.147	6.679
Bimonthly2 ⊟	160	110	80	61	48	[illegible]	32	27	23	20	17	15	14	12	11	9.763	8.855	8.068	7.382	6.76	6.248	5.777	5.357	4.981	4.643	4.339

Samples



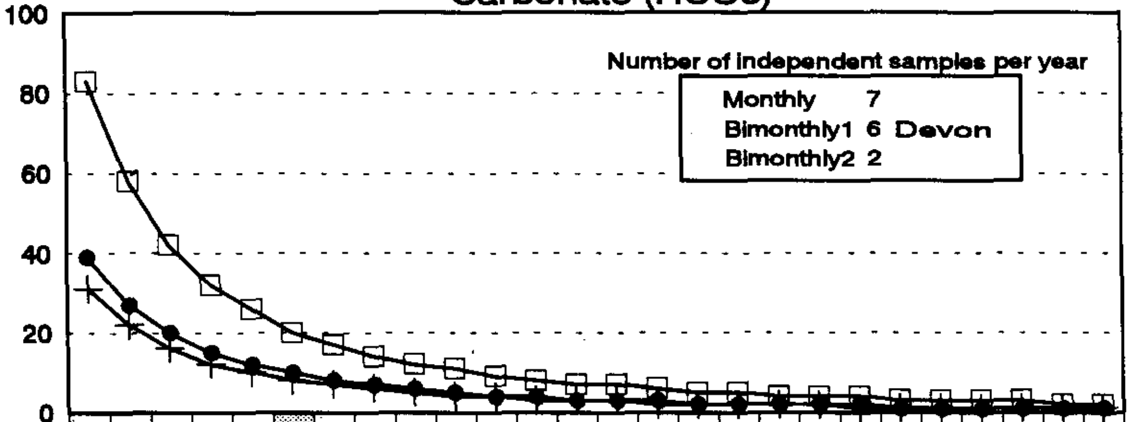
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	150	100	76	58	46	37	31	26	22	19	17	15	13	11	10	9.269	8.425	7.677	7.024	6.451	5.945	5.496	5.097	4.739	4.418	4.128
Bimonthly1 +	190	130	94	72	57	[illegible]	38	32	27	24	21	18	16	14	13	12	10	9.562	8.748	8.034	7.404	6.846	6.348	5.903	5.503	5.142
Bimonthly2 ⊟	150	110	79	60	48	[illegible]	32	27	23	20	17	15	13	12	11	9.62	8.728	7.951	7.274	6.661	6.157	5.693	5.279	4.906	4.576	4.276

Samples

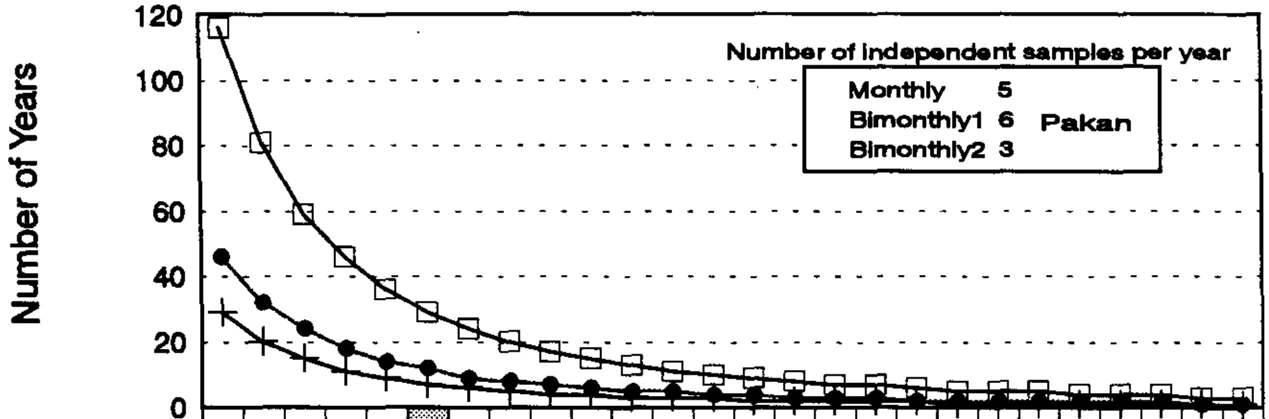
Size of Linear Trend (Percent of baseline value)

Fig. 6a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

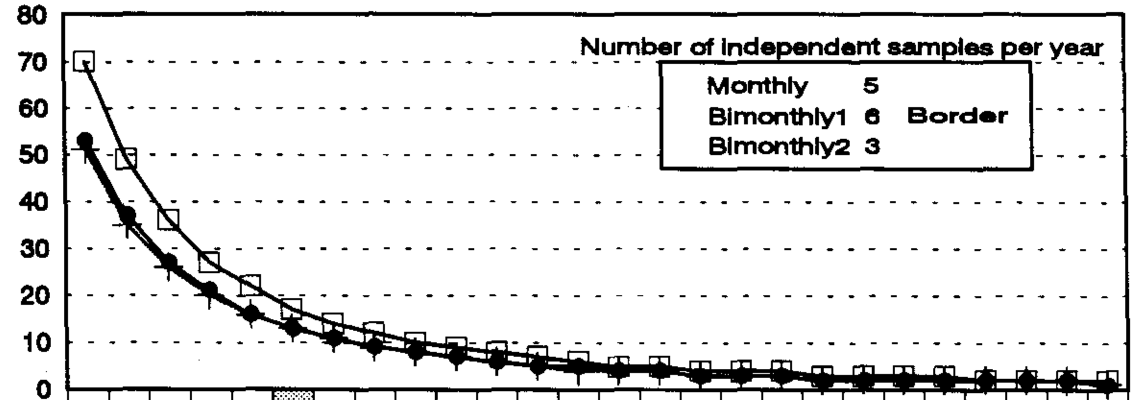
Carbonate (HCO3)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	39	27	20	15	12	10	8	7	6	5	4	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	Years
Bimonthly1 +	31	22	16	12	10	8	7	6	5	4	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	
Bimonthly2 ⊟	83	58	42	32	26	20	17	14	12	11	9	8	7	7	6	5	5	4	4	4	3	3	3	3	2	2	

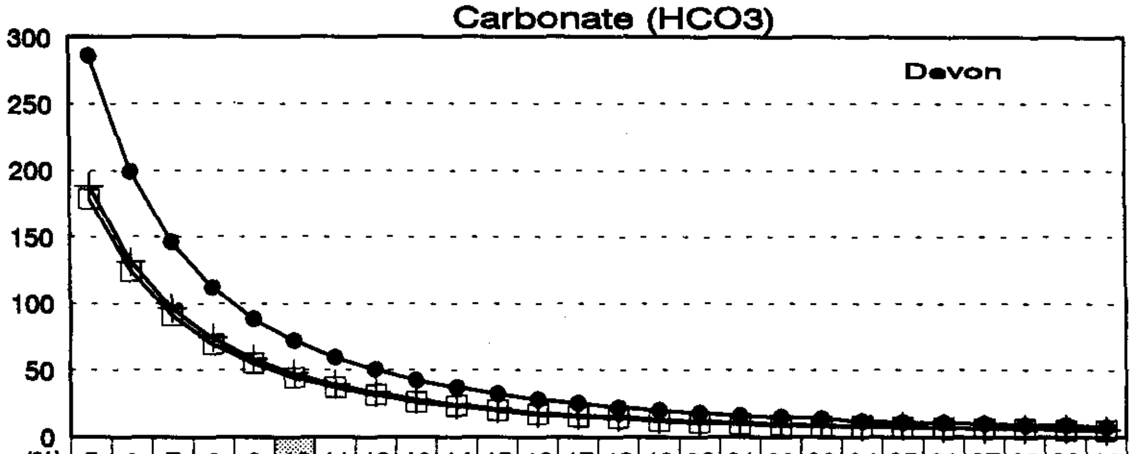


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	46	32	24	18	14	12	9	8	7	6	5	5	4	4	3	3	3	2	2	2	2	2	2	2	1	1	Years
Bimonthly1 +	29	20	15	11	9	7	6	5	4	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	
Bimonthly2 ⊟	116	81	59	46	36	29	24	20	17	15	13	11	10	9	8	7	7	6	5	5	5	4	4	4	3	3	

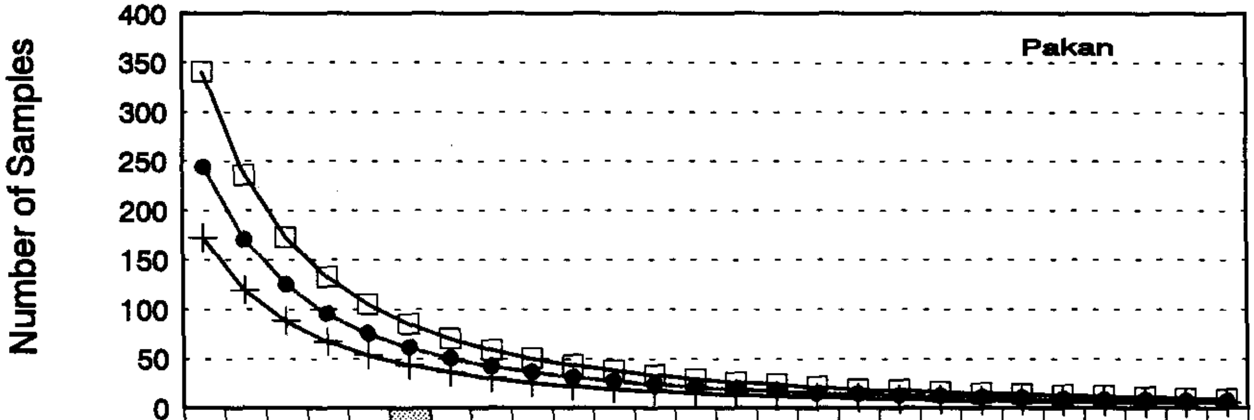


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	53	37	27	21	16	13	11	9	8	7	6	5	5	4	4	3	3	3	2	2	2	2	2	2	2	1	Years
Bimonthly1 +	51	35	26	20	16	13	11	9	8	7	6	5	4	4	4	3	3	3	2	2	2	2	2	2	2	1	
Bimonthly2 ⊟	70	49	36	27	22	17	14	12	10	9	8	7	6	5	5	4	4	4	3	3	3	3	2	2	2	2	

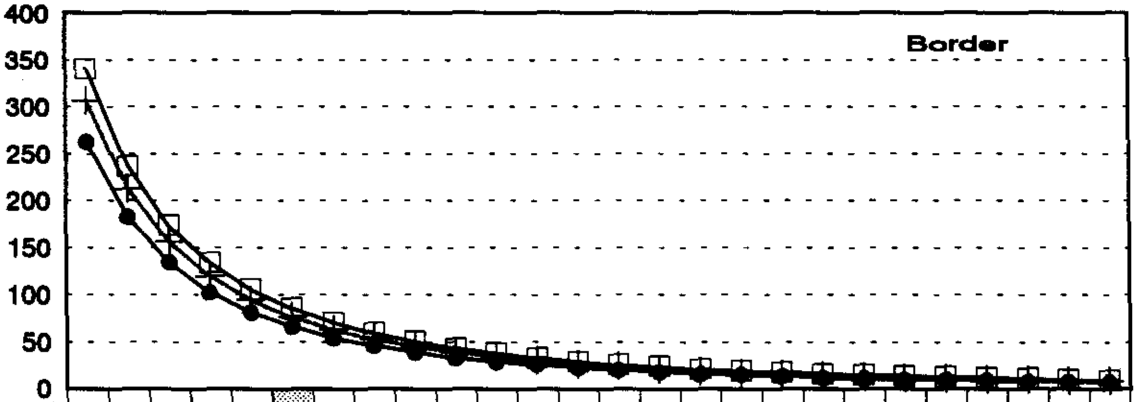
Fig. 6b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	286	199	146	112	88	72	59	50	42	37	32	28	25	22	20	18	16	15	14	12	11	11	10	9	9	8	Samples
Bimonthly1 +	188	131	96	74	58	47	39	33	28	24	21	18	16	15	13	12	11	10	9	8	8	7	6	6	6	5	
Bimonthly2 ⊟	178	124	91	69	55	44	37	31	26	23	20	17	15	14	12	11	10	9	8	8	7	7	6	6	5	5	

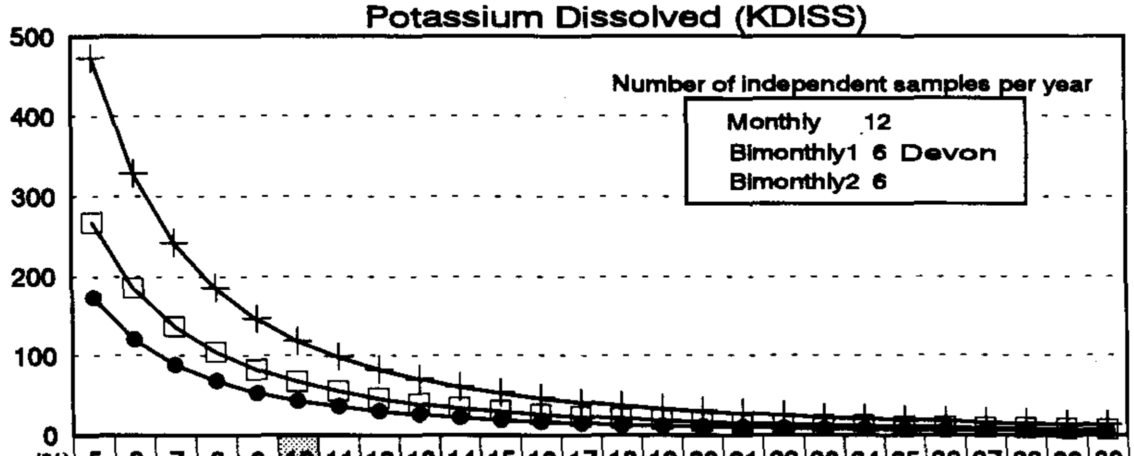


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	244	170	125	95	75	61	50	42	36	31	27	24	21	19	17	15	14	13	12	11	10	9	8	8	7	7	Samples
Bimonthly1 +	172	119	88	67	53	43	36	30	25	22	19	17	15	13	12	11	10	9	8	7	7	6	6	5	5	5	
Bimonthly2 ⊟	340	236	173	133	105	85	70	59	50	43	38	33	29	26	24	21	19	18	16	15	14	13	12	11	10	9	

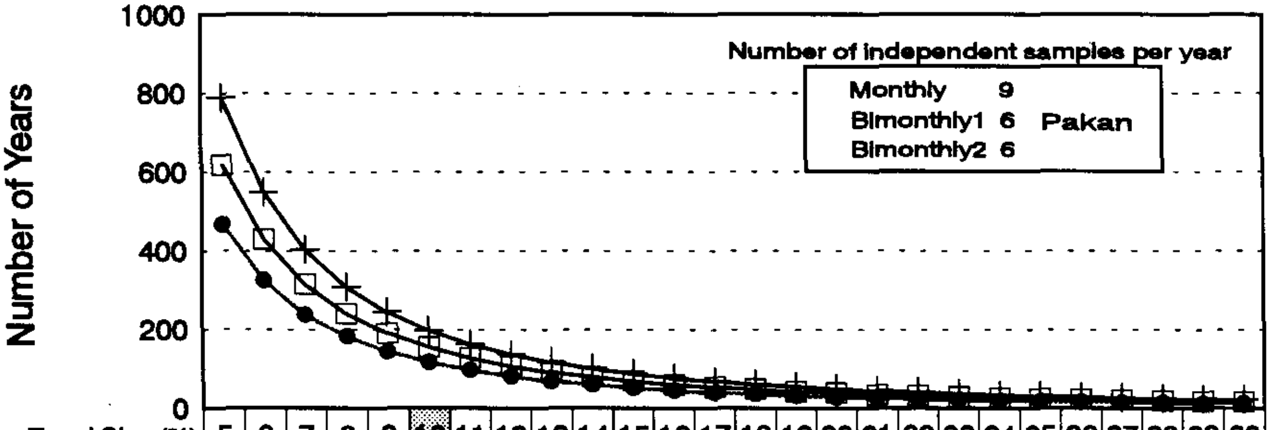


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	262	182	134	102	81	66	54	46	39	33	29	26	23	20	18	16	15	14	12	11	10	10	9	8	8	7	Samples
Bimonthly1 +	306	212	156	119	94	78	63	53	45	39	34	30	26	24	21	19	17	16	14	13	12	11	10	10	9	8	
Bimonthly2 ⊟	340	236	173	133	105	85	70	59	50	43	38	33	29	26	24	21	19	18	16	15	14	13	12	11	10	9	

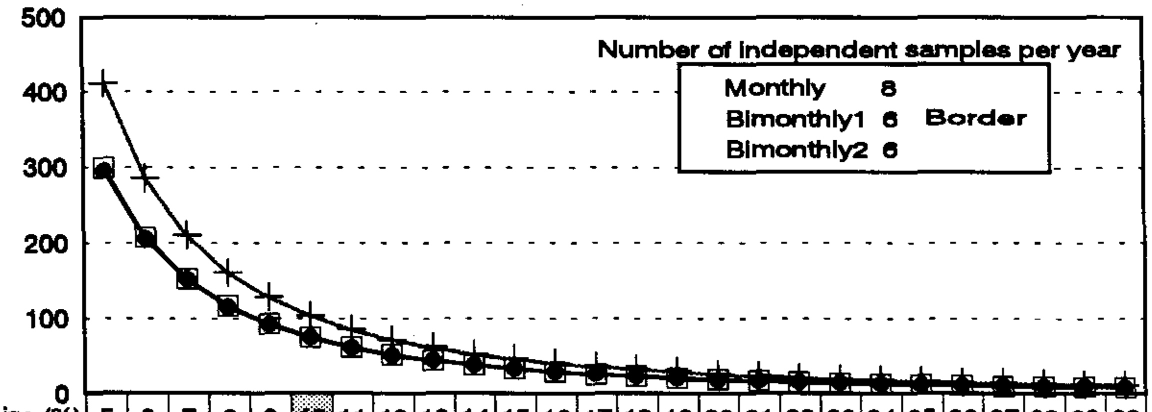
Fig. 7a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	173	120	88	68	53	45	36	30	26	22	19	17	15	13	12	11	10	9	8	8	7	6	6	6	5	5	Years
Bimonthly1 +	473	328	241	185	146	118	98	82	70	60	53	46	41	37	33	30	27	25	22	21	19	18	16	15	14	13	
Bimonthly2 ⊟	267	185	136	104	82	67	55	46	39	34	30	26	23	21	19	17	15	14	13	12	11	10	9	9	8	7	



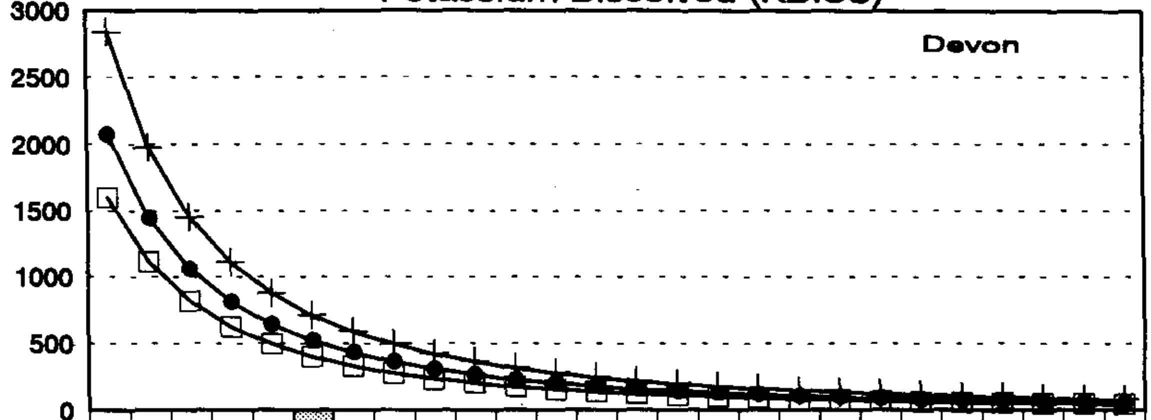
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	468	325	238	183	144	117	97	81	69	60	52	46	40	36	32	29	27	24	22	20	19	17	16	15	14	13	Years
Bimonthly1 +	789	548	403	308	244	197	163	137	117	101	88	77	68	61	55	49	45	41	37	34	32	29	27	25	24	22	
Bimonthly2 ⊟	618	429	315	241	191	155	128	107	91	79	69	60	54	48	43	39	35	32	29	27	25	23	21	20	18	17	



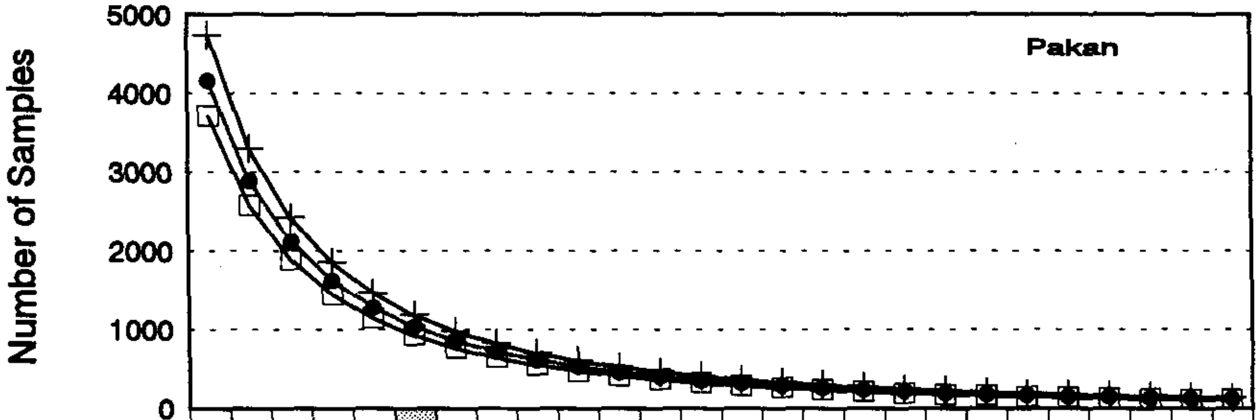
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	295	205	151	115	91	74	61	51	44	38	33	29	26	23	20	18	17	15	14	13	12	11	10	9	9	8	Years
Bimonthly1 +	411	285	210	160	127	106	85	71	61	52	46	40	36	32	29	26	23	21	19	18	17	15	14	13	12	11	
Bimonthly2 ⊟	299	207	152	117	92	75	62	52	44	38	33	29	26	23	21	19	17	16	14	13	12	11	10	10	9	8	

Fig. 7b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

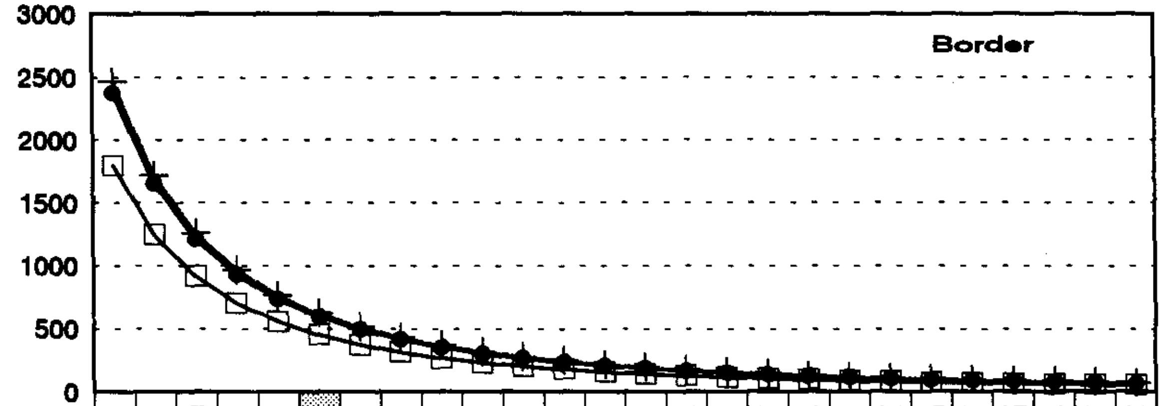
Potassium Dissolved (KDISS)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	2074	1440	1058	810	640	519	429	360	307	265	230	203	179	160	144	130	118	107	98	90	83	77	71	66	62	58	Samples
Bimonthly1 +	2837	1970	1448	1108	876	709	586	493	420	362	315	277	245	219	196	177	161	147	134	123	113	105	97	90	84	79	
Bimonthly2 ⊟	1599	1110	816	624	499	400	330	278	236	204	178	156	136	123	111	100	91	83	76	69	64	59	55	51	48	44	



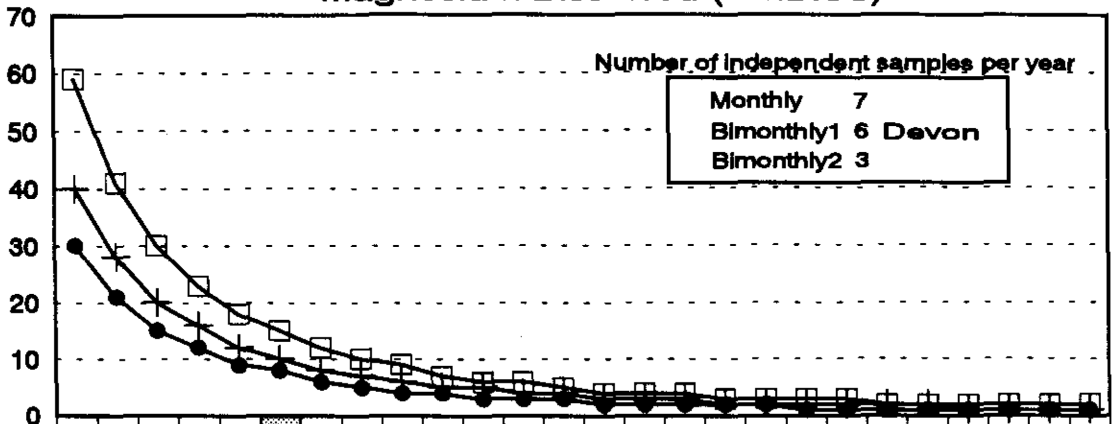
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	4156	2886	2120	1623	1283	1039	859	721	615	530	462	406	359	321	288	260	236	215	196	180	166	154	143	133	124	115	Samples
Bimonthly1 +	4736	3289	2416	1850	1462	1184	978	822	701	604	526	462	410	365	328	296	268	245	224	206	189	175	162	151	141	132	
Bimonthly2 ⊟	3706	2574	1891	1448	1144	927	766	643	548	473	412	362	321	286	257	232	210	191	175	161	148	137	127	118	110	103	



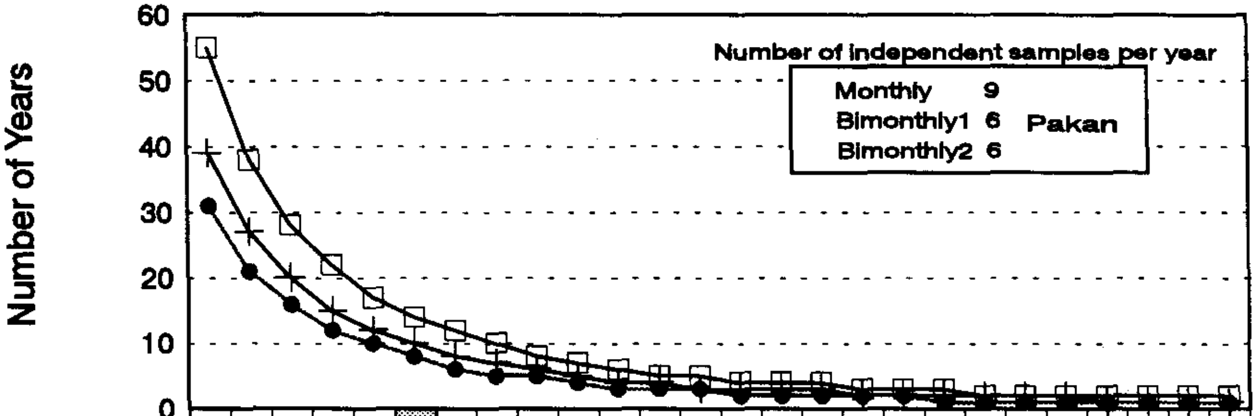
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	2371	1647	1210	926	732	593	490	412	351	302	263	232	205	183	164	148	134	122	112	103	95	88	81	76	70	66	Samples
Bimonthly1 +	2464	1711	1257	962	760	615	509	428	364	314	274	241	213	190	171	154	140	127	116	107	99	91	84	79	73	68	
Bimonthly2 ⊟	1792	1244	914	700	553	448	370	311	265	229	199	175	155	138	124	112	102	93	85	78	72	66	61	57	53	50	

Fig. 8a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

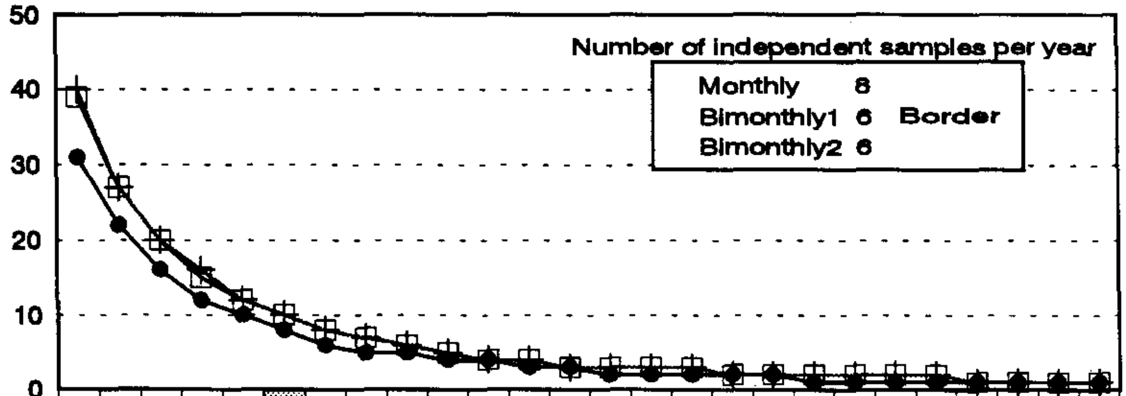
Magnesium Dissolved (MGDISS)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	30	21	15	12	9	8	6	5	4	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	Years
Bimonthly1 +	40	28	20	16	12	10	8	7	6	5	5	4	4	3	3	3	2	2	2	2	2	2	1	1	1	1	
Bimonthly2 ⊟	59	41	30	23	18	15	12	10	9	7	6	6	5	4	4	4	3	3	3	3	2	2	2	2	2	2	



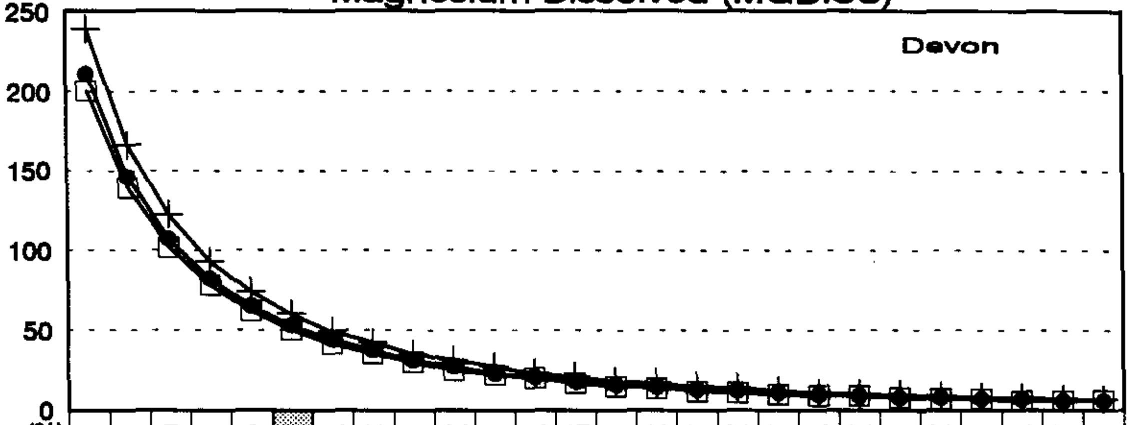
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	31	21	16	12	10	8	6	5	5	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	Years
Bimonthly1 +	39	27	20	15	12	10	8	7	6	5	4	4	3	3	3	3	2	2	2	2	2	2	1	1	1	1	
Bimonthly2 ⊟	55	38	28	22	17	14	12	10	8	7	6	5	5	4	4	4	3	3	3	2	2	2	2	2	2	2	



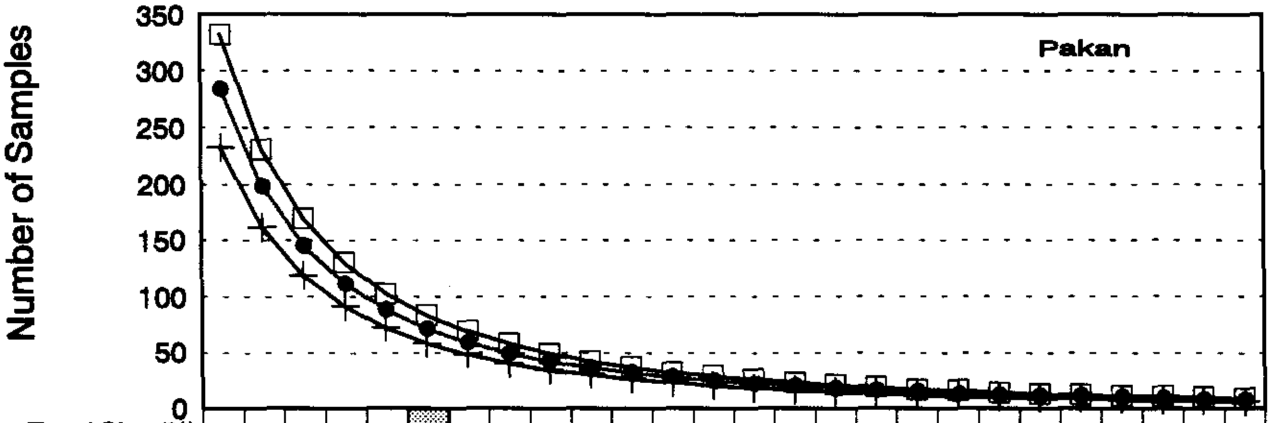
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	31	22	16	12	10	8	6	5	5	4	4	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	Years
Bimonthly1 +	40	27	20	16	12	10	8	7	6	5	4	4	3	3	3	3	2	2	2	2	2	2	1	1	1	1	
Bimonthly2 ⊟	39	27	20	15	12	10	8	7	6	5	4	4	3	3	3	3	2	2	2	2	2	2	1	1	1	1	

Fig. 8b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

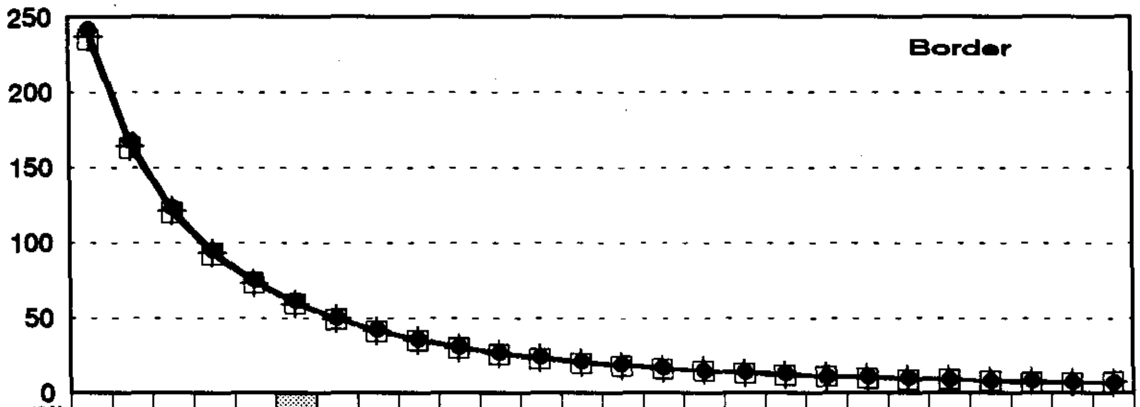
Magnesium Dissolved (MGDISS)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly ●	211	146	107	82	65	53	44	37	31	27	23	21	18	16	15	13	12	11	10	9	8	8	7	7	6	6	
Bimonthly1 +	239	166	122	93	74	60	49	42	35	31	27	23	21	18	17	15	14	12	11	10	10	9	8	8	7	7	
Bimonthly2 ⊟	200	139	102	78	62	50	41	35	30	25	22	20	17	15	14	12	11	10	9	9	8	7	7	6	6	6	



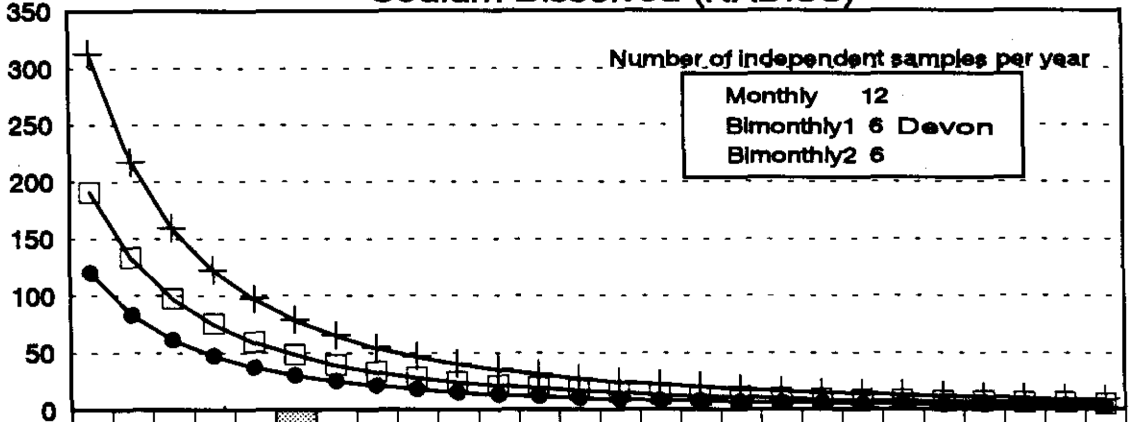
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly ●	284	198	145	111	88	71	59	49	42	36	32	28	25	22	20	18	16	15	13	12	11	11	10	9	8	8	
Bimonthly1 +	232	161	118	91	72	58	48	40	34	30	26	23	20	18	16	15	13	12	11	10	9	9	8	7	7	6	
Bimonthly2 ⊟	332	230	169	130	102	83	69	58	49	42	37	32	29	26	23	21	19	17	16	14	13	12	11	11	10	9	



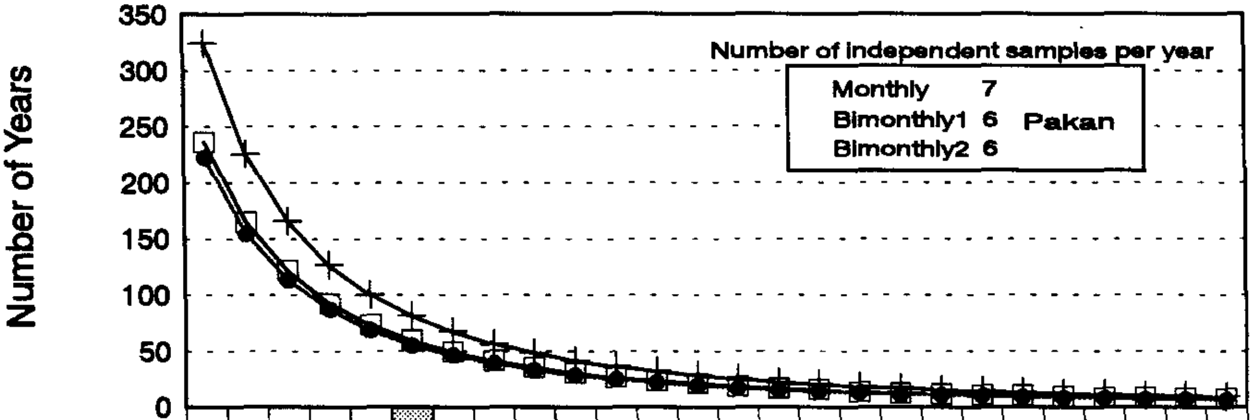
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly ●	242	168	123	95	75	61	50	42	36	31	27	24	21	19	17	15	14	13	11	11	10	9	8	8	7	7	
Bimonthly1 +	237	164	121	93	73	59	49	41	35	30	26	23	20	18	16	15	13	12	11	10	9	9	8	8	7	7	
Bimonthly2 ⊟	235	163	120	92	73	59	49	41	35	30	26	23	20	18	16	15	13	12	11	10	9	9	8	7	7	7	

Fig. 9a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

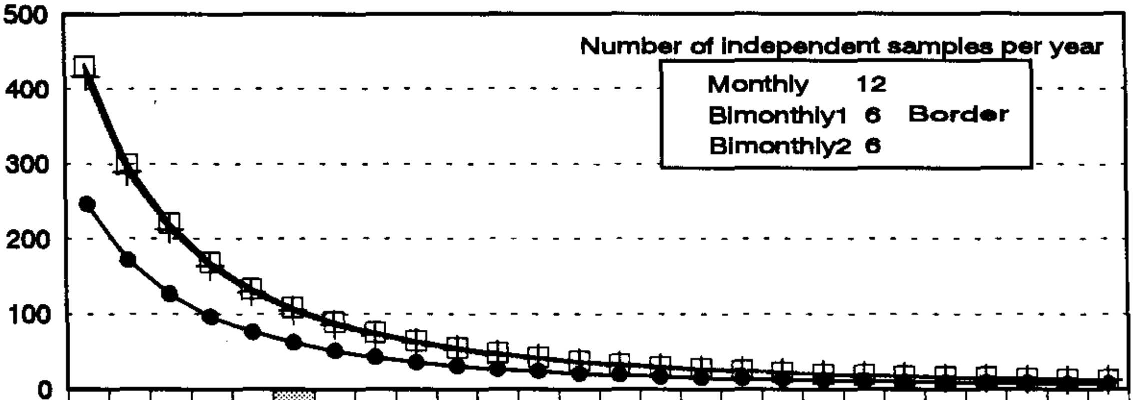
Sodium Dissolved (NADISS)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	120	83	61	47	37	30	25	21	18	15	13	12	10	9	8	8	7	6	6	5	5	4	4	4	4	3	Years
Bimonthly1 +	313	217	159	122	97	78	65	54	46	40	35	31	27	24	22	20	18	16	15	14	13	12	11	10	9	9	
Bimonthly2 ⊟	191	133	97	75	59	48	39	33	28	24	21	19	17	15	13	12	11	10	9	8	8	7	7	6	6	5	



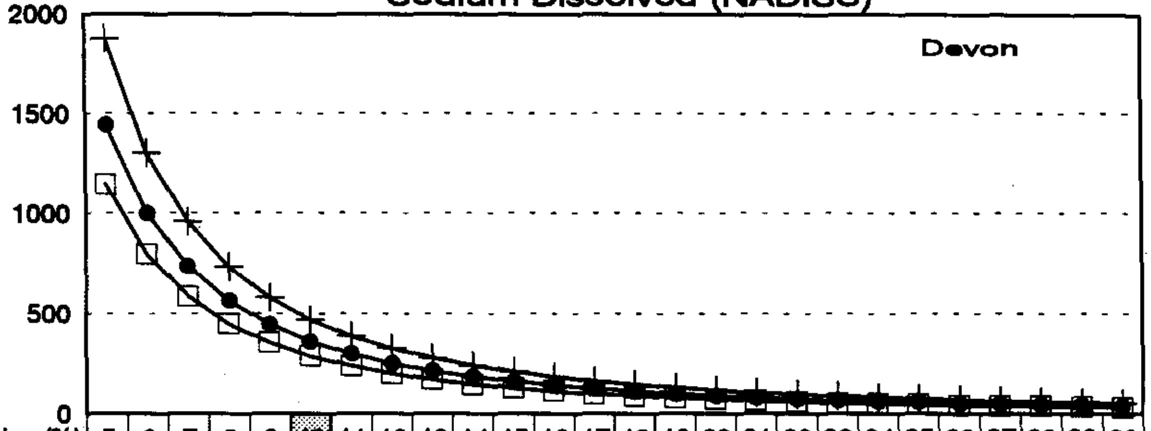
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	222	154	113	87	68	55	46	39	33	28	25	22	19	17	15	14	13	11	11	10	9	8	8	7	7	6	Years
Bimonthly1 +	324	225	165	126	100	81	67	56	48	41	36	32	28	25	22	20	18	17	15	14	13	12	11	10	10	9	
Bimonthly2 ⊟	236	164	121	92	73	59	49	41	35	30	26	23	21	18	16	15	13	12	11	10	10	9	8	8	7	7	



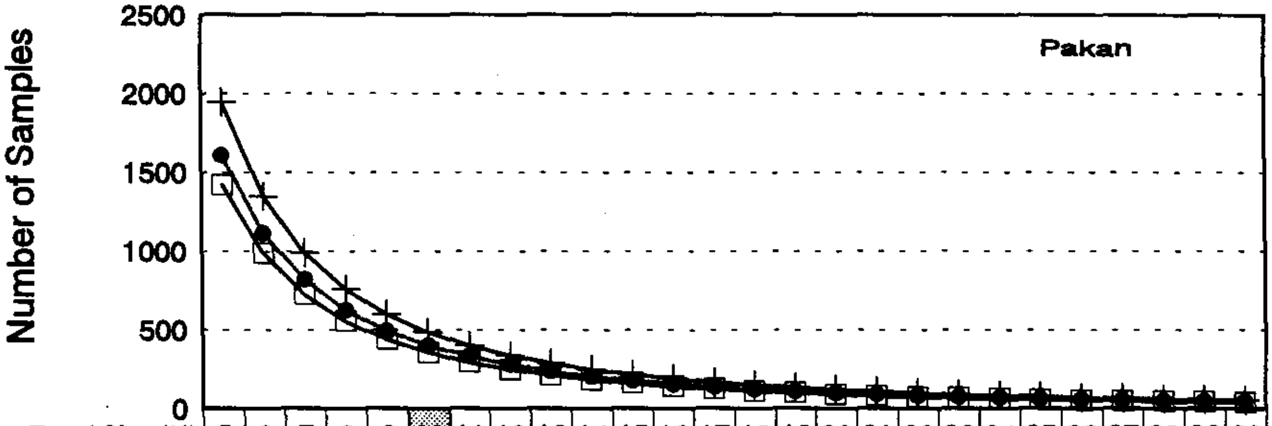
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	246	171	126	96	76	62	51	43	36	31	27	24	21	19	17	15	14	13	12	11	10	9	8	8	7	7	Years
Bimonthly1 +	416	289	212	163	129	104	86	72	62	53	46	41	36	32	29	26	24	22	20	18	17	15	14	13	12	12	
Bimonthly2 ⊟	431	299	220	168	133	108	89	75	64	55	48	42	37	33	30	27	25	22	20	19	17	16	15	14	13	12	

Fig. 9b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

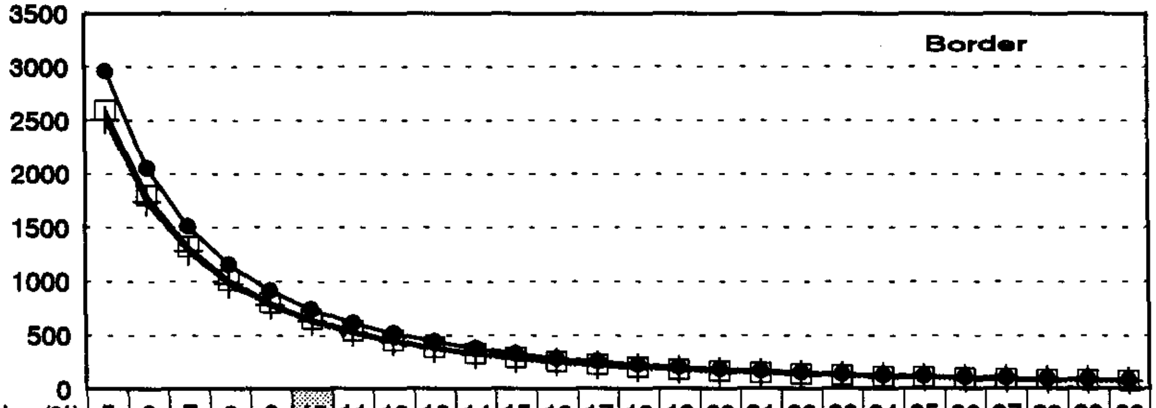
Sodium Dissolved (NADISS)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly ●	1440	1000	735	563	444	360	298	250	213	184	160	141	125	111	100	90	82	74	68	63	58	53	49	46	43	40	
Bimonthly1 +	1875	1302	956	732	579	469	387	325	277	239	208	183	162	145	130	117	106	97	89	81	75	69	64	60	56	52	
Bimonthly2 ⊟	1144	795	584	447	353	286	236	199	169	146	127	112	99	88	79	72	65	59	54	50	46	42	39	36	34	32	

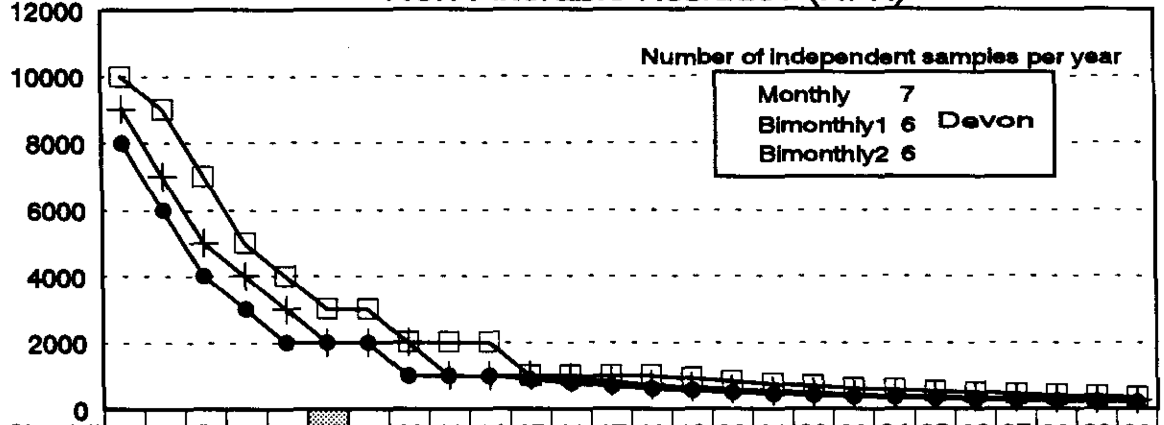


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly ●	1605	1114	819	627	495	401	332	279	237	205	178	157	139	124	111	100	91	83	76	70	64	59	55	51	48	45	
Bimonthly1 +	1941	1348	990	758	599	485	401	337	287	248	216	190	168	150	134	121	110	100	92	84	78	72	67	62	58	54	
Bimonthly2 ⊟	1418	985	724	554	436	355	293	246	210	181	158	139	123	109	98	89	80	73	67	62	57	52	49	45	42	39	

