ROYAL OAK MINES INC. - YELLOWKNIFE DIVISION

THE GIANT MINE

TERMS OF REFERENCE FOR AN ENVIRONMENTAL STUDY
FOR THE NORTHWEST TERRITORIES WATER BOARD

AN ASSESSMENT OF SCIENTIFIC DATA RELATING TO THE PERMANENT STORAGE OF ARSENIC TRIOXIDE IN THE UNDERGROUND MINE WORKINGS AT THE GIANT MINE

Terms of Reference

Underground Arsenic Storage Vaults

Purpose:

The purpose of this study is to collect and assess scientific data relating to the permanent storage of arsenic trioxide in the underground mine workings at the Giant mine.

Mining and milling operations commenced at the Giant mine in 1948. The gold in the Giant ore is refractory in nature to recovery by conventional milling techniques. Specifically the majority of the gold contained in the ore is in solid solution within an arsenic sulphide mineral called arsenopyrite. To recover this gold it is necessary to liberate the gold from the arsenopyrite. In the late 1940's the best available technology for treating this complex ore was autogenous roasting of an arsenopyrite concentrate followed by calcine cyanidation. This was the process selected for use at the Giant mine and although the type of autogenous roasting and gas cleaning equipment have been modernized over the subsequent years, the process fundamentally has remained the same. In fact autogenous roasting is still a viable technology in addressing other refractory gold ores.

Roasting of arsenopyrite concentrates results in the formation of impure arsenic trioxide vapours which are subsequently condensed and captured as a byproduct in fabric filters. Arsenic bearing dusts removed from the Giant roaster off gas have been stored in underground chambers since 1951. Today there are approximately 236,000 tons of arsenic bearing dusts in underground storage, containing approximately 141,000 ounces of gold and 185,000 tons of arsenic trioxide. Current production at the Giant mine adds approximately 5500 tons per year of arsenic bearing dusts to these storage chambers.

During the 1980's, a serious effort was made to market a portion of the crude arsenic trioxide being produced at the time and a surface storage and bulk loading facility were built for that purpose. Unfortunately it was found that the arsenic bearing dust from Giant was incompatible with the wood preservers processing plant in Georgia and shipments were stopped after a period of intermittent operation.

At this same time period a program of metallurgical testing was undertaken to determine a practical means of upgrading the arsenic bearing dust to improve the potential marketability of the contained arsenic trioxide and to recover the contained gold. While technically a success, the market conditions for the sale of an arsenic trioxide product precluded proceeding with this option. The arsenic trioxide market remains poor to this date.

The arsenic bearing dust recovered since 1951 at Giant is stored in fourteen underground chambers of varying dimensions called "stopes". The location of these storage chambers has been chosen to place them within the discontinous zones of permafrost. The minimum thickness of the rock between the top of these storage chambers and surface varies from a low of 30 feet to 188 feet with an average thickness of 80.8 feet. Each of the chambers has been isolated from the remaining mine workings by means of concrete bulkheads. Only one of these chambers is currently being used as an active storage chamber, the remaing thirteen being considered full.

In planning for final abandonment and restoration of the Giant mine, it is intended that actions be taken so that these stopes would remain in a frozen condition isolated from active groundwater by either concrete bulkheads or permanent ice. The purpose of this study is to provide additional information in relation to this plan of abandonment along with technical backup.

Areas of Investigation:

This study is envisioned as a multi-disciplinary study involving geologists, hydrogeologists, geotechnical, mining and civil engineers, chemists along with specialists in the area of permafrost and rock stability. The majority of the work will be done by Royal Oak personnel with the involvement of contract specialists where appropriate. The Royal Oak personnel working on the various portions of the study will be competent in the appropriate disciplines and will be supervised by professional staff. The study will consist of both the collection and assessment of existing data and the collection and assessment of new data to specifically address areas of concern where little or no data exists. The study will take four to five years to complete, consequently annual progress reports are proposed. The areas of investigation to be covered by this study are as follows:

A) Assessment of the Physical Stability of the Storage Chambers:

An engineering review of the available information on each of the fourteen underground arsenic storage chambers would be undertaken. This review would include:

- An analysis of the rock type and competency of the rock surrounding each chamber. This analysis will be based upon the collection of geological information about the rock types, structures and faults in the immediate vicinity of each of the storage chambers. The amount of information required for each chamber will depend upon the specific nature of each of the rock structures in the vicinity of each chamber. Information will be collected by reviewing the existing geological information and by collecting new field data where possible from the exposed rock in the vicinity of these chambers (ie: access drifts). Access to the rock in the chambers is precluded by the arsenic bearing materials already in place. In some cases collection of the required data may require new diamond drilling although this would only be undertaken when it was felt that the data to be collected was vital and could not be obtained by other means. The purpose of this phase of the study is to assess rock competency and to predict potential flow paths for groundwater into and away from these storage chambers.