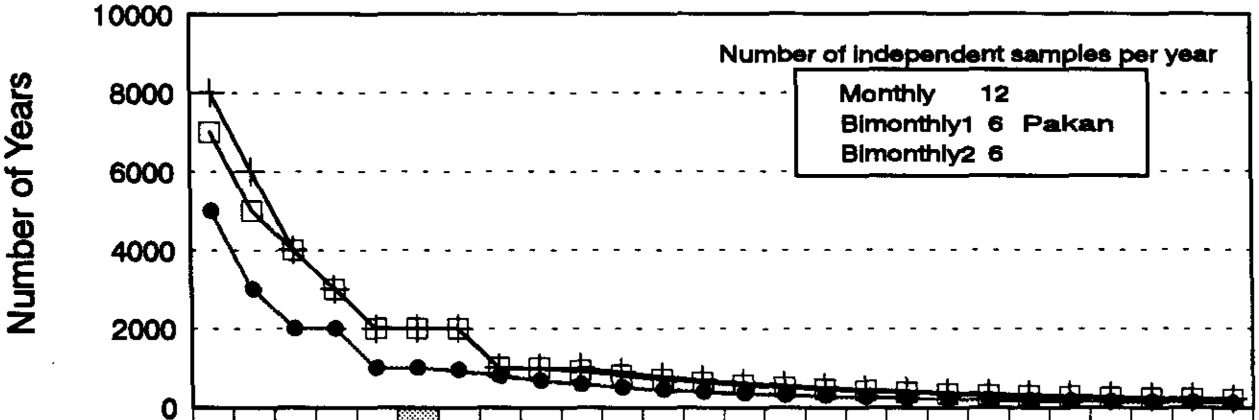


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly ●	2954	2052	1507	1154	912	739	610	513	437	377	328	288	256	228	205	185	167	153	140	128	118	109	101	94	88	82	
Bimonthly1 +	2497	1734	1274	975	771	624	516	433	369	318	277	244	216	193	173	156	142	129	118	108	100	92	86	80	74	69	
Bimonthly2 ⊟	2586	1796	1319	1010	798	648	534	449	382	330	287	253	224	200	179	162	147	134	122	112	103	96	89	82	77	72	

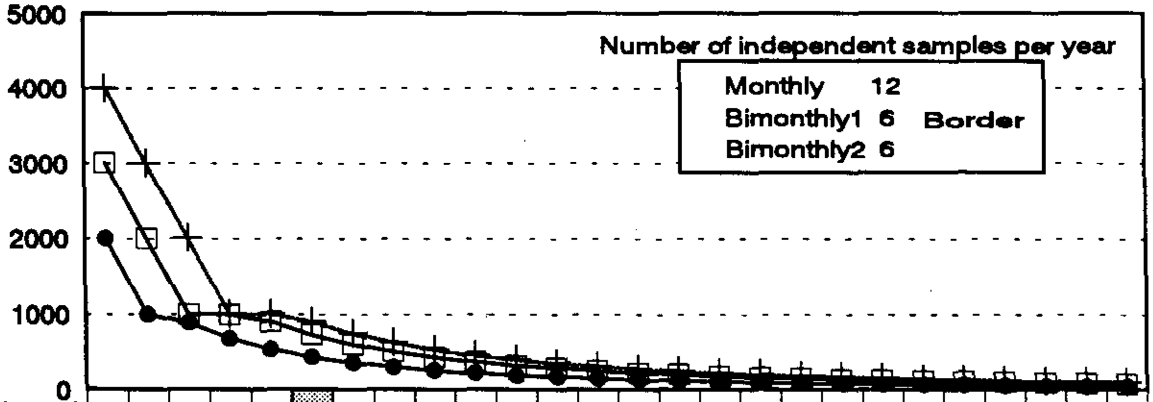
Fig. 10a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes
Non-Filterable Residues (NFR)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	8000	6000	4000	3000	2000	2000	2000	1000	1000	1000	889	781	692	617	554	500	454	413	378	347	320	296	274	255	236	222	Years
Bimonthly1 +	9000	7000	5000	4000	3000	2000	2000	2000	1000	1000	1000	921	816	728	653	589	535	487	446	409	377	349	323	301	280	262	
Bimonthly2 ☐	10000	9000	7000	5000	4000	3000	3000	2000	2000	2000	1000	1000	1000	1000	921	831	754	687	626	577	532	492	456	424	395	369	



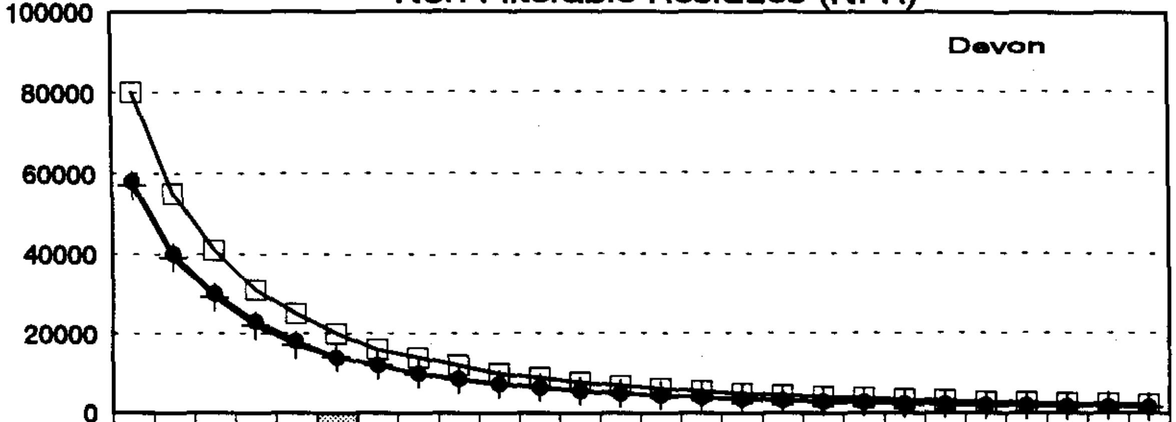
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	5000	3000	2000	2000	1000	1000	946	797	679	585	510	448	397	354	318	287	260	237	217	199	184	170	157	146	136	126	Years
Bimonthly1 +	8000	6000	4000	3000	2000	2000	2000	1000	1000	1000	886	780	691	616	553	499	453	413	376	347	320	296	274	255	236	222	
Bimonthly2 ☐	7000	5000	4000	3000	2000	2000	2000	1000	1000	936	815	716	635	566	506	459	416	379	347	316	293	271	252	234	218	204	



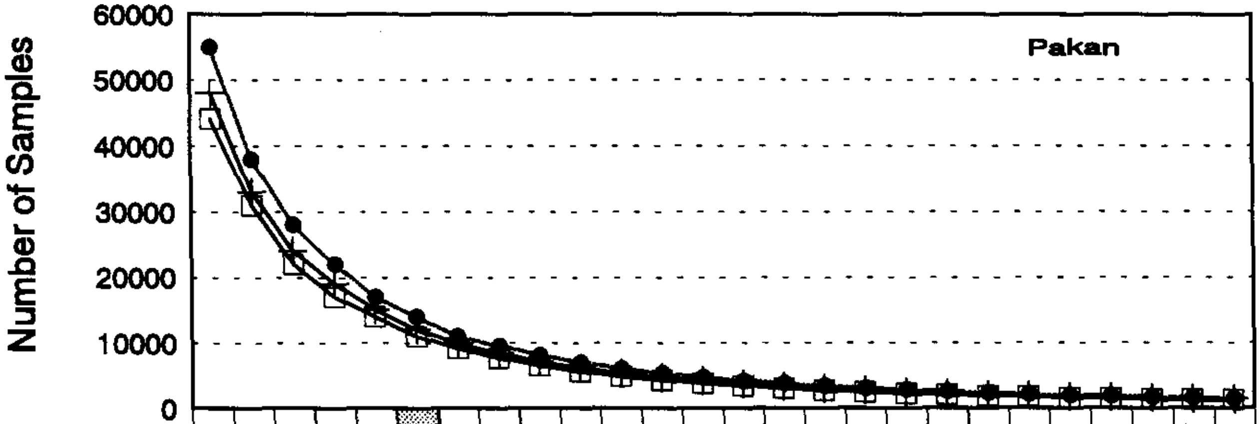
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	2000	1000	892	683	540	437	361	304	259	223	194	171	151	135	121	109	99	90	83	76	70	65	60	56	52	49	Years
Bimonthly1 +	4000	3000	2000	1000	1000	902	746	626	534	460	401	352	312	278	250	226	205	186	171	157	144	134	124	115	107	100	
Bimonthly2 ☐	3000	2000	1000	1000	904	792	605	509	433	374	326	286	253	226	203	183	166	151	139	127	117	108	101	93	87	81	

Fig. 10b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

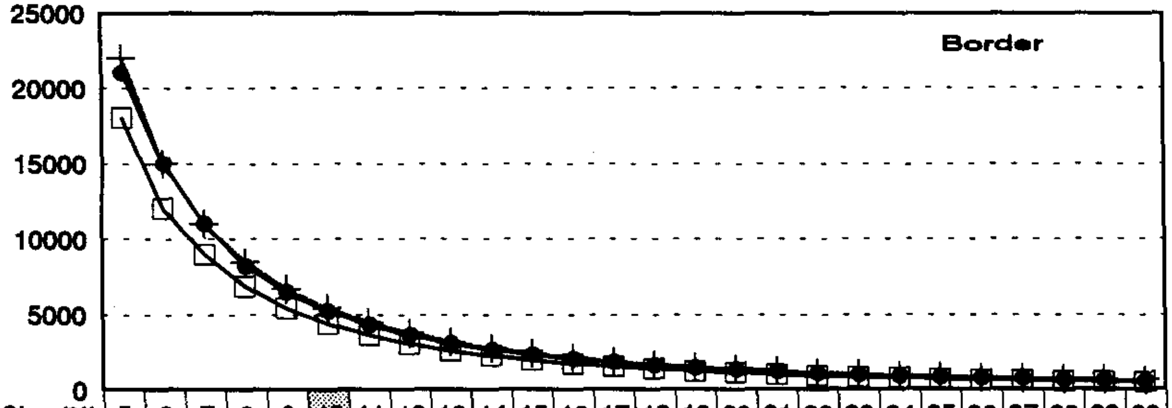
Non-Filterable Residues (NFR)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	58000	40000	30000	23000	18000	14000	12000	10000	8555	7376	6426	5646	5003	4462	4005	3614	3276	2967	2733	2510	2313	2139	1983	1844	1719	1606	Samples
Bimonthly1 +	57000	39000	29000	22000	17000	14000	12000	9623	8570	7217	6267	5525	4894	4366	3918	3536	3207	2923	2674	2456	2263	2092	1940	1804	1682	1572	
Bimonthly2 ⊟	80000	55000	41000	31000	25000	20000	16000	14000	12000	10000	8661	7786	6899	6154	5523	4985	4521	4119	3769	3461	3190	2949	2735	2543	2371	2216	



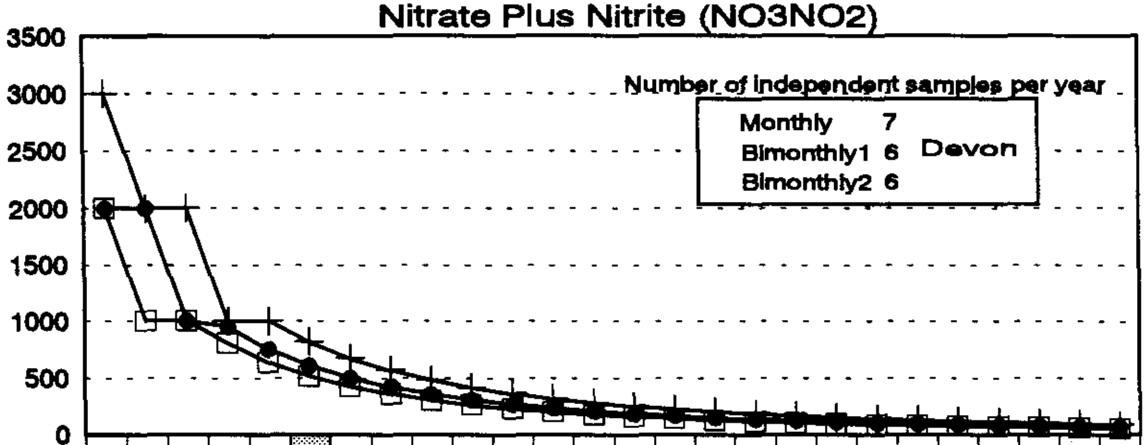
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	55000	38000	28000	22000	17000	14000	11000	9561	8147	7025	6119	5378	4764	4249	3814	3442	3122	2845	2603	2390	2203	2037	1889	1756	1637	1530	Samples
Bimonthly1 +	48000	33000	24000	19000	15000	[illegible]	9905	8321	7090	6114	5326	4681	4146	3698	3319	2996	2717	2476	2265	2080	1917	1773	1644	1528	1425	1331	
Bimonthly2 ⊟	44000	31000	22000	17000	14000	[illegible]	9093	7640	6510	5613	4890	4298	3807	3396	3048	2751	2495	2273	2080	1910	1760	1628	1509	1403	1308	1222	



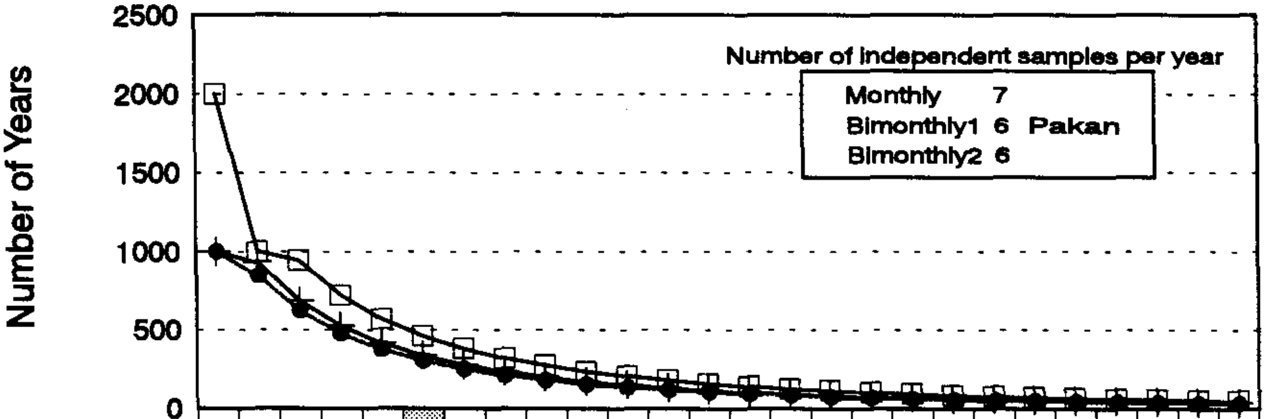
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	21000	15000	11000	8199	6476	5247	4337	3644	3105	2677	2332	2050	1816	1620	1454	1312	1190	1084	992	911	840	776	720	669	624	583	Samples
Bimonthly1 +	22000	15000	11000	8456	6681	5412	4473	3758	3202	2761	2405	2114	1873	1670	1499	1353	1227	1116	1023	940	866	801	742	690	644	601	
Bimonthly2 ⊟	18000	12000	8967	6965	5425	4394	3631	3051	2600	2242	1953	1716	1520	1356	1217	1098	996	906	831	763	703	650	603	560	522	488	

Fig. 11a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

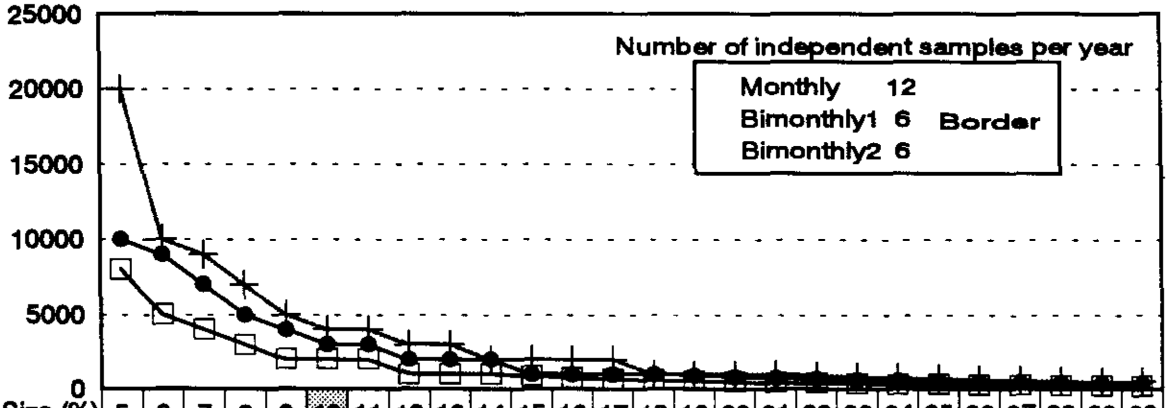
Nitrate Plus Nitrite (NO3NO2)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Years
Monthly ●	2000	2000	1000	951	751	609	503	423	360	310	270	238	211	188	169	152	138	126	115	106	97	90	83	78	72	68	
Bimonthly1 +	3000	2000	2000	1000	1000	814	672	565	481	415	362	318	282	251	225	203	185	168	154	141	130	120	112	104	97	90	
Bimonthly2 ☐	2000	1000	1000	806	637	518	427	358	305	263	229	202	179	159	143	129	117	107	98	90	83	76	71	66	61	57	



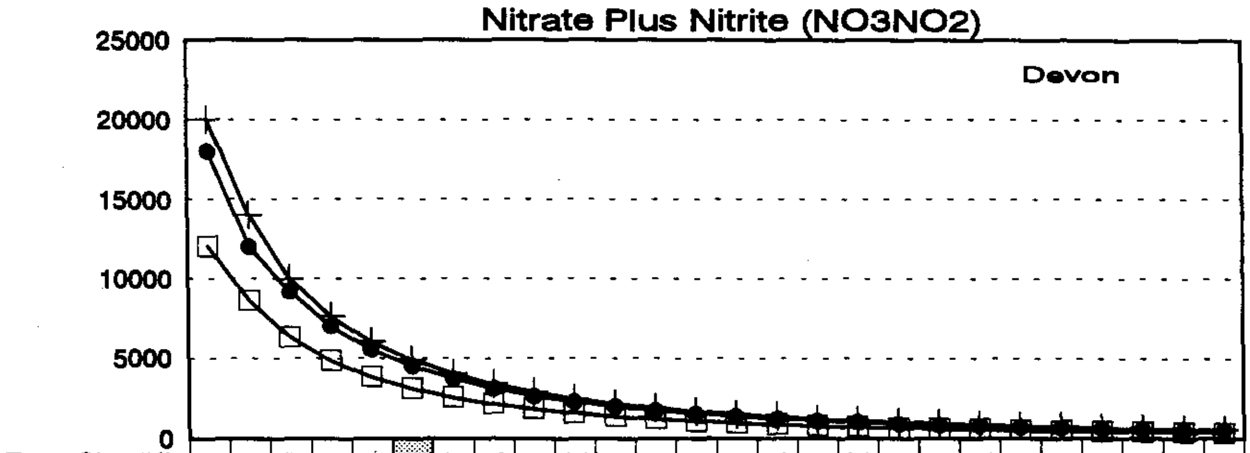
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Years
Monthly ●	1000	848	623	477	377	305	252	212	181	156	136	119	106	94	85	76	69	63	58	53	49	45	42	39	36	34	
Bimonthly1 +	1000	934	686	525	415	326	278	234	199	172	150	131	116	104	93	84	76	70	64	58	54	50	46	43	40	37	
Bimonthly2 ☐	2000	1000	944	722	571	452	382	321	274	236	206	181	160	143	128	116	105	96	87	80	74	68	63	59	55	51	



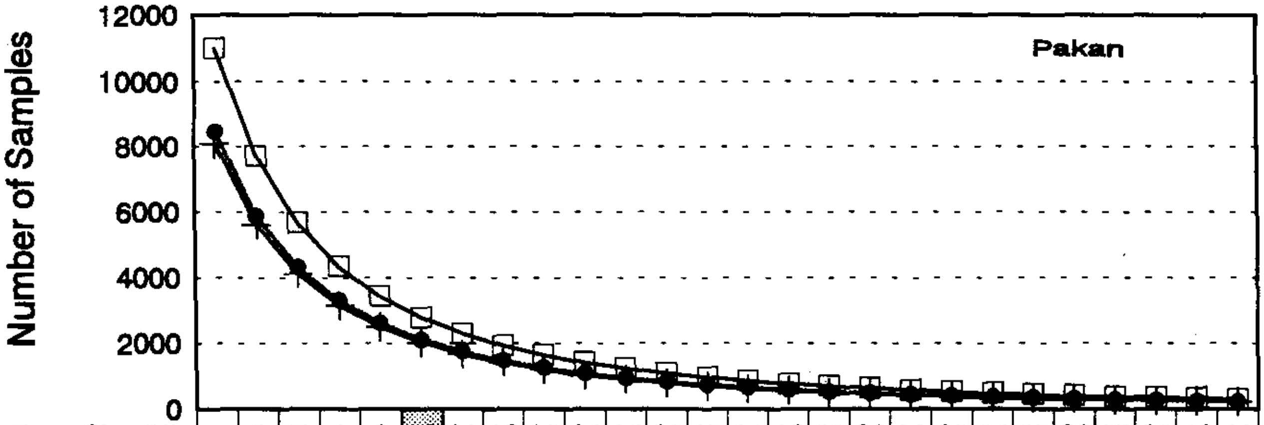
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Years
Monthly ●	10000	9000	7000	5000	4000	3000	3000	2000	2000	2000	1000	1000	1000	1000	918	829	752	685	627	576	530	490	455	423	394	366	
Bimonthly1 +	20000	10000	9000	7000	5000	4000	4000	3000	3000	2000	2000	2000	2000	1000	1000	1000	1000	916	836	769	709	656	606	565	527	492	
Bimonthly2 ☐	8000	5000	4000	3000	2000	2000	2000	1000	1000	1000	871	766	678	605	543	490	444	405	371	340	314	290	269	250	233	218	

Fig. 11b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

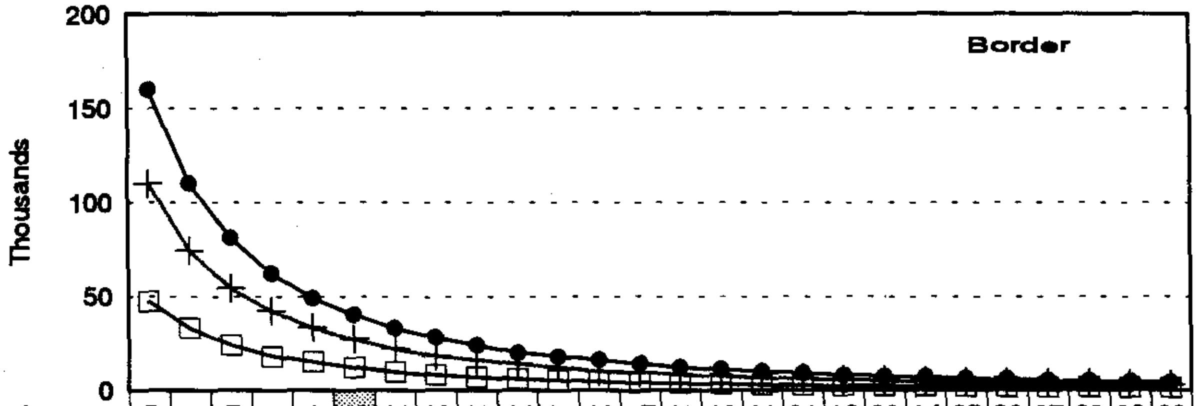
Nitrate Plus Nitrite (NO3NO2)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	18000	12000	9167	7018	5545	4482	3712	3119	2658	2292	1996	1755	1554	1386	1244	1123	1019	926	849	780	719	664	616	573	534	499	Samples
Bimonthly1 +	20000	14000	9961	7626	6026	4851	4034	3369	2866	2490	2169	1907	1689	1506	1352	1220	1107	1006	923	847	781	722	670	623	580	542	
Bimonthly2 ⊟	12000	8601	6319	4836	3823	3097	2559	2150	1832	1580	1376	1210	1071	956	858	774	702	640	585	536	495	458	425	395	368	344	



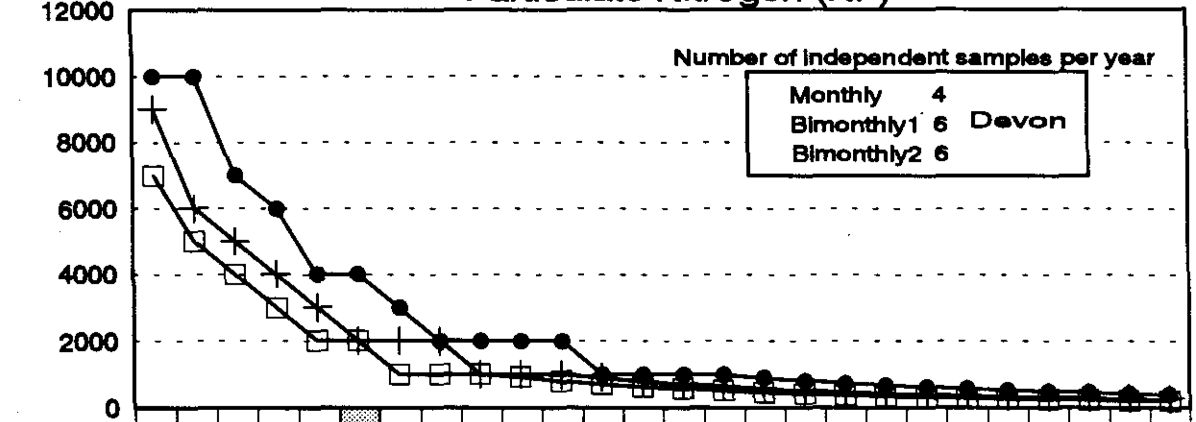
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	8456	5874	4315	3304	2610	2114	1747	1468	1251	1079	940	826	732	653	586	529	479	437	400	367	338	313	290	270	251	235	Samples
Bimonthly1 +	8069	5604	4117	3152	2491	2017	1667	1401	1194	1029	897	788	698	623	559	504	457	417	381	350	323	298	277	257	240	224	
Bimonthly2 ⊟	11000	7705	5661	4334	3424	2774	2292	1926	1641	1415	1233	1084	960	856	768	693	629	573	524	482	444	410	380	354	330	308	



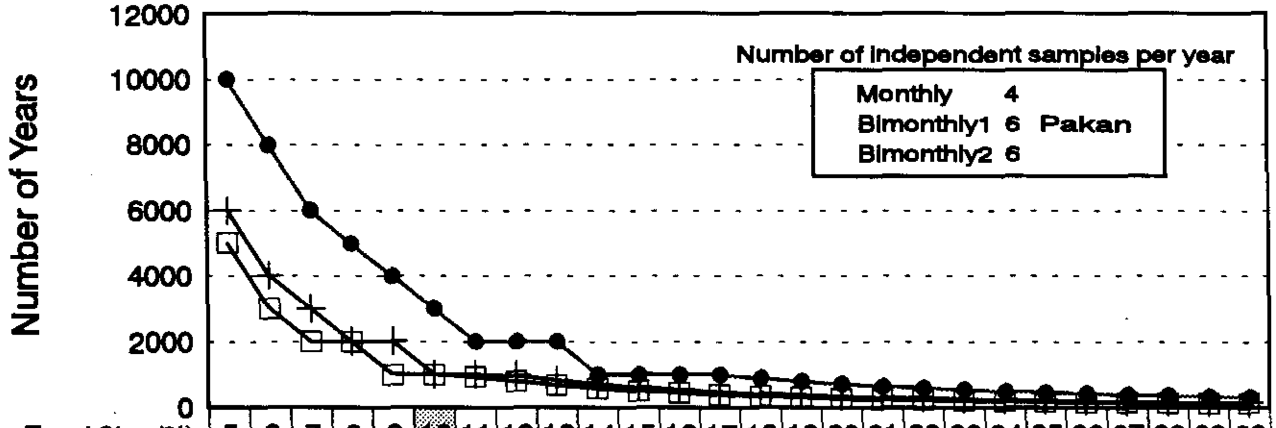
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	160	110	81	62	49	40	33	28	24	20	18	16	14	12	11	9.945	9.021	8.219	7.52	6.906	6.365	5.885	5.457	5.074	4.73	4.42	Samples
Bimonthly1 +	110	74	54	42	33	27	22	18	16	14	12	10	9.2	8.207	7.365	6.647	6.029	5.494	5.026	4.616	4.254	3.933	3.647	3.391	3.162	2.954	
Bimonthly2 ⊟	47	33	24	18	15	12	9.717	8.165	6.957	5.999	5.226	4.593	4.068	3.629	3.257	2.939	2.666	2.429	2.223	2.041	1.881	1.739	1.613	1.5	1.398	1.306	

Fig. 12a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

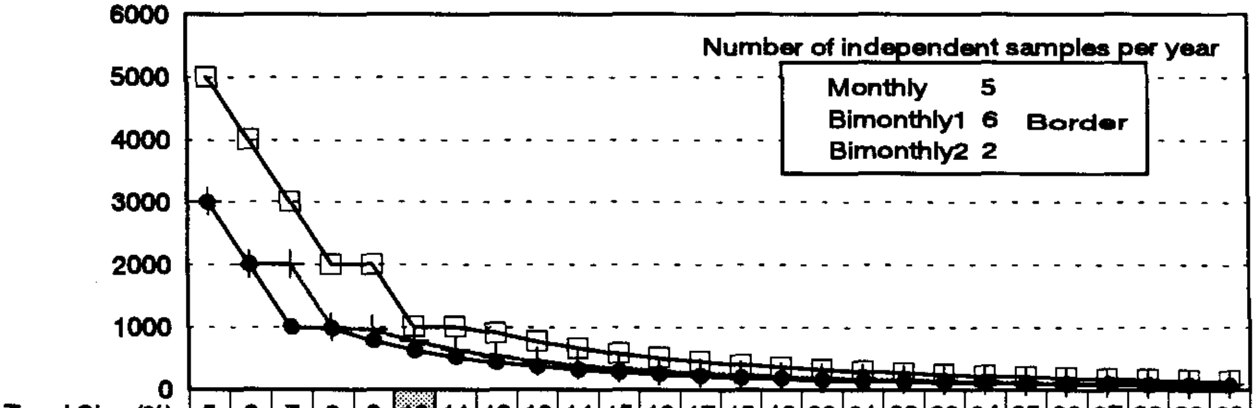
Particulate Nitrogen (NP)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	10000	10000	7000	6000	4000	4000	3000	2000	2000	2000	2000	1000	1000	1000	986	892	809	737	674	619	571	526	489	455	424	396	Years
Bimonthly1 +	9000	6000	5000	4000	3000	2000	2000	2000	1000	1000	1000	894	792	706	634	572	519	473	433	397	366	339	314	292	272	254	
Bimonthly2 ⊟	7000	5000	4000	3000	2000	2000	1000	1000	1000	922	803	706	625	558	501	452	410	373	342	314	289	267	248	231	215	201	

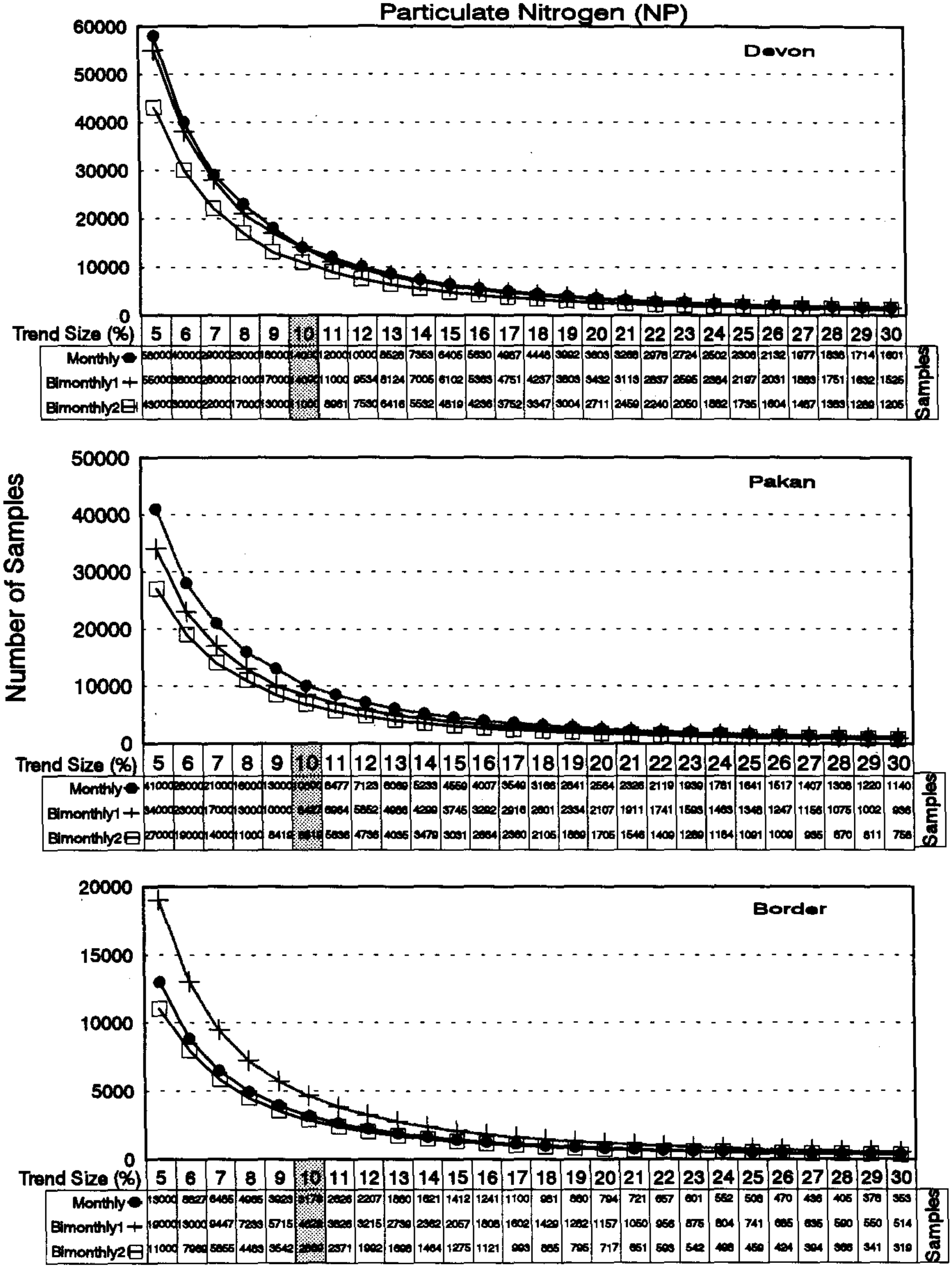


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	10000	8000	6000	5000	4000	3000	2000	2000	2000	1000	1000	1000	1000	898	806	727	660	601	550	505	466	430	399	371	346	323	Years
Bimonthly1 +	6000	4000	3000	2000	2000	1000	1000	975	831	717	624	549	486	434	389	351	319	290	266	244	225	208	193	179	167	156	
Bimonthly2 ⊟	5000	3000	2000	2000	1000	1000	939	789	673	580	505	444	393	351	315	284	258	235	215	197	182	168	156	145	135	126	



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	3000	2000	1000	982	776	625	519	436	372	321	279	245	216	194	174	157	143	130	119	109	100	93	86	80	75	70	Years
Bimonthly1 +	3000	2000	2000	1000	953	772	636	536	457	394	343	301	267	238	214	193	175	159	146	134	124	114	106	98	92	86	
Bimonthly2 ⊟	5000	4000	3000	2000	2000	1000	1000	905	771	665	579	509	451	402	361	326	296	269	246	226	208	193	179	166	155	145	

Fig. 12b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes



Devon

Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	58000	40000	29000	23000	18000	[illegible]	12000	10000	8528	7353	6405	5630	4967	4446	3992	3603	3268	2978	2724	2502	2306	2132	1977	1836	1714	1601
Bimonthly1 +	55000	38000	28000	21000	17000	[illegible]	11000	9534	8124	7005	6102	5363	4751	4237	3803	3432	3113	2837	2595	2384	2197	2031	1883	1751	1632	1525
Bimonthly2 ⊟	43000	30000	22000	17000	13000	11000	8961	7530	6416	5532	4819	4236	3752	3347	3004	2711	2459	2240	2050	1882	1735	1604	1487	1383	1289	1205

Pakan

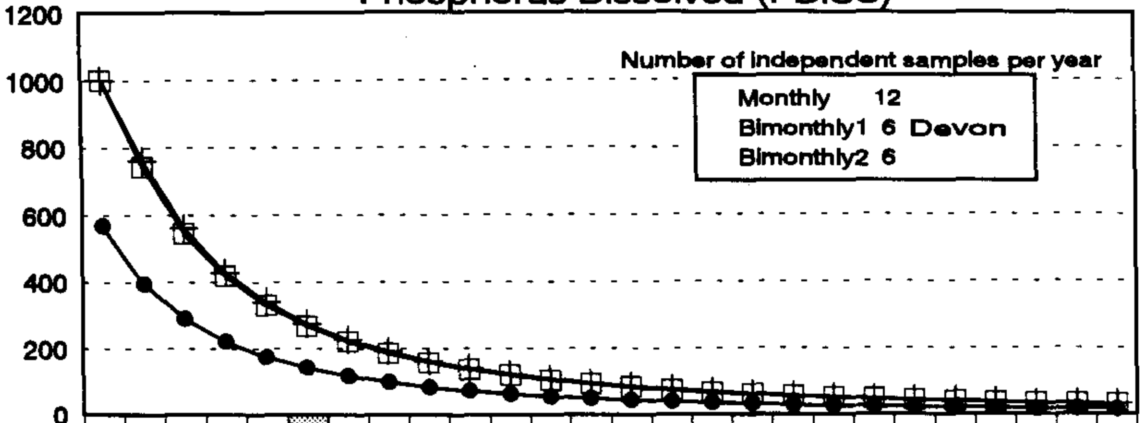
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	41000	28000	21000	16000	13000	[illegible]	8477	7123	6069	5233	4559	4007	3549	3166	2841	2564	2326	2119	1939	1781	1641	1517	1407	1308	1220	1140
Bimonthly1 +	34000	23000	17000	13000	10000	[illegible]	6964	5852	4986	4299	3745	3292	2916	2601	2334	2107	1911	1741	1593	1463	1348	1247	1156	1075	1002	936
Bimonthly2 ⊟	27000	19000	14000	11000	8419	[illegible]	5836	4736	4035	3479	3031	2664	2360	2105	1869	1705	1546	1409	1289	1184	1091	1009	935	870	811	758

Border

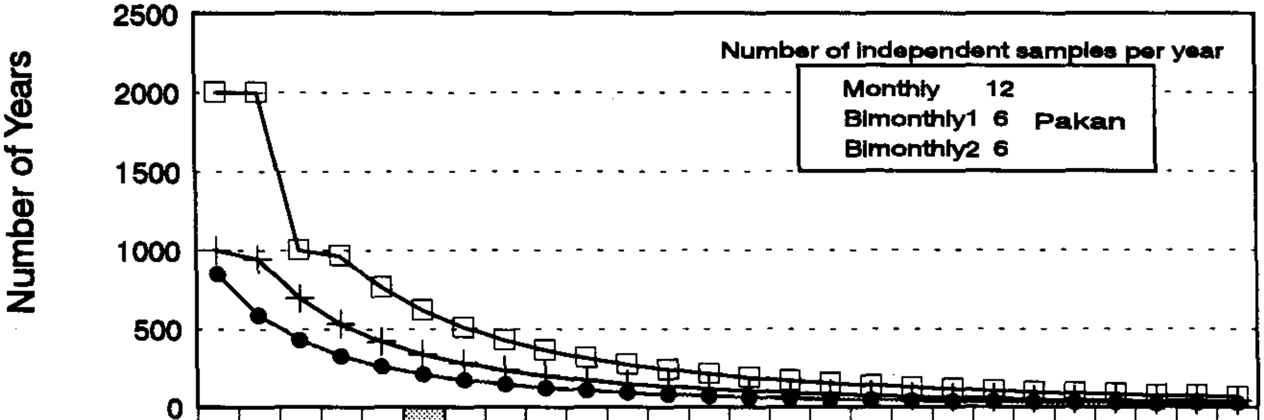
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	13000	8827	6465	4965	3923	3178	2626	2207	1880	1621	1412	1241	1100	981	880	794	721	657	601	552	508	470	436	405	376	353
Bimonthly1 +	19000	13000	9447	7233	5715	4628	3826	3215	2739	2362	2057	1808	1602	1429	1282	1157	1050	956	875	804	741	685	635	590	550	514
Bimonthly2 ⊟	11000	7969	5855	4463	3542	2869	2371	1992	1696	1464	1275	1121	993	885	795	717	651	593	542	498	459	424	394	366	341	319

Fig. 13a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

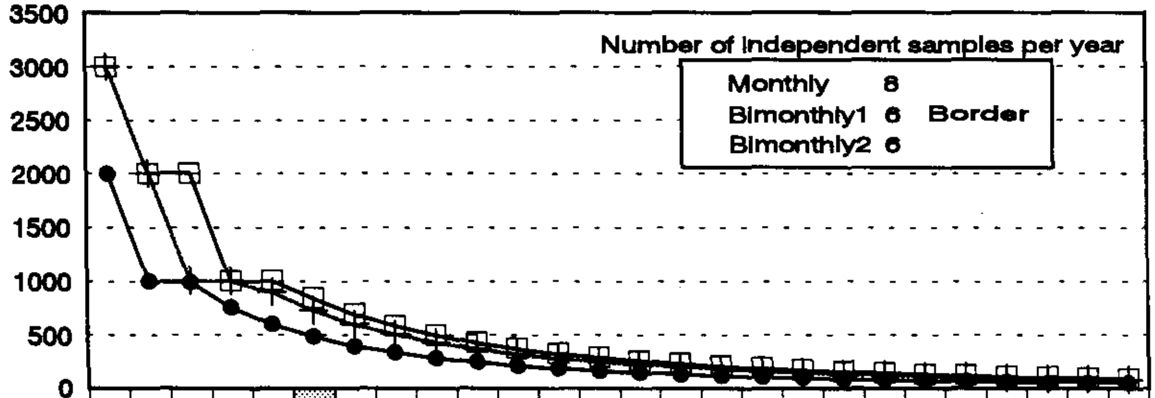
Phosphorus Dissolved (PDISS)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	568	394	290	222	175	142	117	99	84	72	63	55	49	44	39	36	32	29	27	25	23	21	20	18	17	16	Years
Bimonthly1 +	1000	762	560	429	339	274	227	191	162	140	122	107	95	85	76	69	62	57	52	48	44	41	38	35	33	31	
Bimonthly2 ⊟	1000	743	546	418	330	268	221	186	158	137	119	105	93	83	74	67	61	55	51	47	43	40	37	34	32	30	



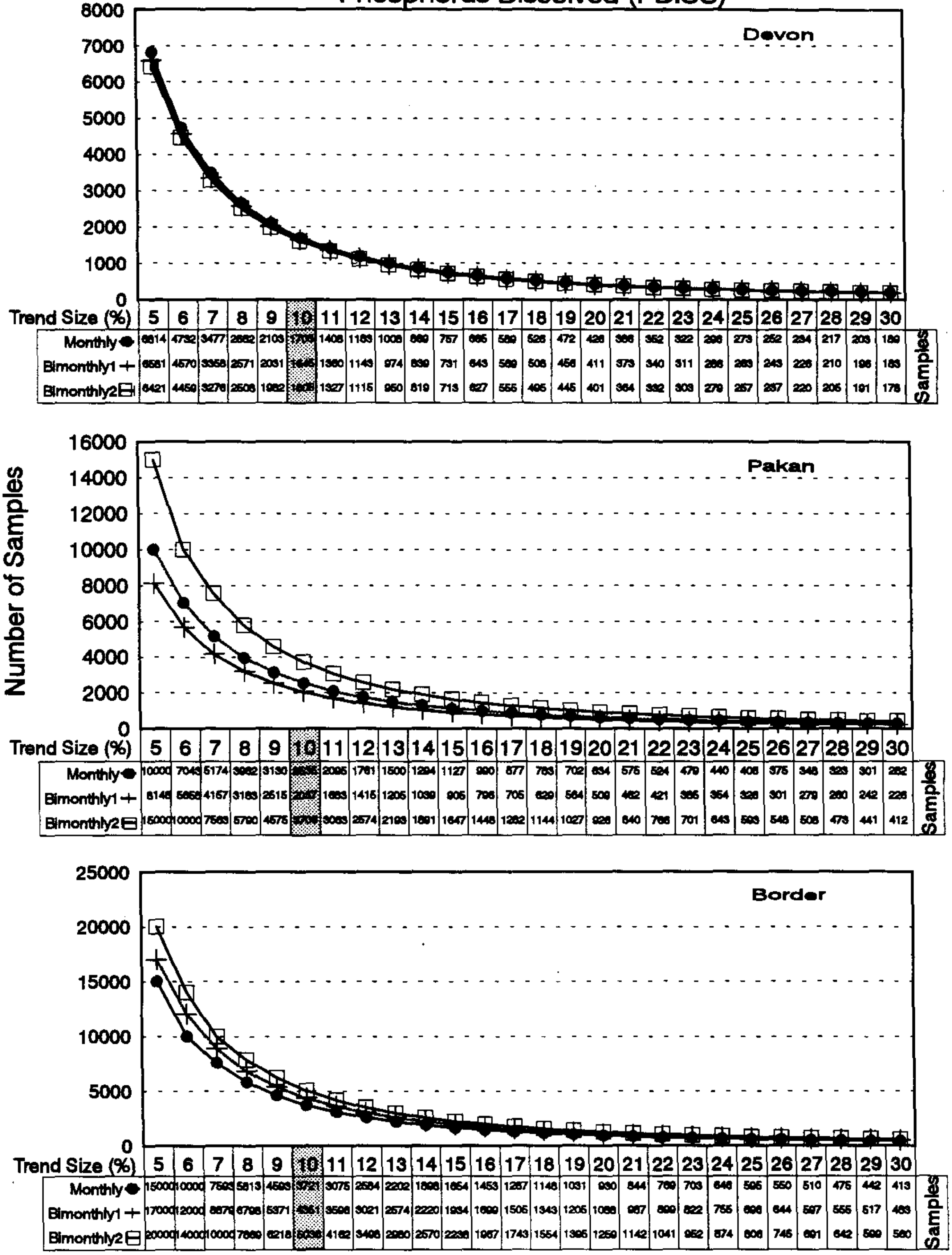
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	845	587	431	330	261	211	175	147	125	108	94	83	73	65	59	53	48	44	40	37	34	31	29	27	25	24	Years
Bimonthly1 +	1000	943	693	531	419	340	281	236	201	173	151	133	118	105	94	85	77	70	64	59	54	50	47	43	40	38	
Bimonthly2 ⊟	2000	2000	1000	965	763	618	511	429	366	315	275	241	214	191	171	154	140	128	117	107	99	91	85	79	74	69	



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	2000	1000	986	755	597	483	399	336	286	247	215	189	167	149	134	121	110	100	91	84	77	71	66	62	57	54	Years
Bimonthly1 +	3000	2000	1000	1000	895	725	599	504	429	370	322	283	251	224	201	181	165	150	137	126	116	107	100	93	86	81	
Bimonthly2 ⊟	3000	2000	2000	1000	1000	859	694	583	497	428	373	328	291	259	233	210	190	174	159	146	134	124	115	107	100	93	

Fig. 13b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

Phosphorus Dissolved (PDISS)



Devon

Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	6814	4732	3477	2662	2103	1709	1408	1163	1008	869	757	665	589	526	472	426	386	352	322	296	273	252	234	217	203	189
Bimonthly1 +	6581	4570	3358	2571	2031	1645	1360	1143	974	839	731	643	569	506	456	411	373	340	311	286	263	243	226	210	196	183
Bimonthly2 ⊟	6421	4459	3276	2506	1982	1605	1327	1115	950	819	713	627	555	495	445	401	364	332	303	279	257	237	220	205	191	178

Pakan

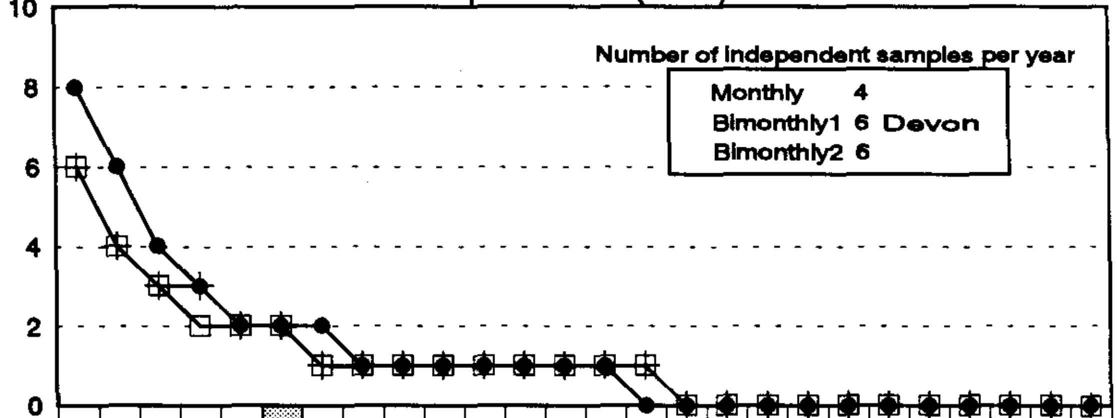
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	10000	7043	5174	3962	3130	[illegible]	2095	1761	1500	1294	1127	990	877	783	702	634	575	524	479	440	406	375	346	323	301	282
Bimonthly1 +	8146	5658	4157	3183	2515	2047	1683	1415	1205	1039	905	796	705	629	564	509	462	421	386	354	326	301	279	260	242	226
Bimonthly2 ⊟	15000	10000	7563	5790	4576	3706	3063	2574	2193	1891	1647	1448	1282	1144	1027	926	840	766	701	643	593	546	506	473	441	412

Border

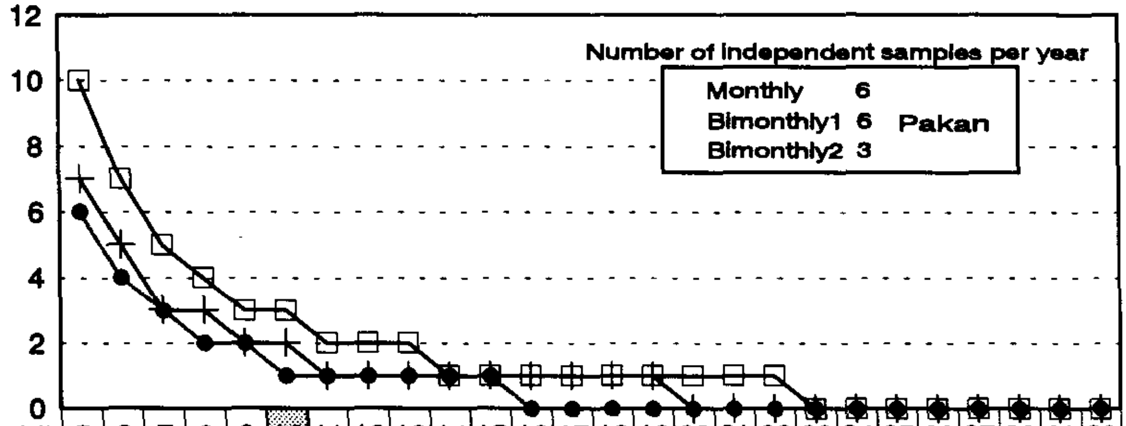
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	15000	10000	7593	5813	4593	3721	3075	2584	2202	1898	1654	1453	1287	1146	1031	930	844	769	703	646	595	550	510	475	442	413
Bimonthly1 +	17000	12000	8879	6798	5371	4351	3596	3021	2574	2220	1934	1699	1505	1343	1205	1088	987	899	822	755	696	644	597	555	517	483
Bimonthly2 ⊟	20000	14000	10000	7869	6218	5038	4162	3496	2960	2570	2236	1967	1743	1554	1395	1259	1142	1041	952	874	806	746	691	642	599	560

Fig. 14a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

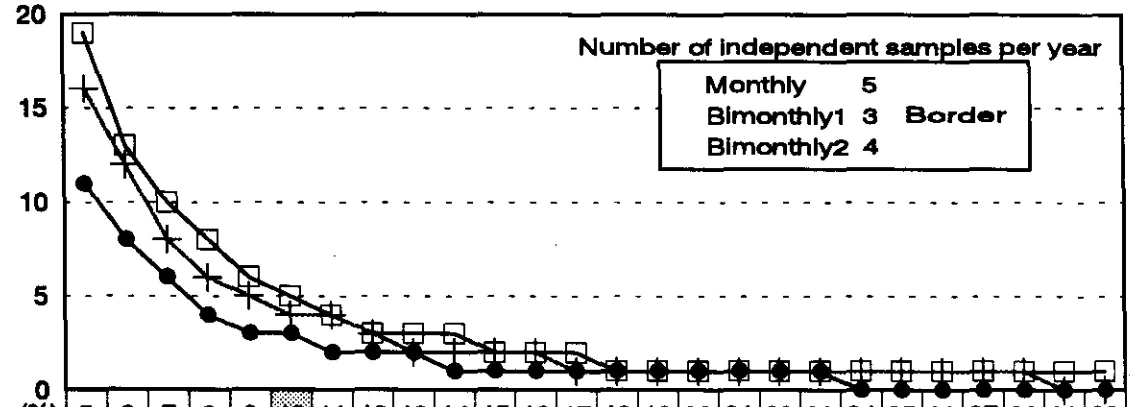
pH Flield (PHF)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	8	6	4	3	2	2	2	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	Years
Bimonthly1 +	6	4	3	3	2	2	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	
Bimonthly2 ⊞	6	4	3	2	2	2	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	



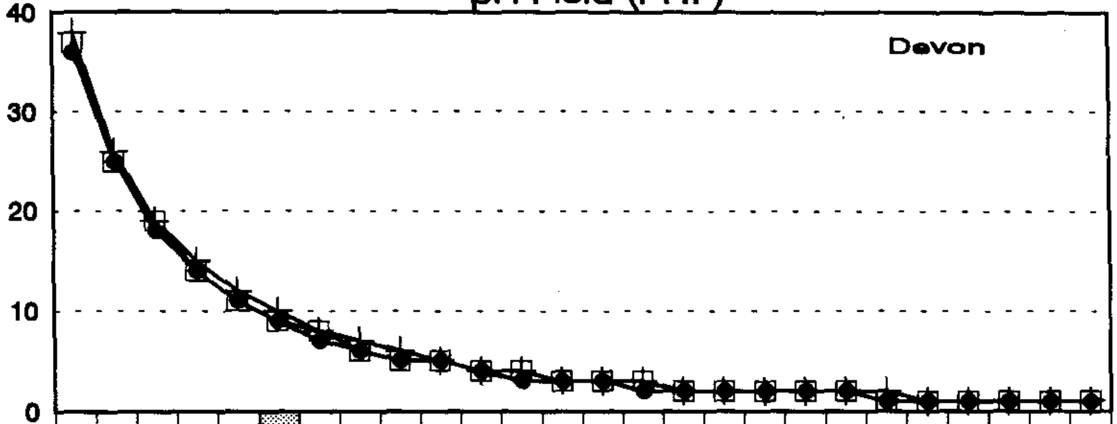
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	6	4	3	2	2	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Years
Bimonthly1 +	7	5	3	3	2	2	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	
Bimonthly2 ⊟	10	7	5	4	3	3	2	2	2	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	



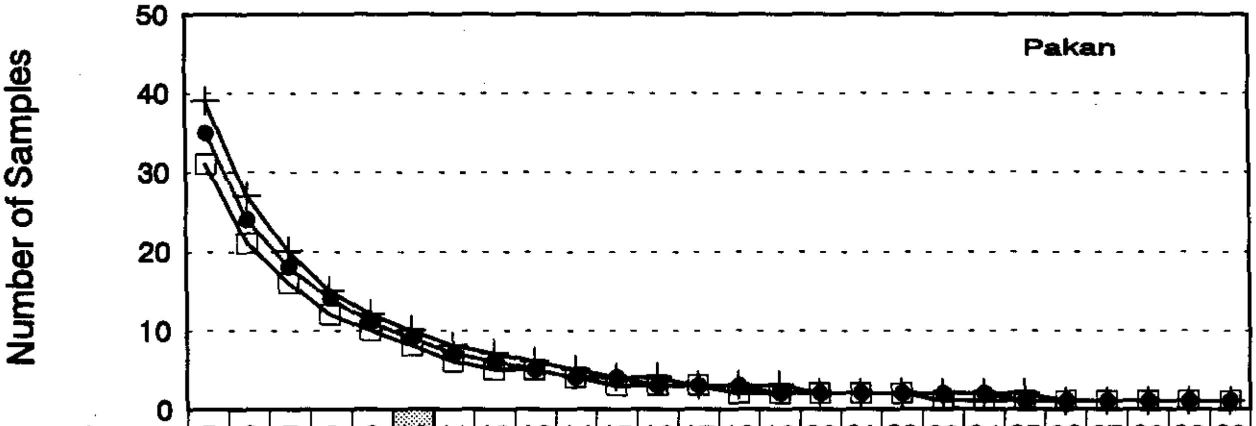
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	11	8	6	4	3	3	2	2	2	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	Years
Bimonthly1 +	16	12	8	6	5	4	4	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	0	0	
Bimonthly2 ⊟	19	13	10	8	6	5	4	3	3	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	

Fig. 14b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

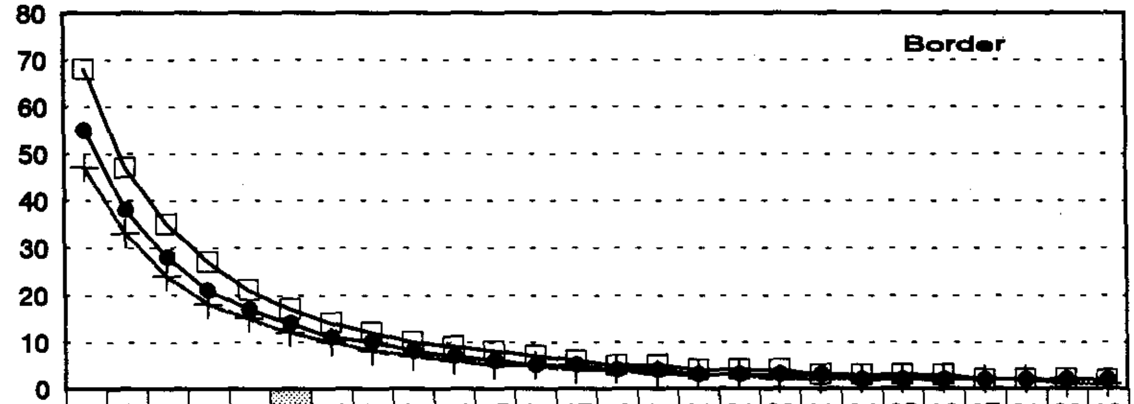
pH Field (PHF)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly●	36	25	18	14	11	9	7	6	5	5	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1	Samples
Bimonthly1 +	38	26	19	15	12	10	8	7	6	5	4	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	
Bimonthly2 ⊟	37	25	19	14	11	9	8	6	5	5	4	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly●	35	24	18	14	11	9	7	6	5	4	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1	Samples
Bimonthly1 +	39	27	20	15	12	10	8	7	6	5	4	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	
Bimonthly2 ⊟	31	21	16	12	10	8	6	5	5	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly●	55	38	28	21	17	14	11	10	8	7	6	5	5	4	4	3	3	3	3	2	2	2	2	2	2	2	Samples
Bimonthly1 +	47	33	24	18	15	12	10	8	7	6	5	5	4	4	3	3	3	2	2	2	2	2	2	2	1	1	
Bimonthly2 ⊟	68	47	35	27	21	17	14	12	10	9	8	7	6	5	5	4	4	4	3	3	3	3	2	2	2	2	

APPENDIX D: STUDY ONE: PLOTS OF TOTAL NUMBER OF SAMPLES AND NUMBER OF YEARS TO DETECT LINEAR TREND SIZES, 5 TO 30% OF THE SERIES MEAN, AND NUMBER OF INDEPENDENT SAMPLES PER YEAR FOR MONTHLY AND BIMONTHLY MONITORING SCHEDULES AT THREE LONG- TERM MONITORING STATIONS ON THE NORTH SASKATCHEWAN RIVER

Appendix C-1

Table 1. Water Quality, Three Stations

SITE=DEVON SCHEME=MONTHLY

VARIABLE		CODE	FITTED MODEL	Log SE	Bt SE	R	N	Log Baseline Mean	Bt Baseline Mean
A-BHC	Alpha-BHC	18075L		.	.	.	.	.	.
ALKTOT	Total Alkalinity	10101L	AR(1)	0.0705	8.799	0.42	137	4.823	124.647
BDISS	Boron Dissolved	05105L	AR(1)	0.6156	0.025	0.61	136	-3.5041	0.036
DO	Dissolved Oxygen	08101F	WN	0.085	0.919	0	118	2.3754	10.794
DOC	Dissolved Organic Carbon	06101L	WN	0.6679	2.093	0	140	0.8033	2.791
FCOLI	Fecal Coliforms	36011L	WN	0.9061	8.584	0	142	1.6188	7.609
HCO3	Carbonate	06201L	AR(1)	0.0909	13.802	0.24	137	5.0166	151.522
KDISS	Potassium Dissolved	19101L	WN	0.2416	0.184	0	136	-0.3151	0.751
MGDISS	Manganese Dissolved	12102L	AR(1)	0.078	0.969	0.27	140	2.515	12.404
NADISS	Sodium Dissolved	11101L	WN	0.2022	0.803	0	140	1.3479	3.929
NFR	Non-Filterable Residues	10401L	AR(1)	0.9921	22.378	0.25	138	2.3578	17.287
NO3NO2	Nitrate Plus Nitrite	07110L	AR(1)	0.6474	0.018	0.24	140	-3.9102	0.025
NP	Particulate Nitrogen	07901L	AR(1)	0.9911	0.1	0.5	137	-3.0514	0.077
PDISS	Phosphorus Dissolved	15103L	WN	0.4245	0.002	0	139	-5.5166	0.004
PH	pH	10301F	AR(1)	0.2615	0.262	0.46	142	8.1317	8.132
POC	Organic Carbon as Particulate	06901L	AR(1)	0.9008	0.67	0.33	133	-0.9183	0.599
PP	Phosphorus as Particulate	15901L	WN	1.059	0.031	0	141	-4.3944	0.022
PTOT	Phosphorus Total	15406L	WN	0.9819	0.032	0	141	-4.1615	0.025
SO4	Sulfate	16301L	WN	0.1132	4.05	0	140	3.5676	35.659
TCOLI	Total Coliforms	36001L	AR(1)	1.3353	111.932	0.63	142	3.0269	50.321
TDS	Total Dissolved Solids	00201L	AR(1)	0.0642	11.294	0.15	137	5.1669	175.732
TEMP	Temperature	02061F	AR(1)	3.1529	3.153	0.4	141	8.1302	8.13
TURB	Turbidity	02071L		.	.	.	.	.	.

Appendix C-2

Table 2. Water Quality, Three Stations

SITE=PAKAN SCHEME=MONTHLY

VARIABLE		CODE	FITTED MODEL	Log SE	Bt SE	R	N	Log Baseline Mean	Bt Baseline Mean
A-BHC	Alpha-BHC	18075L		.	.	.	.	.	.
ALKTOT	Total Alkalinity	10101L	AR(1)	0.0858	10.97	0.29	137	4.8451	127.58
BDISS	Boron Dissolved	05105L	AR(1)	0.6232	0.03	0.61	136	-3.19	0.05
DO	Dissolved Oxygen	08101F	WN	0.0894	0.93	0	116	2.3307	10.33
DOC	Dissolved Organic Carbon	06101L	AR(1)	0.4629	1.54	0.19	140	1.0433	3.16
FCOLI	Fecal Coliforms	36011L	AR(1)	1.3815	682.86	0.33	140	4.698	284.94
HCO3	Carbonate	06201L	AR(1)	0.084	13.03	0.39	137	5.0386	154.8
KDISS	Potassium Dissolved	19101L	AR(1)	0.3372	0.43	0.15	140	0.1606	1.24
MGDISS	Manganese Dissolved	12102L	AR(1)	0.0906	1.16	0.13	140	2.5471	12.82
NADISS	Sodium Dissolved	11101L	AR(1)	0.2132	1.51	0.25	140	1.9239	7.01
NFR	Non-Filterable Residues	10401L	WN	0.9767	28.44	0	138	2.6371	22.51
NO3NO2	Nitrate Plus Nitrite	07110L	AR(1)	0.4682	0.14	0.27	140	-1.3445	0.29
NP	Particulate Nitrogen	07901L	AR(1)	0.8851	0.18	0.55	136	-2.1823	0.17
PDISS	Phosphorus Dissolved	15103L	WN	0.5076	0.04	0	134	-2.7799	0.07
PH	pH	10301F	AR(1)	0.2555	0.26	0.33	139	8.0608	8.06
POC	Organic Carbon as Particulate	06901L	AR(1)	0.6786	0.7	0.48	135	-0.3244	0.91
PP	Phosphorus as Particulate	15901L	AR(1)	0.6115	0.03	0.28	135	-3.2304	0.05
PTOT	Phosphorus Total	15406L	AR(1)	0.4875	0.07	0.25	140	-2.1276	0.13
SO4	Sulfate	16301L	WN	0.1293	5.27	0	139	3.6944	40.56
TCOLI	Total Coliforms	36001L	AR(1)	1.2544	5667.79	0.31	140	7.1852	2898.53
TDS	Total Dissolved Solids	00201L	WN	0.0867	16.44	0	136	5.2393	189.25
TEMP	Temperature	02061F	AR(1)	3.3296	3.33	0.31	139	8.2496	8.25
TURB	Turbidity	02071L	WN	0.8136	11.97	0	140	2.1835	12.36

Appendix C-3
Table 3. Water Quality, Three Stations

SITE=BORDER SCHEME=MONTHLY

VARIABLE		CODE	FITTED MODEL	Log SE	Bt SE	R	N	Log Baseline Mean	Bt Baseline Mean
A-BHC	Alpha-BHC	18075L	AR(1)	0.5241	0.001	0.29	142	-6.165	0.002
ALKTOT	Total Alkalinity	10101L	AR(1)	0.1155	15.415	0.23	144	4.8838	133.016
BDISS	Boron Dissolved	05105L	AR(1)	0.4211	0.03	0.18	143	-2.7725	0.068
DO	Dissolved Oxygen	08101F	WN	0.1349	1.378	0	144	2.3099	10.165
DOC	Dissolved Organic Carbon	06101L	AR(1)	0.409	1.416	0.29	137	1.1155	3.317
FCOLI	Fecal Coliforms	36011L	AR(1)	1.2919	50.765	0.43	137	2.3626	24.462
HCO3	Carbonate	06201L	AR(1)	0.087	13.74	0.42	132	5.0565	157.635
KDISS	Potassium Dissolved	19101L	AR(1)	0.2578	0.359	0.2	137	0.2805	1.369
MGDISS	Manganese Dissolved	12102L	AR(1)	0.0836	1.11	0.22	144	2.5804	13.249
NADISS	Sodium Dissolved	11101L	WN	0.2866	2.513	0	138	2.1094	8.589
NFR	Non-Filterable Residues	10401L	WN	0.6893	10.996	0	139	2.4086	14.1
NO3NO2	Nitrate Plus Nitrite	07110L	WN	1.3133	0.759	0	139	-1.902	0.354
NP	Particulate Nitrogen	07901L	AR(1)	0.56	0.072	0.41	139	-2.2912	0.118
PDISS	Phosphorus Dissolved	15103L	AR(1)	0.5988	0.032	0.22	137	-3.2049	0.049
PH	pH	10301F	AR(1)	0.3205	0.321	0.41	144	8.0316	8.032
POC	Organic Carbon as Particulate	06901L	WN	0.5234	0.503	0	137	-0.247	0.896
PP	Phosphorus as Particulate	15901L	AR(1)	0.5603	0.024	0.42	137	-3.3779	0.04
PTOT	Phosphorus Total	15406L	AR(1)	0.3939	0.043	0.46	144	-2.3222	0.106
SO4	Sulfate	16301L	WN	0.1398	5.83	0	139	3.7159	41.499
TCOLI	Total Coliforms	36001L	AR(1)	1.4918	468.396	0.44	136	3.981	162.997
TDS	Total Dissolved Solids	00201L	WN	0.087	17.103	0	144	5.2754	196.21
TEMP	Temperature	02061F	AR(1)	3.9979	3.998	0.22	144	8.0721	8.072
TURB	Turbidity	02071L	AR(1)	0.6371	5.967	0.16	137	1.9292	8.433

Appendix C-4
Table 4. Water Quality, Three Stations

SITE=DEVON SCHEME=BIMONTHLY1

VARIABLE		CODE	FITTED MODEL	Log SE	Bt SE	R	N	Log Baseline Mean	Bt Baseline Mean
A-BHC	Alpha-BHC	18075L		.	.	.	.	.	.
ALKTOT	Total Alkalinity	10101L	WN	0.0741	9.372	0	68	4.8359	126.298
BDISS	Boron Dissolved	05105L	AR(1)	0.6361	0.027	0.54	68	-3.4623	0.038
DO	Dissolved Oxygen	08101F	WN	0.0945	1.03	0	59	2.3819	10.874
DOC	Dissolved Organic Carbon	06101L	WN	0.7453	2.462	0	70	0.7719	2.857
FCOLI	Fecal Coliforms	36011L	WN	0.9511	9.827	0	71	1.6399	8.103
HCO3	Carbonate	06201L	WN	0.0738	11.333	0	68	5.03	153.35
KDISS	Potassium Dissolved	19101L	WN	0.2811	0.223	0	68	-0.2914	0.777
MGDISS	Manganese Dissolved	12102L	WN	0.0831	1.038	0	70	2.5196	12.467
NADISS	Sodium Dissolved	11101L	WN	0.23	0.942	0	70	1.3701	4.041
NFR	Non-Filterable Residues	10401L	WN	0.9852	19.526	0	70	2.2392	15.249
NO3NO2	Nitrate Plus Nitrite	07110L	WN	0.6696	0.018	0	70	-3.9323	0.025
NP	Particulate Nitrogen	07901L	WN	0.9758	0.082	0	68	-3.2119	0.065
PDISS	Phosphorus Dissolved	15103L	WN	0.4178	0.002	0	69	-5.5183	0.004
PH	pH	10301F	WN	0.2708	0.271	0	71	8.1505	8.151
POC	Organic Carbon as Particulate	06901L	WN	0.8173	0.488	0	66	-1.0251	0.501
PP	Phosphorus as Particulate	15901L	WN	0.979	0.024	0	71	-4.4268	0.019
PTOT	Phosphorus Total	15406L	WN	0.9911	0.03	0	71	-4.2578	0.023
SO4	Sulfate	16301L	WN	0.1153	4.146	0	70	3.5723	35.836
TCOLI	Total Coliforms	36001L	AR(1)	1.369	123.057	0.43	71	3.0218	52.399
TDS	Total Dissolved Solids	00201L	WN	0.0622	11.033	0	68	5.1754	177.21
TEMP	Temperature	02061F	WN	3.8198	3.82	0	71	7.9459	7.946
TURB	Turbidity	02071L		.	.	.	.	.	.

Appendix C-5
Table 5. Water Quality, Three Stations

SITE=PAKAN SCHEME=BIMONTHLY1

VARIABLE		CODE	FITTED MODEL	Log SE	Bt SE	R	N	Log Baseline Mean	Bt Baseline Mean
A-BHC	Alpha-BHC	18075L		.	.	.	.	.	.
ALKTOT	Total Alkalinity	10101L	WN	0.0698	9	0	68	4.8557	128.78
BDISS	Boron Dissolved	05105L	AR(1)	0.5754	0.03	0.72	68	-3.1231	0.05
DO	Dissolved Oxygen	08101F	WN	0.0938	0.98	0	58	2.336	10.39
DOC	Dissolved Organic Carbon	06101L	WN	0.5044	1.66	0	70	1.001	3.09
FCOLI	Fecal Coliforms	36011L	WN	1.4406	770.68	0	70	4.639	291.97
HCO3	Carbonate	06201L	WN	0.0705	11.02	0	68	5.0479	156.08
KDISS	Potassium Dissolved	19101L	WN	0.3586	0.46	0	70	0.149	1.24
MGDISS	Manganese Dissolved	12102L	WN	0.0819	1.07	0	70	2.5613	13
NADISS	Sodium Dissolved	11101L	WN	0.2339	1.68	0	70	1.9303	7.08
NFR	Non-Filterable Residues	10401L	WN	0.9332	24.74	0	70	2.6086	20.99
NO3NO2	Nitrate Plus Nitrite	07110L	WN	0.4584	0.14	0	70	-1.3644	0.28
NP	Particulate Nitrogen	07901L	WN	0.8255	0.15	0	65	-2.2269	0.15
PDISS	Phosphorus Dissolved	15103L	WN	0.4604	0.03	0	68	-2.7557	0.07
PH	pH	10301F	WN	0.2699	0.27	0	69	8.0636	8.06
POC	Organic Carbon as Particulate	06901L	AR(1)	0.7599	0.87	0.36	65	-0.3009	0.99
PP	Phosphorus as Particulate	15901L	WN	0.7126	0.04	0	68	-3.2258	0.05
PTOT	Phosphorus Total	15406L	WN	0.4485	0.06	0	70	-2.1237	0.13
SO4	Sulfate	16301L	WN	0.1132	4.65	0	70	3.7063	40.96
TCOLI	Total Coliforms	36001L	WN	1.0348	3624.89	0	70	7.3346	2617.58
TDS	Total Dissolved Solids	00201L	WN	0.0677	12.99	0	68	5.2532	191.62
TEMP	Temperature	02061F	WN	4.0579	4.06	0	69	8.1814	8.18
TURB	Turbidity	02071L		.	.	.	.	.	.

Appendix C-6

Table 6. Water Quality, Three Stations

SITE=BORDER SCHEME=BIMONTHLY1

VARIABLE		CODE	FITTED MODEL	Log SE	Bt SE	R	N	Log Baseline Mean	Bt Baseline Mean
A-BHC	Alpha-BHC	18075L		.	.	.	.	.	.
ALKTOT	Total Alkalinity	10101L	AR(1)	0.0846	11.16	0.26	72	4.877	131.71
BDISS	Boron Dissolved	05105L	AR(1)	0.4463	0.03	0.32	70	-2.7364	0.07
DO	Dissolved Oxygen	08101F	WN	0.101	1.03	0	72	2.3103	10.13
DOC	Dissolved Organic Carbon	06101L	WN	0.4889	1.77	0	69	1.1076	3.41
FCOLI	Fecal Coliforms	36011L	WN	1.3604	77.95	0	72	2.5909	33.66
HCO3	Carbonate	06201L	WN	0.0939	14.97	0	66	5.0651	159.1
KDISS	Potassium Dissolved	19101L	WN	0.2626	0.36	0	72	0.2719	1.36
MGDISS	Manganese Dissolved	12102L	WN	0.0827	1.1	0	72	2.5851	13.31
NADISS	Sodium Dissolved	11101L	WN	0.2643	2.26	0	72	2.0928	8.4
NFR	Non-Filterable Residues	10401L	WN	0.6978	12.3	0	72	2.4992	15.53
NO3NO2	Nitrate Plus Nitrite	07110L	WN	1.186	0.6	0	72	-1.7825	0.34
NP	Particulate Nitrogen	07901L	WN	0.6554	0.09	0	70	-2.2787	0.13
PDISS	Phosphorus Dissolved	15103L	WN	0.639	0.04	0	70	-3.1889	0.05
PH	pH	10301F	AR(1)	0.296	0.3	0.36	72	8.0082	8.01
POC	Organic Carbon as Particulate	06901L	WN	0.5388	0.56	0	70	-0.1868	0.96
PP	Phosphorus as Particulate	15901L	AR(1)	0.6098	0.03	0.32	70	-3.3614	0.04
PTOT	Phosphorus Total	15406L	WN	0.4676	0.05	0	72	-2.3173	0.11
SO4	Sulfate	16301L	AR(1)	0.1235	5.2	0.34	70	3.7288	41.95
TCOLI	Total Coliforms	36001L	AR(1)	3.4238	7295019	0.52	72	4.0803	20774.95
TDS	Total Dissolved Solids	00201L	WN	0.0854	16.79	0	72	5.2758	196.26
TEMP	Temperature	02061F	WN	4.5453	4.55	0	72	8.2443	8.24
TURB	Turbidity	02071L		.	.	.	.	.	.

Appendix C-7

Table 7. Water Quality, Three Stations

SITE=DEVON SCHEME=BIMONTHLY2

VARIABLE		CODE	FITTED MODEL	Log SE	Bt SE	R	N	Log Baseline Mean	Bt Baseline Mean
A-BHC	Alpha-BHC	18075L		.	.	.	.	.	.
ALKTOT	Total Alkalinity	10101L	AR(1)	0.0746	9.299	0.45	69	4.8214	124.485
BDISS	Boron Dissolved	05105L	AR(1)	0.6272	0.025	0.55	65	-3.5399	0.035
DO	Dissolved Oxygen	08101F	WN	0.0758	0.815	0	59	2.3709	10.738
DOC	Dissolved Organic Carbon	06101L	WN	0.4958	1.361	0	70	0.8242	2.578
FCOLI	Fecal Coliforms	36011L	WN	0.6953	4.467	0	71	1.4926	5.665
HCO3	Carbonate	06201L	AR(1)	0.0717	10.838	0.48	69	5.0145	150.968
KDISS	Potassium Dissolved	19101L	WN	0.2128	0.157	0	68	-0.3383	0.729
MGDISS	Manganese Dissolved	12102L	AR(1)	0.076	0.941	0.28	70	2.5117	12.362
NADISS	Sodium Dissolved	11101L	WN	0.1806	0.698	0	70	1.3269	3.831
NFR	Non-Filterable Residues	10401L	WN	1.0942	33.653	0	70	2.4986	22.137
NO3NO2	Nitrate Plus Nitrite	07110L	WN	0.5538	0.014	0	70	-3.8849	0.024
NP	Particulate Nitrogen	07901L	WN	0.9022	0.08	0	69	-3.0522	0.071
PDISS	Phosphorus Dissolved	15103L	WN	0.4131	0.002	0	70	-5.517	0.004
PH	pH	10301F	WN	0.2635	0.264	0	71	8.0781	8.078
POC	Organic Carbon as Particulate	06901L	AR(1)	0.8525	0.622	0.3	67	-0.8715	0.602
PP	Phosphorus as Particulate	15901L	AR(1)	1.0263	0.031	0.25	69	-4.3121	0.023
PTOT	Phosphorus Total	15406L	WN	0.9187	0.034	0	70	-3.9475	0.029
SO4	Sulfate	16301L	WN	0.1021	3.664	0	70	3.5726	35.795
TCOLI	Total Coliforms	36001L	AR(1)	1.1722	126.438	0.58	71	3.6116	73.599
TDS	Total Dissolved Solids	00201L	WN	0.0666	11.644	0	69	5.1605	174.638
TEMP	Temperature	02061F	WN	3.2955	3.296	0	70	8.0078	8.008
TURB	Turbidity	02071L		.	.	.	.	.	.

Appendix C-8
Table 8. Water Quality, Three Stations

SITE=PAKAN SCHEME=BIMONTHLY2

VARIABLE		CODE	FITTED MODEL	Log SE	Bt SE	R	N	Log Baseline Mean	Bt Baseline Mean
A-BHC	Alpha-BHC	18075L		.	.	.	.	.	.
ALKTOT	Total Alkalinity	10101L	WN	0.1844	23.39	0	69	4.8173	125.75
BDISS	Boron Dissolved	05105L	AR(1)	0.7181	0.04	0.42	65	-3.2502	0.05
DO	Dissolved Oxygen	08101F	WN	0.1019	1.05	0	58	2.3234	10.26
DOC	Dissolved Organic Carbon	06101L	WN	0.4453	1.51	0	70	1.0732	3.23
FCOLI	Fecal Coliforms	36011L	AR(1)	1.3075	558.78	0.3	70	4.716	262.64
HCO3	Carbonate	06201L	AR(1)	0.099	15.27	0.35	69	5.0313	153.88
KDISS	Potassium Dissolved	19101L	WN	0.3194	0.41	0	70	0.172	1.25
MGDISS	Manganese Dissolved	12102L	WN	0.0978	1.24	0	70	2.5344	12.67
NADISS	Sodium Dissolved	11101L	WN	0.2007	1.41	0	70	1.9188	6.95
NFR	Non-Filterable Residues	10401L	WN	0.9067	24.39	0	70	2.6617	21.6
NO3NO2	Nitrate Plus Nitrite	07110L	WN	0.528	0.17	0	70	-1.3215	0.31
NP	Particulate Nitrogen	07901L	WN	0.7632	11.01	0	69	2.225	12.38
PDISS	Phosphorus Dissolved	15103L	WN	0.5978	0.05	0	68	-2.7601	0.08
PH	pH	10301F	AR(1)	0.2413	0.24	0.31	70	8.0585	8.06
POC	Organic Carbon as Particulate	06901L	WN	0.7285	0.76	0	69	-0.3672	0.9
PP	Phosphorus as Particulate	15901L	WN	0.5375	0.03	0	68	-3.2283	0.05
PTOT	Phosphorus Total	15406L	WN	0.581	0.09	0	70	-2.1347	0.14
SO4	Sulfate	16301L	WN	0.1495	6.06	0	70	3.6847	40.28
TCOLI	Total Coliforms	36001L	AR(1)	1.3663	6760.08	0.37	70	7.036	2891.09
TDS	Total Dissolved Solids	00201L	WN	0.1046	19.67	0	69	5.2284	187.52
TEMP	Temperature	02061F	AR(1)	2.8204	2.82	0.26	70	8.1804	8.18
TURB	Turbidity	02071L	WN	0.7196	9.66	0	70	2.2032	11.73

Appendix C-9

Table 9. Water Quality, Three Stations

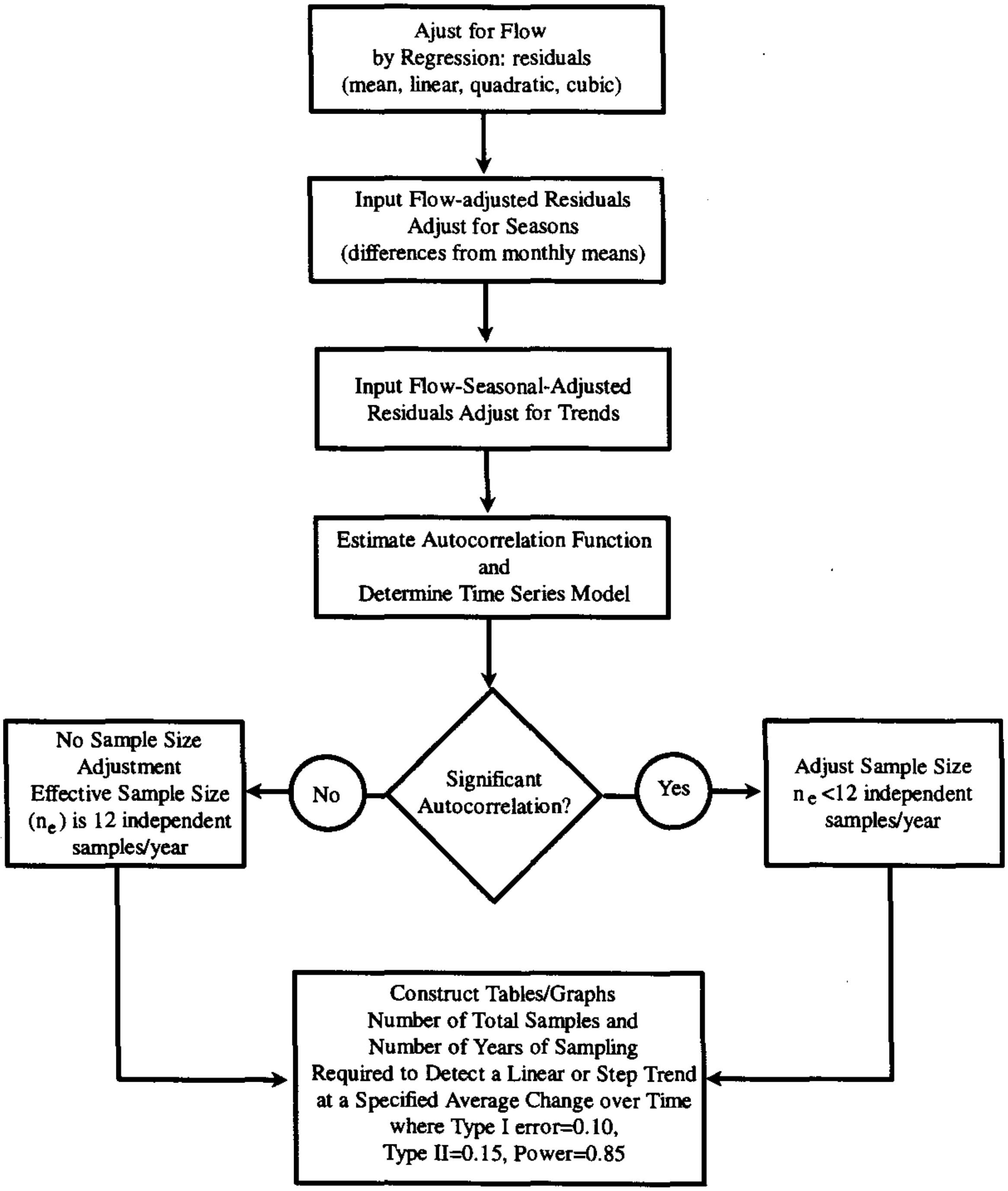
SITE=BORDER SCHEME=BIMONTHLY2

VARIABLE		CODE	FITTED MODEL	Log SE	Bt SE	R	N	Log Baseline Mean	Bt Baseline Mean
A-BHC	Alpha-BHC	18075L	AR(1)	0.505	0.001	0.42	71	-6.3061	0.002
ALKTOT	Total Alkalinity	10101L	WN	0.0958	12.527	0	71	4.8665	130.463
BDISS	Boron Dissolved	05105L	WN	0.3784	0.025	0	72	-2.807	0.065
DO	Dissolved Oxygen	08101F	WN	0.1129	1.154	0	72	2.3145	10.185
DOC	Dissolved Organic Carbon	06101L	WN	0.3457	1.19	0	68	1.1459	3.339
FCOLI	Fecal Coliforms	36011L	AR(1)	1.3029	44.217	0.39	72	2.1927	20.936
HCO3	Carbonate	06201L	AR(1)	0.0821	12.854	0.29	66	5.0484	156.299
KDISS	Potassium Dissolved	19101L	WN	0.225	0.302	0	72	0.2565	1.326
MGDISS	Manganese Dissolved	12102L	WN	0.0824	1.09	0	72	2.5768	13.2
NADISS	Sodium Dissolved	11101L	WN	0.2688	2.352	0	71	2.1147	8.592
NFR	Non-Filterable Residues	10401L	WN	0.6416	10.306	0	72	2.4643	14.442
NO3NO2	Nitrate Plus Nitrite	07110L	WN	0.9273	0.316	0	72	-1.7373	0.271
NP	Particulate Nitrogen	07901L	AR(1)	0.5358	0.069	0.47	69	-2.2712	0.119
PDISS	Phosphorus Dissolved	15103L	WN	0.6781	0.039	0	68	-3.1986	0.051
PH	pH	10301F	AR(1)	0.3576	0.358	0.26	72	8.0542	8.054
POC	Organic Carbon as Particulate	06901L	WN	0.5147	0.473	0	69	-0.2854	0.858
PP	Phosphorus as Particulate	15901L	WN	0.5577	0.023	0	68	-3.4073	0.039
PTOT	Phosphorus Total	15406L	AR(1)	0.3538	0.034	0.26	72	-2.4336	0.093
SO4	Sulfate	16301L	WN	0.1497	6.169	0	69	3.7019	40.981
TCOLI	Total Coliforms	36001L	WN	1.3655	265.763	0	72	3.8022	113.806
TDS	Total Dissolved Solids	00201L	WN	0.082	16.09	0	72	5.2742	195.892
TEMP	Temperature	02061F	WN	3.5538	3.554	0	72	7.9102	7.91
TURB	Turbidity	02071L	WN	0.6386	7.311	0	68	2.1285	10.303

APPENDIX B: STATISTICAL PROTOCOL FOR STUDIES ONE AND TWO

APPENDIX B - 2

Fig. 1. Protocol for Determining the Times Series Sample Sizes Required to Detect Specified Amounts of Change in Water Quality Variables for Monitoring the North Saskatchewan River.

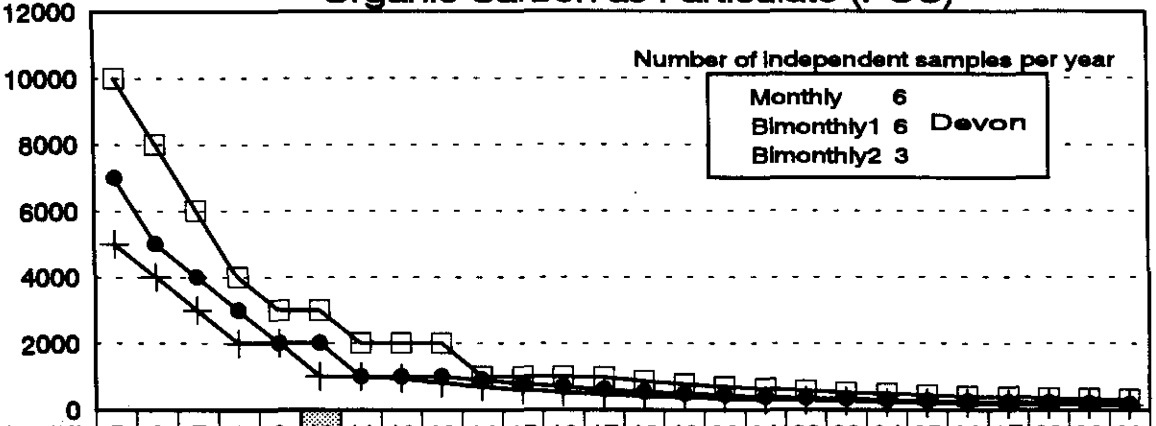


APPENDIX C: STUDY ONE: WATER QUALITY VARIABLES, NAQUADAT CODES NAQUADAT CODES AND MODEL SUMMARIES FOR THREE STATIONS ON THE NORTH SASKATCHEWAN RIVER

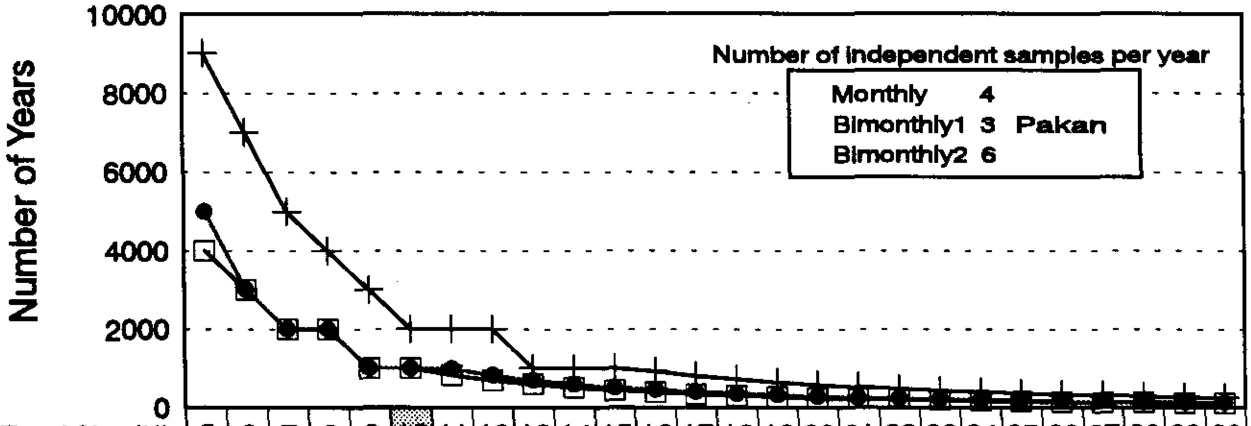
(Note: Bt=back transform from ln).