- An analysis of the engineering competency of the concrete bulkheads isolating each of the fourteen storage chambers. This will include an assessment of the hydraulic loading that will be placed on these bulkheads once the mine has flooded and the ability of the bulkheads to withstand the required pressure. In most cases it will be necessary to conduct an assessment of the concrete used in the construction of the existing bulkheads. In some circumstances the engineering evaluation may point out the need to reconstuct bulkheads built in the 1950's and 60's to meet current standards and to ensure that the bulkheads will be capable of withstanding the calculated hydraulic forces once the mine is flooded. Remedial measures required to upgrade the existing storage vaults will be identified in the final report.

- An analysis of the forced ventilation in the vicinity of these storage chambers.

- Preparation of plan and section views through each storage chamber indicating access drifts, raises, bulkheads, pipes, etc. that have an impact on the conditions in and around these storage chambers.

- Preparation of a written engineering standard for the development of future arsenic storage chambers. This standard will include factors to be used in selecting a location (such as rock stability, location of permafrost, etc.) and engineering standards for the construction of the chamber (such as the design of isolating bulkheads, preparation of the stope walls prior to filling, grouting, etc.).

- Development of a written monitoring program for both active and inactive storage vaults, including seepage analysis, assessment of bulkhead integrity, condition of the permafrost both in the immediate area inside the chambers and monitoring of surrounding rock temperatures.

This work will be directed by mine engineering staff with appropriate assistance from consultants where a particular expertise is required. The study will concentrate on reviewing what information is available from current records. This primary review will identify areas where additional information or data will be required to complete an assessment of the physical stability of the storage chambers. Plans will then be made to collect the missing data or initiate programs as required to fill in the gaps in the knowledge base.

Schedule:

1994 Begin collecting available data on the arsenic dust storage chambers. Conduct engineering assessments of the rock competency, concrete bulkheads, ventilation, etc. Where data is missing initiate actions to collect the required data. Include data in an annual progress report to be completed by year end.

1995 Complete engineering assessments and develop written engineering specifications for all future arsenic storage vaults. Include assessments in the annual progress report to be completed by year end.

1996	Complete the preparation of a full set of plan and sectional views of the storage chambers and surrounding mine workings including the geological features of note. Update engineering assessments if additional information is available. Include updates in the annual progress report to be completed by year end.
1997	Include the stability assessments and completed drawings in a final study report to be completed by the end of 1997.

B) Analysis of the Technical Options for Permanent Abandonment

While the stated objective is to leave these storage chambers in a permanently frozen condition, a number of options can be taken to technically enhance this objective. This portion of the study would first list the actions that can be taken to enhance permanent abandonment of these storage chambers. The types of concepts to be addressed in this study include but not necessarily limited to:

- Use of winter air by means of forced ventilation to enhance the reestablishment of the permafrost in the vicinity of these storage chambers.
- Use of additional or secondary bulkheads to isolate the storage chambers from the groundwater regime.
- Use of grout curtains to isolate the storage chambers from the groundwater regime.
- Creation of artificial ice plugs behind the bulkheads to enhance isolation of the storage chambers from the groundwater regime.

The intent of this portion of the study is to further develop the engineering feasibility of each of these enhancements or options for closing out the storage chambers. The intent would be to eliminate those ideas found not feasible and to initiate programs to collect additional data for those concepts which are shown to be potentially feasible. The technical review of each option will include an assessment of the potential impact on the groundwater regime in the areas of each stope.

Schedule:

1994 Develop a detailed description of the options to be investigated and the data that will be required to conduct an engineering feasibility of these options. Begin collection of this data.

1995 Complete collection of data and engineering feasibility. Include the results in the annual progress report.

1996 Update the results to incorporate new concepts in the annual progess report.

1997 Again update the results for inclusion in the final study report targeted for the end of 1997.

C) Analysis of the Permafrost Regime in the Areas of the Storage Chambers

To provide a more complete understanding of how the zones of discontinous permafrost behave in the area of the arsenic dust storage chambers, it is proposed to collect rock temperature data where possible. The goal would be to provide a mapping of the rock temperatures in the areas surrounding the arsenic storage stopes in both the horizontal and vertical dimensions. These temperatures would be recorded at different points throughout the year to assess whether there is any noticeable seasonal variation. To accomplish this objective it will be necessary to install a series of thermistors in either existing holes or in specially drilled holes to collect data from the desired points. At the same time, the temperature within the storage chambers will be measured for inclusion with the other data.