Fig. 15a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

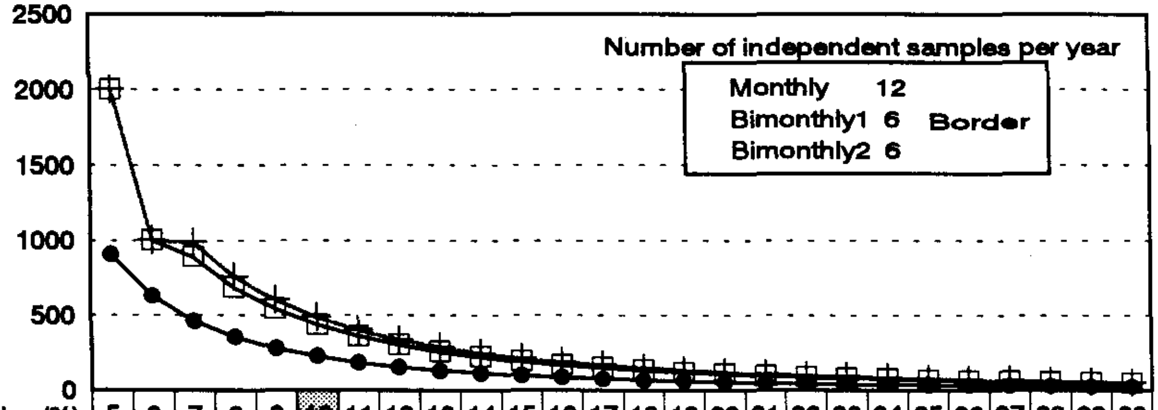
Organic Carbon as Particulate (POC)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	7000	5000	4000	3000	2000	2000	1000	1000	1000	906	789	694	614	546	492	444	403	367	336	306	284	263	244	227	211	197	Years
Bimonthly1 +	5000	4000	3000	2000	2000	1000	1000	949	809	697	607	534	473	422	379	342	310	282	258	237	219	202	186	174	163	152	
Bimonthly2 ⊟	10000	8000	6000	4000	3000	3000	2000	2000	2000	1000	1000	1000	977	872	782	706	641	584	534	490	452	418	387	360	336	314	



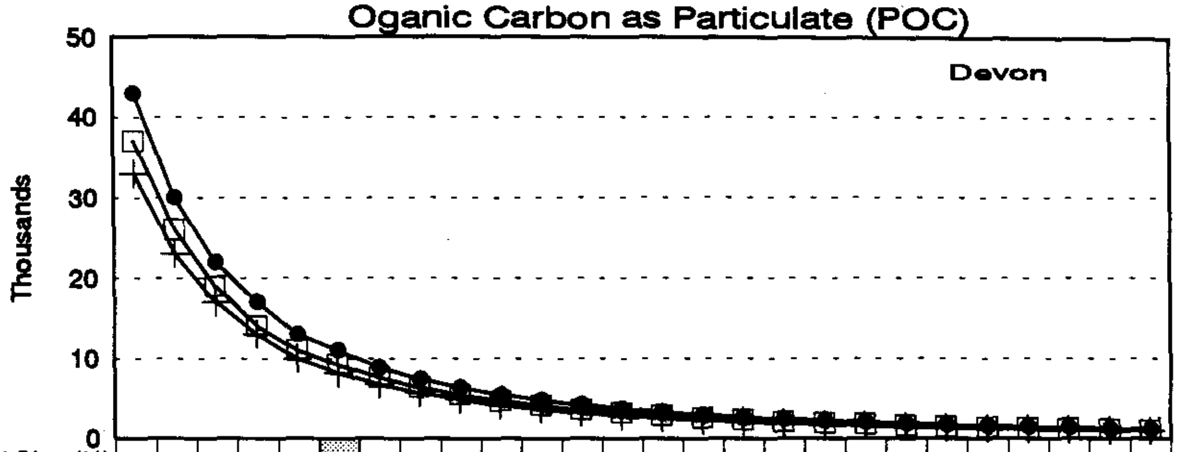
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	5000	3000	2000	2000	1000	1000	980	823	702	605	527	463	410	366	329	296	269	245	224	206	190	175	163	151	141	132	Years
Bimonthly1 +	9000	7000	5000	4000	3000	2000	2000	2000	1000	1000	1000	921	816	728	653	590	535	487	445	409	377	349	323	301	280	262	
Bimonthly2 ⊟	4000	3000	2000	2000	1000	1000	832	699	596	514	448	393	348	311	279	252	228	208	190	175	161	149	138	128	120	112	



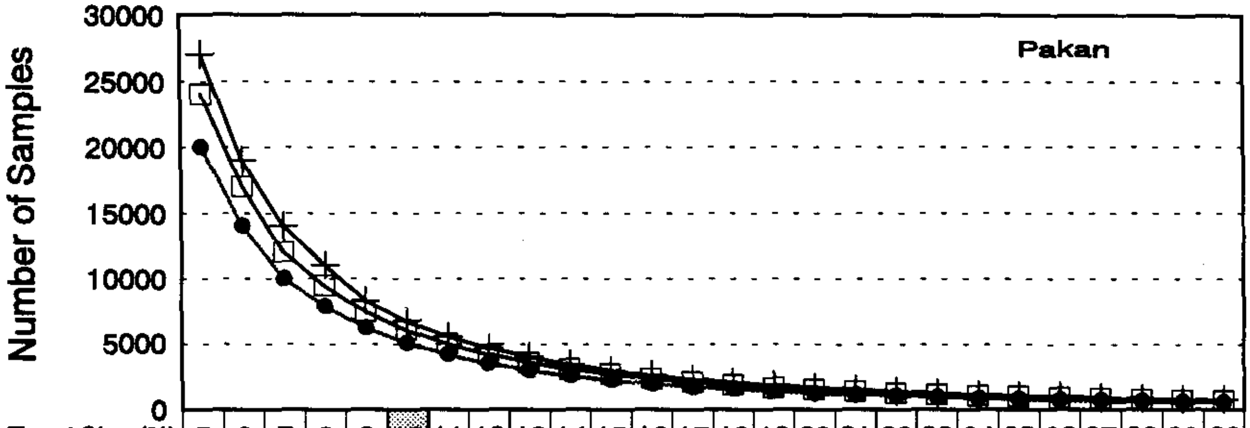
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	906	629	462	354	280	227	187	157	134	116	101	89	78	70	63	57	51	47	43	39	36	34	31	29	27	25	Years
Bimonthly1 +	2000	1000	988	757	598	484	400	336	287	247	215	189	168	150	134	121	110	100	92	84	78	72	67	62	58	54	
Bimonthly2 ⊟	2000	1000	890	682	539	436	361	303	258	223	194	170	151	135	121	109	99	90	83	76	70	65	60	56	52	49	

Fig. 15b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

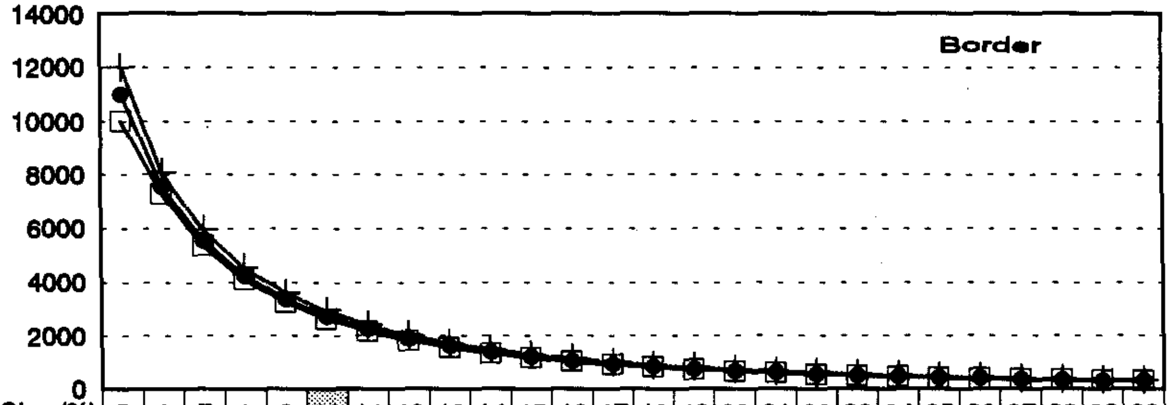
Oganic Carbon as Particulate (POC)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly ●	43	30	22	17	13	11	8.921	7.495	6.367	5.507	4.797	4.216	3.735	3.331	2.99	2.696	2.446	2.23	2.04	1.874	1.727	1.597	1.481	1.377	1.283	1.199	
Bimonthly1 +	33	23	17	13	10	8.198	6.775	5.690	4.861	4.183	3.644	3.202	2.837	2.53	2.271	2.05	1.859	1.694	1.55	1.423	1.312	1.213	1.125	1.046	0.975	0.911	
Bimonthly2 ⊟	37	26	19	14	11	9.217	7.617	6.401	5.454	4.703	4.096	3.6	3.169	2.845	2.553	2.304	2.09	1.904	1.742	1.6	1.475	1.363	1.264	1.176	1.096	1.024	



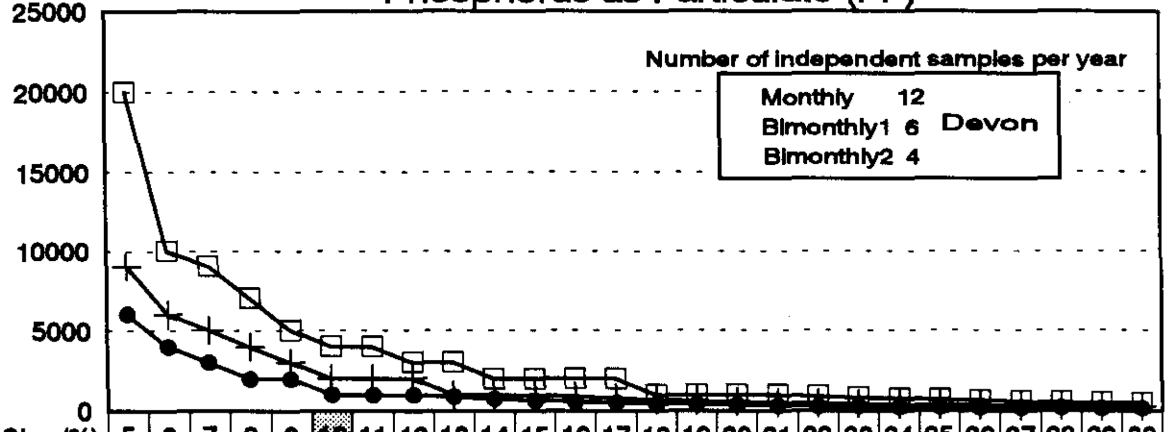
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly ●	20000	14000	10000	7864	6229	5046	4170	3504	2986	2574	2243	1971	1746	1557	1398	1261	1144	1043	954	876	807	746	692	644	600	561	
Bimonthly1 +	27000	19000	14000	11000	8323	6742	5572	4682	3989	3440	2996	2634	2333	2081	1866	1686	1529	1393	1274	1170	1079	997	925	860	802	749	
Bimonthly2 ⊟	24000	17000	12000	9436	7457	6040	4992	4195	3574	3082	2685	2359	2090	1864	1673	1510	1370	1248	1142	1049	966	894	829	770	718	671	



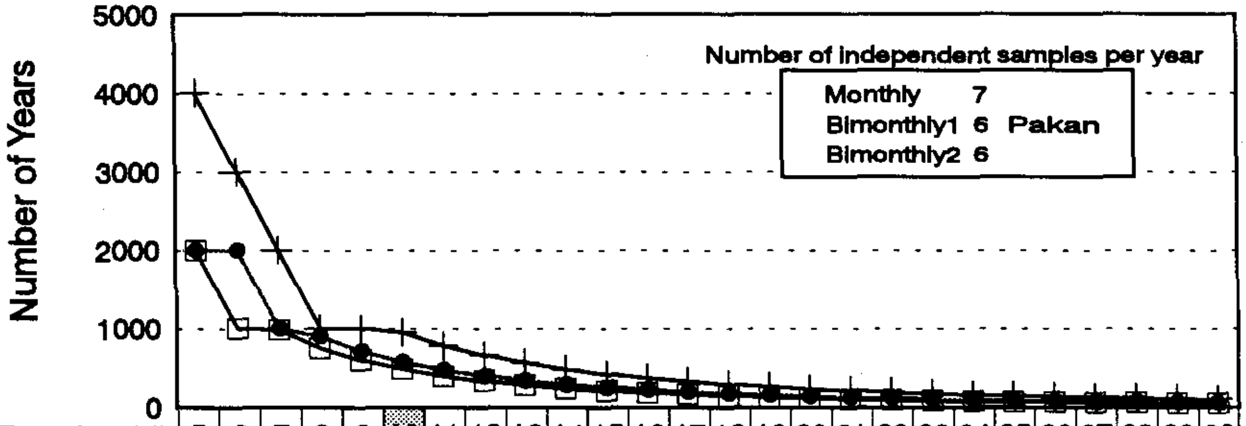
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly ●	11000	7552	5549	4248	3357	2719	2247	1888	1609	1387	1208	1062	941	839	753	680	617	562	514	472	436	402	373	347	323	302	
Bimonthly1 +	12000	8072	5930	4541	3588	2906	2402	2018	1719	1483	1292	1135	1006	897	805	726	659	600	549	505	465	430	399	371	346	323	
Bimonthly2 ⊟	10000	7269	5340	4089	3231	2617	2163	1817	1548	1335	1163	1022	905	806	725	654	593	541	495	454	419	387	359	334	311	291	

Fig. 16a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

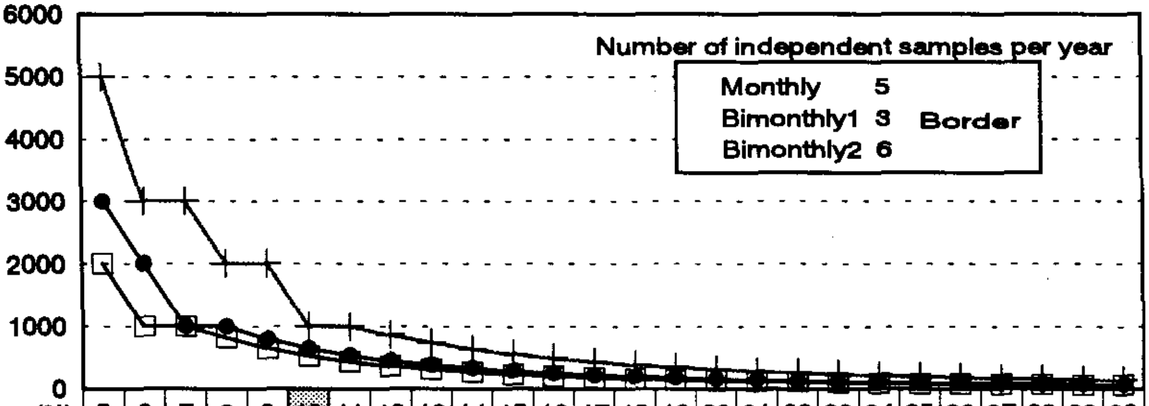
Phosphorus as Particulate (PP)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	6000	4000	3000	2000	2000	1000	1000	1000	880	759	661	581	515	459	412	372	337	307	281	258	236	220	204	190	177	165	Years
Bimonthly1 +	9000	6000	5000	4000	3000	2000	2000	2000	1000	1000	1000	903	800	714	640	578	524	478	437	401	370	342	317	295	275	257	
Bimonthly2 ⊟	20000	10000	9000	7000	5000	4000	4000	3000	3000	2000	2000	2000	2000	1000	1000	1000	1000	917	839	771	710	657	609	566	528	493	

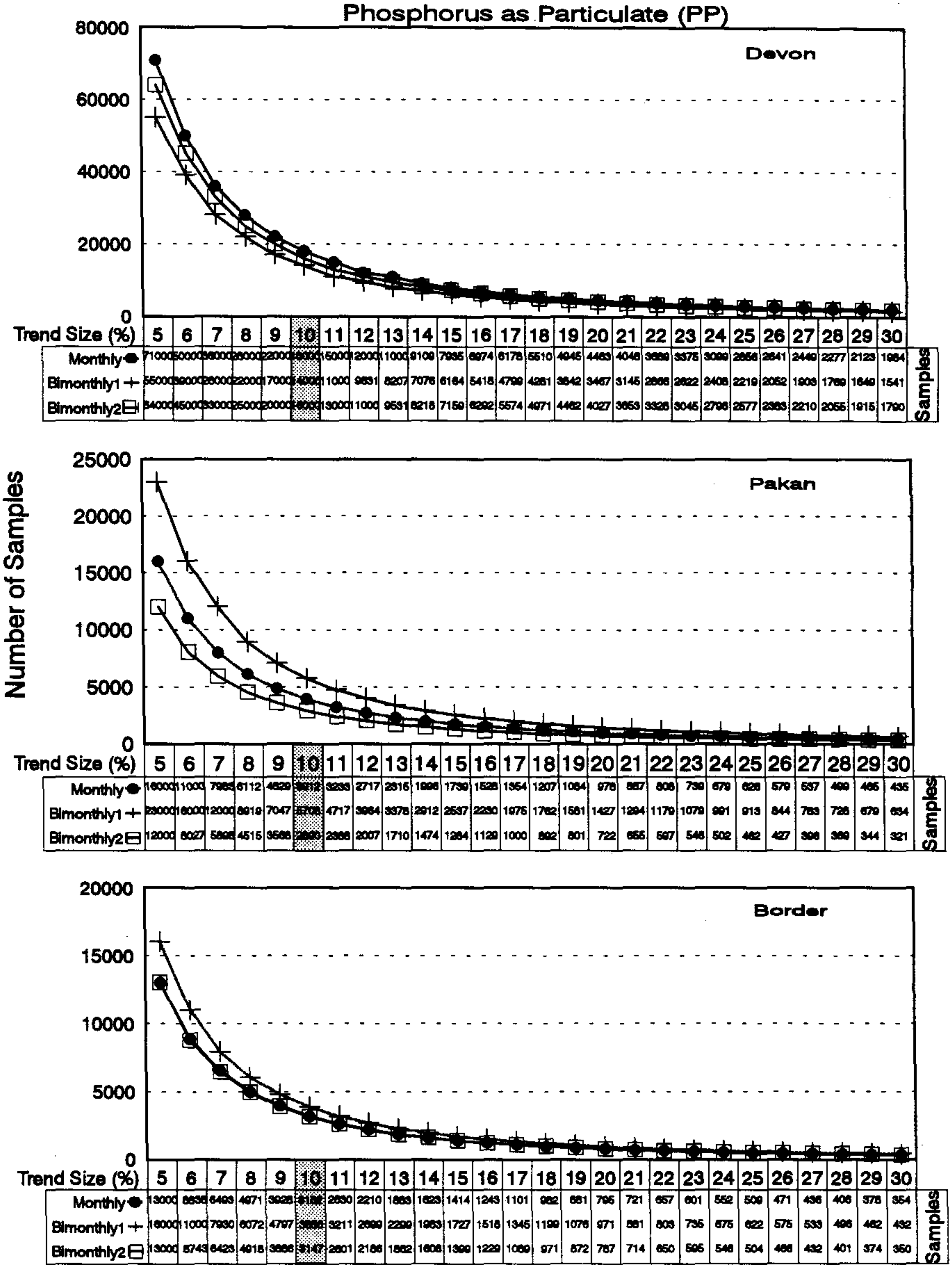


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	2000	2000	1000	901	712	577	477	401	341	294	256	225	200	178	160	144	131	119	109	100	92	85	79	74	69	64	Years
Bimonthly1 +	4000	3000	2000	1000	1000	951	786	661	563	485	423	372	329	294	264	236	216	197	180	165	152	141	131	121	113	106	
Bimonthly2 ⊟	2000	1000	983	753	595	492	396	335	285	246	214	186	167	149	134	120	109	100	91	84	77	71	66	62	57	54	



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	3000	2000	1000	1000	795	644	533	448	381	329	286	252	223	199	178	161	146	133	122	112	103	95	88	82	77	72	Years
Bimonthly1 +	5000	3000	3000	2000	2000	1000	1000	864	736	635	553	486	431	384	345	311	282	257	235	216	199	184	171	159	148	136	
Bimonthly2 ⊟	2000	1000	1000	820	646	528	434	364	310	266	233	205	182	162	145	131	119	108	99	91	84	78	72	67	62	58	

Fig. 16b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes



Devon

Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	71000	50000	36000	28000	22000	18000	15000	12000	11000	9109	7935	6974	6178	5510	4945	4463	4046	3689	3375	3099	2856	2641	2449	2277	2123	1984
Bimonthly1 +	55000	39000	28000	22000	17000	14000	11000	9631	8207	7076	6164	5418	4799	4281	3842	3467	3145	2866	2622	2408	2219	2052	1909	1769	1649	1541
Bimonthly2 ⊟	64000	45000	33000	25000	20000	16000	13000	11000	9531	8218	7159	6292	5574	4971	4462	4027	3653	3326	3045	2796	2577	2363	2210	2055	1915	1790

Pakan

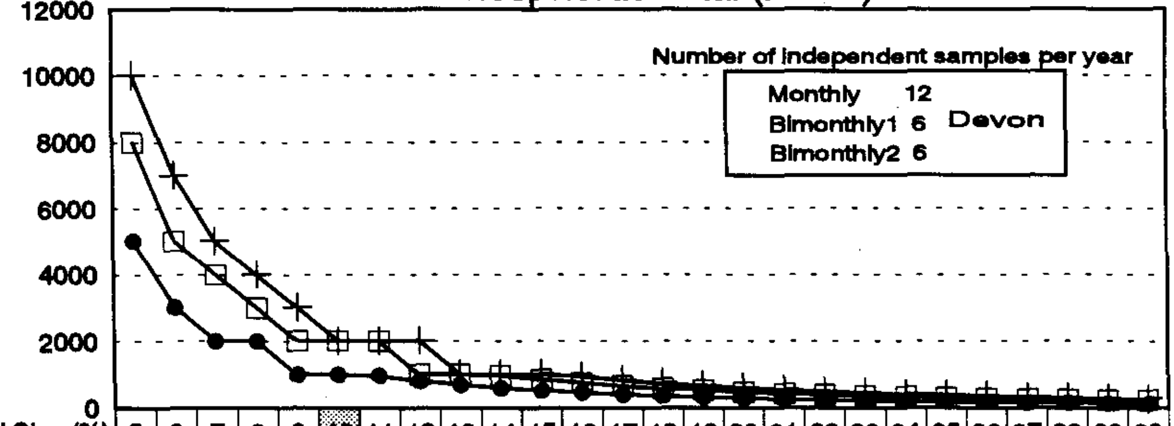
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	16000	11000	7985	6112	4829	3912	3233	2717	2316	1996	1739	1528	1354	1207	1084	978	867	808	739	679	628	579	537	499	465	435
Bimonthly1 +	23000	16000	12000	8919	7047	5708	4717	3964	3378	2912	2537	2230	1975	1762	1561	1427	1294	1179	1079	991	913	844	783	726	679	634
Bimonthly2 ⊟	12000	8027	5895	4515	3568	2890	2388	2007	1710	1474	1284	1129	1000	892	801	722	655	597	546	502	462	427	398	369	344	321

Border

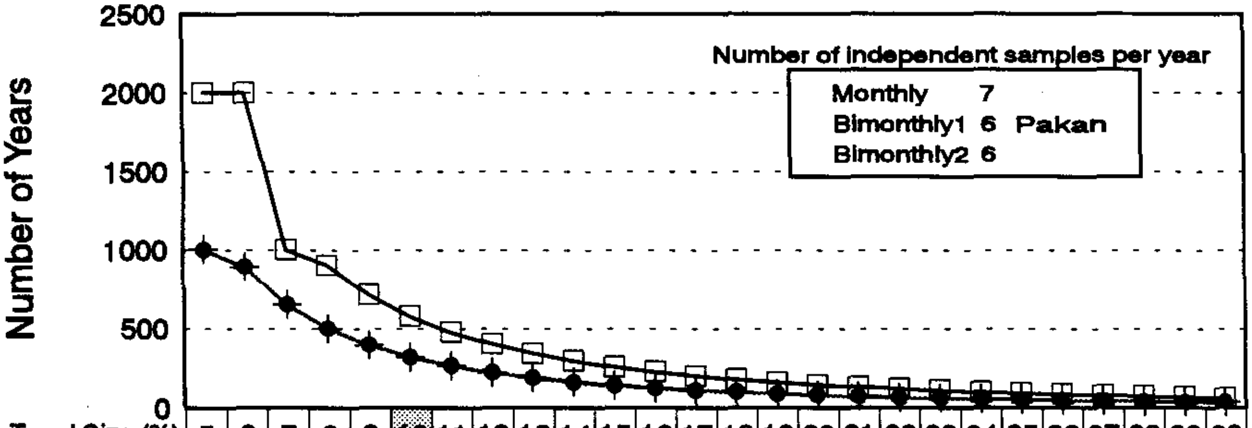
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	13000	8836	6493	4971	3928	3182	2630	2210	1883	1623	1414	1243	1101	982	881	795	721	657	601	552	509	471	436	406	378	354
Bimonthly1 +	16000	11000	7930	6072	4797	3850	3211	2699	2299	1963	1727	1516	1345	1199	1076	971	881	803	735	675	622	575	533	496	462	432
Bimonthly2 ⊟	13000	8743	6423	4918	3886	3147	2601	2166	1862	1606	1399	1229	1069	971	872	787	714	650	595	546	504	466	432	401	374	350

Fig. 17a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

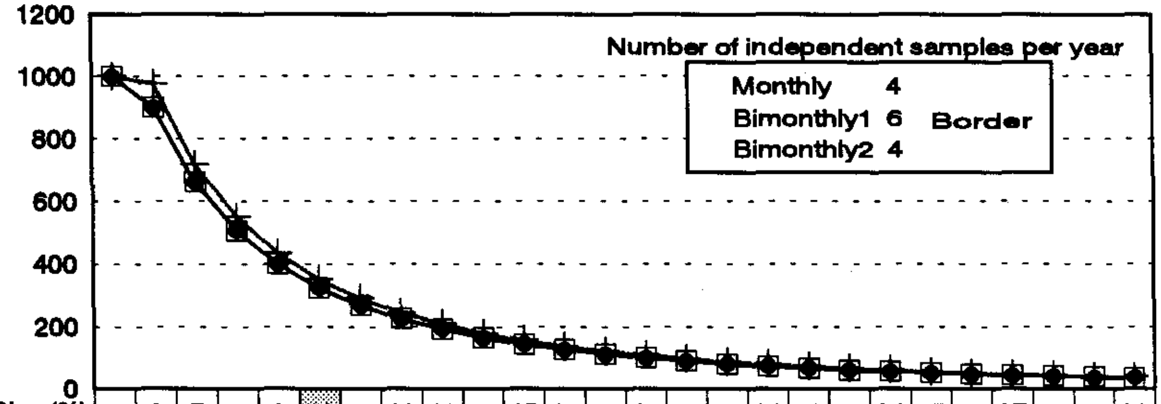
Phosphorus Total (PTOT)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Years
Monthly ●	5000	3000	2000	2000	1000	1000	964	810	690	595	518	456	404	360	325	292	265	241	221	203	187	173	160	149	139	130	
Bimonthly1 +	10000	7000	5000	4000	3000	2000	2000	2000	1000	1000	1000	936	831	741	665	601	545	498	454	417	384	355	330	306	286	267	
Bimonthly2 ⊟	8000	5000	4000	3000	2000	2000	2000	1000	1000	973	847	745	660	586	526	477	432	394	360	331	305	282	262	243	227	212	



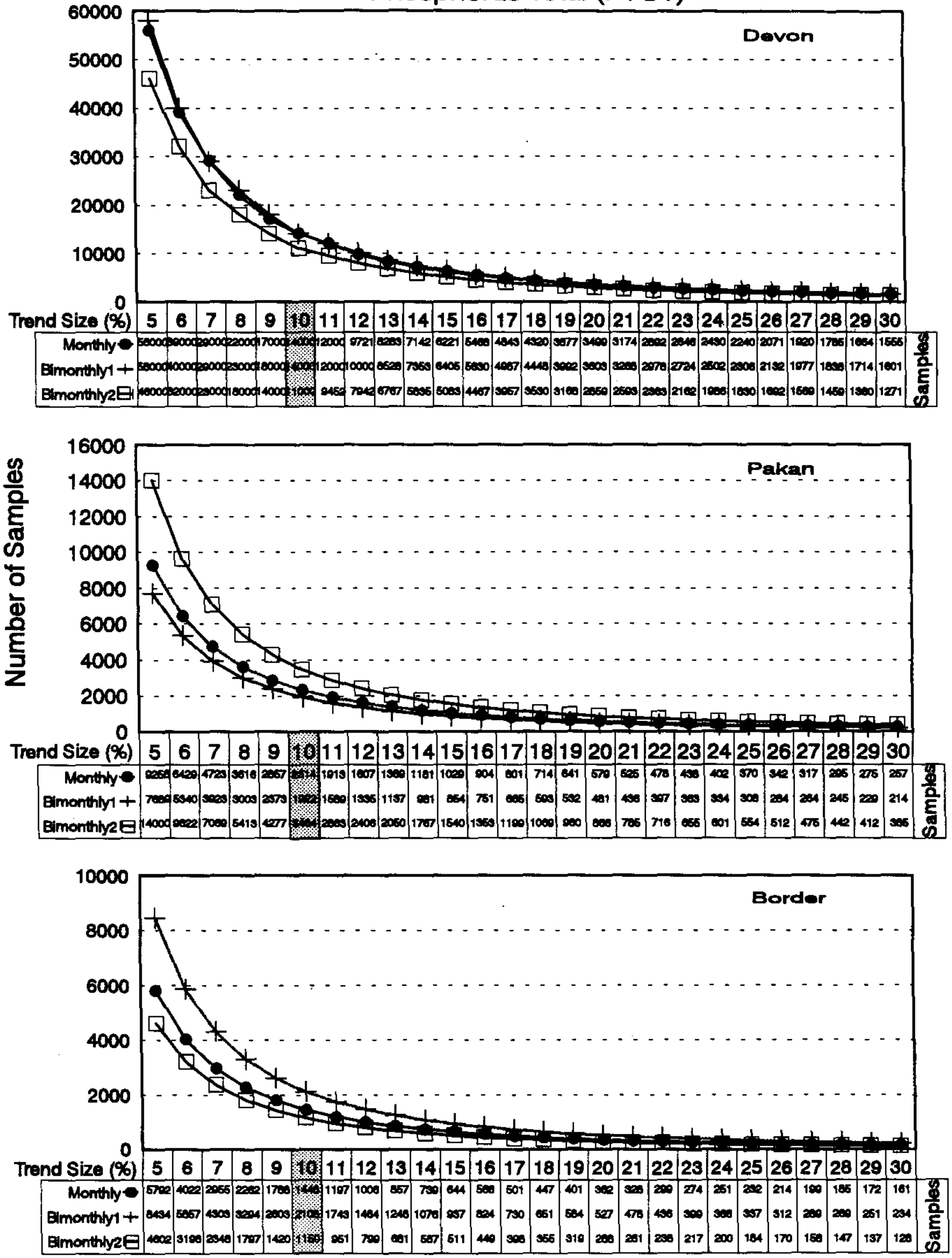
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Years
Monthly ●	1000	890	653	500	395	320	265	222	189	163	142	125	111	99	89	80	73	66	61	56	51	47	44	41	38	36	
Bimonthly1 +	1000	890	654	501	396	320	265	223	190	164	142	125	111	99	89	80	73	66	61	56	51	47	44	41	38	36	
Bimonthly2 ⊟	2000	2000	1000	902	713	577	477	401	342	295	257	226	200	178	160	144	131	119	109	100	92	85	79	74	69	64	



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Years
Monthly ●	1000	899	660	506	400	324	268	225	192	165	144	126	112	100	90	81	73	67	61	56	52	48	44	41	38	36	
Bimonthly1 +	1000	976	717	549	434	361	291	244	208	179	156	137	122	109	97	88	80	73	67	61	56	52	48	45	42	39	
Bimonthly2 ⊟	1000	900	661	506	400	324	268	225	192	165	144	126	112	100	90	81	73	67	61	56	52	48	44	41	39	36	

Fig. 17b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

Phosphorus Total (PTOT)

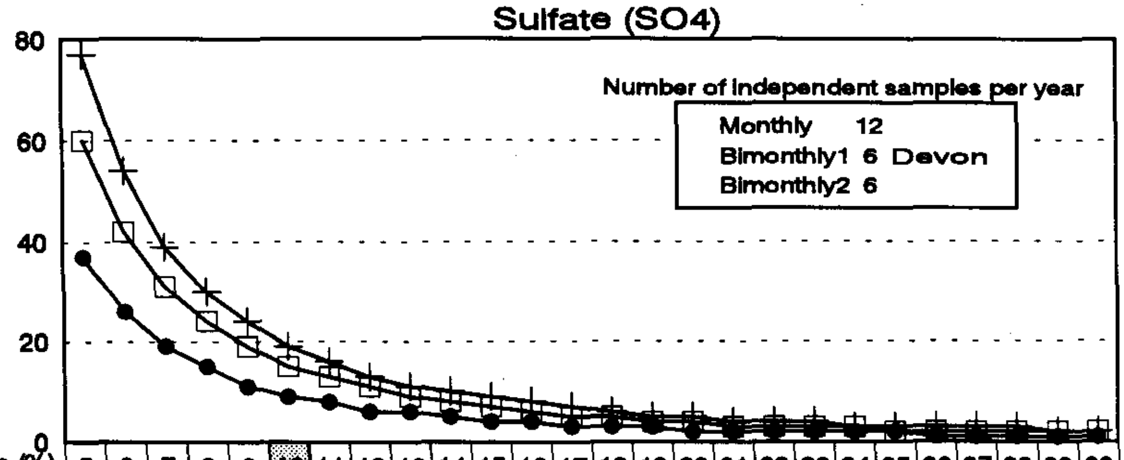


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	56000	39000	29000	22000	17000	14000	12000	9721	8283	7142	6221	5468	4843	4320	3877	3499	3174	2892	2646	2430	2240	2071	1920	1785	1664	1555
Bimonthly1 +	58000	40000	29000	23000	18000	14000	12000	10000	8528	7353	6405	5630	4967	4448	3992	3603	3268	2978	2724	2502	2306	2132	1977	1838	1714	1601
Bimonthly2 ⊟	46000	32000	23000	18000	14000	11000	9452	7942	6767	5835	5083	4467	3957	3530	3168	2859	2593	2363	2162	1986	1830	1692	1569	1459	1360	1271

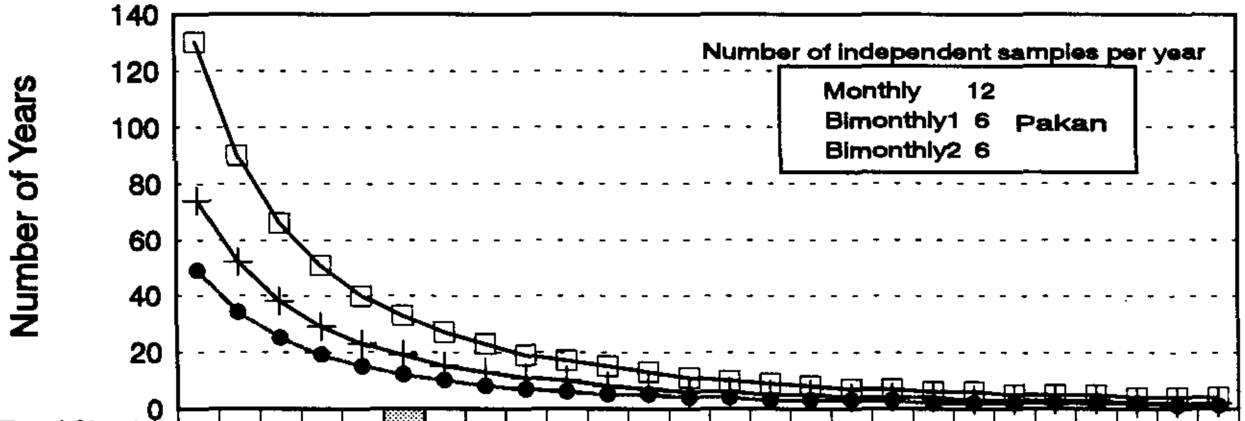
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	9258	6429	4723	3616	2857	2314	1913	1607	1369	1181	1029	904	801	714	641	579	525	478	438	402	370	342	317	295	275	257
Bimonthly1 +	7689	5340	3923	3003	2373	1922	1589	1335	1137	981	854	751	665	593	532	481	436	397	363	334	308	284	264	245	229	214
Bimonthly2 ⊟	14000	9622	7069	5413	4277	3464	2863	2406	2050	1767	1540	1353	1199	1069	960	866	785	716	655	601	554	512	475	442	412	385

Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	5792	4022	2955	2262	1788	1448	1197	1006	857	739	644	566	501	447	401	362	328	299	274	251	232	214	199	185	172	161
Bimonthly1 +	8434	5857	4303	3294	2603	2108	1743	1464	1246	1076	937	824	730	651	584	527	478	436	399	366	337	312	289	269	251	234
Bimonthly2 ⊟	4602	3196	2348	1797	1420	1150	951	799	681	587	511	449	398	355	319	288	261	238	217	200	184	170	158	147	137	128

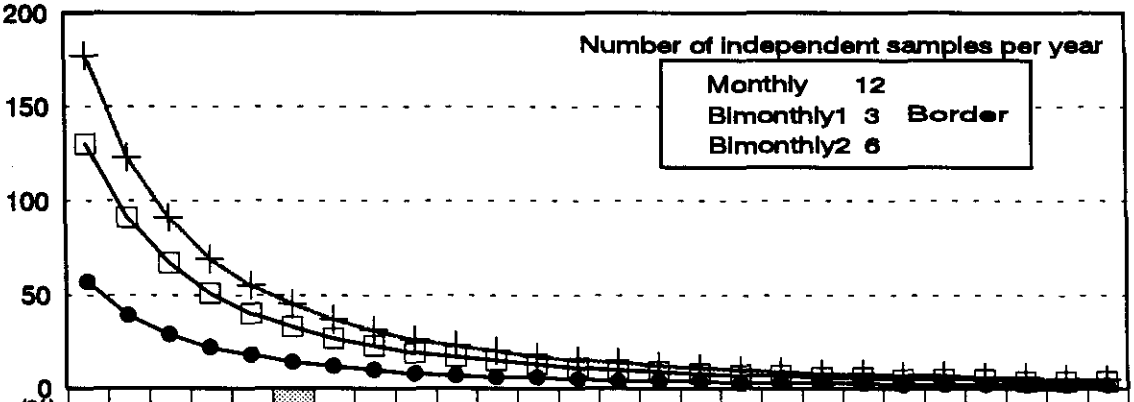
Fig. 18a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes


Sulfate (SO4)

Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	37	26	19	15	11	9	8	6	6	5	4	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	Years
Bimonthly1 +	77	54	39	30	24	19	16	13	11	10	9	8	7	6	5	5	4	4	4	3	3	3	3	3	2	2	
Bimonthly2 ⊟	60	42	31	24	19	15	13	11	9	8	7	6	5	5	4	4	3	3	3	3	2	2	2	2	2	2	



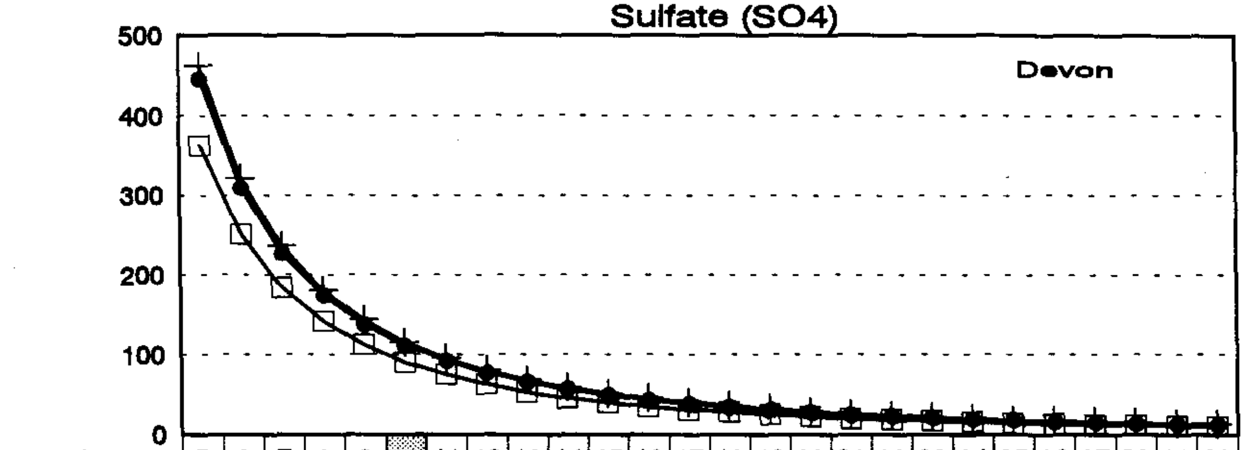
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	49	34	25	19	15	12	10	8	7	6	5	5	4	4	3	3	3	3	2	2	2	2	2	2	1	1	Years
Bimonthly1 +	74	52	38	29	23	19	15	13	11	10	8	7	6	6	5	5	4	4	4	3	3	3	3	2	2	2	
Bimonthly2 ⊟	130	90	66	51	40	33	27	23	19	17	15	13	11	10	9	8	7	7	6	6	5	5	5	4	4	4	



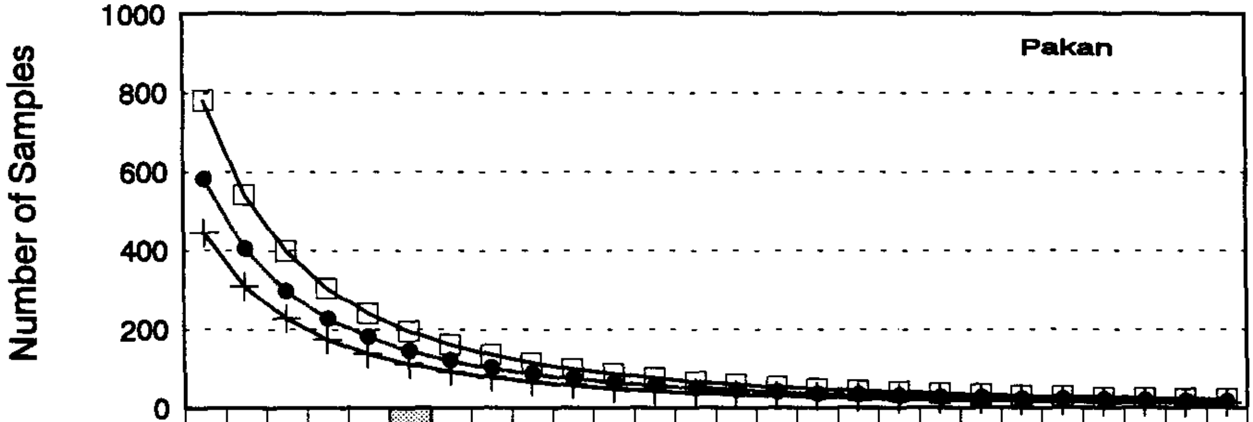
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	57	39	29	22	18	14	12	10	8	7	6	6	5	4	4	4	3	3	3	3	2	2	2	2	2	2	Years
Bimonthly1 +	177	123	91	69	55	45	37	31	26	23	20	17	15	14	12	11	10	9	8	8	7	7	6	6	5	5	
Bimonthly2 ⊟	130	91	67	51	40	33	27	23	19	17	15	13	11	10	9	8	7	7	6	6	5	5	5	4	4	4	

Fig. 18b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

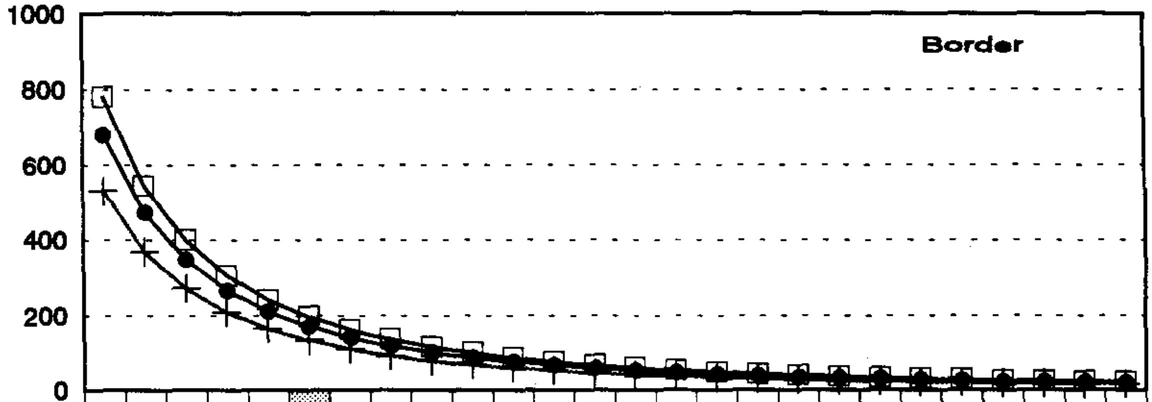
Sulfate (SO4)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	445	309	227	174	137	111	92	77	66	57	49	43	38	34	31	28	25	23	21	19	18	16	15	14	13	12	Samples
Bimonthly1 +	462	321	236	180	143	115	95	80	68	59	51	45	40	36	32	29	26	24	22	20	18	17	16	15	14	13	
Bimonthly2 ☐	362	251	184	141	112	90	75	63	53	46	40	35	31	28	25	23	20	19	17	16	14	13	12	12	11	10	

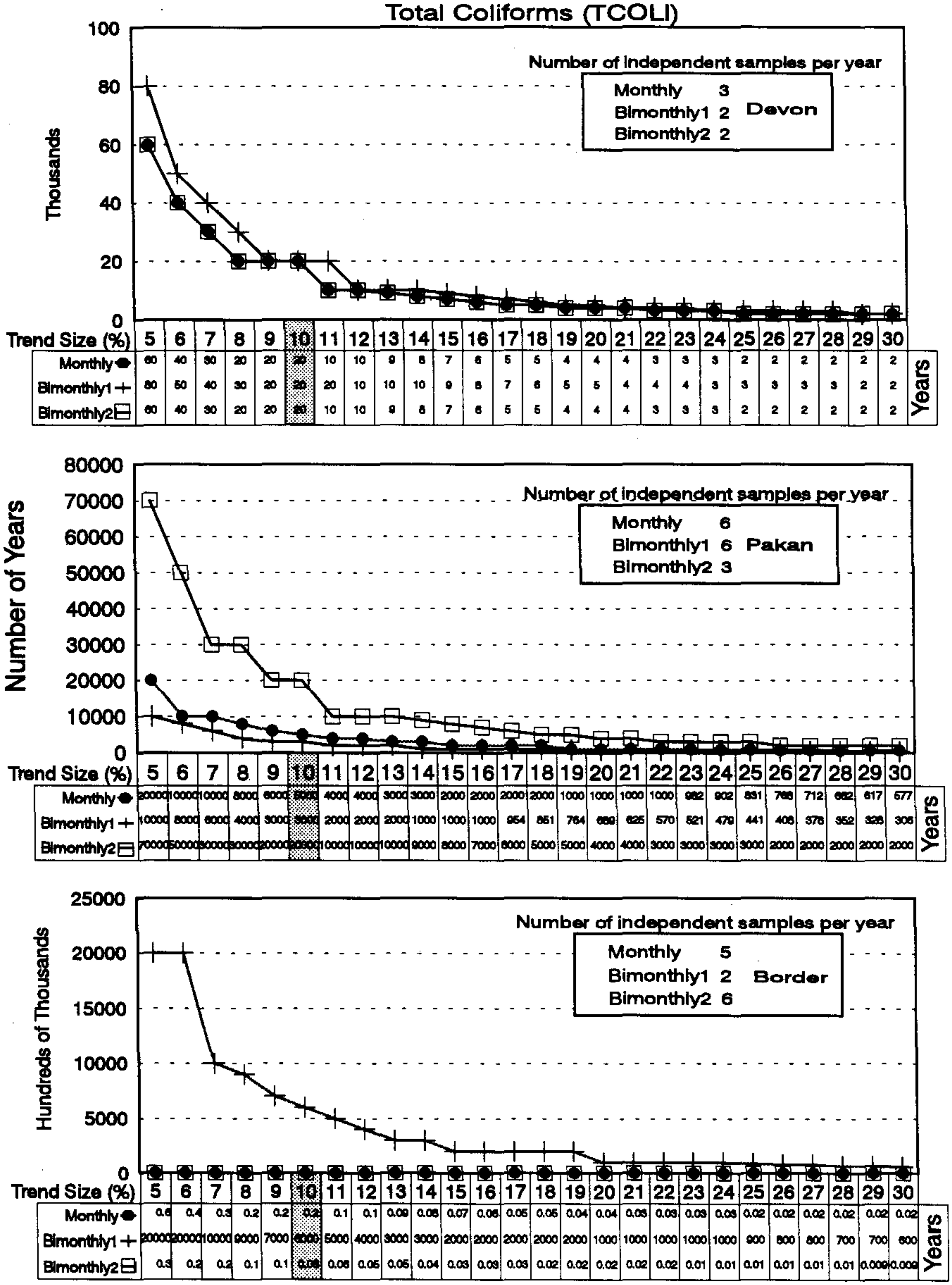


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	582	404	297	227	180	145	120	101	86	74	65	57	50	45	40	36	33	30	27	25	23	22	20	19	17	16	Samples
Bimonthly1 +	445	309	227	174	137	111	92	77	66	57	49	43	38	34	31	28	25	23	21	19	18	16	15	14	13	12	
Bimonthly2 ☐	780	542	398	305	241	195	161	135	115	99	87	76	67	60	54	49	44	40	37	34	31	29	27	25	23	22	



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	681	473	347	266	210	170	141	118	101	87	76	67	59	53	47	43	39	35	32	30	27	25	23	22	20	19	Samples
Bimonthly1 +	530	368	271	207	164	133	110	92	78	68	59	52	46	41	37	33	30	27	25	23	21	20	18	17	16	15	
Bimonthly2 ☐	762	543	399	305	241	196	162	136	116	100	87	76	68	60	54	49	44	40	37	34	31	29	27	25	23	22	

Fig. 19a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes



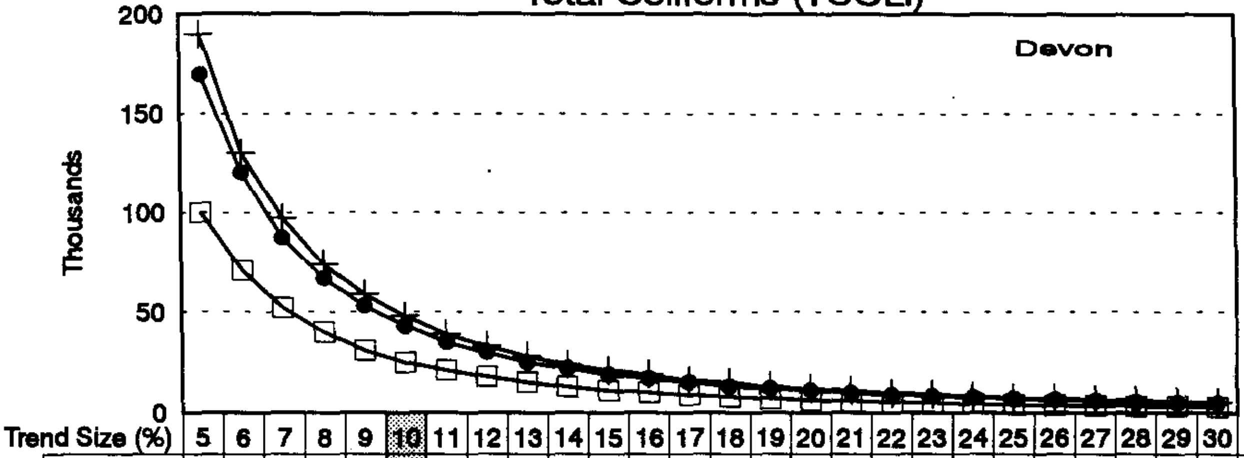
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	60	40	30	20	20	20	10	10	9	8	7	6	5	5	4	4	4	3	3	3	2	2	2	2	2	2	Years
Bimonthly1 +	80	50	40	30	20	20	20	10	10	10	9	8	7	6	5	5	4	4	4	3	3	3	3	3	2	2	
Bimonthly2 ⊟	60	40	30	20	20	20	10	10	9	8	7	6	5	5	4	4	4	3	3	3	2	2	2	2	2	2	

Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	20000	10000	10000	8000	6000	5000	4000	4000	3000	3000	2000	2000	2000	2000	1000	1000	1000	1000	982	902	831	766	712	662	617	577	Years
Bimonthly1 +	10000	8000	6000	4000	3000	3000	2000	2000	2000	1000	1000	1000	954	851	764	689	625	570	521	479	441	406	378	352	328	306	
Bimonthly2 ⊟	70000	50000	30000	30000	20000	20000	10000	10000	10000	9000	8000	7000	6000	5000	5000	4000	4000	3000	3000	3000	3000	2000	2000	2000	2000	2000	

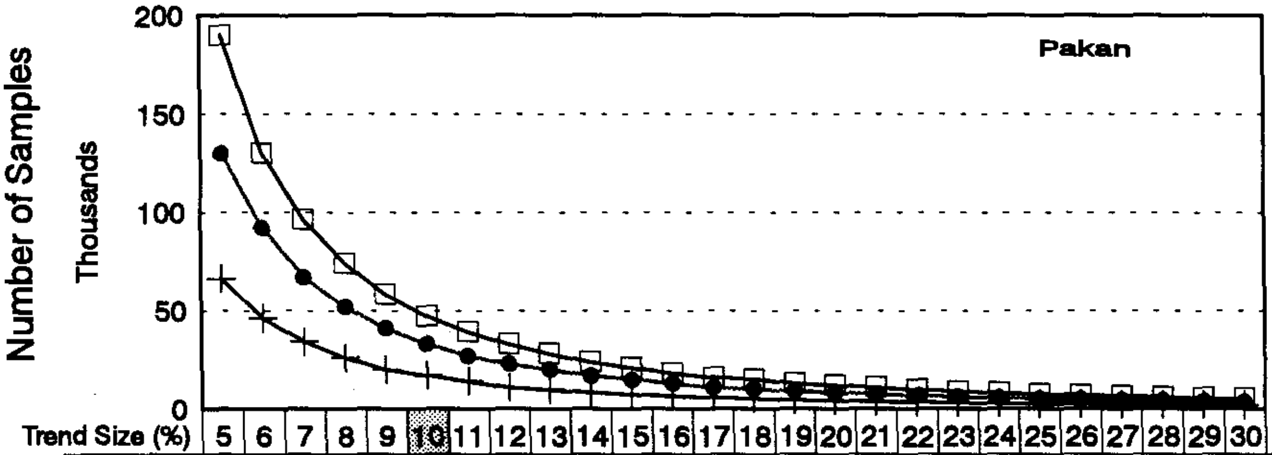
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	0.6	0.4	0.3	0.2	0.2	0.2	0.1	0.1	0.09	0.08	0.07	0.06	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	Years
Bimonthly1 +	20000	20000	10000	9000	7000	6000	5000	4000	3000	3000	2000	2000	2000	2000	2000	1000	1000	1000	1000	1000	900	800	800	700	700	600	
Bimonthly2 ⊟	0.3	0.2	0.2	0.1	0.1	0.08	0.06	0.05	0.05	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.009	0.009	

Fig. 19b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

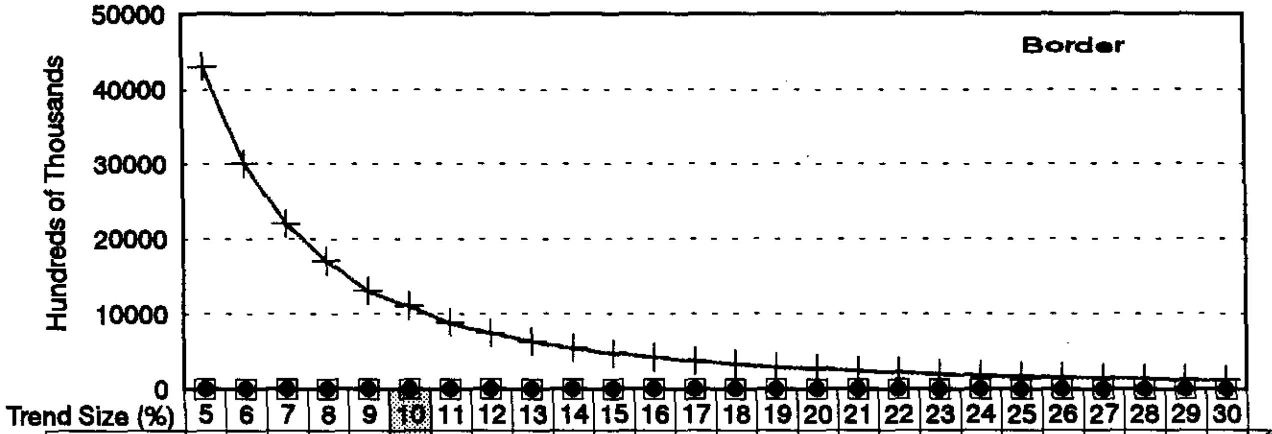
Total Coliforms (TCOLI)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly ●	170	120	87	67	53	43	35	30	25	22	19	17	15	13	12	11	9.679	8.819	8.069	7.411	6.83	6.314	5.855	5.445	5.076	4.743	
Bimonthly1 +	190	130	97	74	59	48	39	33	28	24	21	19	16	15	13	12	11	9.831	8.995	8.261	7.613	7.039	6.527	6.069	5.658	5.287	
Bimonthly2 ⊟	100	71	52	40	31	25	21	18	15	13	11	9.946	8.81	7.859	7.053	6.365	5.774	5.261	4.813	4.42	4.074	3.767	3.493	3.248	3.028	2.829	



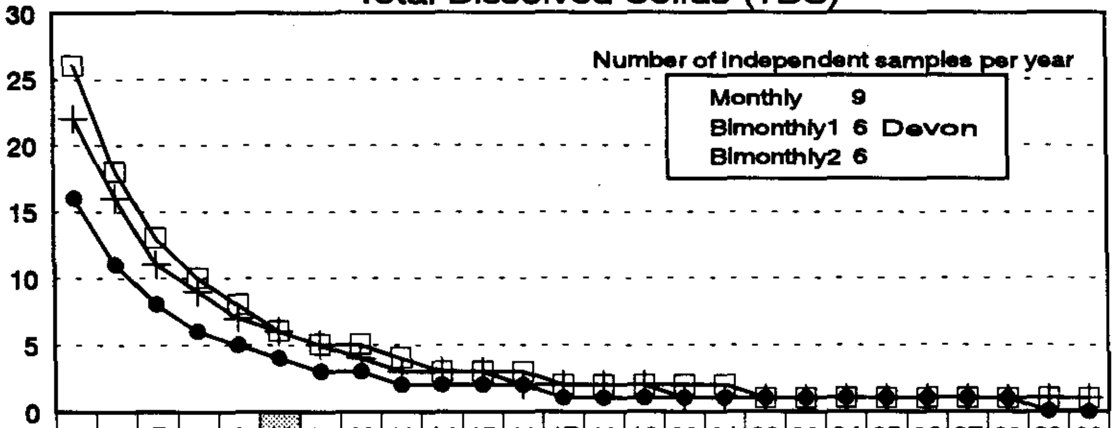
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly ●	130	92	67	52	41	33	27	23	20	17	15	13	11	10	9.138	8.247	7.46	6.815	6.236	5.727	5.278	4.86	4.525	4.207	3.922	3.665	
Bimonthly1 +	66	46	34	26	20	17	14	11	9.79	8.441	7.353	6.463	5.725	5.106	4.583	4.136	3.752	3.418	3.128	2.872	2.647	2.447	2.27	2.11	1.967	1.836	
Bimonthly2 ⊟	190	130	96	74	58	47	39	33	28	24	21	18	16	15	13	12	11	9.745	8.916	8.189	7.547	6.976	6.47	6.016	5.609	5.241	



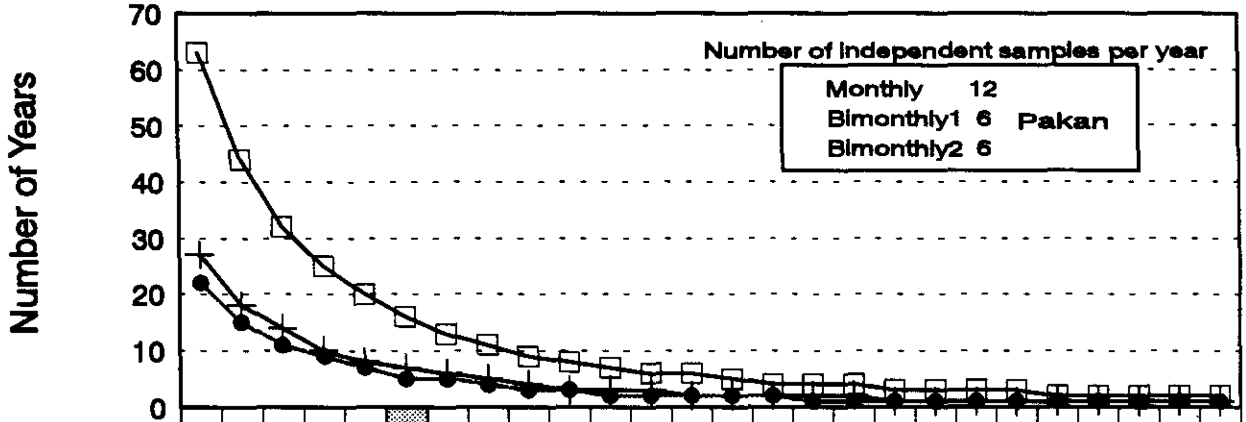
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly ●	2.6	2	1.5	1.1	0.86	0.71	0.59	0.49	0.42	0.36	0.32	0.28	0.25	0.22	0.2	0.18	0.16	0.15	0.13	0.12	0.11	0.11	0.098	0.091	0.085	0.079	
Bimonthly1 +	43000	30000	22000	17000	13000	11000	8800	7400	6300	5400	4700	4200	3700	3300	2900	2700	2400	2200	2000	1800	1700	1600	1500	1400	1300	1200	
Bimonthly2 ⊟	1.9	1.3	0.96	0.74	0.58	0.47	0.39	0.33	0.28	0.24	0.21	0.18	0.16	0.15	0.13	0.12	0.11	0.097	0.089	0.082	0.075	0.07	0.065	0.06	0.056	0.052	

Fig. 20a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

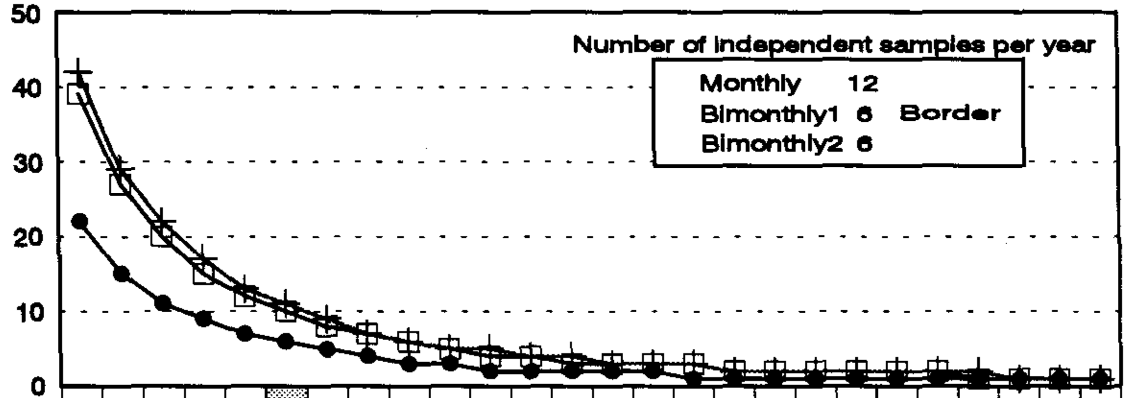
Total Dissolved Solids (TDS)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	16	11	8	6	5	4	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	0	0	Years
Bimonthly1 +	22	16	11	9	7	6	5	4	3	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	
Bimonthly2 ⊟	26	18	13	10	8	6	5	5	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	1	



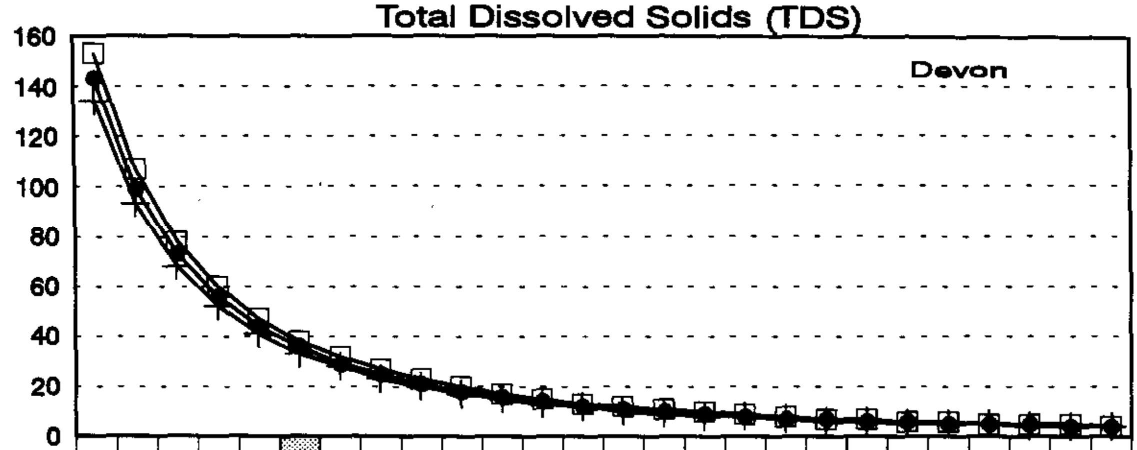
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	22	15	11	9	7	5	5	4	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	Years
Bimonthly1 +	27	18	14	10	8	7	6	5	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	1	
Bimonthly2 ⊟	63	44	32	25	20	16	13	11	9	8	7	6	6	5	4	4	4	3	3	3	3	2	2	2	2	2	



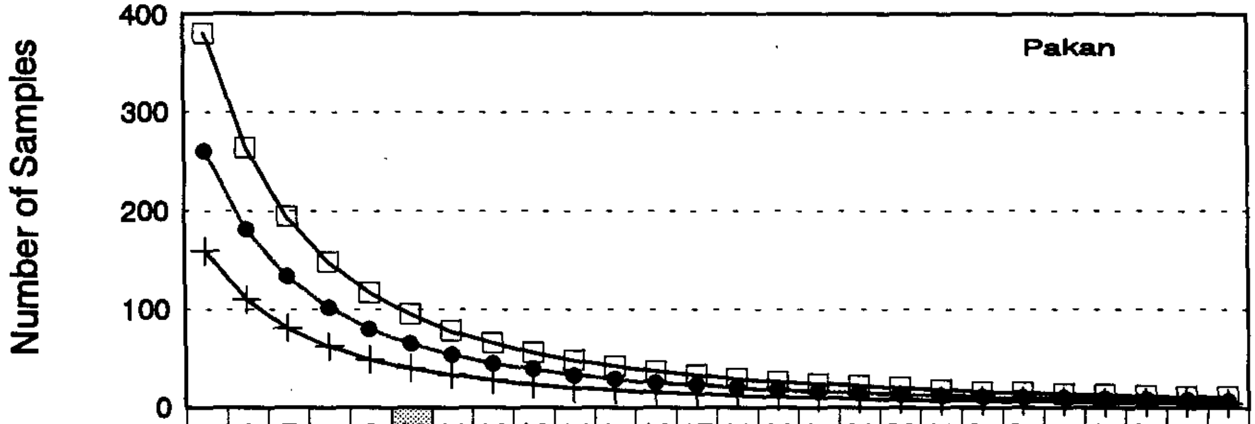
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	22	15	11	9	7	6	5	4	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	Years
Bimonthly1 +	42	29	22	17	13	11	9	7	6	5	5	4	4	3	3	3	2	2	2	2	2	2	2	1	1	1	
Bimonthly2 ⊟	39	27	20	15	12	10	8	7	6	5	4	4	3	3	3	3	2	2	2	2	2	2	1	1	1	1	

Fig. 20b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

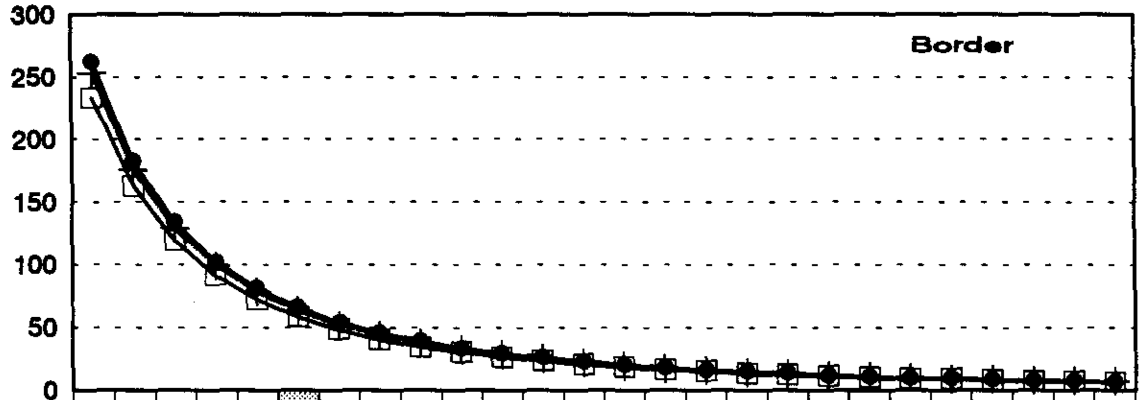
Total Dissolved Solids (TDS)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	143	99	73	56	44	36	29	25	21	18	16	14	12	11	10	9	8	7	7	6	6	5	5	5	4	4	Samples
Bimonthly1 +	134	93	68	52	41	33	28	23	20	17	15	13	12	10	9	8	8	7	6	6	5	5	5	4	4	4	
Bimonthly2 ⊟	153	107	78	60	47	38	32	27	23	20	17	15	13	12	11	10	9	8	7	7	6	6	5	5	5	4	

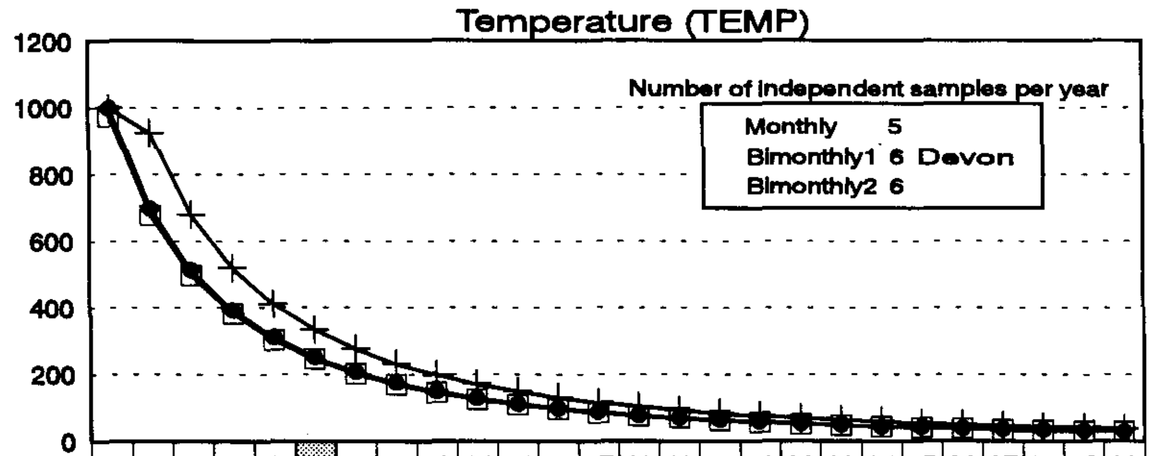


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	260	181	133	102	80	65	54	45	39	33	29	25	23	20	18	16	15	13	12	11	10	10	9	8	8	7	Samples
Bimonthly1 +	159	110	81	62	49	40	33	28	23	20	18	15	14	12	11	10	9	8	7	7	6	6	5	5	5	4	
Bimonthly2 ⊟	380	264	194	148	117	95	78	66	56	48	42	37	33	29	26	24	22	20	18	16	15	14	13	12	11	11	

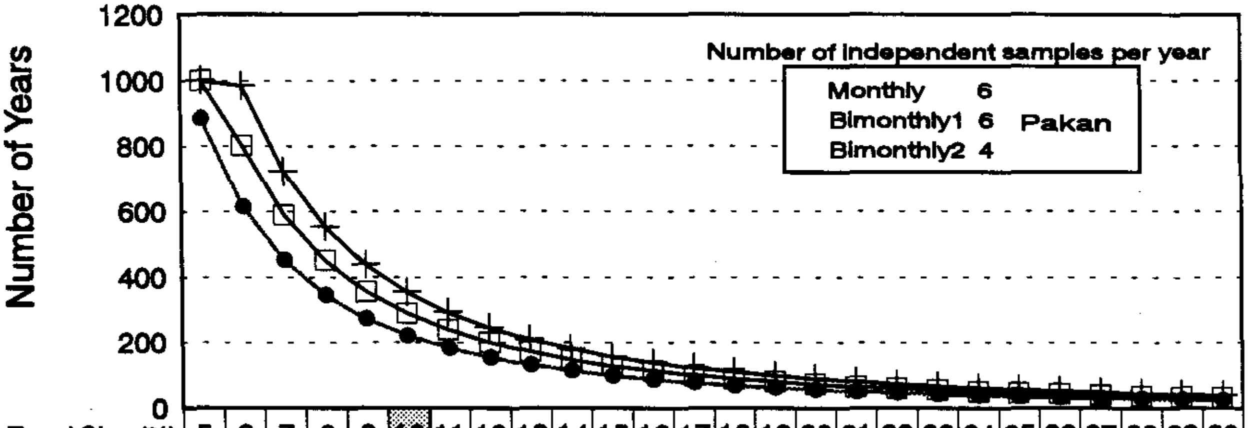


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	262	182	134	102	81	66	54	46	39	33	29	26	23	20	18	16	15	14	12	11	10	10	9	8	8	7	Samples
Bimonthly1 +	253	175	129	99	78	63	52	44	37	32	28	25	22	19	17	16	14	13	12	11	10	9	9	8	8	7	
Bimonthly2 ⊟	233	162	119	91	72	58	48	40	34	30	26	23	20	18	16	15	13	12	11	10	9	9	8	7	7	6	

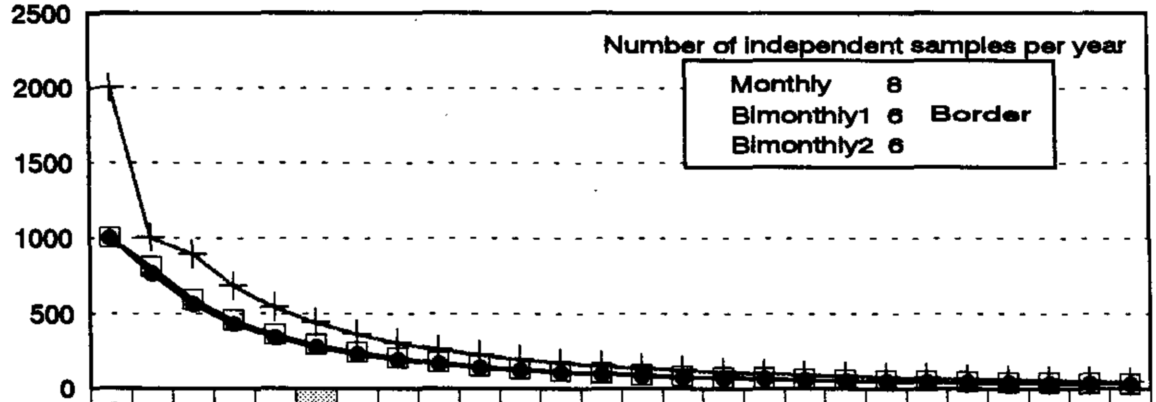
Fig. 21a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	1000	696	511	391	309	250	207	174	148	128	111	98	87	77	69	63	57	52	47	43	40	37	34	32	30	28	Years
Bimonthly1 +	1000	923	678	519	410	332	275	231	197	170	148	130	115	103	92	83	75	69	63	58	53	49	46	42	40	37	
Bimonthly2 ⊟	974	677	497	381	301	244	201	169	144	124	108	95	84	75	68	61	55	50	46	42	39	36	33	31	29	27	



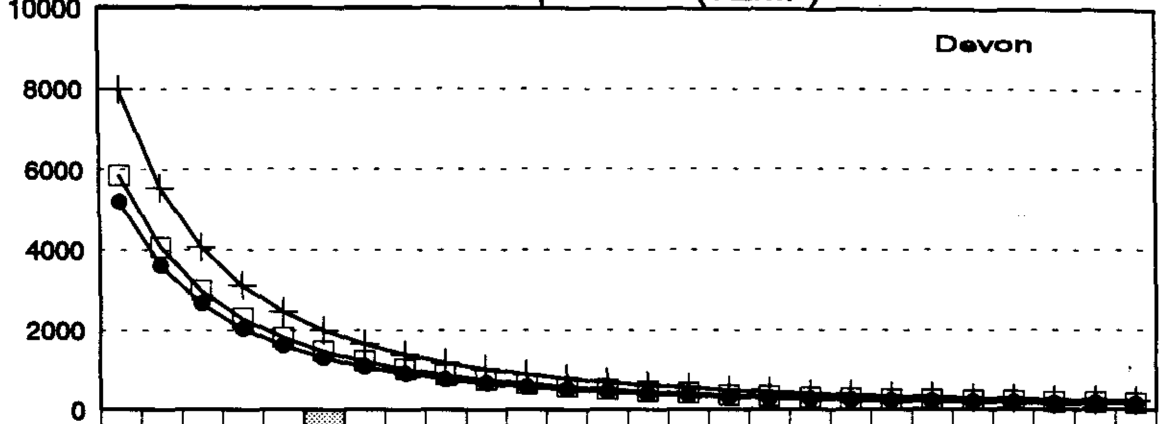
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	885	615	452	346	273	221	183	154	131	113	98	86	77	68	61	55	50	46	42	38	35	33	30	28	26	25	Years
Bimonthly1 +	1000	983	722	553	437	354	292	246	209	181	157	138	122	109	98	89	80	73	67	61	57	52	49	45	42	39	
Bimonthly2 ⊟	1000	802	589	451	356	288	239	200	171	147	128	113	100	89	80	72	66	60	55	50	46	43	40	37	34	32	



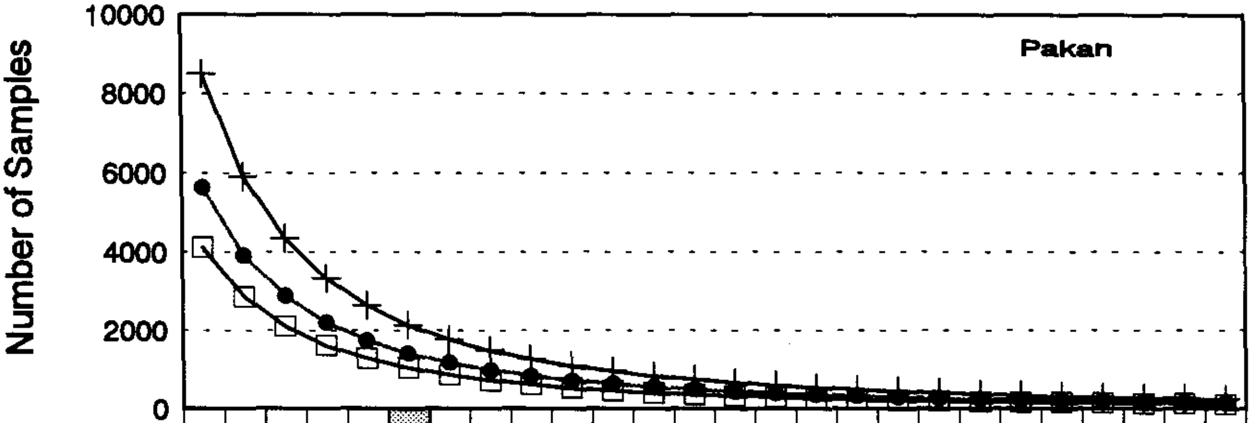
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	1000	764	561	430	339	275	227	191	163	140	122	107	95	85	76	69	62	57	52	48	44	41	38	35	33	31	Years
Bimonthly1 +	2000	1000	892	683	540	437	361	304	259	223	194	171	151	135	121	109	99	90	83	76	70	65	60	56	52	49	
Bimonthly2 ⊟	1000	806	592	454	358	290	240	202	172	148	129	113	101	90	80	73	66	60	55	50	47	43	40	37	35	32	

Fig. 21b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

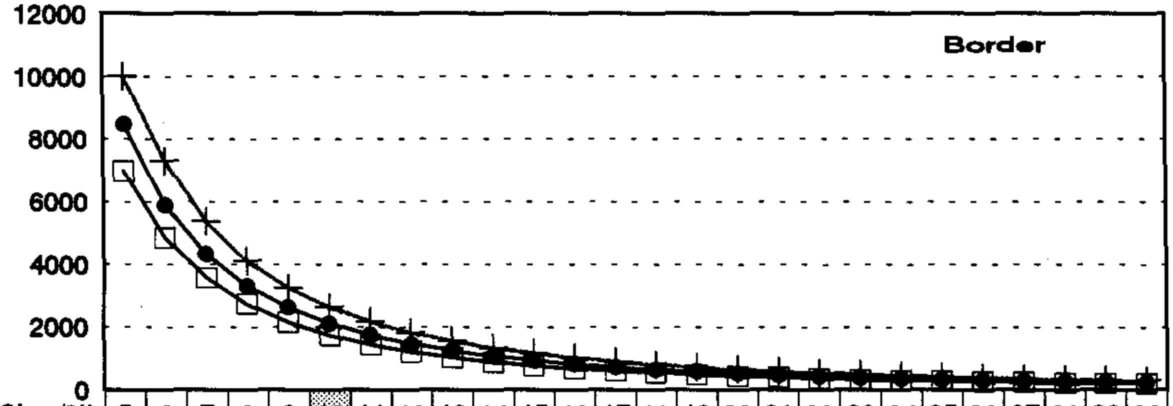
Temperature (TEMP)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	5190	3604	2648	2027	1602	1297	1072	901	768	662	577	507	449	400	359	324	294	268	245	225	208	192	178	165	154	144	Samples
Bimonthly1 +	7975	5538	4069	3115	2461	1994	1648	1385	1180	1017	886	779	690	615	552	498	452	412	377	346	319	295	273	254	237	222	
Bimonthly2 ⊟	5844	4059	2982	2283	1804	1461	1208	1015	865	745	649	571	506	451	405	365	331	302	276	254	234	216	200	186	174	162	



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	5621	3904	2868	2196	1735	1405	1161	976	832	717	625	549	486	434	389	351	319	290	266	244	225	208	193	179	167	156	Samples
Bimonthly1 +	8489	5895	4331	3316	2620	2122	1754	1474	1256	1083	943	829	734	655	588	531	481	439	401	368	340	314	291	271	252	236	
Bimonthly2 ⊟	4102	2849	2093	1602	1266	1026	848	712	607	523	456	401	355	317	284	256	233	212	194	178	164	152	141	131	122	114	



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	8465	5878	4319	3307	2613	2116	1749	1470	1252	1080	941	827	732	653	586	529	480	437	400	367	339	313	290	270	252	235	Samples
Bimonthly1 +	10000	7284	5352	4097	3237	2622	2167	1821	1552	1338	1165	1024	907	809	726	656	595	542	496	455	420	388	360	334	312	291	
Bimonthly2 ⊟	6965	4837	3554	2721	2150	1741	1439	1209	1030	888	774	680	603	537	482	435	395	360	329	302	279	258	239	222	207	193	

APPENDIX E: STUDY ONE: NUMBER OF YEARS TO DETECT TREND SIZES EQUAL TO THE ESTIMATE OF RESIDUAL ERROR IN THE TIME SERIES (RATIO = 1) AT THREE LONG-TERM MONITORING STATIONS ON THE NORTH SASKATCHEWAN RIVER

Appendix E-1
Table 1. Water Quality, Three Stations

		SCHEME=MONTHLY					
		SITE					
		DEVON		PAKAN		BORDER	
VARIABLE		N Years to Detect	Trend Size %	N Years to Detect	Trend Size %	N Years to Detect	Trend Size %
A-BHC	Alpha-BHC	.	.	.	.	13	56.2
ALKTOT	Total Alkalinity	17	7.1	13	8.6	11	11.6
BDISS	Boron Dissolved	29	67.9	29	68.9	10	44.0
DO	Dissolved Oxygen	7	8.5	7	9.0	7	13.6
DOC	Dissolved Organic Carbon	7	75.0	10	48.9	13	42.7
FCOLI	Fecal Coliforms	7	112.8	14	239.7	18	207.5
HCO3	Carbonate	12	9.1	16	8.4	17	8.7
KDISS	Potassium Dissolved	7	24.5	10	34.7	11	26.2
MGDISS	Manganese Dissolved	12	7.8	9	9.1	11	8.4
NADISS	Sodium Dissolved	7	20.4	12	21.6	7	29.3
NFR	Non-Filterable Residues	12	129.5	7	126.3	7	78.0
NO3NO2	Nitrate Plus Nitrite	12	72.2	12	49.5	7	214.7
NP	Particulate Nitrogen	21	129.2	24	109.0	17	60.7
PDISS	Phosphorus Dissolved	7	44.4	7	54.2	11	65.7
PH	pH	19	3.2	14	3.2	17	4.0
POC	Organic Carbon as Particulate	14	111.9	20	76.5	7	56.1
PP	Phosphorus as Particulate	7	143.9	13	67.3	17	60.7
PTOT	Phosphorus Total	7	127.4	12	51.8	19	41.0
SO4	Sulfate	7	11.4	7	13.0	7	14.0
TCOLI	Total Coliforms	31	222.4	14	195.5	18	287.4
TDS	Total Dissolved Solids	10	6.4	7	8.7	7	8.7
TEMP	Temperature	17	38.8	14	40.4	11	49.5
TURB	Turbidity	.	.	7	96.9	10	70.8

Appendix E-2

Table 2. Water Quality, Three Stations

VARIABLE		SCHEME=BIMONTHLY1					
		SITE					
		DEVON		PAKAN		BORDER	
		N Years to Detect	Trend Size %	N Years to Detect	Trend Size %	N Years to Detect	Trend Size %
A-BHC	Alpha-BHC	.	.	.	.	.	.
ALKTOT	Total Alkalinity	14	7.4	14	7.0	24	8.5
BDISS	Boron Dissolved	47	70.6	84	62.6	28	47.0
DO	Dissolved Oxygen	14	9.5	14	9.4	14	10.1
DOC	Dissolved Organic Carbon	14	86.2	14	53.8	14	52.0
FCOLI	Fecal Coliforms	14	121.3	14	264.0	14	231.6
HCO3	Carbonate	14	7.4	14	7.1	14	9.4
KDISS	Potassium Dissolved	14	28.7	14	37.0	14	26.7
MGDISS	Manganese Dissolved	14	8.3	14	8.2	14	8.3
NADISS	Sodium Dissolved	14	23.3	14	23.7	14	26.9
NFR	Non-Filterable Residues	14	128.0	14	117.9	14	79.2
NO3NO2	Nitrate Plus Nitrite	14	75.2	14	48.4	14	175.6
NP	Particulate Nitrogen	14	126.1	14	98.8	14	73.3
PDISS	Phosphorus Dissolved	14	43.7	14	48.6	14	71.0
PH	pH	14	3.3	14	3.3	30	3.7
POC	Organic Carbon as Particulate	14	97.5	30	88.4	14	58.0
PP	Phosphorus as Particulate	14	126.8	14	81.3	28	67.1
PTOT	Phosphorus Total	14	129.2	14	47.2	14	49.4
SO4	Sulfate	14	11.6	14	11.4	29	12.4
TCOLI	Total Coliforms	35	234.8	14	138.5	44	35114.5
TDS	Total Dissolved Solids	14	6.2	14	6.8	14	8.6
TEMP	Temperature	14	48.1	14	49.6	14	55.1
TURB	Turbidity	.	.	.	.	.	.

Appendix E-3

Table 3. Water Quality, Three Stations

		SCHEME=BIMONTHLY2					
		SITE					
		DEVON		PAKAN		BORDER	
VARIABLE		N Years to Detect	Trend Size %	N Years to Detect	Trend Size %	N Years to Detect	Trend Size %
A-BHC	Alpha-BHC	.	.	.	.	35	53.9
ALKTOT	Total Alkalinity	37	7.5	14	18.6	14	9.6
BDISS	Boron Dissolved	48	69.4	35	82.1	14	39.2
DO	Dissolved Oxygen	14	7.6	14	10.2	14	11.3
DOC	Dissolved Organic Carbon	14	52.8	14	46.8	14	35.6
FCOLI	Fecal Coliforms	14	78.8	26	212.8	32	211.2
HCO3	Carbonate	40	7.2	29	9.9	26	8.2
KDISS	Potassium Dissolved	14	21.5	14	32.8	14	22.8
MGDISS	Manganese Dissolved	25	7.6	14	9.8	14	8.3
NADISS	Sodium Dissolved	14	18.2	14	20.3	14	27.4
NFR	Non-Filterable Residues	14	152.0	14	112.9	14	71.4
NO3NO2	Nitrate Plus Nitrite	14	59.9	14	56.7	14	116.7
NP	Particulate Nitrogen	14	112.1	14	88.9	39	57.7
PDISS	Phosphorus Dissolved	14	43.1	14	65.5	14	76.4
PH	pH	14	3.3	27	3.0	24	4.4
POC	Organic Carbon as Particulate	26	103.4	14	83.7	14	55.1
PP	Phosphorus as Particulate	24	136.6	14	57.9	14	60.4
PTOT	Phosphorus Total	14	115.1	14	63.4	24	36.5
SO4	Sulfate	14	10.2	14	15.0	14	15.1
TCOLI	Total Coliforms	53	171.8	31	233.8	14	233.5
TDS	Total Dissolved Solids	14	6.7	14	10.5	14	8.2
TEMP	Temperature	14	41.2	24	34.5	14	44.9
TURB	Turbidity	.	.	14	82.4	14	71.0

APPENDIX F: STUDY TWO: WATER QUALITY VARIABLES, NAQUADAT CODES AND MODEL SUMMARIES FOR THE BORDER STATION, YEARS 1974-1991, ON THE NORTH SASKATCHEWAN RIVER

(Note: Bt=back transform from ln)

Appendix F-1
Table 1. Water Quality, Border (PPWB)

SCHEME=MONTHLY

VARIABLE		CODE	FITTED MODEL	Log SE	Bt SE	R	N	Log Baseline Mean	Bt Baseline Mean
ALKTOT	Total Alkalinity	10101L	AR(1)	0.124	16.6575	0.21	213	4.8888	133.819
BDISS	Boron Dissolved	05105D	AR(1)	0.433	0.0302	0.38	195	-2.8034	0.067
CADISS	Calcium Dissolved	20101L	AR(1)	0.0853	3.77	0.22	213	3.7832	44.117
CLDISS	Cloride Dissolved	17206L	WN	0.4723	2.3399	0	213	1.4319	4.681
CONDF	Conductivity Field	02041F	AR(1)	0.1094	37.7783	0.37	213	5.8355	344.29
CUDISS	Copper Dissolved	29005P	WN	0.6674	0.0019	0	141	-6.1765	0.003
DO	Dissolved Oxygen	08101F	AR(1)	0.1276	1.3043	0.15	213	2.3123	10.18
FCOLI	Fecal Coliforms	36011F	AR(1)	1.1935	33.3381	0.49	212	2.2199	18.767
KDISS	Potassium Dissolved	19103L	AR(1)	0.3	0.4484	0.13	213	0.3343	1.461
MGDISS	Manganese Dissolved	25104D	WN	0.1602	2.1437	0	213	2.5746	13.296
NADISS	Sodium Dissolved	11103L	AR(1)	0.3128	3.0077	0.26	213	2.1898	9.381
NFR	Non-Filterable Residues	10401L	AR(1)	0.6981	11.2949	0.27	211	2.4133	14.253
NO3NO2	Nitrate Plus Nitrite	07106L	WN	1.1144	0.5244	0	213	-1.717	0.334
PDISS	Phosphorus Dissolved	15103D	AR(1)	0.6411	0.035	0.3	194	-3.2193	0.049
PH	pH	10301F	AR(1)	0.2355	0.2355	0.29	213	8.09	8.09
PHF	pH Field	10301F	AR(1)	0.3171	0.3171	0.45	213	8.05	8.05
PTOT	Phosphorus Total	15406L	AR(1)	0.3639	0.0366	0.52	213	-2.3963	0.097
SO4DIS	Sulfate Dissolved	16304L	WN	0.1741	7.2429	0	213	3.7054	41.287
SPCOND	Specific Conductivity	02041F	AR(1)	0.0881	31.2319	0.38	213	5.8649	353.817
TDS	Total Dissolved Solids	00201L	AR(1)	0.0912	18.1259	0.26	213	5.2858	198.335
TEMPF	Temperature Field	02061F	AR(1)	3.8727	3.8727	0.31	213	8.1	8.1
TN	Toatal Nitrogen	07602L	AR(1)	0.3633	0.2834	0.23	213	-0.3476	0.755
TURBF	Turbidity Field	02073F	AR(1)	0.7212	10.6897	0.9	175	2.3004	12.942
TURBL	Turbidity Lab	02071L	AR(1)	0.6462	7.0665	0.37	213	2.0752	9.816
ZNTOT	Zinc Total	30005P	WN	0.5466	0.003	0	141	-5.43	0.005

Appendix F-2
Table 2. Water Quality, Border (PPWB)

SCHEME=BIMONTHLY1

VARIABLE		CODE	FITTED MODEL	Log SE	Bt SE	R	N	Log Baseline Mean	Bt Baseline Mean
ALKTOT	Total Alkalinity	10101L	WN	0.0837	11.0755	0	106	4.88	132.093
BDISS	Boron Dissolved	05105D	AR(1)	0.4908	0.0313	0.42	97	-2.93462	0.06
CADISS	Calcium Dissolved	20101L	WN	0.0808	3.5773	0	106	3.7855	44.202
CLDISS	Cloride Dissolved	17206L	AR(1)	0.5103	2.4297	0.4	106	1.3638	4.455
CONDF	Conductivity Field	02041F	AR(1)	0.1057	36.446	0.27	106	5.8346	343.843
CUDISS	Copper Dissolved	29005P	WN	0.7447	0.0024	0	70	-6.1451	0.003
DO	Dissolved Oxygen	08101F	WN	0.1329	1.361	0	106	2.3131	10.195
FCOLI	Fecal Coliforms	36011F	WN	1.3867	88.9897	0	72	2.6446	36.821
KDISS	Potassium Dissolved	19103L	WN	0.3205	0.4812	0	106	0.3291	1.463
MGDISS	Manganese Dissolved	25104D	WN	0.1932	2.5958	0	106	2.5699	13.311
NADISS	Sodium Dissolved	11103L	WN	0.3044	2.8733	0	106	2.1752	9.221
NFR	Non-Filterable Residues	10401L	AR(1)	0.6576	10.6809	0.27	105	2.4594	14.521
NO3NO2	Nitrate Plus Nitrite	07106L	WN	1.2184	0.6852	0	106	-1.734	0.371
PDISS	Phosphorus Dissolved	15103D	WN	0.6517	0.035	0	97	-3.2462	0.048
PH	pH	10301F	WN	0.2601	0.2601	0	104	8.108	8.108
PHF	pH Field	10301F	AR(1)	0.3192	0.3192	0.43	104	8.0531	8.053
PTOT	Phosphorus Total	15406L	WN	0.4361	0.0407	0	104	-2.5142	0.089
SO4DIS	Sulfate Dissolved	16304L	WN	0.1304	5.4331	0	106	3.7169	41.488
SPCOND	Specific Conductivity	02041F	AR(1)	0.0842	29.7866	0.34	106	5.8633	353.133
TDS	Total Dissolved Solids	00201L	WN	0.0824	16.3385	0	106	5.2846	197.946
TEMPF	Temperature Field	02061F	AR(1)	4.4317	4.4317	0.21	104	8.375	8.375
TN	Toatal Nitrogen	07602L	WN	0.381	0.2522	0	106	-0.5218	0.638
TURBF	Turbidity Field	02073F	AR(1)	0.5786	7.7382	0.44	75	2.3399	12.272
TURBL	Turbidity Lab	02071L	AR(1)	0.6219	6.4819	0.2	106	2.0508	9.433
ZNTOT	Zinc Total	30005P	AR(1)	0.5014	0.0027	0.37	70	-5.3966	0.005

Appendix F-3

Table 3. Water Quality, Border (PPWB)

SCHEME=BIMONTHLY2

VARIABLE		CODE	FITTED MODEL	Log SE	Bt SE	R	N	Log Baseline Mean	Bt Baseline Mean
ALKTOT	Total Alkalinity	10101L	WN	0.1447	19.5489	0	107	4.8903	134.393
BDISS	Boron Dissolved	05105D	AR(1)	0.45	0.0305	0.56	98	-2.8427	0.064
CADISS	Calcium Dissolved	20101L	WN	0.0919	4.0563	0	107	3.781	44.045
CLDISS	Cloride Dissolved	17206L	WN	0.4184	2.0691	0	107	1.4665	4.73
CONDF	Conductivity Field	02041F	AR(1)	0.1094	37.8312	0.23	107	5.8369	344.772
CUDISS	Copper Dissolved	29005P	WN	0.6239	0.0017	0	71	-6.2051	0.002
DO	Dissolved Oxygen	08101F	WN	0.1094	1.1071	0	107	2.3055	10.089
FCOLI	Fecal Coliforms	36011F	AR(1)	1.3537	54.9278	0.36	72	2.2607	23.974
KDISS	Potassium Dissolved	19103L	WN	0.2832	0.4227	0	107	0.3402	1.463
MGDISS	Manganese Dissolved	25104D	WN	0.1112	1.5101	0	107	2.5993	13.538
NADISS	Sodium Dissolved	11103L	WN	0.3282	3.2263	0	107	2.20443	9.567
NFR	Non-Filterable Residues	10401L	AR(1)	0.6986	10.2002	0.31	106	2.3101	12.86
NO3NO2	Nitrate Plus Nitrite	07106L	WN	0.9538	0.3414	0	107	-1.7268	0.28
PDISS	Phosphorus Dissolved	15103D	WN	0.7055	0.0324	0	97	-3.4591	0.04
PH	pH	10301F	WN	0.2192	0.2192	0	105	8.078	8.078
PHF	pH Field	10301F	WN	0.3497	0.3497	0	105	8.048	8.048
PTOT	Phosphorus Total	15406L	AR(1)	0.4066	0.0415	0.39	107	-2.4063	0.098
SO4DIS	Sulfate Dissolved	16304L	AR(1)	0.1864	7.6946	0.49	107	3.6943	40.922
SPCOND	Specific Conductivity	02041F	AR(1)	0.094	33.4037	0.22	107	5.8665	354.574
TDS	Total Dissolved Solids	00201L	WN	0.1003	19.9845	0	107	5.287	198.746
TEMPF	Temperature Field	02061F	AR(1)	3.5342	3.5342	0.28	105	7.8273	7.827
TN	Toatal Nitrogen	07602L	WN	0.3303	0.2549	0	107	-0.3413	0.751
TURBF	Turbidity Field	02073F	AR(1)	0.6943	9.0505	0.83	88	2.2013	11.5
TURBL	Turbidity Lab	02071L	AR(1)	0.6866	8.7363	0.31	107	2.1853	11.257
ZNTOT	Zinc Total	30005P	WN	0.5294	0.0027	0	71	-5.488	0.005

Appendix F-4

Table 4. Water Quality, Border (PPWB)

SCHEME=QUARTERLY1

VARIABLE		CODE	FITTED MODEL	Log SE	Bt SE	R	N	Log Baseline Mean	Bt Baseline Mean
ALKTOT	Total Alkalinity	10101L	WN	0.1363	18.1332	0	71	4.8767	132.421
BDISS	Boron Dissolved	05105D	WN	0.4175	0.0331	0	65	-2.667	0.076
CADISS	Calcium Dissolved	20101L	WN	0.0822	3.5433	0	71	3.7586	43.033
CLDISS	Cloride Dissolved	17206L	WN	0.5624	2.9141	0	71	1.4058	4.778
CONDF	Conductivity Field	02041F	AR(1)	0.1112	37.3619	0.41	71	5.8078	334.95
CUDISS	Copper Dissolved	29005P	WN	0.6597	0.0021	0	47	-6.0597	0.003
DO	Dissolved Oxygen	08101F	WN	0.1158	1.1747	0	71	2.3068	10.11
FCOLI	Fecal Coliforms	36011F	WN	1.1261	7.3758	0	70	0.8953	4.615
KDISS	Potassium Dissolved	19103L	WN	0.3633	0.6364	0	71	0.4613	1.694
MGDISS	Manganese Dissolved	25104D	WN	0.124	1.6105	0	71	2.5525	12.938
NADISS	Sodium Dissolved	11103L	WN	0.3589	3.5763	0	71	2.2021	9.646
NFR	Non-Filterable Residues	10401L	AR(1)	0.6561	11.4543	0.57	70	2.5331	15.617
NO3NO2	Nitrate Plus Nitrite	07106L	WN	0.9442	0.508	0	71	-1.305	0.423
PDISS	Phosphorus Dissolved	15103D	WN	0.6447	0.0415	0	64	-3.0594	0.058
PH	pH	10301F	WN	0.1942	0.1942	0	71	8.0422	8.042
PHF	pH Field	10301F	AR(1)	0.2842	0.2842	0.33	71	8.0174	8.017
PTOT	Phosphorus Total	15406L	AR(1)	0.4104	0.0479	0.21	71	-2.2741	0.112
SO4DIS	Sulfate Dissolved	16304L	WN	0.1682	6.7831	0	71	3.6758	40.043
SPCOND	Specific Conductivity	02041F	AR(1)	0.0777	26.892	0.41	71	5.8422	345.578
TDS	Total Dissolved Solids	00201L	WN	0.0905	17.7705	0	71	5.2738	195.957
TEMPF	Temperature Field	02061F	AR(1)	4.3064	4.3064	0.3	71	7.9072	7.907
TN	Toatal Nitrogen	07602L	WN	0.3473	0.3107	0	71	-0.202	0.868
TURBF	Turbidity Field	02073F	AR(1)	0.5888	9.3413	0.47	50	2.5016	14.512
TURBL	Turbidity Lab	02071L	AR(1)	0.5711	6.6084	0.35	70	2.2017	10.642
ZNTOT	Zinc Total	30005P	WN	0.4934	0.003	0	47	-5.2969	0.006

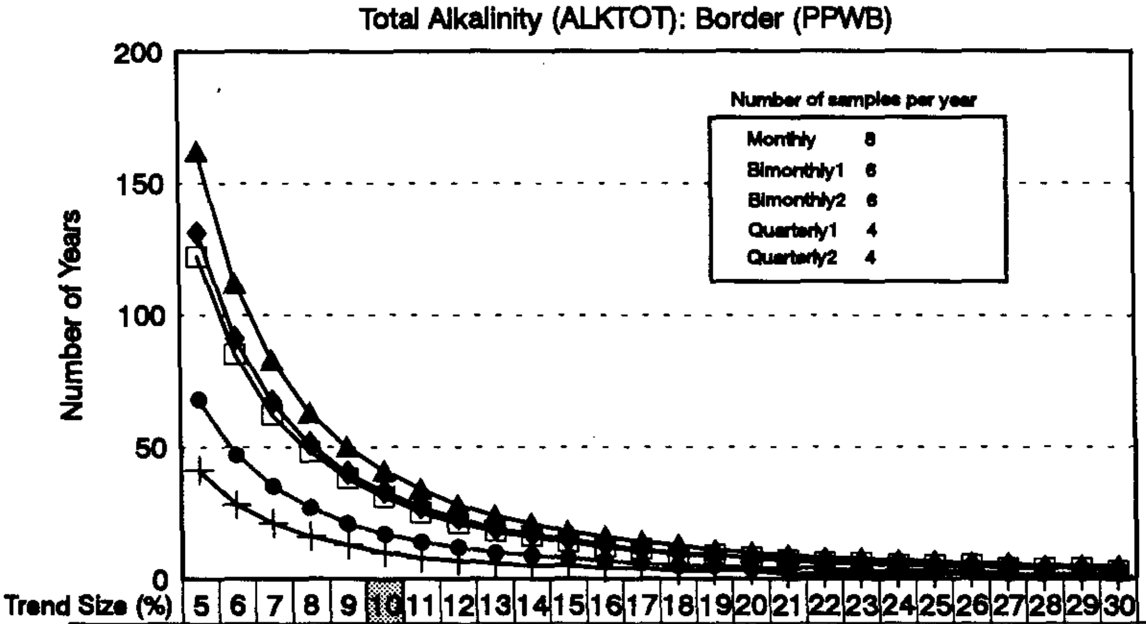
Appendix F-5
Table 5. Water Quality, Border (PPWB)

SCHEME=QUARTERLY2

VARIABLE		CODE	FITTED MODEL	Log SE	Bt SE	R	N	Log Baseline Mean	Bt Baseline Mean
ALKTOT	Total Alkalinity	10101L	WN	0.1225	16.6318	0	71	4.8997	135.261
BDISS	Boron Dissolved	05105D	AR(1)	0.4451	0.0307	0.25	65	-2.8243	0.066
CADISS	Calcium Dissolved	20101L	WN	0.0882	3.9511	0	71	3.7963	44.71
CLDISS	Cloride Dissolved	17206L	WN	0.4263	1.9638	0	71	1.3905	4.399
CONDF	Conductivity Field	02041F	AR(1)	0.0879	30.2695	0.31	71	5.8359	343.698
CUDISS	Copper Dissolved	29005P	WN	0.5572	0.0013	0	47	-6.2798	0.002
DO	Dissolved Oxygen	08101F	WN	0.0973	0.9997	0	71	2.3226	10.251
FCOLI	Fecal Coliforms	36011F	WN	1.1813	34.5583	0	71	2.2895	19.831
KDISS	Potassium Dissolved	19103L	WN	0.2378	0.3313	0	71	0.2891	1.374
MGDISS	Manganese Dissolved	25104D	WN	0.0818	1.1023	0	71	2.5959	13.454
NADISS	Sodium Dissolved	11103L	WN	0.2769	2.5642	0	71	2.1681	9.083
NFR	Non-Filterable Residues	10401L	WN	0.7049	12.6315	0	69	2.5081	15.745
NO3NO2	Nitrate Plus Nitrite	07106L	WN	1.1733	0.4503	0	71	-2.0291	0.262
PDISS	Phosphorus Dissolved	15103D	WN	0.6291	0.0294	0	65	-3.3617	0.042
PH	pH	10301F	WN	0.2387	0.2387	0	71	8.1131	8.113
PHF	pH Field	10301F	WN	0.3148	0.3148	0	71	8.1047	8.105
PTOT	Phosphorus Total	15406L	WN	0.3735	0.0347	0	71	-2.4825	0.09
SO4DIS	Sulfate Dissolved	16304L	WN	0.109	4.6312	0	71	3.7403	42.362
SPCOND	Specific Conductivity	02041F	WN	0.088	31.6169	0	71	5.8783	358.587
TDS	Total Dissolved Solids	00201L	WN	0.0896	17.9685	0	71	5.295	200.139
TEMPF	Temperature Field	02061F	WN	4.1901	4.1901	0	71	8.049	8.049
TN	Toatal Nitrogen	07602L	WN	0.3628	0.2523	0	71	-0.4624	0.673
TURBF	Turbidity Field	02073F	WN	0.5806	6.7828	0	50	2.2029	10.713
TURBL	Turbidity Lab	02071L	WN	0.7015	7.2782	0	71	1.9653	9.128
ZNTOT	Zinc Total	30005P	WN	0.5375	0.0026	0	47	-5.5329	0.005