A review of the current state of the knowledge base on permafrost will be undertaken to determine whether any previous experience or scientific data can be applied to this situation to aid in predicting future events.

Schedule:

1994 Design a rock temperature monitoring program to meet the stated objectives. Order thermistors and temperature monitoring equipment. Drill the required access holes and install thermistors. Begin monitoring rock temperatures. Include data in annual progress report.

1995	Continue monitoring rock temperatures. Include data in annual progress report.
1996	Continue monitoring rock temperatures. Include data in annual progress report.
1997	Assess data and modify monitoring program if necessary. Aim to complete final study report by the end of 1997.

D) Analysis of the Hyrdogeology in the area of the Arsenic Storage Chambers:

In this portion of the study, data relating to the geochemistry of the arsenic bearing dust produced at Giant would be collected. Arsenic trioxide is water soluble but it is known to have a fairly steep temperature solubility curve, ie it is much less soluble at cold temperature than at higher temperatures. This information needs to be documented and interpreted with a view to understanding the risks that would be involved if large volumes of groundwater came into contact with the stored arsenic bearing dust.

Information will have to be collected to permit a hydrogeologist to make meaningful predictions relating to the groundwater flow regime that would be expected in the vicinity of these storage chambers once the mine has been fully flooded. A previous assessment of the groundwater inflow rates into the Giant mine indicate that it make require as much as 100 years to fully flood the mine workings. Consequently information regarding the current groundwater flow will have to be used in predicting the groundwater flows in the future. To enable a hydrogeologist to predict the future groundwater flow regime, information relating to rock porosity, geological structures such as faults and slips and an understanding of current groundwater flow conditions will have to be obtained over the next two to three years. The prescence of discontinous zones of permafrost, the realignment of Baker Creek, the presecence of the open pits will all have to be taken into consideration during this assessment.

Schedule:

1994	Design a data collection program with input from a hydrogeologist and the mine geologists. Implement the data collection program. Preliminary assessment of this data would be included in the annual progress report. The data collection program would be modified as needed to fill voids in the information base.

1995 Continue data collection. Assessment of data would be included in the annual progress report.

1996 Continue data collection. Assessment of data would be included in the annual progress report.

1997 Prepare an assessment of the data collected for inclusion in the final study report.

E) Underground Arsenic Storage - Risk Assessment

Kaplan and Garrick define a risk assessment of consisting of an answer to the following three questions:

- What can happen? (ie. what can go wrong)
- How likely is it that it will happen?
- If it does happen, what are the consequences?

A Risk has two necessary elements:
- Hazard (what can go wrong and with what consequences?)
- Likelihood (probability)

A hazard with no likelihood is not a risk.

A qualitative risk assessment is a formal tool used to both identify and assess hazards, their consequences and the probability of their occurrence. The information can then be used to manage or if possible eliminate those risks that have both a high degree of hazard and a high probability of occurrence.

The steps used to prepare a qualitative risk assessment can be summarized as follows (source: Golder Associates):

1) Identify potential failure modes and mechanisms

2) Conduct a hazard Assessment which would include:
   - Development of hazard descriptors (Negligible, very low, low, medium, and high)
   - Qualitative hazard assessment for failure modes based on site area/component/phase.

3) Conduct an exposure assessment which would include:
   - Failure mechanism
   - Initiating Events
   - Magnitude of Release
   - Duration of Release
   - Pathways
   - Ecosystem at Risk
   - Qualitative exposure assessment for failure modes, based on site area/component/phase.

4) Consequence Assessment which would include:
   - Qualitative consequence assessment for failure modes, based on site area/component/phase.

5) Risk Characterization which would include:
   - Development of risk characterization description based on hazard exposure and consequence assessment.
   - Qualitative risk characterization for failure modes, based on site area/component/phase.

This risk assessment technique will be used in drawing together all of the previous elements of this study. The hazards, resulting exposures and consequences would be identified for the different failure modes. The results of the risk assessment can be used to:

a) document the evaluation and decision making process used.
b) express the relative risk associated with specific activities or design elements.
c) select those failure modes or release mechanisms that may result in significant risk. These mechanisms can then be developed further in quantitative risk assessments.