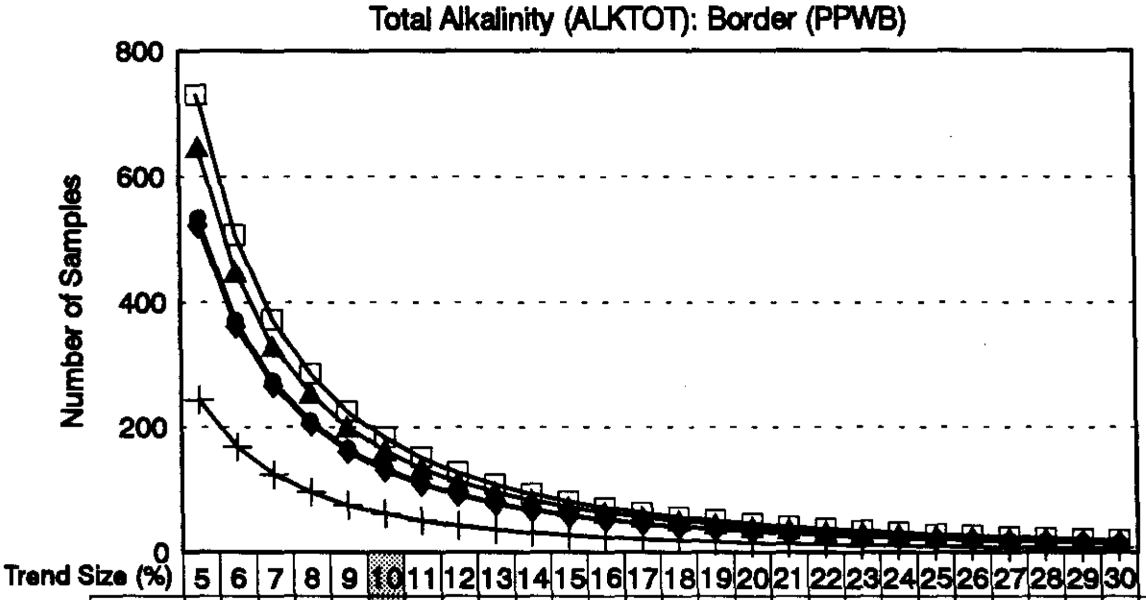
APPENDIX G: STUDY TWO: PLOTS OF TOTAL NUMBER OF SAMPLES AND NUMBER OF YEARS TO DETECT LINEAR TREND SIZES, 5 TO 30% OF THE BASELINE MEAN, AND NUMBER OF INDEPENDENT SAMPLES PER YEAR FOR MONTHLY, BIMONTHLY AND QUARTERLY MONITORING SCHEDULES AT THE BORDER STATION, YEAR 1974-1991, ON THE NORTH SASKATCHEWAN RIVER

Fig. 1a. Number of Years to Detect a Linear Trend (%)
For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	68	47	35	27	21	17	14	12	10	9	8	7	6	5	5	4	4	4	3	3	3	3	2	2	2	2	Years
Bimonthly1 +	41	28	21	16	13	10	8	7	6	5	5	4	4	3	3	3	2	2	2	2	2	2	1	1	1	1	
Bimonthly2 —	122	85	62	48	38	31	25	21	18	16	14	12	11	9	9	8	7	6	6	5	5	5	4	4	4	3	
Quarterly1 ▲	162	112	83	63	50	41	34	28	24	21	18	16	14	13	11	10	9	8	8	7	7	6	6	5	5	5	
Quarterly2 ●	131	91	67	51	40	33	27	23	19	17	15	13	11	10	9	8	8	7	6	6	5	5	5	4	4	4	

Fig. 1b. Number of Independent Samples to Detect a Linear Trend (%)
For Three Monitoring Schemes

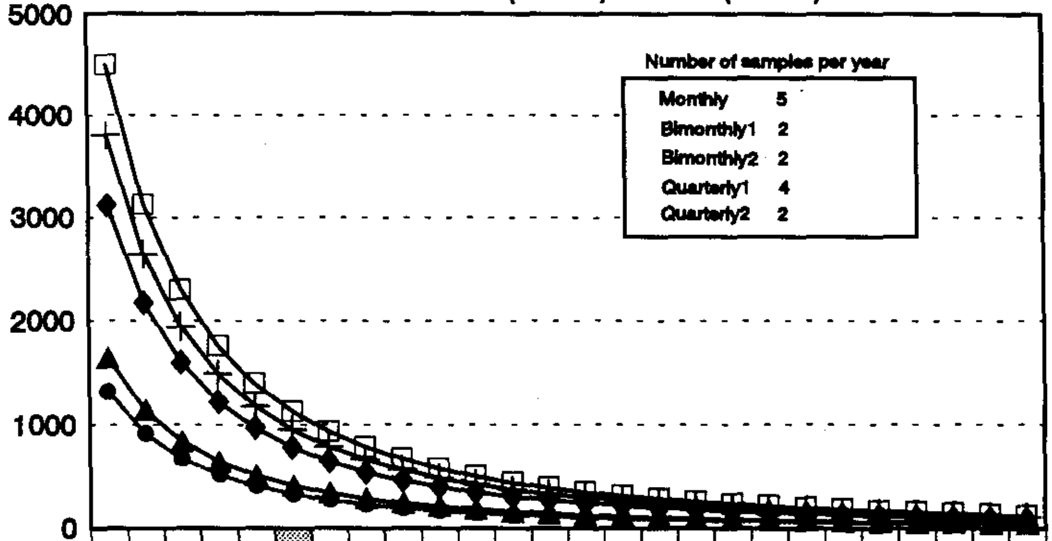


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	535	371	273	209	165	134	110	93	79	68	59	52	46	41	37	33	30	28	25	23	21	20	18	17	16	15	Samples
Bimonthly1	243	168	124	95	75	61	50	42	36	31	27	24	21	19	17	15	14	13	11	11	10	9	8	8	7	7	
Bimonthly2	730	507	373	285	225	188	151	127	108	93	81	71	63	56	51	46	41	38	35	32	29	27	25	23	22	20	
Quarterly1	647	449	330	253	200	162	134	112	96	83	72	63	56	50	45	40	37	33	31	28	26	24	22	21	19	18	
Quarterly2	522	362	266	204	161	130	108	91	77	67	58	51	45	40	36	33	30	27	25	23	21	19	18	17	16	14	

● Monthly + Bimonthly1 □ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 2a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

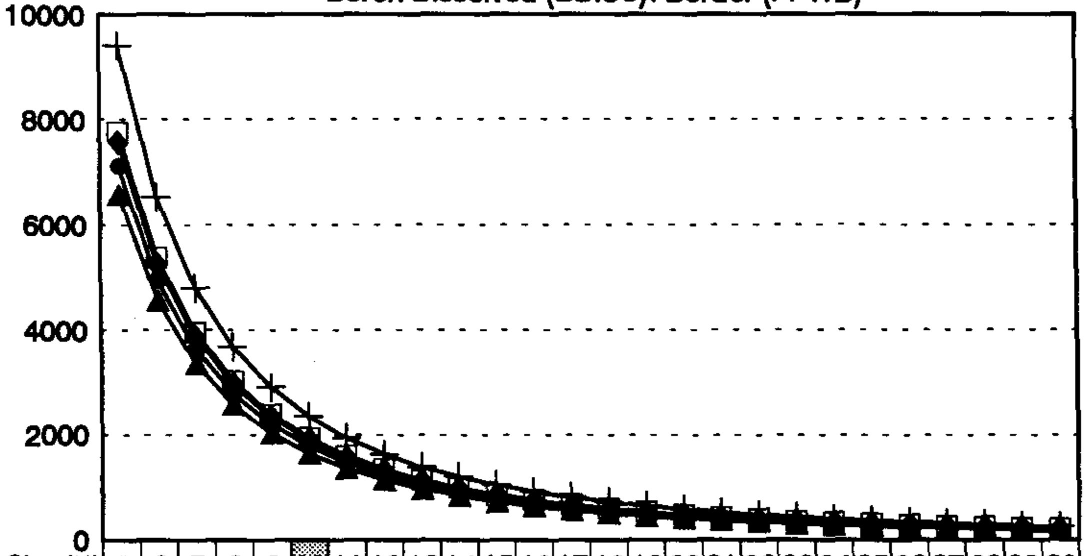
Boron Dissolved (BDISS): Border (PPWB)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	1314	912	670	519	405	[illegible]	271	228	194	165	146	128	114	101	91	82	74	68	62	57	53	49	46	42	39	37	Years
Bimonthly1 +	3808	2641	1941	1486	1174	[illegible]	786	660	562	485	422	371	329	293	263	238	216	196	180	165	152	141	130	121	113	106	
Bimonthly2 —	4501	3126	2296	1758	1389	[illegible]	930	782	666	574	500	439	389	347	311	281	255	232	213	195	180	166	155	144	134	125	
Quarterly1 ▲	1649	1141	838	642	507	[illegible]	340	285	246	210	183	161	142	127	114	103	93	85	78	71	66	61	56	53	49	46	
Quarterly2 ◆	3125	2170	1594	1220	965	[illegible]	645	549	462	398	347	305	270	241	217	195	177	162	148	136	126	116	107	100	93	87	

Fig. 2b Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

Boron Dissolved (BDISS): Border (PPWB)

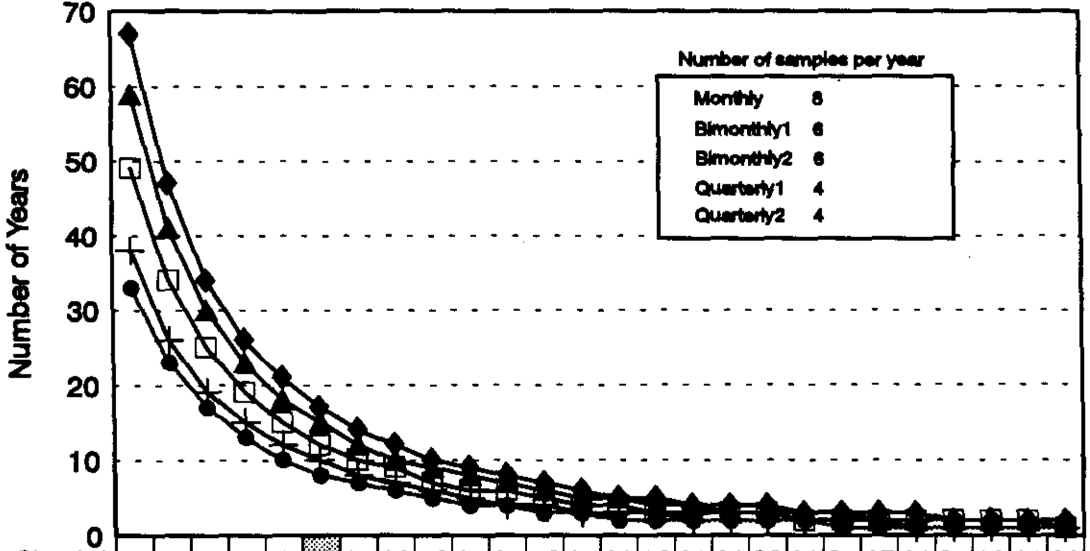


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	7116	4942	3631	2780	2196	1779	1470	1235	1053	908	791	695	616	549	493	445	403	368	336	309	285	263	244	227	212	198	Samples
Bimonthly1	9399	6527	4706	3672	2901	[illegible]	1942	1632	1390	1199	1044	918	813	725	651	587	533	485	444	408	376	348	322	300	279	261	
Bimonthly2	7746	5379	3952	3028	2391	[illegible]	1600	1345	1146	988	861	756	670	598	536	484	439	400	366	336	310	286	266	247	230	215	
Quarterly1	6571	4563	3353	2567	2028	[illegible]	1356	1141	972	838	730	642	568	507	455	411	373	339	311	285	263	243	225	210	195	183	
Quarterly2	7561	5251	3858	2953	2334	[illegible]	1562	1313	1118	964	840	738	654	583	524	473	429	391	357	328	302	280	259	241	225	210	

● Monthly + Bimonthly1 □ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 3a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

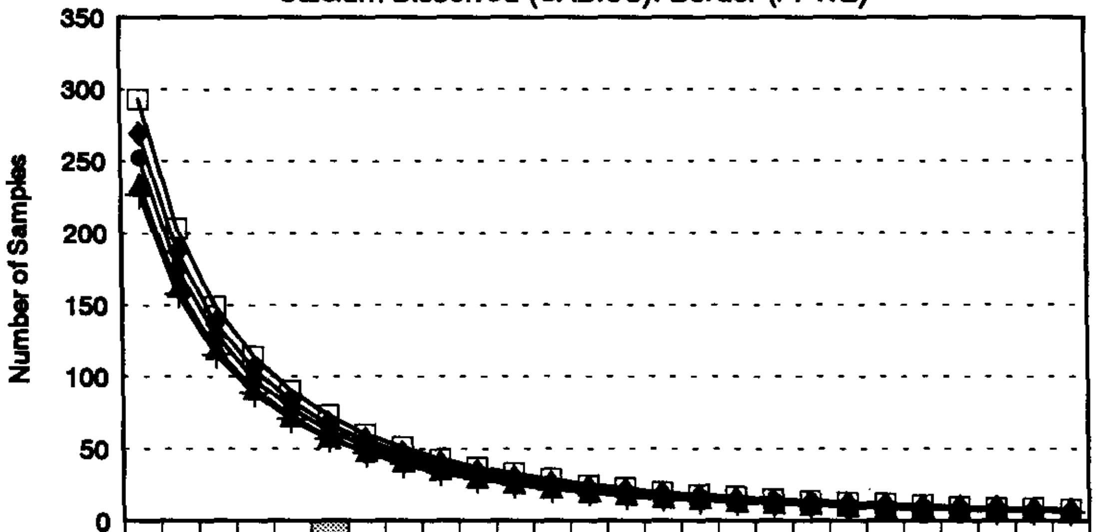
Calcium Dissolved (CADISS): Border (PPWB)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	33	23	17	13	10	8	7	6	5	4	4	3	3	2	2	2	2	2	2	1	1	1	1	1	1	1	Years
Bimonthly1 +	38	26	19	15	12	10	8	7	6	5	4	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	
Bimonthly2 —	49	34	25	19	15	12	10	9	7	6	6	5	4	4	3	3	3	3	2	2	2	2	2	2	2	1	
Quarterly1 ▲	59	41	30	23	18	15	12	10	9	8	7	6	5	5	4	4	3	3	3	3	2	2	2	2	2	2	
Quarterly2 ●	67	47	34	26	21	17	14	12	10	9	8	7	6	5	5	4	4	4	3	3	3	3	2	2	2	2	

Fig. 3b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

Calcium Dissolved (CADISS): Border (PPWB)

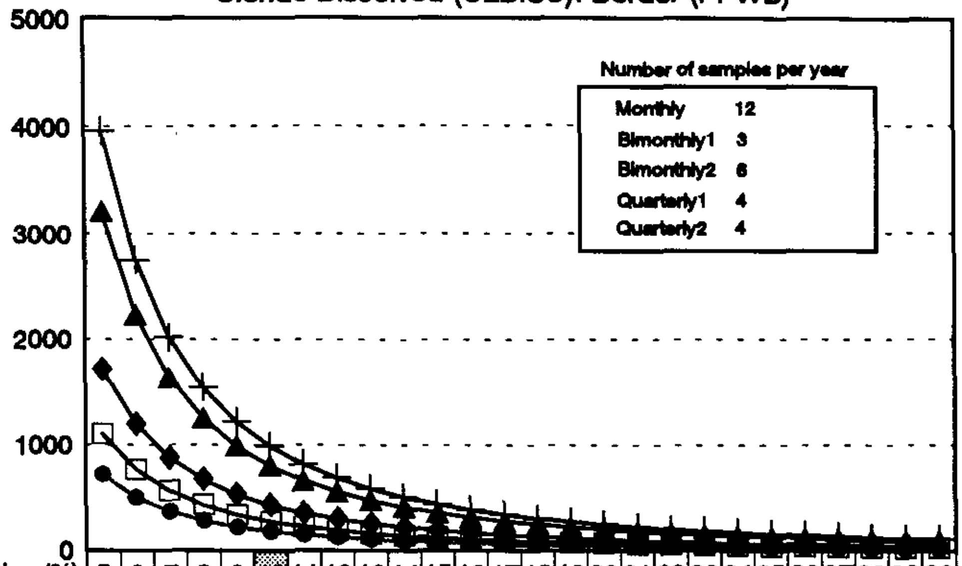


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	252	175	129	98	78	63	52	44	37	32	28	25	22	19	17	16	14	13	12	11	10	9	9	8	7	7	Samples
Bimonthly1	226	157	115	88	70	57	47	39	33	29	25	22	20	17	16	14	13	12	11	10	9	8	8	7	7	6	
Bimonthly2	293	203	149	114	90	73	60	51	43	37	33	29	25	23	20	18	17	15	14	13	12	11	10	9	9	8	
Quarterly1	234	162	119	91	72	56	48	41	35	30	26	23	20	18	16	15	13	12	11	10	9	9	8	7	7	6	
Quarterly2	269	187	137	105	83	67	56	47	40	34	30	26	23	21	19	17	15	14	13	12	11	10	9	9	8	7	

● Monthly + Bimonthly1 □ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 4a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

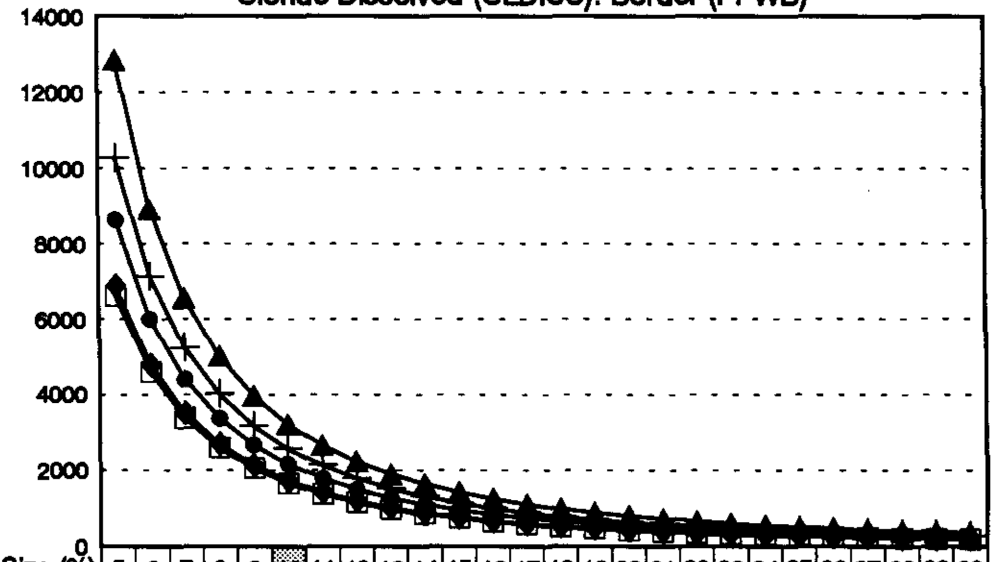
Cloride Dissolved (CLDISS): Border (PPWB)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	716	499	367	281	222	[illegible]	149	125	106	92	80	70	62	55	50	45	41	37	34	31	29	27	25	23	21	20	Years
Bimonthly1 +	3958	2747	2018	1545	1221	[illegible]	817	687	585	504	440	388	342	305	274	247	224	204	187	172	158	146	136	126	118	110	
Bimonthly2 —	1100	764	561	430	340	[illegible]	227	191	163	140	122	108	95	85	76	69	62	57	52	48	44	41	38	35	33	31	
Quarterly1 ▲	3210	2229	1638	1254	991	[illegible]	663	557	475	410	357	314	278	248	222	201	182	166	152	139	129	119	110	102	96	89	
Quarterly2 ◆	1719	1194	877	672	531	[illegible]	355	299	254	219	191	168	149	133	119	108	98	89	81	75	69	64	59	55	51	48	

Fig. 4b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

Cloride Dissolved (CLDISS): Border (PPWB)

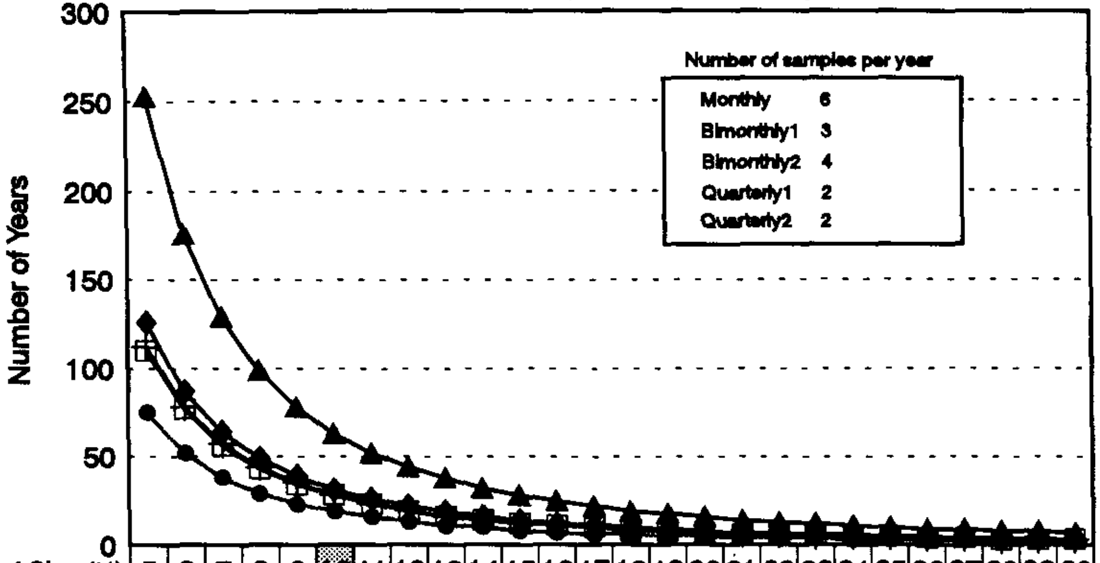


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	8594	5989	4400	3369	2662	[illegible]	1782	1497	1276	1100	958	842	746	665	597	539	489	445	405	374	345	319	296	275	256	240	Samples
Bimonthly1	10266	7128	5287	4010	3168	[illegible]	2121	1782	1518	1309	1141	1002	888	792	711	642	582	530	485	446	411	380	352	327	305	285	
Bimonthly2	6602	4586	3368	2579	2085	[illegible]	1364	1146	977	842	734	645	571	509	457	418	374	341	312	287	264	244	226	211	196	186	
Quarterly1	12838	8916	6550	5016	3962	[illegible]	2653	2229	1899	1639	1428	1254	1111	991	889	802	728	663	607	557	514	475	440	409	382	357	
Quarterly2	6877	4776	3509	2686	2129	[illegible]	1421	1194	1017	877	764	672	595	531	476	430	390	355	325	298	275	254	235	219	204	191	

● Monthly + Bimonthly1 □ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 5a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

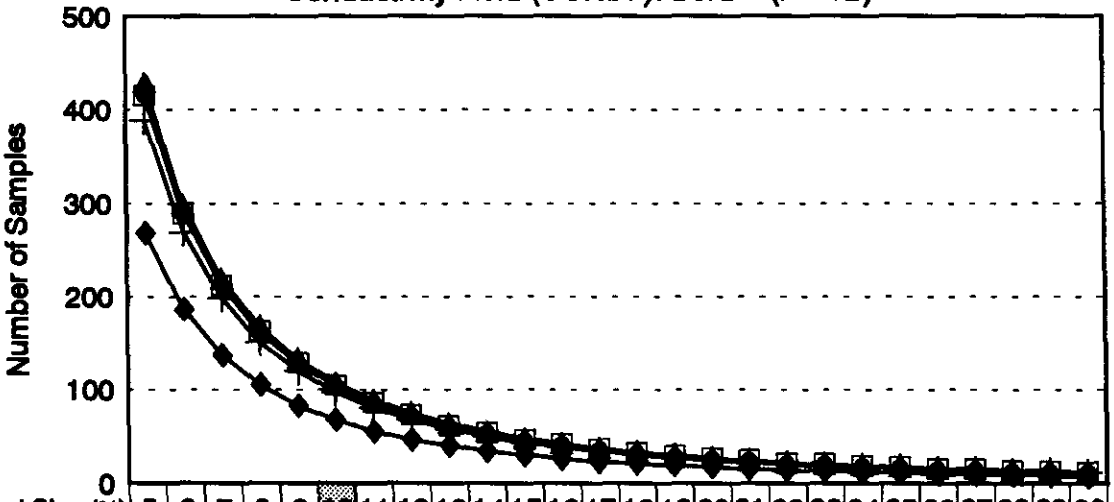
Conductivity Field (CONDF): Border (PPWB)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	75	52	38	29	23	19	16	13	11	10	8	7	6	6	5	5	4	4	4	3	3	3	3	2	2	2	Years
Bimonthly1 +	112	78	57	44	35	28	23	19	16	14	12	11	10	9	8	7	6	6	5	5	5	4	4	3	3	3	
Bimonthly2 —	110	77	56	43	34	28	23	19	16	14	12	11	10	8	8	7	6	6	5	5	5	4	4	3	3	3	
Quarterly1 ▲	253	176	129	99	78	63	52	44	38	32	28	25	22	19	16	16	14	13	12	11	10	9	9	8	8	7	
Quarterly2 ●	126	87	64	49	39	31	26	22	19	16	14	12	11	10	9	8	7	7	6	6	5	5	4	4	4	3	

Fig. 5b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

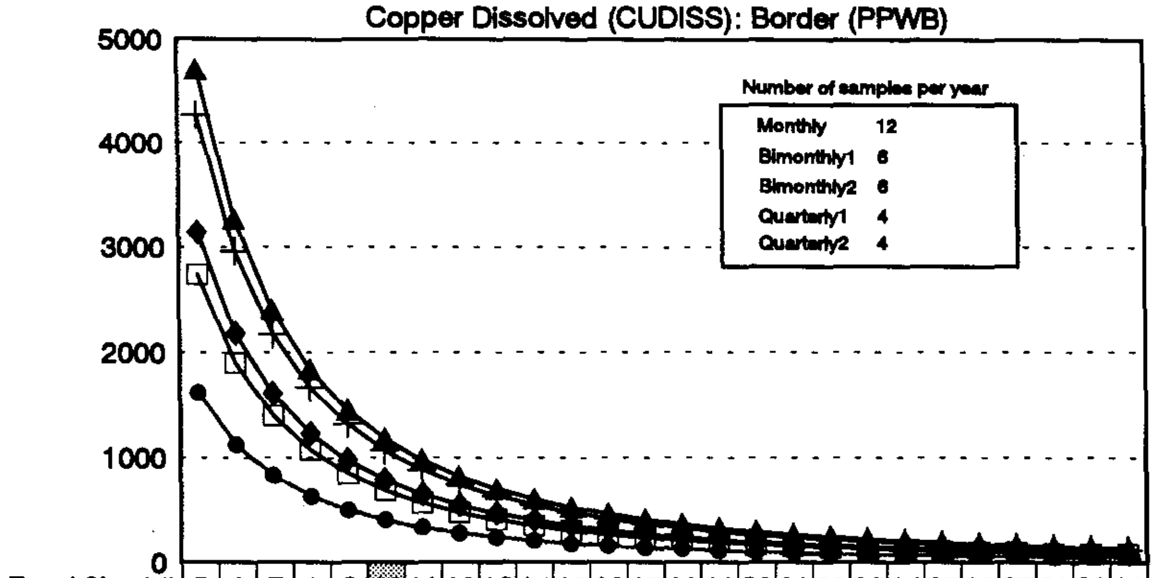
Conductivity Field (CONDF): Border (PPWB)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	415	289	212	162	128	104	86	72	61	53	46	41	36	32	29	26	24	21	20	18	17	15	14	13	12	12	Samples
Bimonthly1	388	269	198	151	120	97	80	67	57	49	43	38	34	30	27	24	22	20	18	17	16	14	13	12	12	11	
Bimonthly2	415	289	212	162	128	104	86	72	61	53	46	41	36	32	29	26	24	21	20	18	17	15	14	13	12	12	
Quarterly1	429	298	219	168	133	107	89	75	64	55	48	42	37	33	30	27	24	22	20	19	17	16	15	14	13	12	
Quarterly2	268	186	137	105	83	67	55	46	40	34	30	26	23	21	19	17	15	14	13	12	11	10	9	9	8	7	

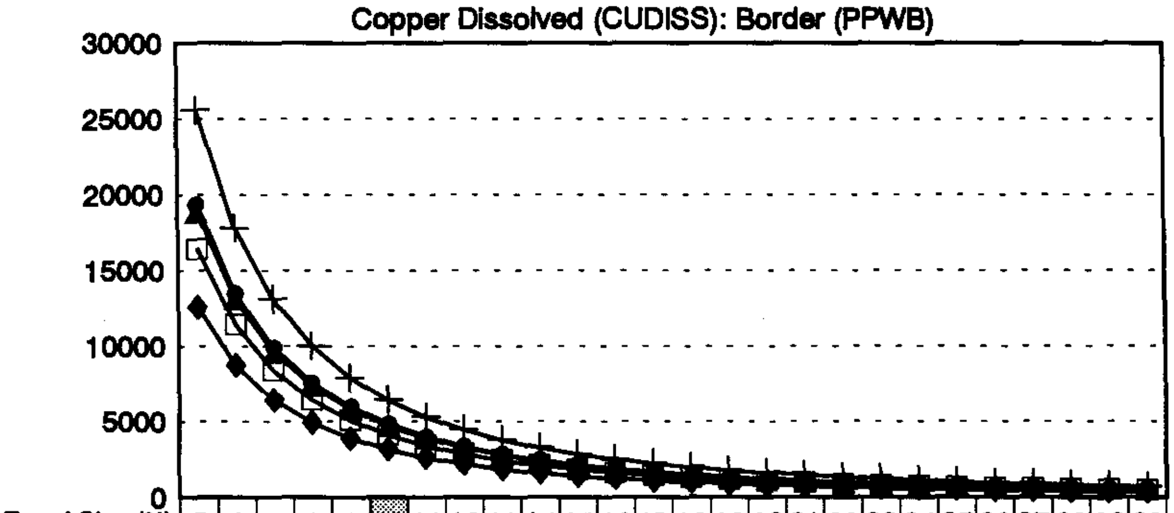
● Monthly + Bimonthly1 □ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 6a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes



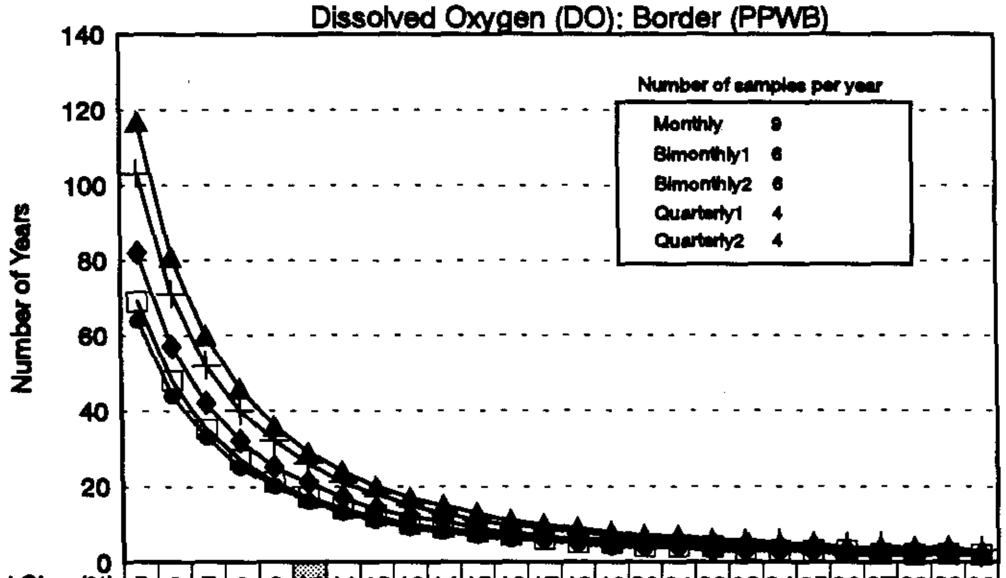
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	1614	1121	823	630	498	[illegible]	333	280	239	206	179	158	140	125	112	101	92	83	76	70	65	60	55	51	48	45	Years
Bimonthly1 +	4263	2961	2176	1665	1316	[illegible]	881	740	631	544	474	416	370	329	295	267	242	220	202	185	171	158	146	136	127	118	
Bimonthly2 —	2787	1901	1396	1069	845	[illegible]	566	475	405	349	304	267	237	211	190	171	155	141	129	119	110	101	94	87	81	76	
Quarterly1 ▲	4704	3267	2400	1963	1452	1176	972	817	696	600	523	460	407	363	326	294	267	243	222	204	189	174	161	150	140	131	
Quarterly2 ◆	3141	2181	1603	1227	970	[illegible]	649	545	465	401	349	307	272	242	218	196	178	162	149	136	126	116	108	100	93	87	

Fig. 6b Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes



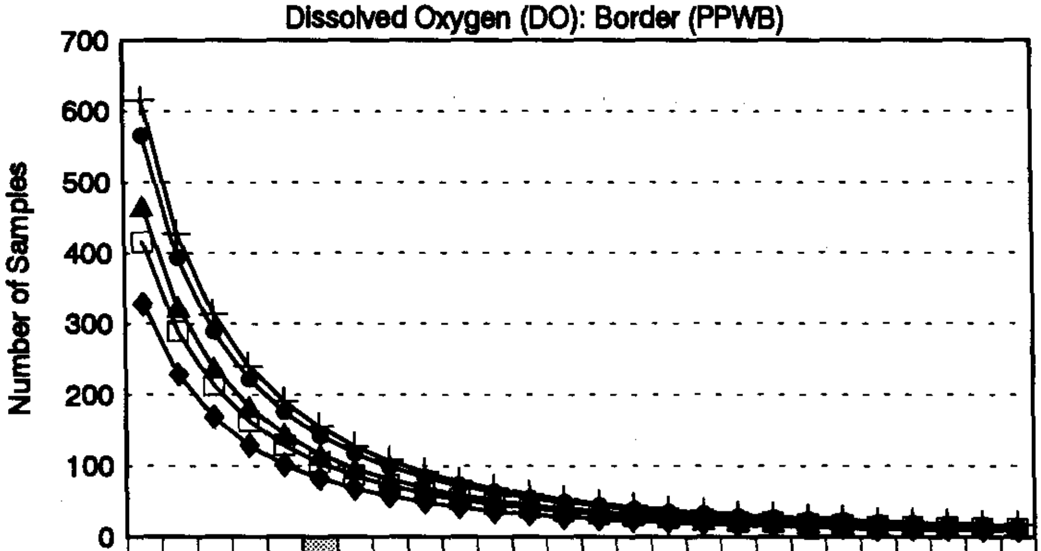
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	19368	13448	9880	7564	5977	[illegible]	4001	3362	2865	2470	2152	1891	1675	1494	1341	1210	1098	1000	915	840	775	716	664	617	576	536	Samples
Bimonthly1	25578	17766	13056	9991	7894	[illegible]	5286	4441	3784	3266	2842	2496	2218	1974	1771	1599	1450	1321	1209	1110	1026	946	877	816	760	711	
Bimonthly2	16722	11404	8376	6415	5068	[illegible]	3399	2851	2429	2095	1825	1604	1421	1267	1137	1028	931	846	776	713	657	607	563	524	486	456	
Quarterly1	18817	13067	9600	7850	5808	[illegible]	3888	3267	2784	2400	2091	1839	1626	1452	1306	1176	1067	972	889	817	756	696	645	600	559	523	
Quarterly2	12564	8725	6410	4908	3878	[illegible]	2596	2181	1859	1602	1396	1227	1087	969	870	785	712	649	594	545	503	465	431	401	373	349	

Fig. 7a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes


Dissolved Oxygen (DO): Border (PPWB)

Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	64	44	33	25	20	16	13	11	9	8	7	6	6	5	4	4	4	3	3	3	3	2	2	2	2	2	Years
Bimonthly1 +	103	71	52	40	32	26	21	18	15	13	11	10	9	8	7	6	6	5	5	5	4	4	4	3	3	3	
Bimonthly2 —	69	48	35	27	21	17	14	12	10	9	8	7	6	5	5	4	4	4	3	3	3	3	2	2	2	2	
Quarterly1 ▲	117	81	60	46	36	29	24	20	17	15	13	11	10	9	8	7	7	6	6	5	5	4	4	4	4	3	
Quarterly2 ●	82	57	42	32	25	21	17	14	12	11	9	8	7	6	6	5	5	4	4	4	3	3	3	3	3	2	

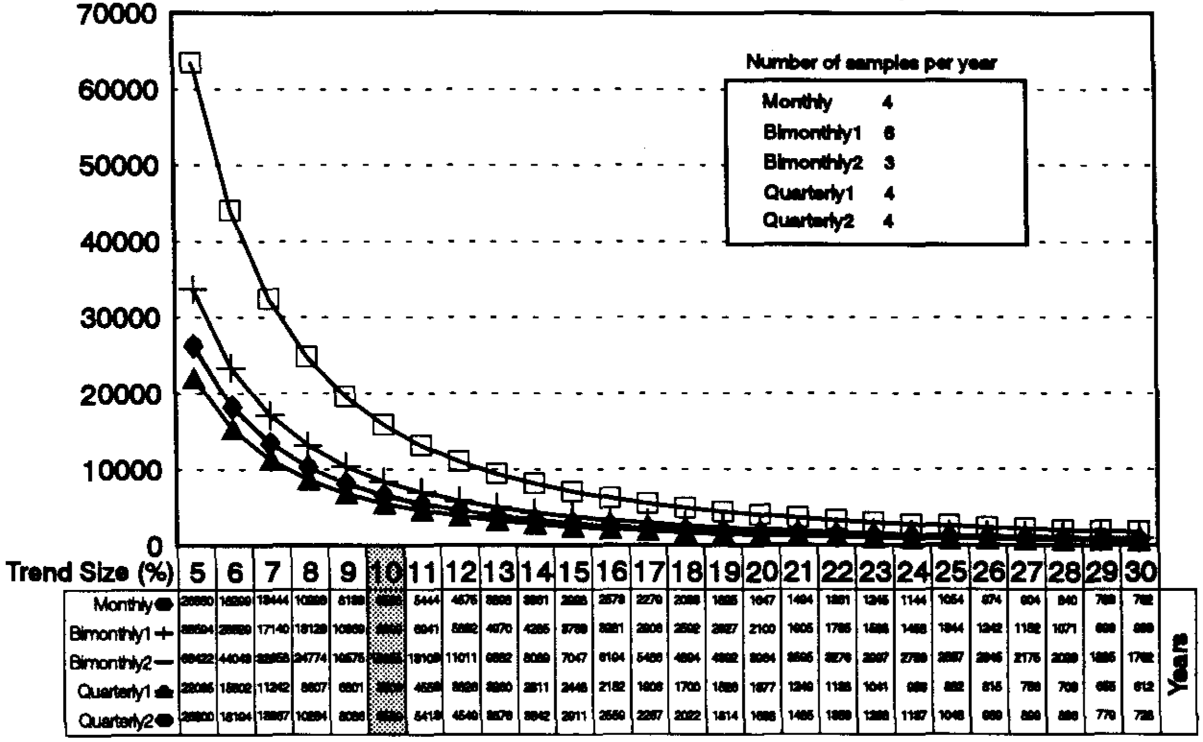
Fig. 7b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes


Dissolved Oxygen (DO): Border (PPWB)

Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	566	393	289	221	175	142	117	98	84	72	63	55	49	44	39	35	32	29	27	25	23	21	19	18	17	16	Samples
Bimonthly1	615	427	314	240	190	154	127	107	91	78	68	60	53	47	43	38	35	32	29	27	25	23	21	20	18	17	
Bimonthly2	415	289	212	162	128	104	86	72	61	53	46	41	36	32	29	26	24	21	20	18	17	15	14	13	12	12	
Quarterly1	466	324	238	182	144	116	96	81	69	59	52	45	40	36	32	29	26	24	22	20	19	17	16	15	14	13	
Quarterly2	328	228	167	128	101	82	68	57	49	42	36	32	28	25	23	21	19	17	16	14	13	12	11	10	10	9	

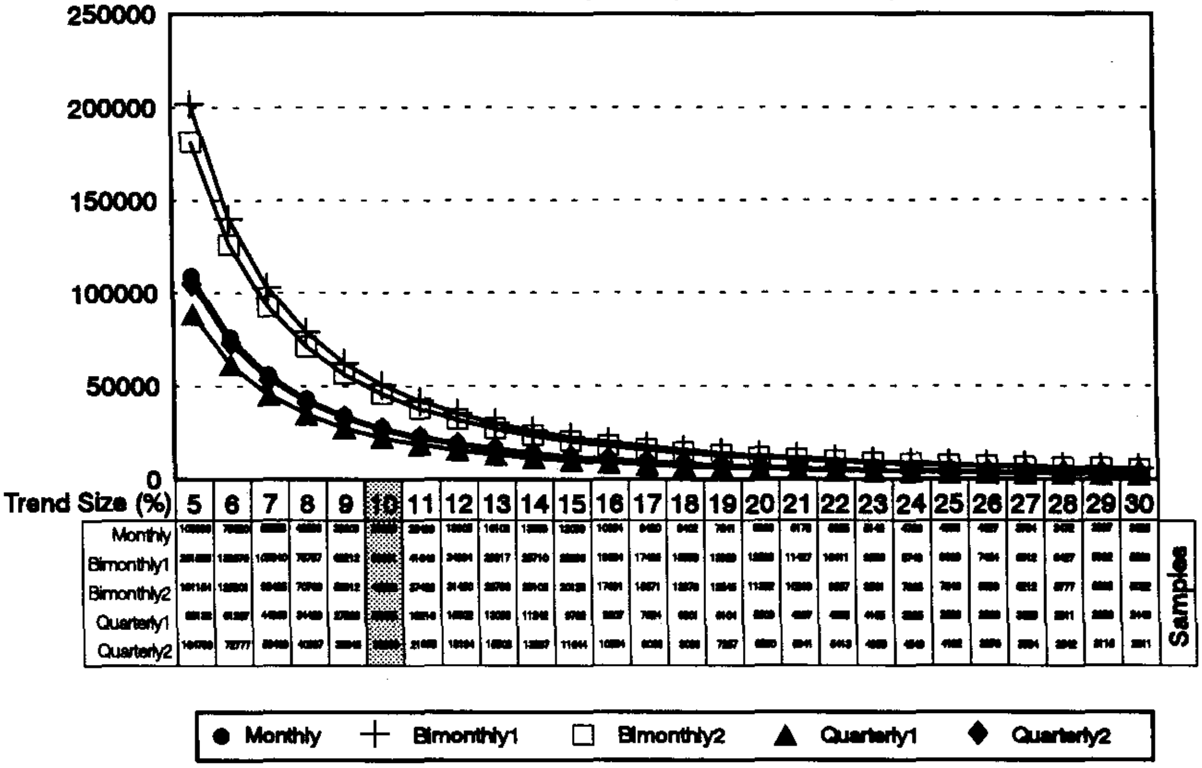
● Monthly + Bimonthly1 ☐ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 8a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes



Fecal Coliforms (FCOLI): Border (PPWB)

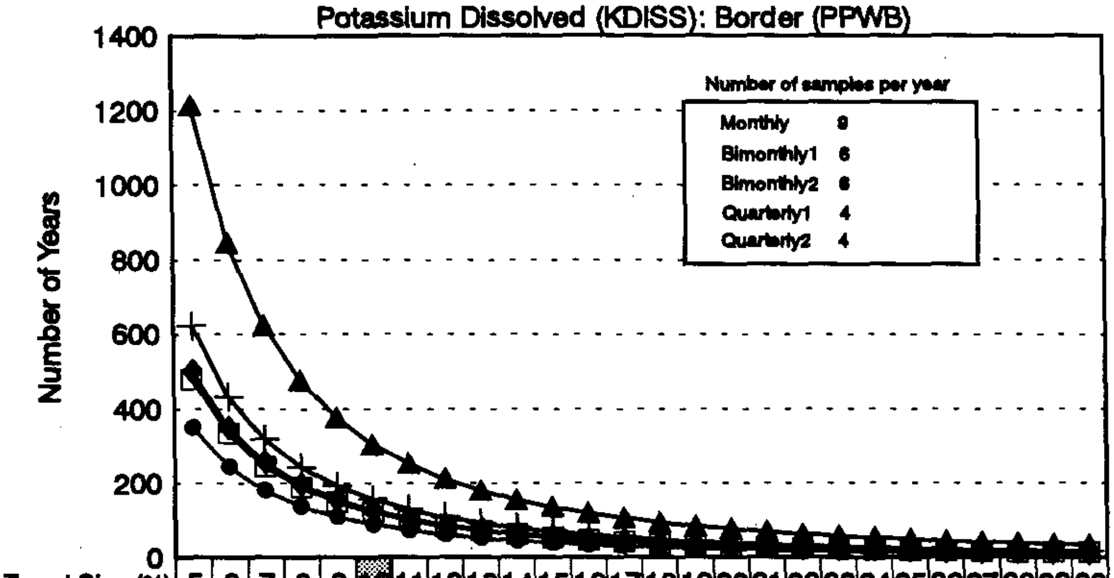
Fig. 8b Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes



Fecal Coliforms (FCOLI): Border (PPWB)

Fig. 9a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

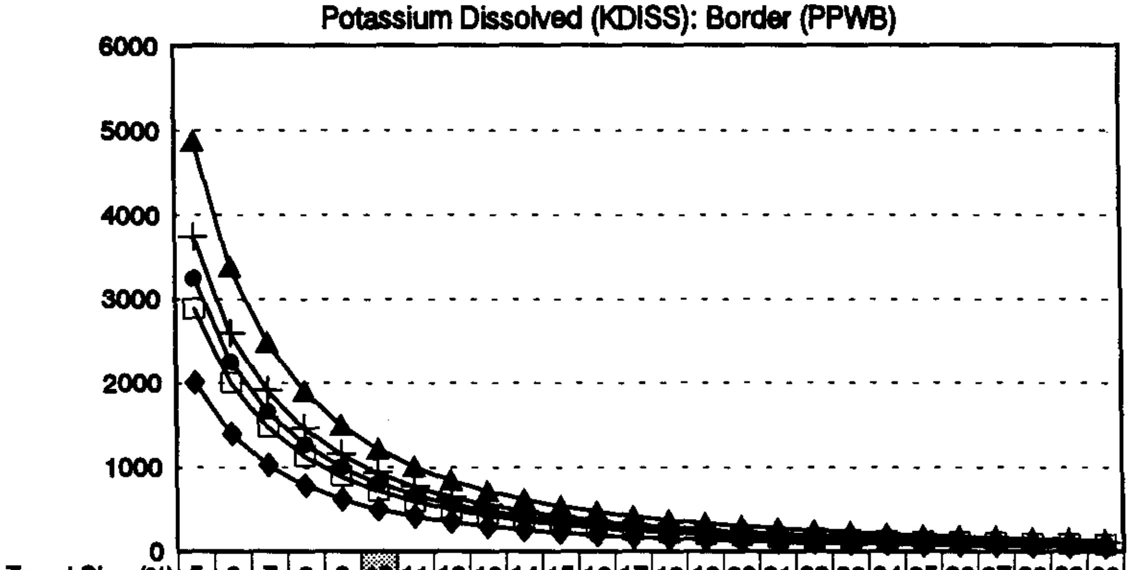
Potassium Dissolved (KDISS): Border (PPWB)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	351	244	179	137	108	88	73	61	52	45	39	34	30	27	24	22	20	18	17	15	14	13	12	11	10	10	Years
Bimonthly1 +	622	432	318	243	192	156	129	108	92	79	69	61	54	48	43	39	35	32	29	27	25	23	21	20	19	17	
Bimonthly2 —	480	334	245	188	148	120	99	83	71	61	53	47	42	37	33	30	27	25	23	21	19	18	17	15	14	13	
Quarterly1 ▲	1217	845	621	476	376	304	252	211	180	155	135	119	105	94	84	76	69	63	58	53	49	45	42	39	36	34	
Quarterly2 ◆	502	349	256	196	155	125	104	87	74	64	56	49	44	39	35	31	29	26	24	22	20	19	17	16	15	14	

Fig. 9b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

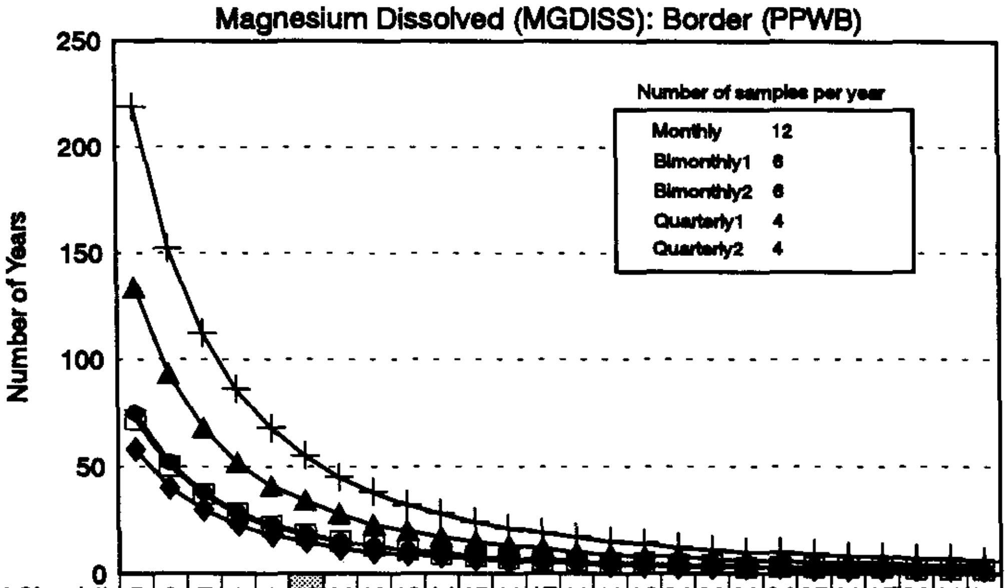
Potassium Dissolved (KDISS): Border (PPWB)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	3250	2257	1658	1269	1009	[illegible]	671	564	481	415	361	317	281	251	226	209	184	165	154	141	130	120	111	104	97	90	Samples
Bimonthly1	3789	2592	1905	1468	1152	[illegible]	771	648	552	476	415	365	320	285	259	238	212	198	176	162	149	138	128	119	111	104	
Bimonthly2	2882	2001	1470	1126	889	[illegible]	595	500	426	368	320	281	249	222	200	180	163	149	136	125	115	107	99	92	86	80	
Quarterly1	4869	3381	2484	1902	1503	[illegible]	1006	845	720	621	541	475	421	376	337	304	276	251	230	211	195	180	167	155	145	135	
Quarterly2	2008	1394	1024	784	620	[illegible]	415	349	297	256	223	196	174	155	139	125	114	104	95	87	80	74	69	64	60	56	

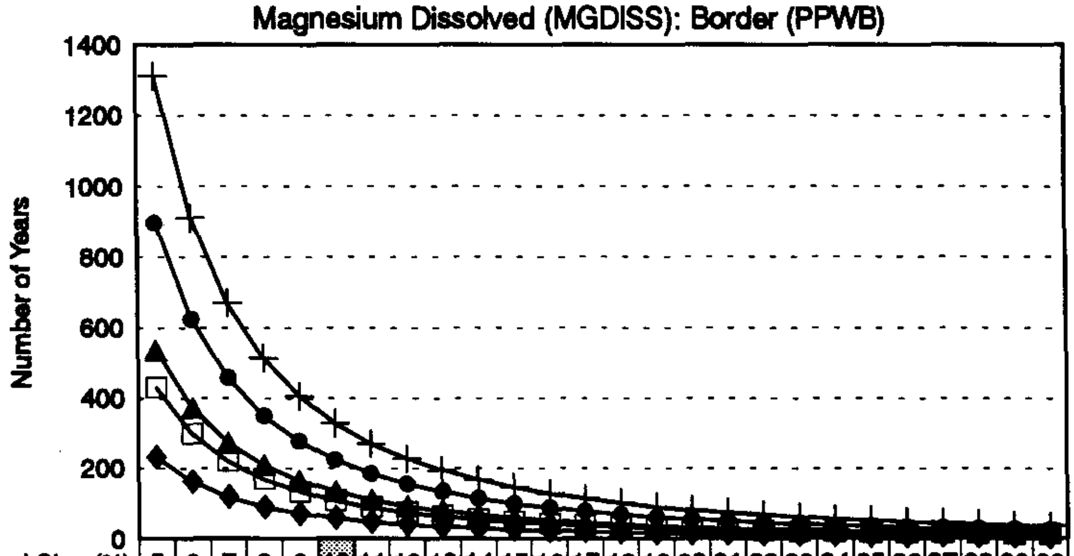
● Monthly + Bimonthly1 □ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 10a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Years
Monthly ●	75	52	38	29	23	18	15	13	11	10	8	7	7	6	5	5	4	4	4	3	3	3	3	2	2	2	
Bimonthly1 +	219	152	112	86	68	55	45	38	32	28	24	21	19	17	15	14	12	11	10	10	9	8	8	7	7	6	
Bimonthly2 —	72	50	37	28	22	18	15	13	11	9	8	7	6	6	5	5	4	4	3	3	3	3	3	2	2	2	
Quarterly1 ▲	134	93	68	52	41	34	28	23	20	17	15	13	12	10	9	8	8	7	6	6	5	6	5	4	4	4	
Quarterly2 ●	58	40	30	23	18	15	12	10	9	8	7	6	5	5	4	4	3	3	3	3	2	2	2	2	2	2	

Fig. 10b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

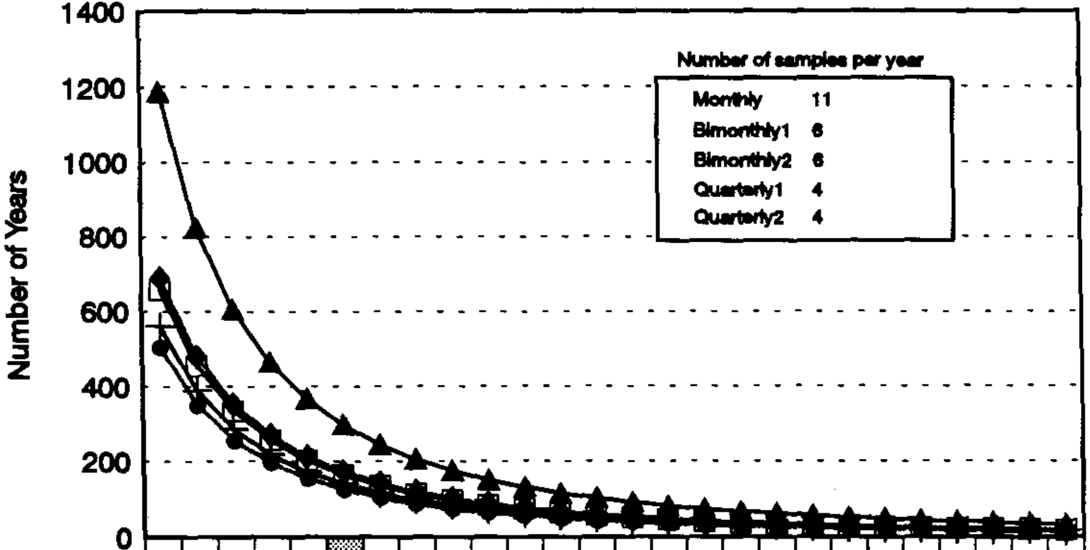


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly	897	623	456	350	277	224	185	156	133	114	100	88	78	69	62	56	51	46	42	39	36	33	31	29	27	25	
Bimonthly1	1312	911	670	513	405	328	271	228	194	167	146	128	114	101	91	82	74	66	62	57	52	49	45	42	39	36	
Bimonthly2	429	298	219	168	133	107	89	75	64	55	48	42	37	33	30	27	24	22	20	19	17	16	15	14	13	12	
Quarterly1	535	371	273	209	165	134	110	93	79	68	59	52	46	41	37	33	30	28	25	23	21	20	18	17	16	15	
Quarterly2	232	161	118	90	72	58	48	40	34	30	26	23	20	18	16	14	13	12	11	10	9	9	8	7	7	6	

● Monthly + Bimonthly1 □ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 11a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

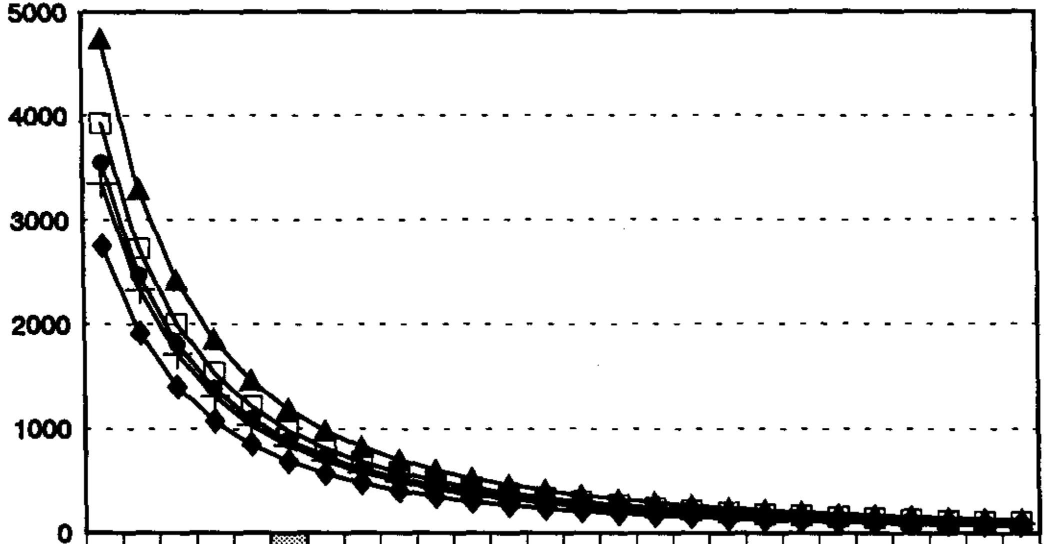
Sodium Dissolved (NADISS): Border (PPWB)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	502	349	256	196	155	126	104	87	74	64	56	49	43	39	35	31	28	26	24	22	20	19	17	16	15	14	Years
Bimonthly1 +	558	388	285	218	172	140	115	97	83	71	62	55	48	43	39	35	32	29	26	24	22	21	19	18	17	16	
Bimonthly2 —	654	454	334	256	202	164	135	114	97	84	73	64	57	51	45	41	37	34	31	28	26	24	23	21	20	18	
Quarterly1 ▲	1186	824	605	463	366	297	245	206	176	151	132	116	103	92	82	74	67	61	56	52	48	44	41	38	35	33	
Quarterly2 ◆	686	478	351	269	212	172	142	119	102	88	77	67	60	53	48	43	39	36	33	30	28	26	24	22	21	19	

Fig. 11b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

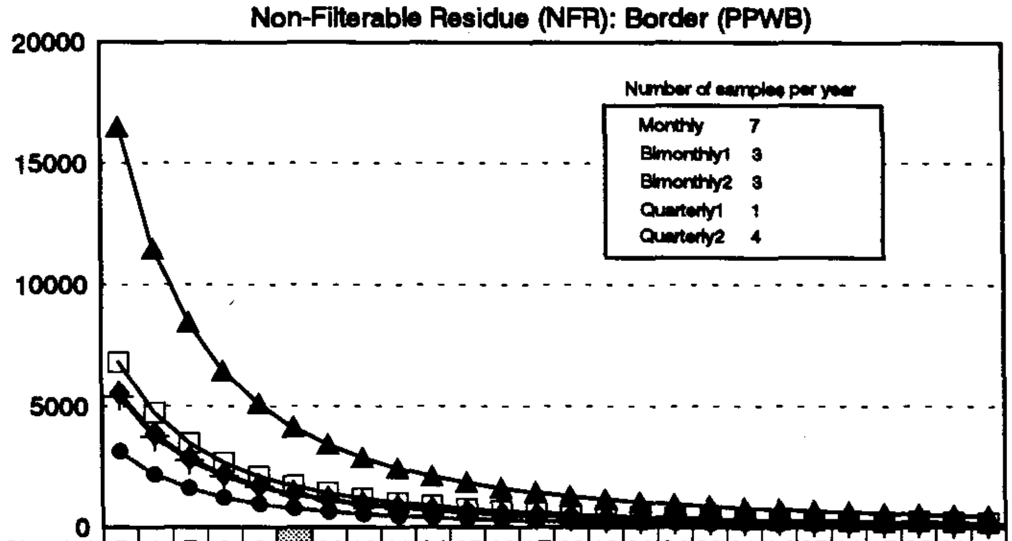
Sodium Dissolved (NADISS): Border (PPWB)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	3547	2469	1810	1386	1095	[illegible]	788	616	525	482	394	346	307	274	246	222	201	186	165	154	142	131	132	119	105	99	Samples
Bimonthly1	3350	2327	1709	1309	1084	[illegible]	682	582	496	427	372	327	290	259	232	209	190	175	158	145	134	124	115	107	100	93	
Bimonthly2	3925	2725	2002	1539	1211	[illegible]	811	681	581	501	436	388	340	309	272	245	222	208	185	170	157	145	135	125	117	109	
Quarterly1	4744	3294	2420	1853	1464	[illegible]	980	824	702	605	527	465	410	366	329	297	269	245	224	208	190	175	163	151	141	132	
Quarterly2	2750	1910	1403	1074	849	[illegible]	568	477	407	351	306	269	238	212	190	172	156	142	130	119	110	102	94	88	82	76	

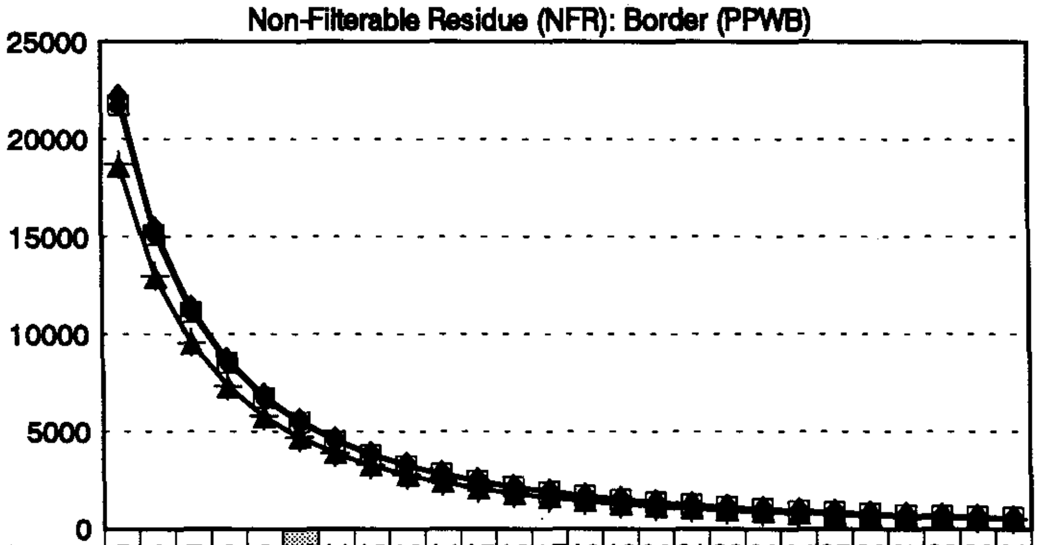
● Monthly + Bimonthly1 □ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 12a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Years
Monthly ●	3188	2176	1599	1224	967	[illegible]	647	544	464	400	348	306	271	242	217	196	178	162	148	[illegible]	125	116	107	100	[illegible]	87	
Bimonthly1 +	[illegible]	[illegible]	2740	2109	1661	[illegible]	1112	935	796	687	598	526	466	416	373	[illegible]	305	278	254	234	216	[illegible]	185	172	160	150	
Bimonthly2 —	[illegible]	4740	3462	2666	2107	[illegible]	1410	1185	1010	871	758	666	590	527	473	427	387	352	[illegible]	[illegible]	273	252	[illegible]	218	203	190	
Quarterly1 ▲	16597	11464	8457	6480	5104	[illegible]	3417	2871	2446	2109	1836	1615	1431	1276	1146	1035	937	854	781	716	662	612	567	527	492	460	
Quarterly2 ●	5552	[illegible]	[illegible]	2169	1714	[illegible]	1147	964	821	708	617	542	480	[illegible]	[illegible]	347	315	287	[illegible]	241	[illegible]	205	101	177	165	154	

Fig. 12b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

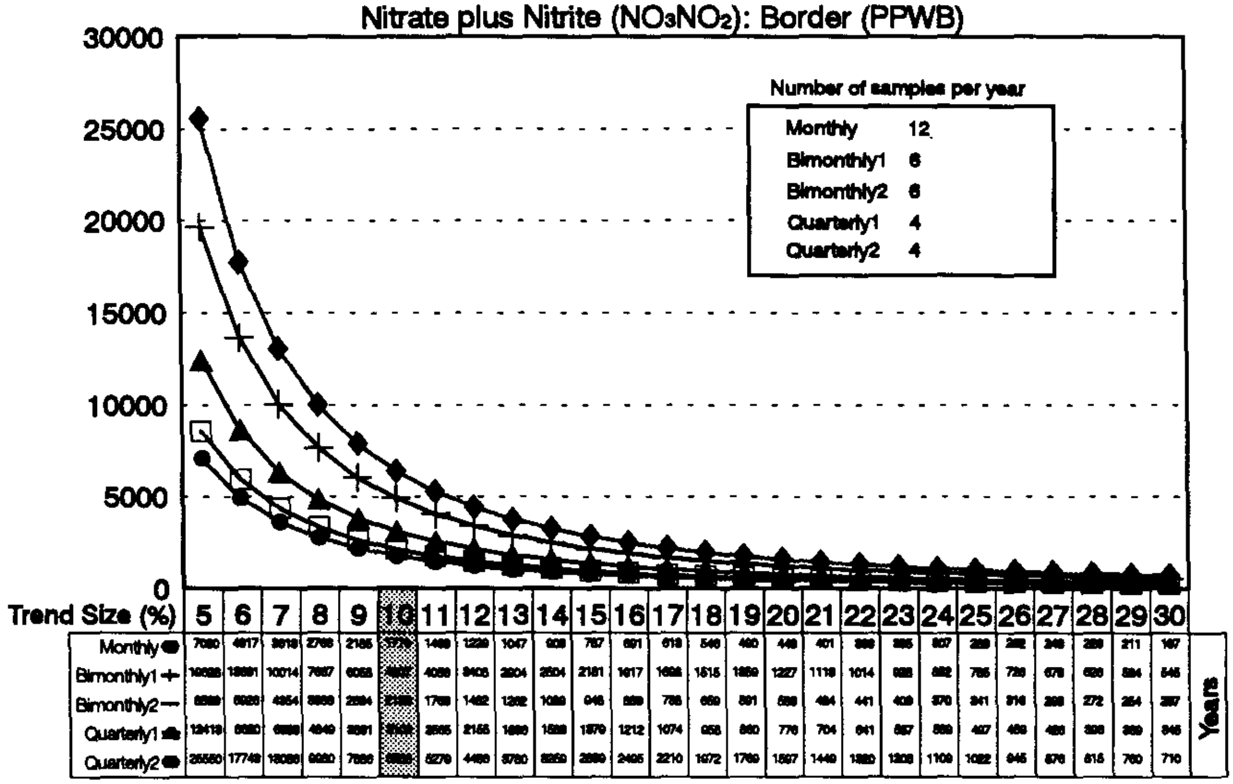


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly	21671	15049	11057	8465	6689	[illegible]	4477	3762	3206	2764	2408	2116	1875	1672	1501	1354	1229	1119	1024	941	867	801	743	691	644	602	
Bimonthly1	18670	12965	9526	7298	5762	[illegible]	3857	3241	2762	2381	2074	1826	1615	1441	1293	1167	1058	964	882	810	747	690	640	595	555	519	
Bimonthly2	21710	15077	11077	8481	6701	[illegible]	4486	3769	3212	2769	2412	2120	1878	1675	1503	1357	1231	1121	1026	942	868	803	745	692	645	603	
Quarterly1	18596	12882	9472	7252	5730	[illegible]	[illegible]	3228	2746	2368	2063	1813	1606	1432	1286	1160	1052	959	877	806	743	687	637	592	552	516	
Quarterly2	22209	15429	11331	8676	6855	[illegible]	4589	3856	3285	2833	2468	2169	1921	1714	1538	1388	1259	1147	1050	964	888	821	762	708	660	617	

● Monthly + Bimonthly1 □ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 13a. Number of Years to Detect a Linear Trend (%)
For Three Monitoring Schemes

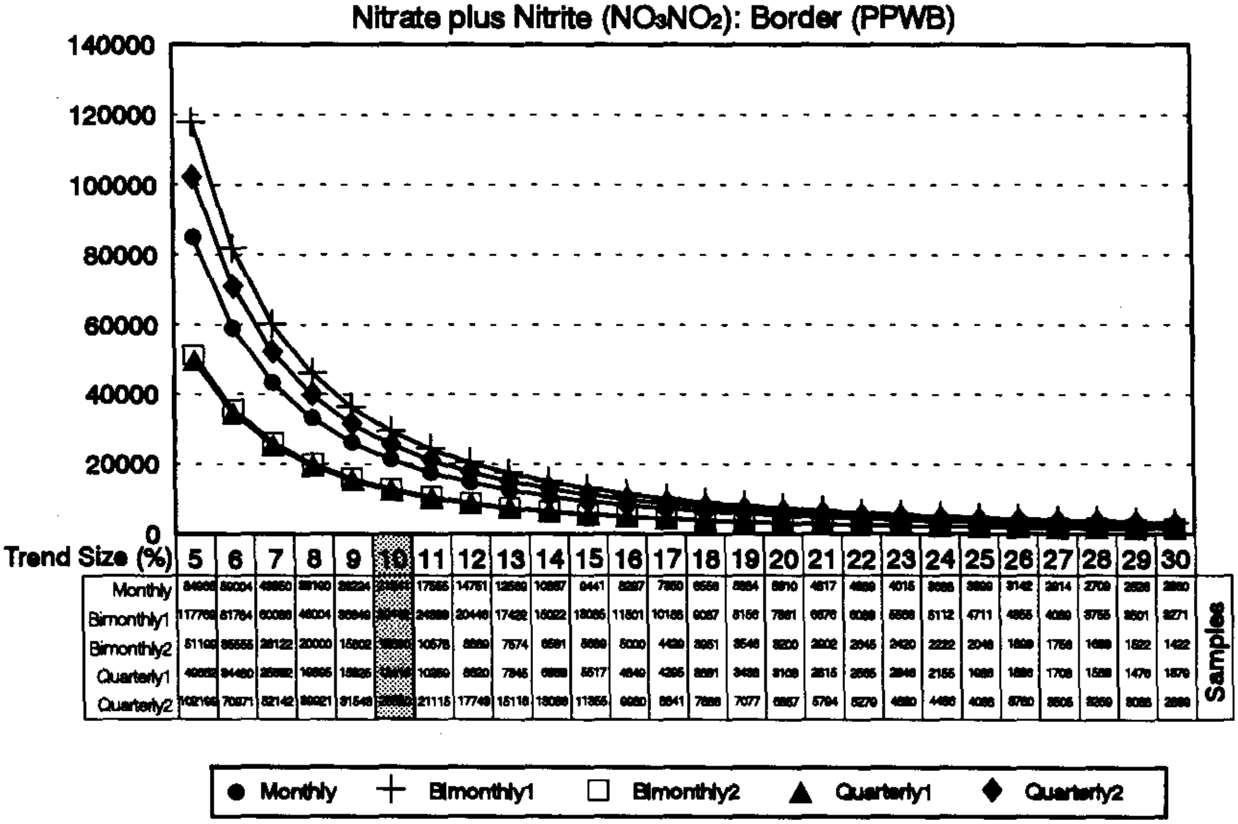
Nitrate plus Nitrite (NO_3NO_2): Border (PPWB)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	7080	4917	3619	2766	2185	[illegible]	1469	1229	1047	908	787	691	618	546	490	449	401	[illegible]	335	307	289	[illegible]	248	229	211	197
Bimonthly1 +	19626	13681	10014	7667	6058	[illegible]	4059	3406	2904	2504	2181	1617	1698	1515	1359	1227	1118	1014	[illegible]	[illegible]	785	726	679	630	584	546
Bimonthly2 —	8589	6026	4354	3359	2694	[illegible]	1769	1462	1262	1089	946	[illegible]	786	669	591	[illegible]	494	441	409	370	341	316	[illegible]	272	254	237
Quarterly1 ▲	12419	[illegible]	[illegible]	4840	3891	[illegible]	2565	2155	1890	1589	1379	1212	1074	958	860	776	704	641	587	539	497	459	425	396	369	345
Quarterly2 ◆	25560	17749	13056	9980	7886	[illegible]	5279	4485	3780	3259	2839	2495	2210	1972	1769	1597	1449	1320	1208	1109	1022	945	876	815	760	710

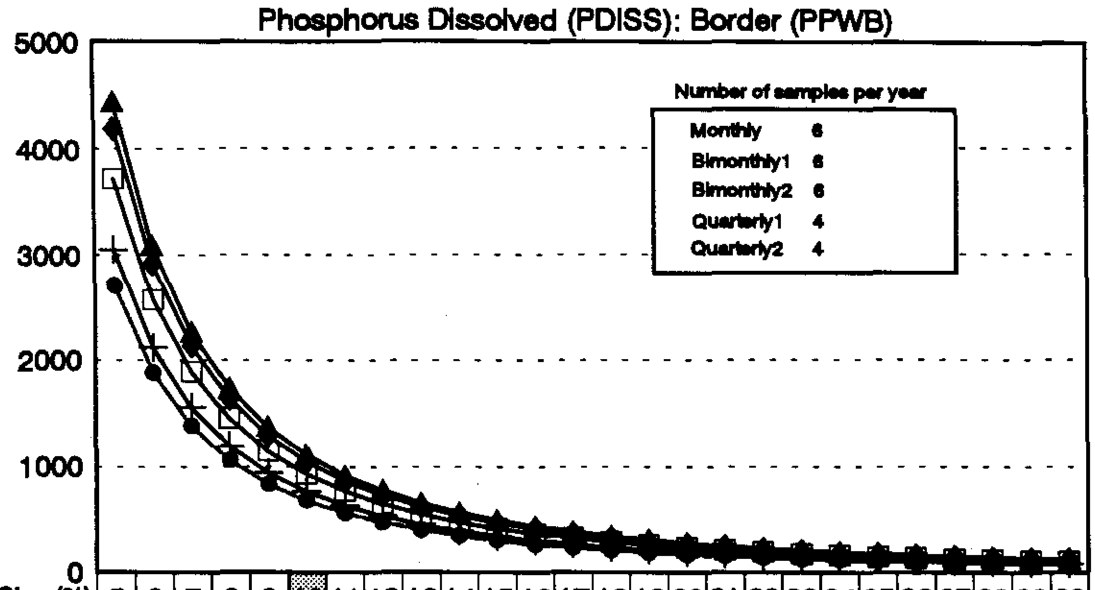
Fig. 13b. Number of Independent Samples to Detect a Linear Trend (%)
For Three Monitoring Schemes

Nitrate plus Nitrite (NO_3NO_2): Border (PPWB)



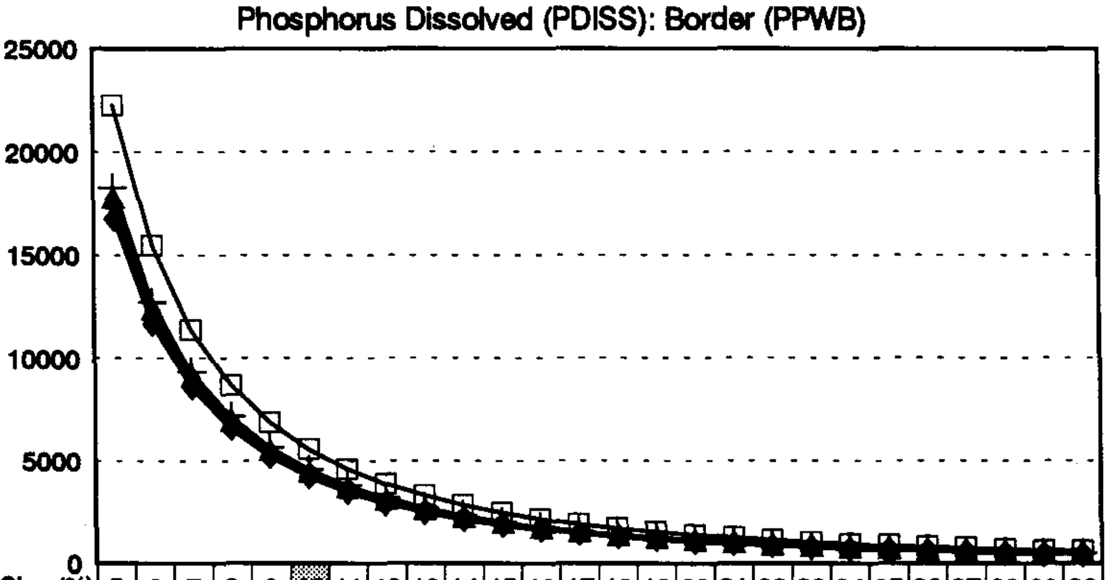
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly	84966	59004	43350	33190	26224	[illegible]	17585	14761	12569	10887	9441	8287	7350	6558	5884	5310	4817	4389	4015	3685	3399	3142	2914	2709	2526	2360
Bimonthly1	117768	81764	60086	46004	36349	[illegible]	24389	20446	17422	15022	13085	11501	10186	9087	8156	7361	6676	6083	5566	5112	4711	4355	4039	3755	3501	3271
Bimonthly2	51109	35555	26122	20000	15802	[illegible]	10578	8889	7574	6531	5689	5000	4429	3951	3546	3200	2902	2645	2420	2222	2048	1893	1756	1633	1522	1422
Quarterly1	49653	34480	25332	19395	15325	[illegible]	10259	8620	7345	6339	5517	4849	4295	3831	3438	3103	2815	2565	2346	2155	1985	1836	1703	1583	1476	1379
Quarterly2	102190	70971	52142	39921	31548	[illegible]	21115	17749	15118	13039	11355	9980	8841	7886	7077	6387	5794	5279	4830	4436	4088	3780	3505	3259	3038	2839

Fig. 14a. Number of Years to Detect a Linear Trend (%)
For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	2708	1879	1380	1057	885	[illegible]	589	470	400	345	301	264	234	209	187	169	153	140	128	117	108	100	93	86	80	75	Years
Bimonthly1 +	3048	2114	1558	1189	880	[illegible]	[illegible]	526	460	[illegible]	[illegible]	297	269	235	211	190	173	157	144	132	122	113	104	97	91	85	
Bimonthly2 —	3710	2579	1899	1449	1145	[illegible]	767	644	549	473	412	362	321	286	257	232	210	192	175	161	149	137	127	118	110	103	
Quarterly1 ▲	4446	3085	2285	1767	1372	[illegible]	919	772	658	567	494	434	385	343	308	278	252	230	210	193	178	165	153	142	132	124	
Quarterly2 ●	4169	2909	2187	1686	1289	[illegible]	868	727	620	534	466	409	362	323	290	262	238	216	198	182	168	155	144	134	125	116	

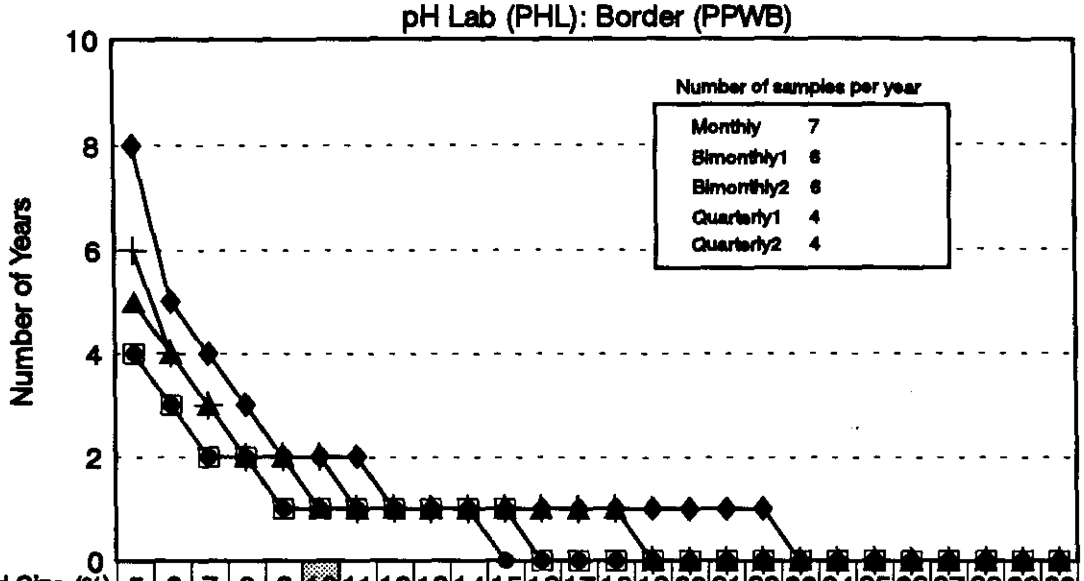
Fig. 14b. Number of Independent Samples to Detect a Linear Trend (%)
For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	17542	12182	8950	6862	5414	[illegible]	3524	3046	2595	2285	1949	1718	1517	1354	1215	1096	994	908	829	761	702	649	602	559	521	487	Samples
Bimonthly1	18260	12681	9316	7138	5686	[illegible]	3779	3170	2701	2329	2029	1783	1580	1409	1265	1141	1035	943	863	793	730	675	629	582	546	507	
Bimonthly2	22257	15457	11356	8694	6870	[illegible]	4599	3864	3298	2850	2478	2174	1925	1717	1541	1391	1262	1150	1052	966	890	[illegible]	758	710	662	619	
Quarterly1	17784	12350	9079	6947	5469	[illegible]	3674	3087	2631	2265	1976	1737	1538	1372	1232	1111	1008	919	840	772	711	653	610	567	529	494	
Quarterly2	16755	11636	8648	6545	5171	[illegible]	3462	2909	2479	2137	1862	1636	1449	1299	1160	1047	950	865	792	727	670	620	575	534	498	465	

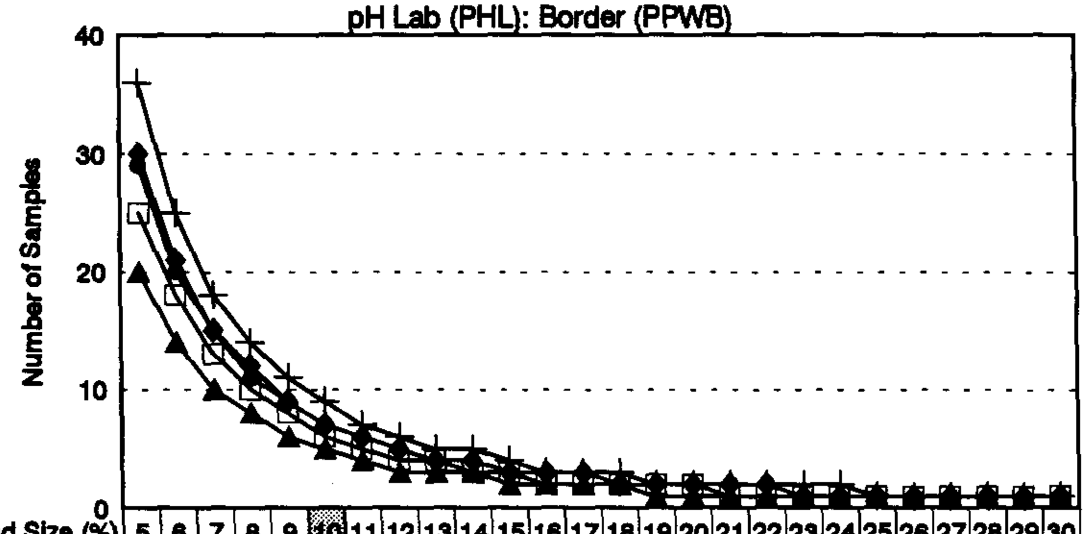
● Monthly + Bimonthly1 □ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 15a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes



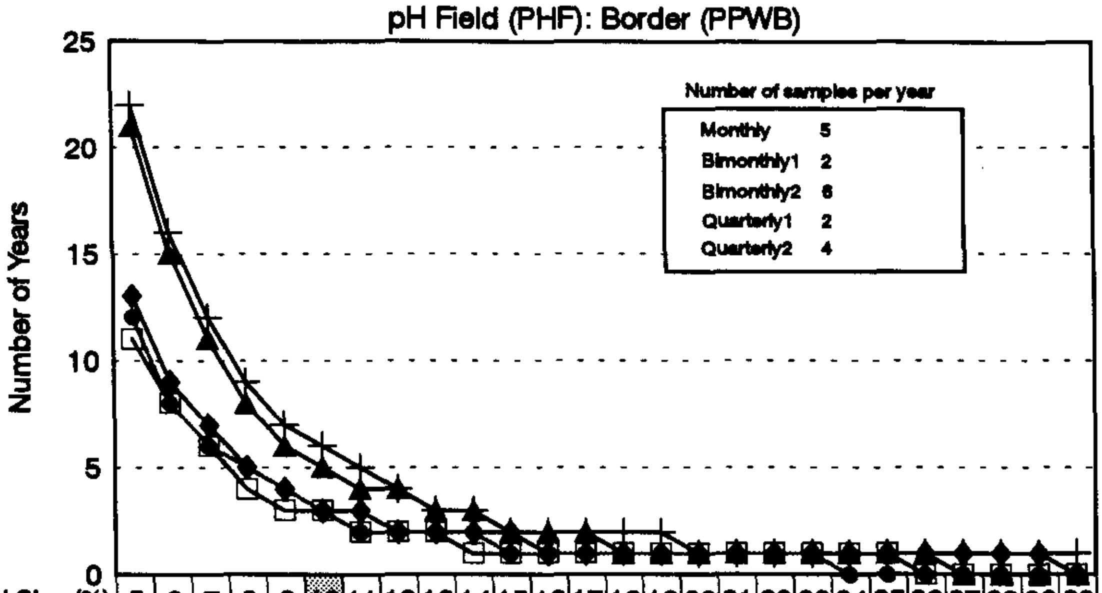
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	4	3	2	2	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Years
Bimonthly1 +	6	4	3	2	2	2	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	
Bimonthly2 —	4	3	2	2	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Quarterly1 ▲	5	4	3	2	2	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	
Quarterly2 ●	8	5	4	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	

Fig. 15b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes



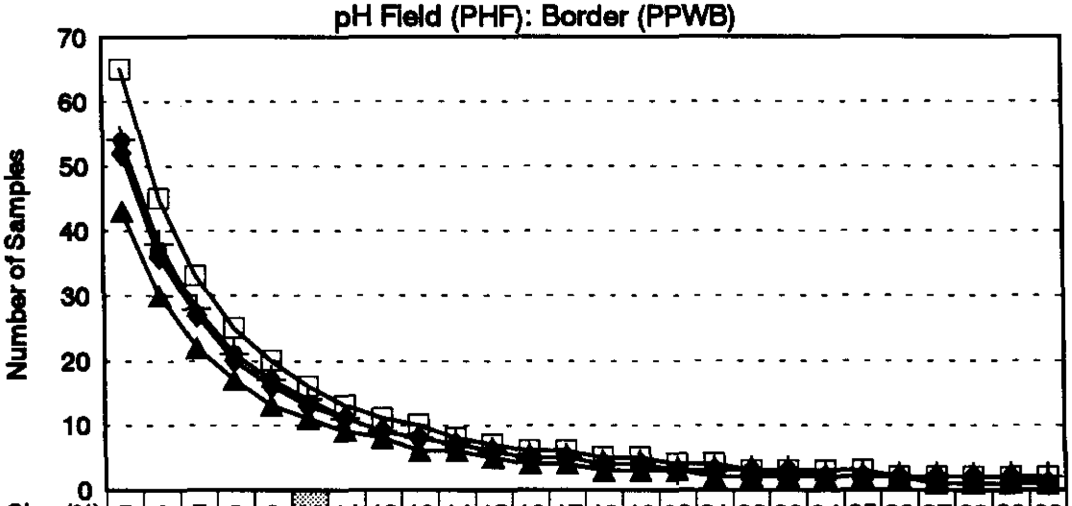
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	29	20	15	11	9	7	6	5	4	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	Samples
Bimonthly1	36	25	18	14	11	9	7	6	5	5	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1	
Bimonthly2	25	18	13	10	8	6	5	4	4	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	
Quarterly1	20	14	10	8	6	5	4	3	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	
Quarterly2	30	21	15	12	9	7	6	5	4	4	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	

Fig. 16a. Number of Years to Detect a Linear Trend (%)
For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Years
Monthly ●	12	8	6	5	4	3	2	2	2	2	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	
Bimonthly1 +	22	16	12	9	7	6	5	4	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	
Bimonthly2 —	11	8	6	4	3	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	
Quarterly1 ▲	21	15	11	8	6	5	4	4	3	3	2	2	2	1	1	1	1	1	1	1	1	1	0	0	0	0	
Quarterly2 ◆	13	9	7	5	4	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	

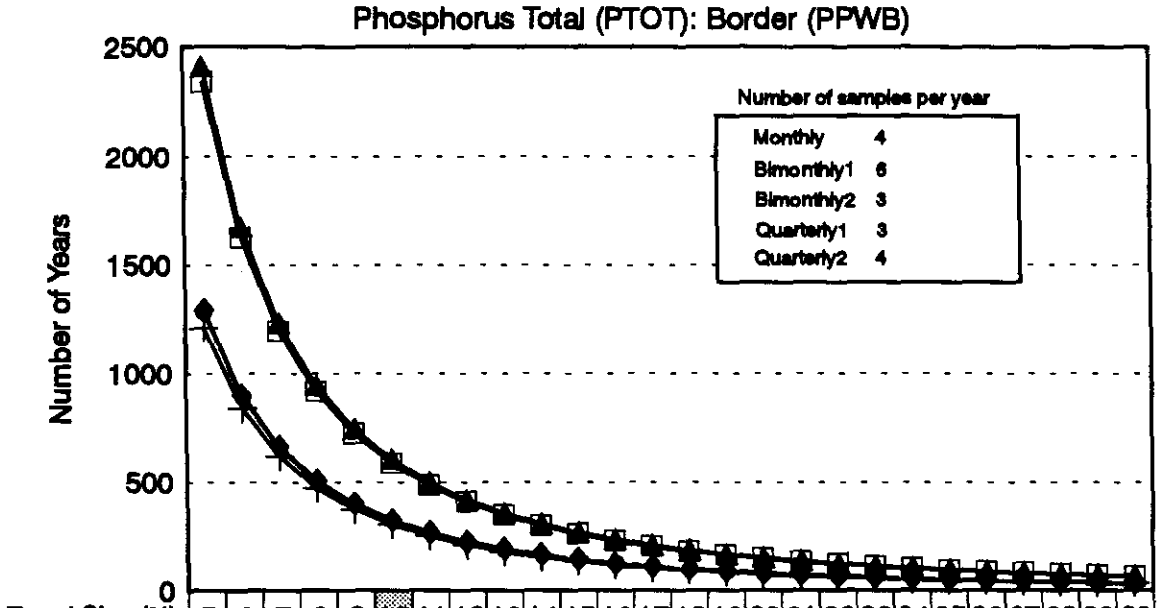
Fig. 16b. Number of Independent Samples to Detect a Linear Trend (%)
For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Samples
Monthly	54	37	27	21	17	13	11	9	8	7	6	5	5	4	4	3	3	3	3	2	2	2	2	2	2	1	
Bimonthly1	54	38	28	21	17	14	11	9	8	7	6	5	5	4	4	3	3	3	3	2	2	2	2	2	2	2	
Bimonthly2	65	45	33	25	20	16	13	11	10	8	7	6	6	5	5	4	4	3	3	3	3	2	2	2	2	2	
Quarterly1	43	30	22	17	13	11	9	8	6	6	5	4	4	3	3	3	2	2	2	2	2	2	1	1	1	1	
Quarterly2	52	36	27	20	16	13	11	9	8	7	6	5	5	4	4	3	3	3	2	2	2	2	2	2	2	1	

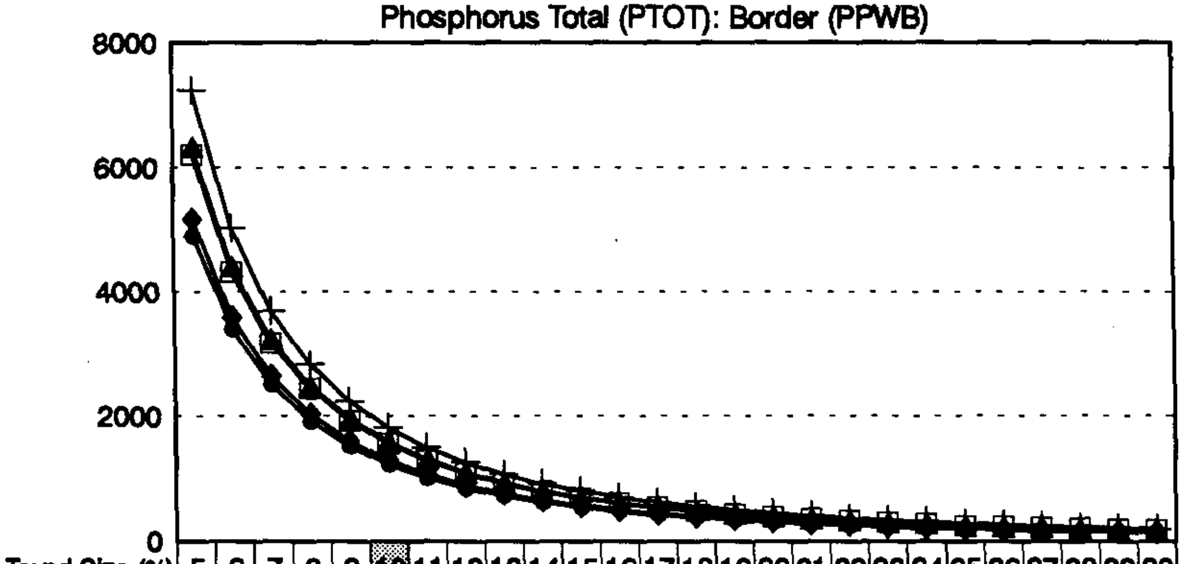
● Monthly + Bimonthly1 □ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 17a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	1281	889	653	500	395	320	265	222	190	163	142	125	111	99	89	80	73	66	61	56	51	47	44	41	38	36	Years
Bimonthly1 +	1205	837	615	471	372	301	249	209	178	154	134	118	104	93	84	75	68	62	57	52	48	45	41	39	36	34	
Bimonthly2 —	2336	1622	1192	912	721	584	483	406	346	298	259	228	202	180	162	146	133	120	110	101	93	86	80	75	69	65	
Quarterly1 ▲	2409	1673	1229	941	744	602	498	418	356	307	268	235	209	186	167	151	137	124	114	105	96	89	83	77	72	67	
Quarterly2 ●	1292	897	659	505	399	323	267	224	191	165	144	126	112	100	90	81	73	67	61	56	52	48	44	41	39	36	

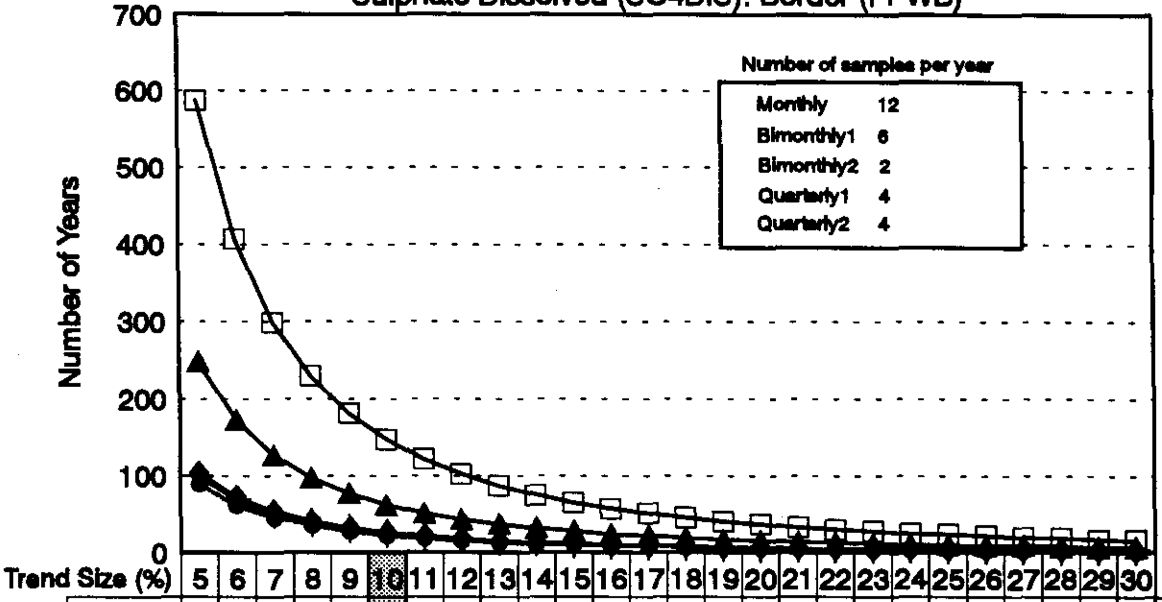
Fig. 17b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	4886	3393	2498	1909	1506	[illegible]	1010	848	728	628	548	477	428	377	338	305	277	252	231	212	195	181	168	156	146	136	Samples
Bimonthly1	7239	5030	3688	2824	2231	[illegible]	1494	1255	1069	922	808	706	626	558	501	452	410	379	342	314	289	267	246	231	215	201	
Bimonthly2	6204	4606	3165	2428	1915	[illegible]	1282	1077	918	791	689	606	537	479	430	388	352	320	293	269	248	229	213	198	184	172	
Quarterly1	6380	4436	3250	2473	1954	[illegible]	1308	1099	936	807	708	618	548	488	436	396	359	327	299	275	253	234	217	202	188	176	
Quarterly2	5166	3587	2636	2016	1594	[illegible]	1067	897	764	659	574	504	447	399	358	323	293	267	244	224	207	191	177	165	154	143	

Fig. 18a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

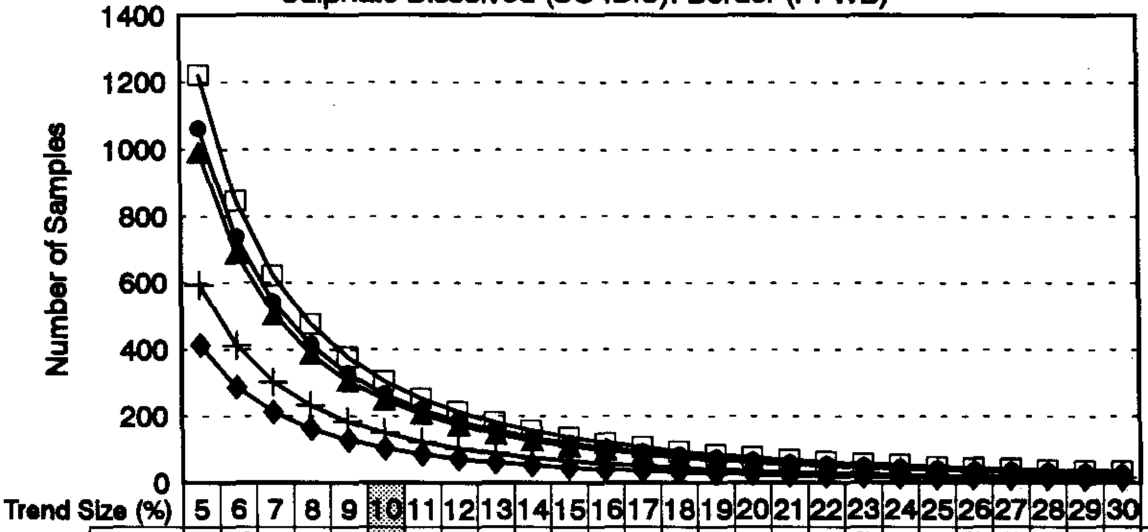
Sulphate Dissolved (SO4DIS): Border (PPWB)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	89	61	45	35	27	22	18	15	13	11	10	9	8	7	6	6	5	5	4	4	4	3	3	3	3	2	Years
Bimonthly1 +	99	69	50	39	31	25	20	17	15	13	11	10	9	8	7	6	6	5	5	4	4	4	3	3	3	3	
Bimonthly2 —	587	407	299	229	181	147	121	102	87	75	65	57	51	45	40	37	33	30	28	25	24	22	20	19	17	16	
Quarterly1 ▲	248	172	126	97	77	62	51	43	37	32	28	24	22	19	17	16	14	13	12	11	10	9	9	8	7	7	
Quarterly2 ●	103	72	53	40	32	26	21	18	15	13	12	10	9	8	7	7	6	5	5	5	4	4	4	3	3	3	

Fig. 18b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

Sulphate Dissolved (SO4DIS): Border (PPWB)

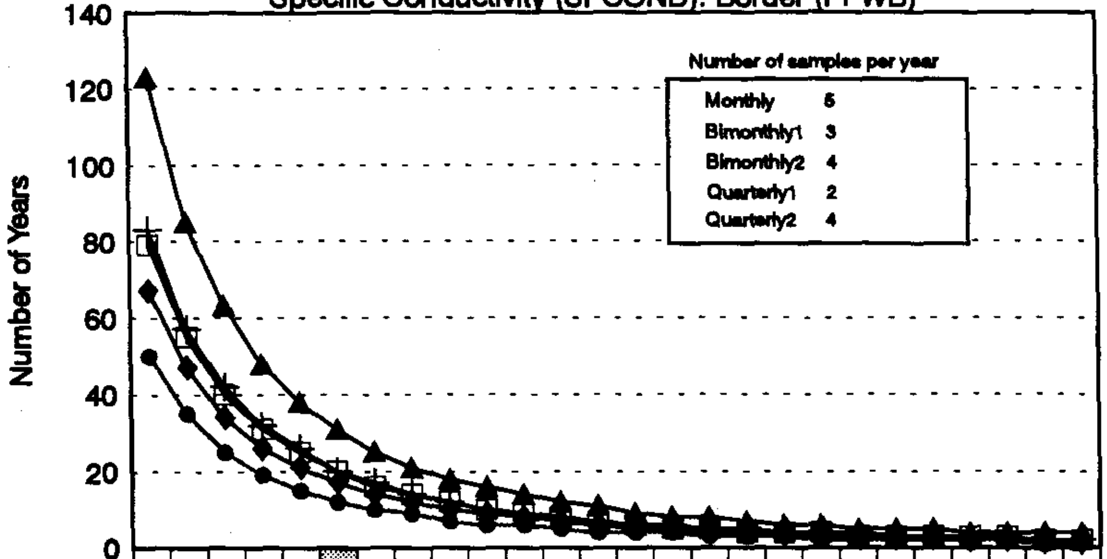


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	1062	737	542	415	326	265	219	184	157	135	118	104	92	82	74	66	60	55	50	46	42	39	36	34	32	29	Samples
Bimonthly1	592	411	302	231	183	148	122	103	88	75	66	58	51	46	41	37	34	31	28	26	24	22	20	19	18	16	
Bimonthly2	1220	847	622	477	377	305	252	212	180	156	136	119	106	94	84	76	69	63	58	53	49	45	42	39	36	34	
Quarterly1	990	686	505	387	306	245	205	172	146	126	110	97	86	76	69	62	56	51	47	43	40	37	34	32	29	28	
Quarterly2	412	286	210	161	127	106	85	72	61	53	46	40	36	32	29	26	23	21	19	18	16	15	14	13	12	11	

● Monthly + Bimonthly1 ☐ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 19a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes

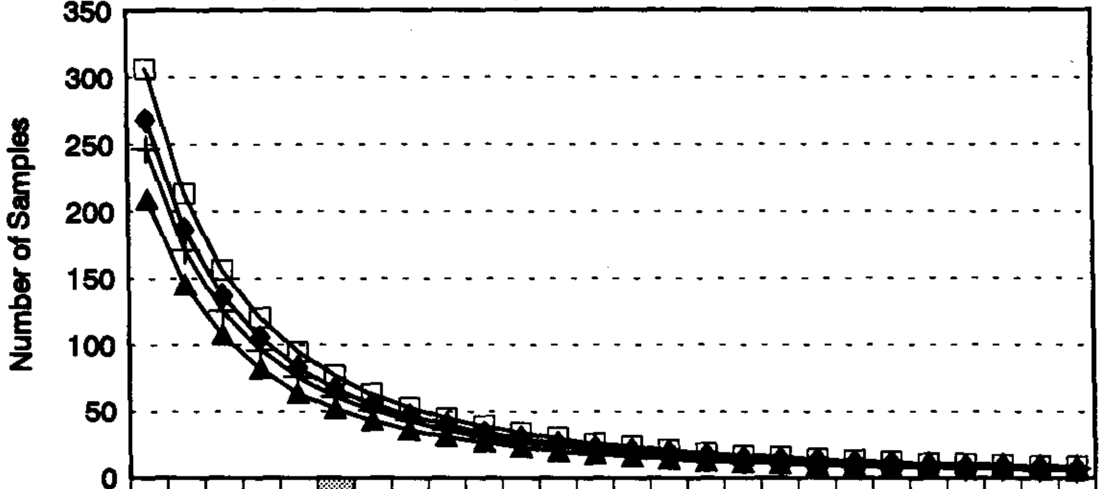
Specific Conductivity (SPCOND): Border (PPWB)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	50	35	25	19	15	12	10	9	7	6	6	5	4	4	4	3	3	3	2	2	2	2	2	2	1	1	Years
Bimonthly1 +	83	57	42	32	26	20	17	14	12	10	9	8	7	6	6	5	5	4	4	4	3	3	3	3	2	2	
Bimonthly2 —	79	55	40	31	25	20	16	14	12	10	9	8	7	6	5	5	4	4	4	3	3	3	3	3	2	2	
Quarterly1 ▲	123	85	63	46	36	31	25	21	18	16	14	12	11	9	8	8	7	6	6	5	5	5	4	4	4	4	
Quarterly2 ●	67	47	34	26	21	17	14	12	10	9	8	7	6	5	5	4	4	4	3	3	3	3	2	2	2	2	

Fig. 19b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

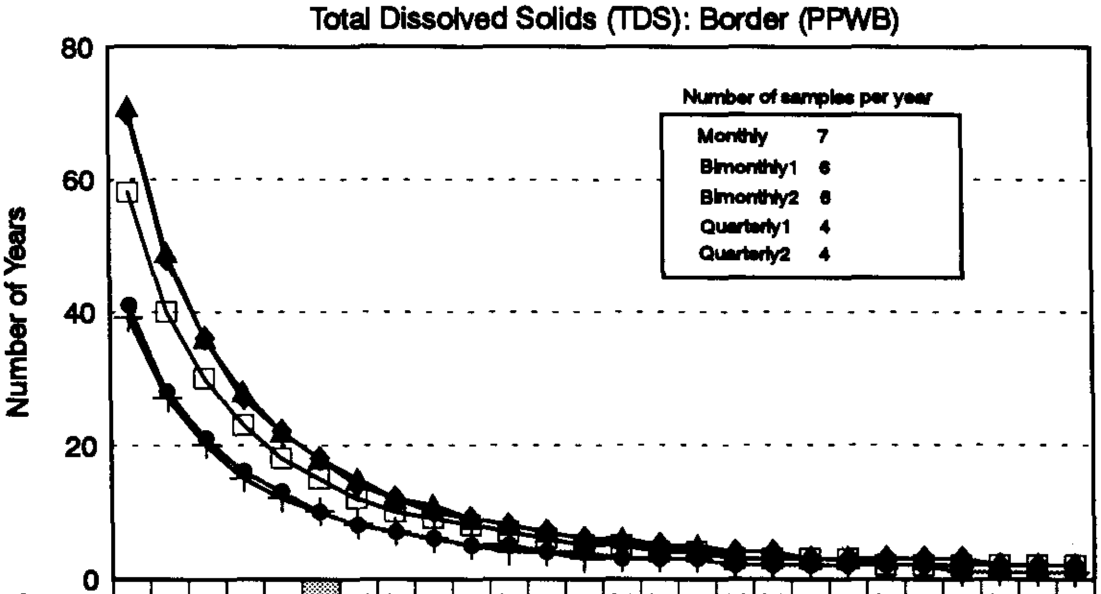
Specific Conductivity (SPCOND): Border (PPWB)



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	269	167	137	105	83	67	56	47	40	34	30	26	23	21	19	17	15	14	13	12	11	10	9	9	8	7	Samples
Bimonthly1	246	171	125	96	76	61	51	43	36	31	27	24	21	19	17	15	14	13	12	11	10	9	8	8	7	7	
Bimonthly2	306	213	156	120	95	77	63	53	45	39	34	30	26	24	21	19	17	16	14	13	12	11	11	10	9	9	
Quarterly1	209	145	107	82	64	52	43	36	31	27	23	20	18	16	14	13	12	11	10	9	8	8	7	7	6	6	
Quarterly2	266	186	137	105	83	67	55	47	40	34	30	26	23	21	19	17	15	14	13	12	11	10	9	9	8	7	

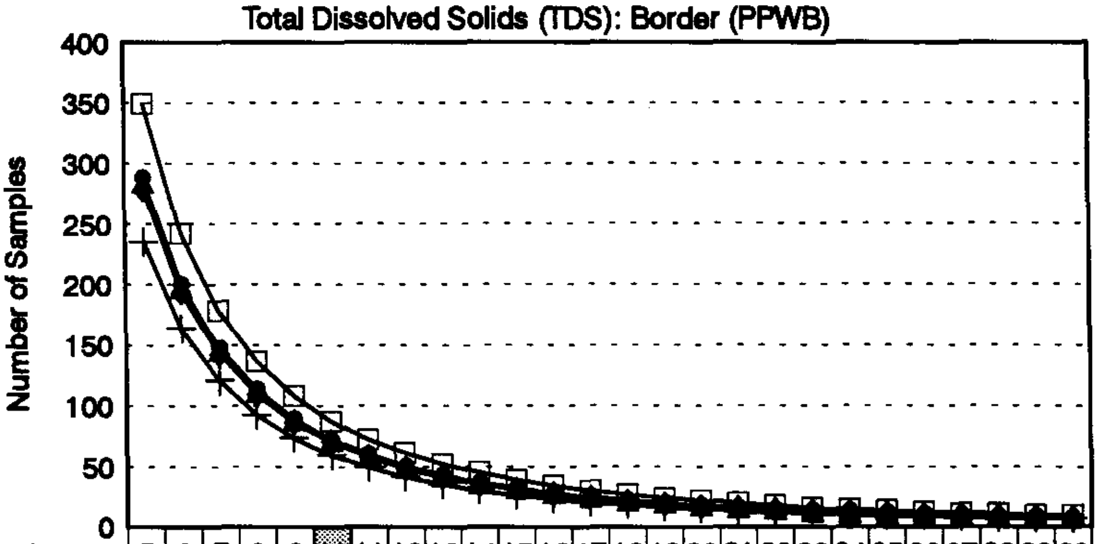
● Monthly + Bimonthly1 □ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 20a. Number of Years to Detect a Linear Trend (%)
For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	41	28	21	16	13	10	8	7	6	5	5	4	4	3	3	3	2	2	2	2	2	2	1	1	1	1	Years
Bimonthly1 +	39	27	20	15	12	10	8	7	6	5	4	4	3	3	3	3	2	2	2	2	2	2	1	1	1	1	
Bimonthly2 —	58	40	30	23	18	15	12	10	9	8	7	6	5	5	4	4	3	3	3	3	2	2	2	2	2	2	
Quarterly1 ▲	71	49	36	28	22	18	15	12	11	9	8	7	6	6	5	5	4	4	3	3	3	3	3	2	2	2	
Quarterly2 ◆	70	48	36	27	22	18	14	12	10	9	8	7	6	5	5	4	4	4	3	3	3	3	3	2	2	2	

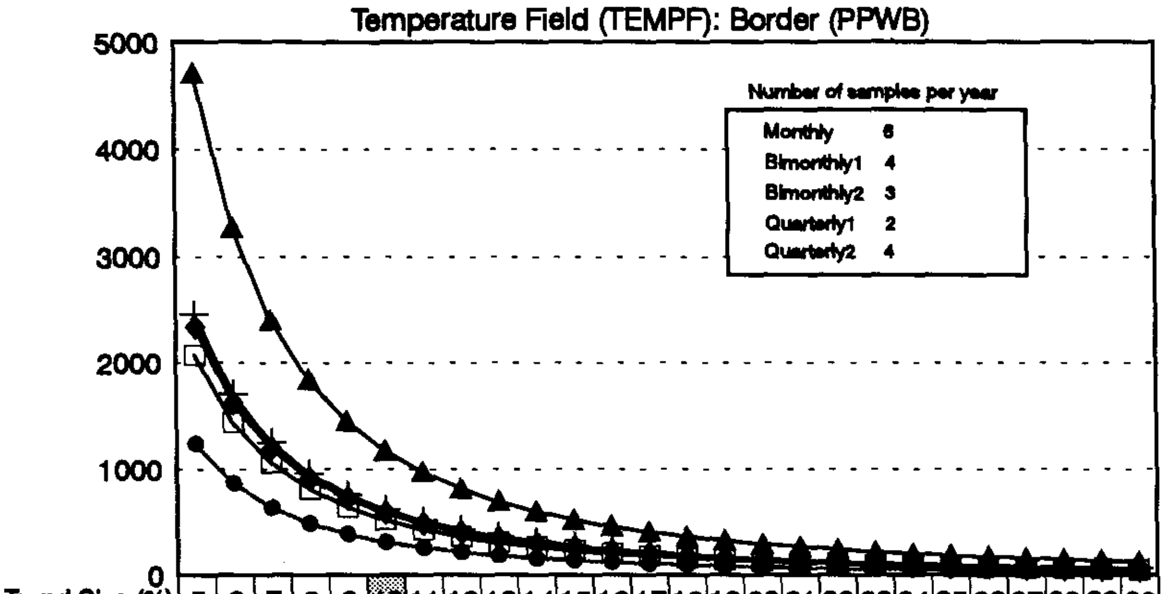
Fig. 20b. Number of Independent Samples to Detect a Linear Trend (%)
For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	288	200	147	113	89	72	60	50	43	37	32	28	25	22	20	18	16	15	14	13	12	11	10	9	9	8	Samples
Bimonthly1	235	163	120	92	73	59	49	41	35	30	26	23	20	18	16	15	13	12	11	10	9	9	8	7	7	7	
Bimonthly2	349	242	178	136	108	87	72	61	52	45	39	34	30	27	24	22	20	18	16	15	14	13	12	11	10	10	
Quarterly1	284	197	145	111	88	71	59	49	42	36	32	28	25	22	20	18	16	15	13	12	11	10	10	9	8	8	
Quarterly2	278	193	142	109	86	70	57	48	41	35	31	27	24	21	19	17	16	14	13	12	11	10	10	9	8	8	

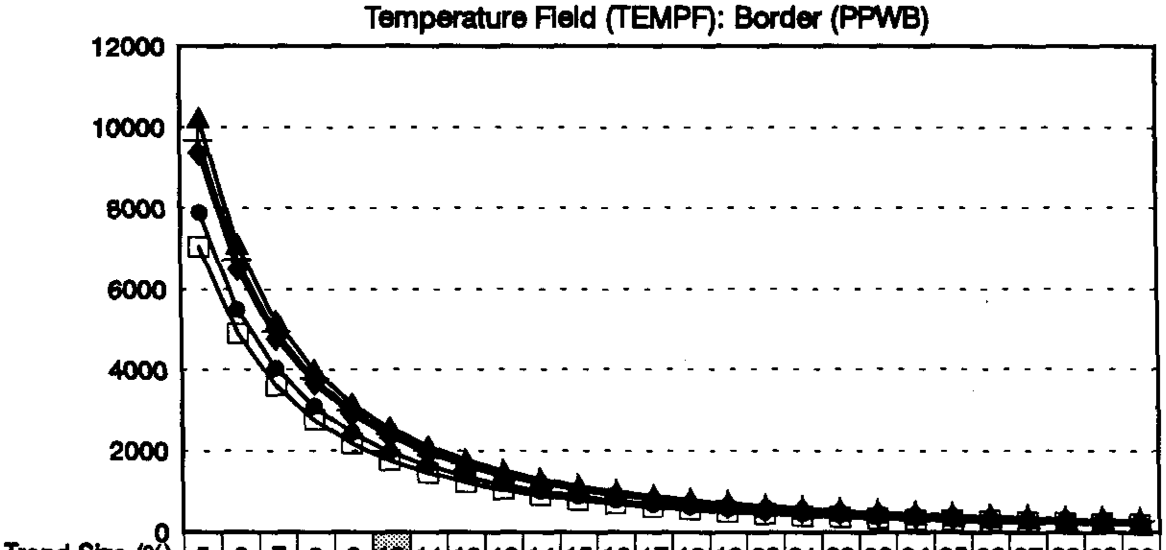
● Monthly + Bimonthly1 ☐ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 21a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	1244	864	635	486	384	311	257	216	184	159	138	121	108	96	86	78	70	64	59	54	50	46	43	40	37	35	Years
Bimonthly1 +	2456	1706	1253	959	758	614	507	427	363	313	273	240	213	190	170	154	139	127	116	107	98	91	84	78	73	68	
Bimonthly2 —	2072	1439	1057	810	640	518	428	360	307	264	230	202	179	160	143	130	118	107	98	90	83	77	71	66	62	57	
Quarterly1 ▲	4708	3269	2402	1839	1453	1177	973	817	696	601	523	460	407	363	326	294	267	243	223	204	188	174	161	150	140	131	
Quarterly2 ◆	2339	1624	1193	914	722	585	483	406	346	298	260	228	202	181	162	146	133	121	111	102	94	87	80	75	70	65	

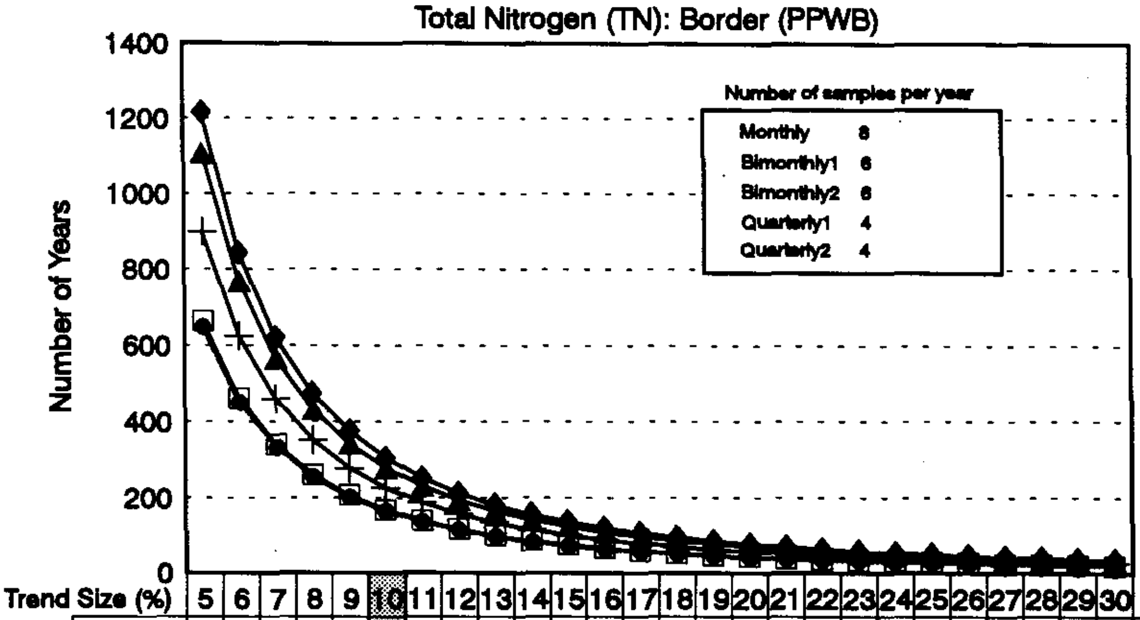
Fig. 21b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	7888	5478	4025	3081	2435	1972	1630	1370	1167	1006	876	770	682	609	546	493	447	407	373	342	316	292	271	252	234	219	Samples
Bimonthly1	9662	6710	4930	3774	2982	2416	1996	1678	1429	1232	1074	944	836	746	669	604	548	499	457	419	387	357	331	308	287	268	
Bimonthly2	7035	4885	3589	2748	2171	1759	1454	1221	1041	897	782	687	609	543	487	440	399	363	332	305	281	260	241	224	209	195	
Quarterly1	10236	7108	5222	3998	3159	2559	2116	1777	1514	1306	1137	1000	885	790	709	640	580	529	484	444	409	379	351	326	304	284	
Quarterly2	9352	6494	4771	3653	2886	2338	1932	1624	1383	1193	1039	913	809	722	648	584	530	483	442	406	374	346	321	298	278	260	

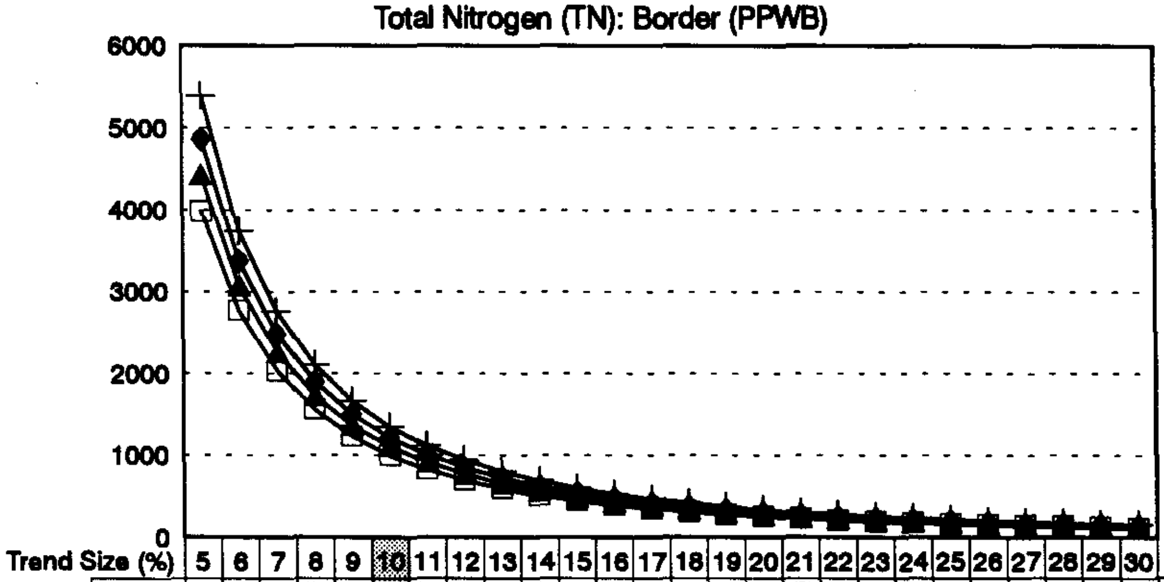
● Monthly + Bimonthly1 □ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 22a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly ●	647	449	330	253	200	162	134	112	96	82	72	63	56	50	45	40	37	33	31	28	26	24	22	21	19	18	Years
Bimonthly1 +	899	624	459	351	277	226	186	156	133	115	100	88	78	69	62	56	51	46	43	39	36	33	31	29	27	25	
Bimonthly2 —	663	460	338	259	205	166	137	115	98	85	74	66	57	51	46	42	38	34	31	29	27	25	23	21	20	18	
Quarterly1 ▲	1106	766	564	432	341	277	229	192	164	141	123	108	96	85	77	69	63	57	52	48	44	41	38	35	33	31	
Quarterly2 ◆	1214	843	619	474	375	304	251	211	180	155	135	119	105	94	84	76	69	63	57	53	49	45	42	39	36	34	

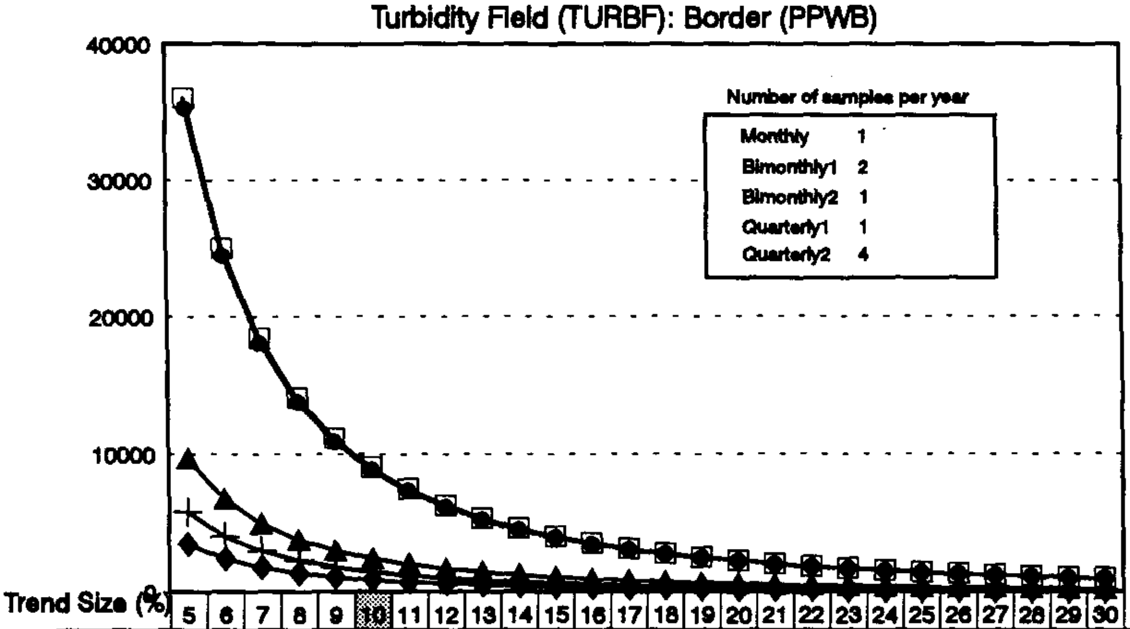
Fig. 22b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Monthly	4669	3361	2484	1902	1508	1257	1006	846	720	621	541	476	421	378	337	304	276	251	230	211	195	180	167	155	145	135	Samples
Bimonthly1	5391	3744	2751	2106	1664	[illegible]	1114	936	798	688	599	526	466	416	373	337	305	278	255	234	216	199	185	172	160	150	
Bimonthly2	3978	2762	2060	1554	1226	[illegible]	822	691	588	507	442	388	344	307	275	249	226	205	186	178	159	147	136	127	118	110	
Quarterly1	4424	3072	2257	1728	1365	[illegible]	914	768	654	564	492	432	385	341	306	276	251	229	209	192	177	164	152	141	132	123	
Quarterly2	4855	3371	2477	1896	1498	1214	1005	849	718	619	539	474	420	375	336	303	275	251	229	211	194	180	168	155	144	136	

● Monthly + Bimonthly1 □ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

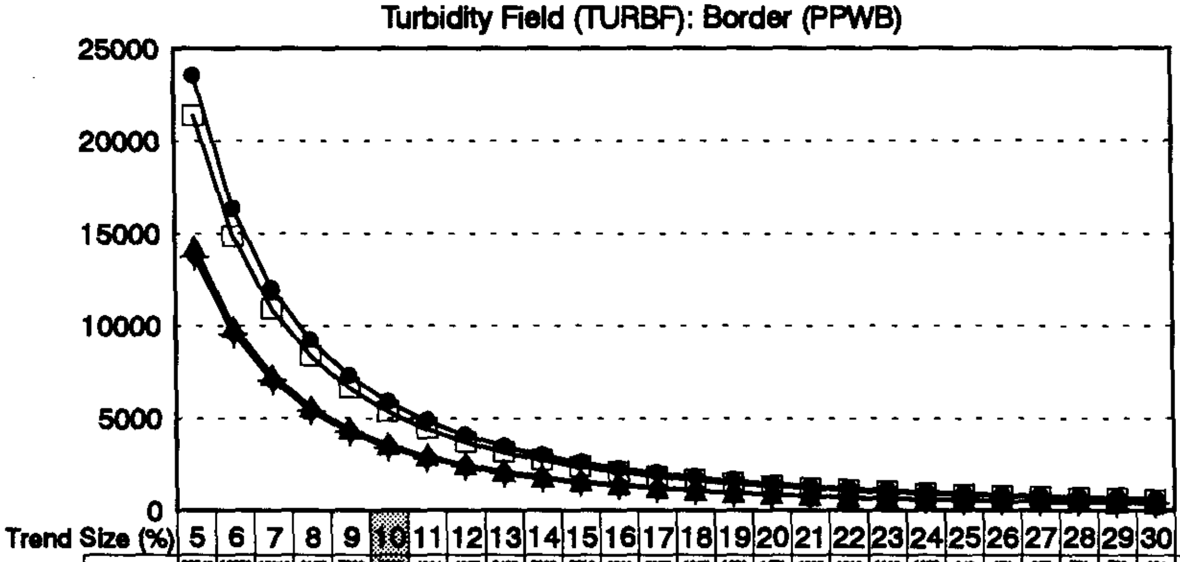
Fig. 23a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	35258	24489	17989	13774	10882	[illegible]	7394	6121	5216	4497	3918	3449	3051	2721	2441	2209	1999	1821	1657	1501	1411	1304	1208	1125	1046	978
Bimonthly1 +	5765	4084	2957	2264	1769	[illegible]	1167	1008	857	739	644	566	501	447	401	362	329	299	274	252	232	214	199	185	172	161
Bimonthly2 —	36022	25015	18376	14071	11116	[illegible]	7442	6254	5389	4694	4008	3517	3116	2779	2494	2252	2048	1861	1702	1564	1441	1331	1235	1149	1070	1001
Quarterly1 ▲	9676	6716	4887	3760	2969	[illegible]	1989	1680	1461	1284	1075	945	837	746	670	605	549	500	457	420	387	358	332	309	288	269
Quarterly2 ◆	3459	2402	1765	1351	1068	[illegible]	715	601	512	441	384	338	299	267	240	216	196	179	164	150	138	128	119	110	103	96

Years

Fig. 23b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes

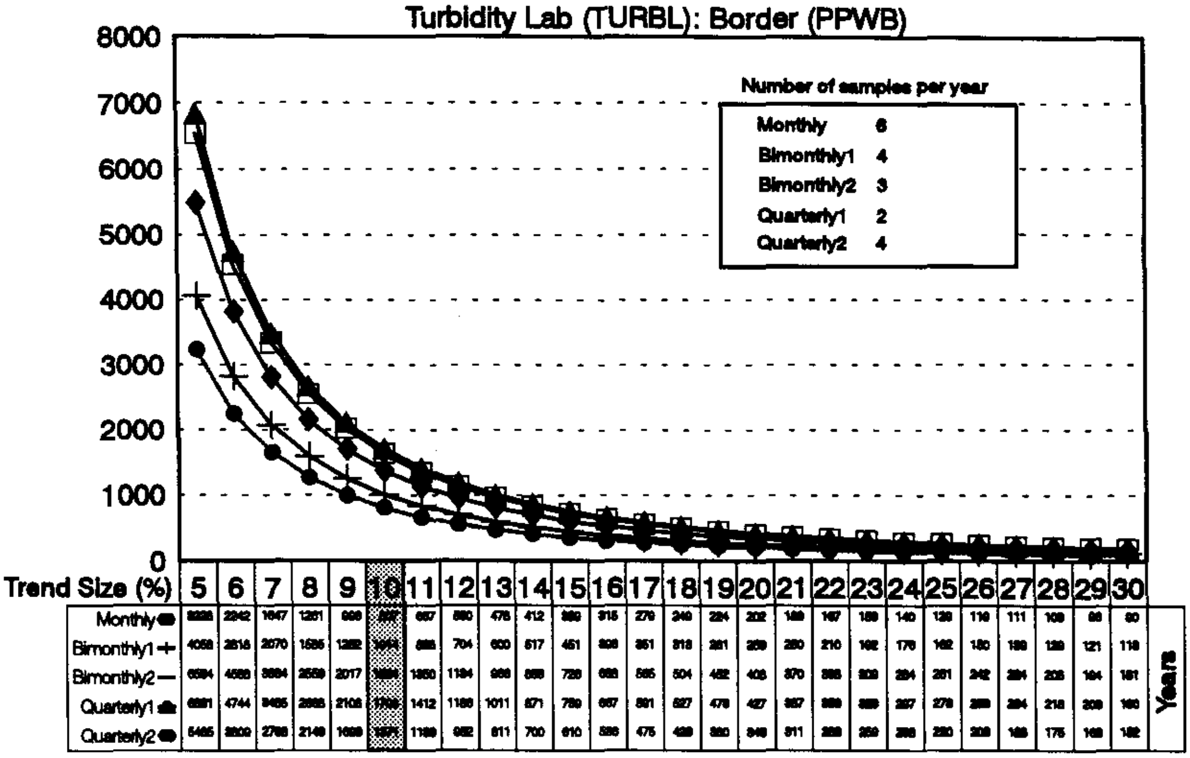


Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly	23549	16350	12012	9197	7266	[illegible]	4864	4087	3469	3008	2616	2299	2067	1817	1630	1471	1335	1216	1113	1022	942	871	807	751	700	654
Bimonthly1	13722	9529	7001	5360	4235	[illegible]	2865	2382	2030	1750	1525	1340	1187	1059	950	858	778	709	648	595	549	507	471	438	408	381
Bimonthly2	21374	14646	10806	8549	6597	[illegible]	4416	3711	3162	2726	2375	2087	1849	1649	1480	1336	1212	1104	1010	928	855	790	733	682	636	594
Quarterly1	14299	9930	7298	5586	4413	[illegible]	2954	2469	2116	1824	1589	1396	1237	1103	990	894	811	739	676	621	572	529	490	456	425	397
Quarterly2	13834	9607	7058	5404	4270	[illegible]	2868	2402	2046	1764	1537	1351	1187	1067	958	865	784	715	654	600	553	512	474	441	411	384

Samples

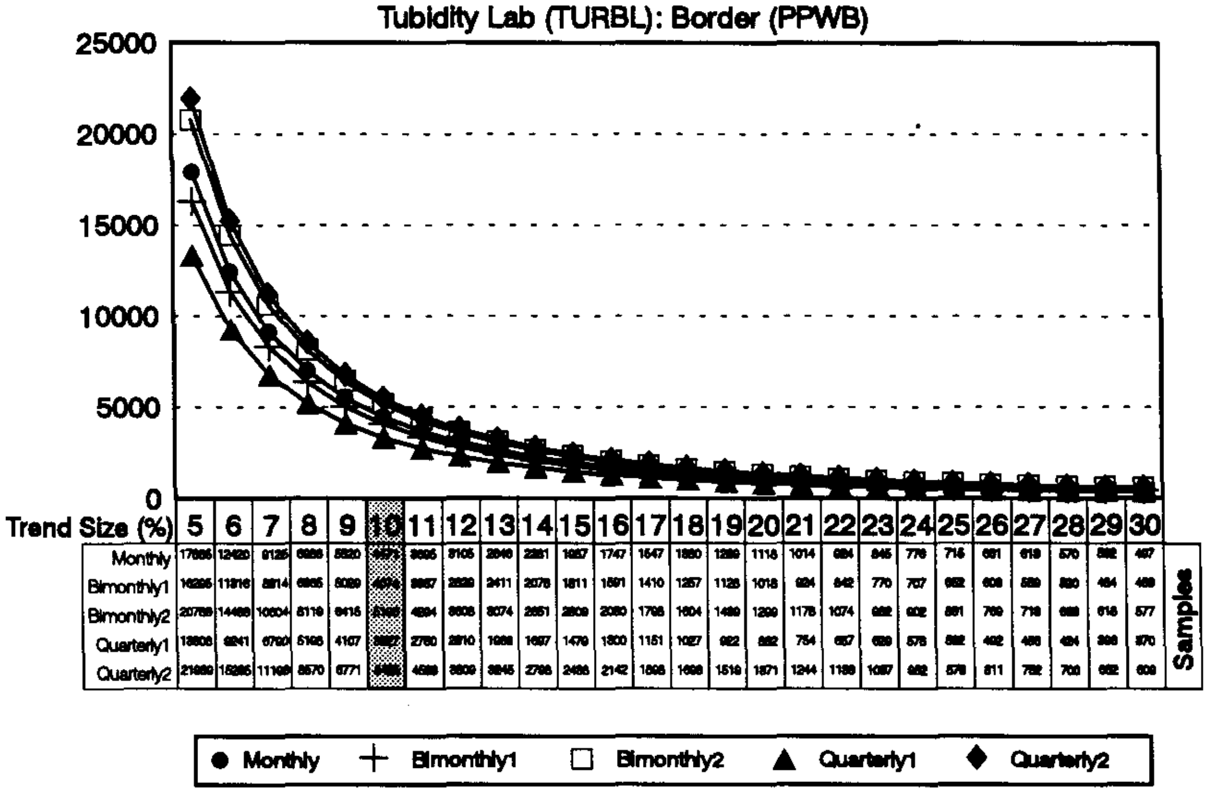
● Monthly + Bimonthly1 □ Bimonthly2 ▲ Quarterly1 ◆ Quarterly2

Fig. 24a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes



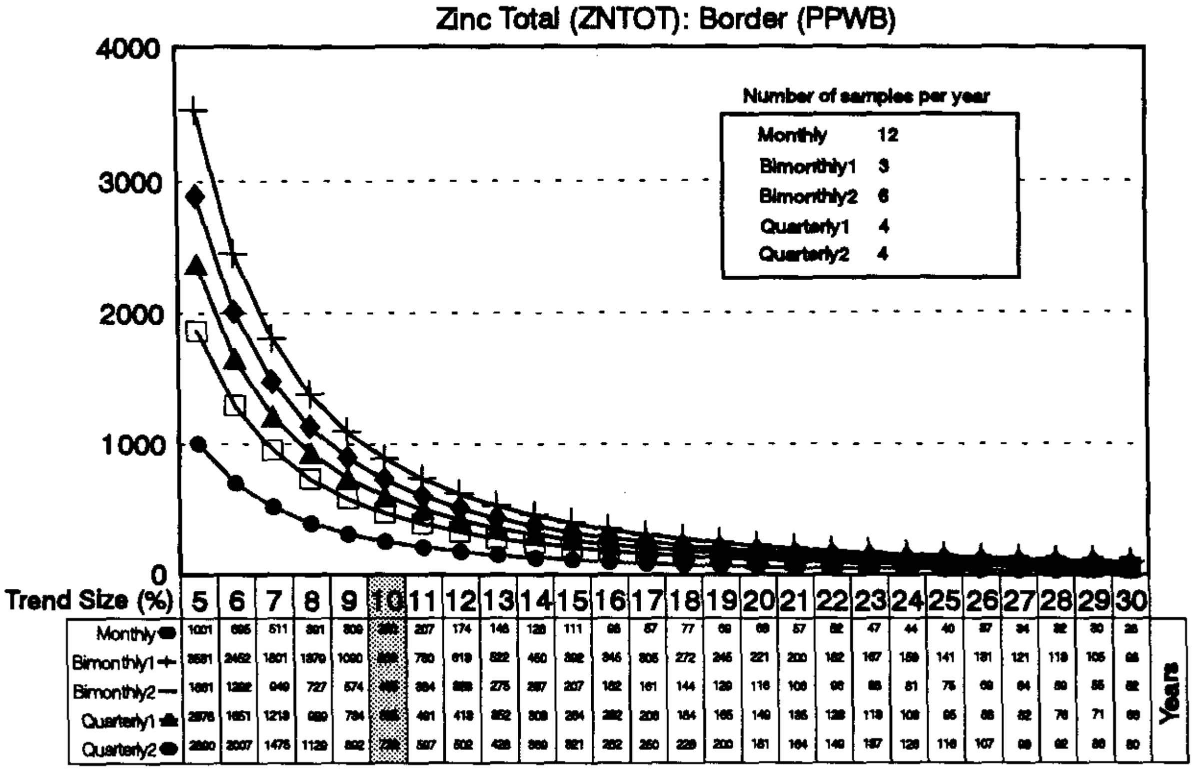
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	3228	2242	1647	1261	996	[illegible]	667	560	478	412	359	315	279	249	224	202	189	167	159	140	129	119	111	109	99	90
Bimonthly1 +	4059	2818	2070	1585	1252	[illegible]	868	704	600	517	451	398	351	313	281	259	230	210	192	176	162	150	139	129	121	118
Bimonthly2 —	6594	4580	3364	2569	2017	[illegible]	1350	1134	966	839	728	633	565	504	452	408	370	338	309	284	261	242	224	208	194	181
Quarterly1 ▲	6881	4744	3485	2668	2105	[illegible]	1412	1180	1011	871	759	667	591	527	476	427	387	353	323	297	276	255	234	218	203	190
Quarterly2 ◆	5485	3809	2798	2148	1698	[illegible]	1139	952	811	700	610	536	475	422	380	345	311	283	259	236	220	203	188	175	163	152

Fig. 24b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes



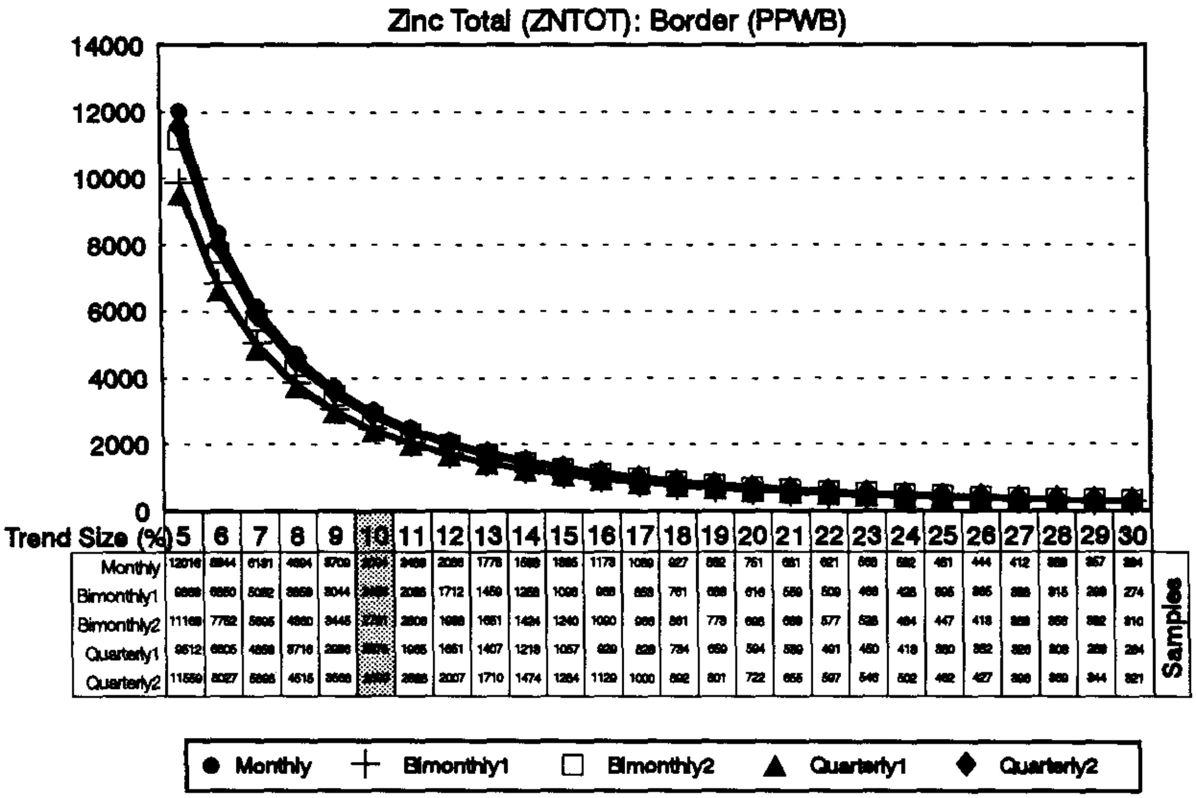
Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly	17986	12420	9125	6986	5520	[illegible]	3695	3105	2640	2281	1987	1747	1547	1380	1239	1116	1014	924	845	776	716	661	613	570	532	497
Bimonthly1	16295	11316	8314	6365	5039	[illegible]	3357	2820	2411	2076	1811	1591	1410	1257	1126	1016	924	842	770	707	652	603	559	520	484	452
Bimonthly2	20768	14469	10604	8119	6415	[illegible]	4294	3608	3074	2651	2309	2030	1798	1604	1439	1299	1176	1074	982	902	831	769	713	663	618	577
Quarterly1	13806	9241	6790	5198	4107	[illegible]	2750	2310	1968	1697	1479	1300	1151	1027	922	832	754	687	629	578	532	492	456	424	395	370
Quarterly2	21939	15235	11193	8570	6771	[illegible]	4539	3809	3245	2798	2436	2142	1898	1693	1519	1371	1244	1133	1037	952	878	811	752	700	652	609

Fig. 25a. Number of Years to Detect a Linear Trend (%) For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly ●	1001	695	511	391	309	[illegible]	207	174	146	128	111	98	87	77	69	63	57	52	47	44	40	37	34	32	30	28
Bimonthly1 +	3551	2452	1801	1379	1090	[illegible]	780	619	522	450	392	345	305	272	245	221	200	182	167	153	141	131	121	113	105	98
Bimonthly2 —	1861	1292	949	727	574	[illegible]	384	323	275	237	207	182	161	144	129	116	106	96	88	81	75	69	64	59	55	52
Quarterly1 ▲	2376	1651	1213	929	734	[illegible]	491	413	352	303	264	232	206	184	165	149	135	123	113	103	95	88	82	76	71	66
Quarterly2 ◆	2890	2007	1475	1129	892	[illegible]	597	502	428	369	321	282	250	223	200	181	164	149	137	126	116	107	99	92	86	80

Fig. 25b. Number of Independent Samples to Detect a Linear Trend (%) For Three Monitoring Schemes



Trend Size (%)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Monthly	12016	8344	6131	4694	3709	[illegible]	2483	2086	1778	1533	1335	1173	1039	927	832	751	681	621	568	522	481	444	412	383	357	334
Bimonthly1	9959	6850	5032	3859	3044	[illegible]	2086	1712	1459	1259	1096	958	853	761	686	616	559	509	466	428	395	365	338	315	293	274
Bimonthly2	11168	7762	5695	4360	3445	[illegible]	2303	1938	1651	1424	1240	1090	966	861	773	698	633	577	528	484	447	413	383	356	332	310
Quarterly1	9512	6605	4859	3716	2936	[illegible]	1965	1651	1407	1213	1057	929	823	734	659	594	539	491	450	413	380	352	326	303	283	264
Quarterly2	11559	8027	5898	4515	3569	[illegible]	2385	2007	1710	1474	1284	1129	1000	892	801	722	655	597	546	502	462	427	396	369	344	321

APPENDIX H: STUDY TWO: NUMBER OF YEARS TO DETECT TREND SIZES EQUAL TO THE ESTIMATE OF RESIDUAL ERROR IN THE TIME SERIES (RATIO = 1) AT THE BORDER STATION, YEARS 1974-1991, ON THE NORTH SASKATCHEWAN RIVER

Appendix H-1
Water Quality, Border (PPWB)

		SCHEME									
		MONTHLY		BIMONTHLY1		BIMONTHLY2		QUARTERLY1		QUARTERLY2	
VARIABLE		N Years to Detect	Trend Size %	N Years to Detect	Trend Size %	N Years to Detect	Trend Size %	N Years to Detect	Trend Size %	N Years to Detect	Trend Size %
ALKTOT	Total Alkalinity	11	12.4	14	8.4	14	14.5	22	13.7	22	12.3
BDISS	Boron Dissolved	16	45.4	35	52.2	50	47.4	22	43.6	36	46.8
CADISS	Calcium Dissolved	11	8.5	14	8.1	14	9.2	22	8.2	22	8.8
CLDISS	Cloride Dissolved	7	50.0	33	54.5	14	43.7	22	61.0	22	44.6
CONDF	Conductivity Field	16	11.0	25	10.6	23	11.0	51	11.2	40	8.8
CUDISS	Copper Dissolved	7	74.9	14	86.1	14	69.0	22	73.8	22	60.3
DO	Dissolved Oxygen	10	12.8	14	13.3	14	11.0	22	11.6	22	9.8
FCOLI	Fecal Coliforms	21	177.6	14	241.7	30	229.1	22	159.8	22	174.3
KDISS	Potassium Dissolved	9	30.7	14	32.9	14	28.9	22	37.6	22	24.1
MGDISS	Manganese Dissolved	7	16.1	14	19.5	14	11.2	22	12.4	22	8.2
NADISS	Sodium Dissolved	12	32.1	14	31.2	14	33.7	22	37.1	22	28.2
NFR	Non-Filterable Residues	12	79.2	25	73.6	27	79.3	77	73.3	22	80.2
NO3NO2	Nitrate Plus Nitrite	7	156.9	14	184.7	14	121.8	22	120.0	22	172.1
PDISS	Phosphorus Dissolved	13	71.3	14	72.7	14	80.3	22	71.8	22	69.7
PH	pH	13	2.9	14	3.2	14	2.7	22	2.4	22	2.9
PHF	pH Field	19	3.9	36	4.0	14	4.3	42	3.5	22	3.9
PTOT	Phosphorus Total	23	37.6	14	45.8	32	42.4	33	42.8	22	38.7
SO4DIS	Sulfate Dissolved	7	17.5	14	13.1	41	18.8	22	16.9	22	10.9
SPCOND	Specific Conductivity	16	8.8	29	8.4	22	9.4	51	7.8	22	8.8
TDS	Total Dissolved Solids	12	9.1	14	8.3	14	10.1	22	9.1	22	9.0
TEMPF	Temperature Field	14	47.8	22	52.9	25	45.2	40	54.5	22	52.1
TN	Toatal Nitrogen	11	37.6	14	39.5	14	34.0	22	35.8	22	37.5
TURBF	Turbidity Field	129	82.6	36	63.1	145	78.7	58	64.4	22	63.3
TURBL	Turbidity Lab	16	72.0	21	68.7	27	77.6	44	62.1	22	79.7
ZNTOT	Zinc Total	7	59.0	31	53.5	14	56.9	22	52.5	22	57.9