A risk management plan can then be developed based on the findings of the risk assessment.

Schedule:

1994	Establish the technique to be used in preparing the risk assessment. Complete the Hazard and Exposure assessment portion of the risk assessment. Initiate programs to collect missing information.
1995	If necessary update the hazard and exposure assessments. Complete the Consequence assessment portion of the risk assessment.
1996	Complete the risk characterization portion of the risk assessment.
1997	Update the risk assessment to include all data collected by the full study. Complete a risk management plan based on the risk assessment.

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17th – Nichols Lake

– Auto-cad – Surveyor

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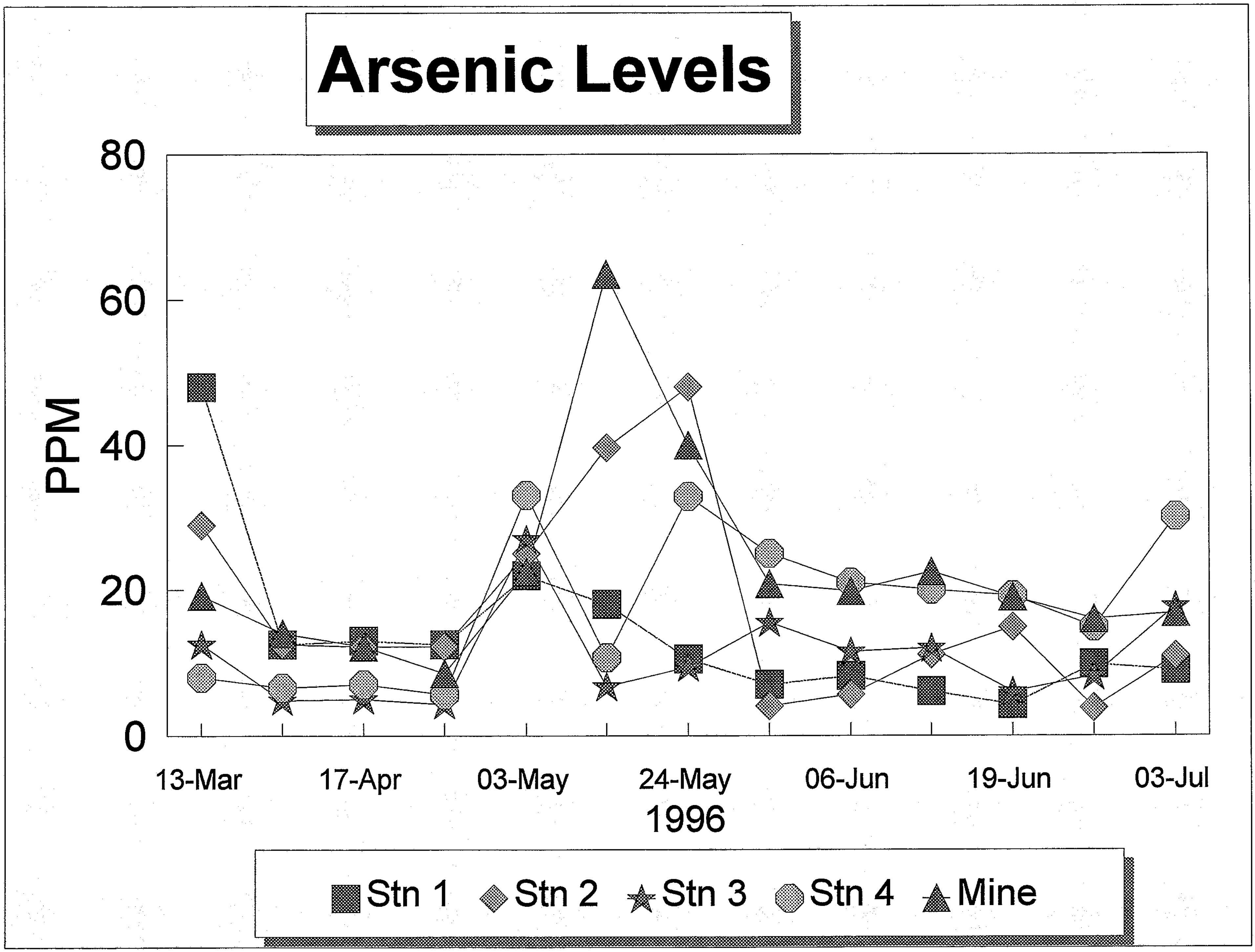
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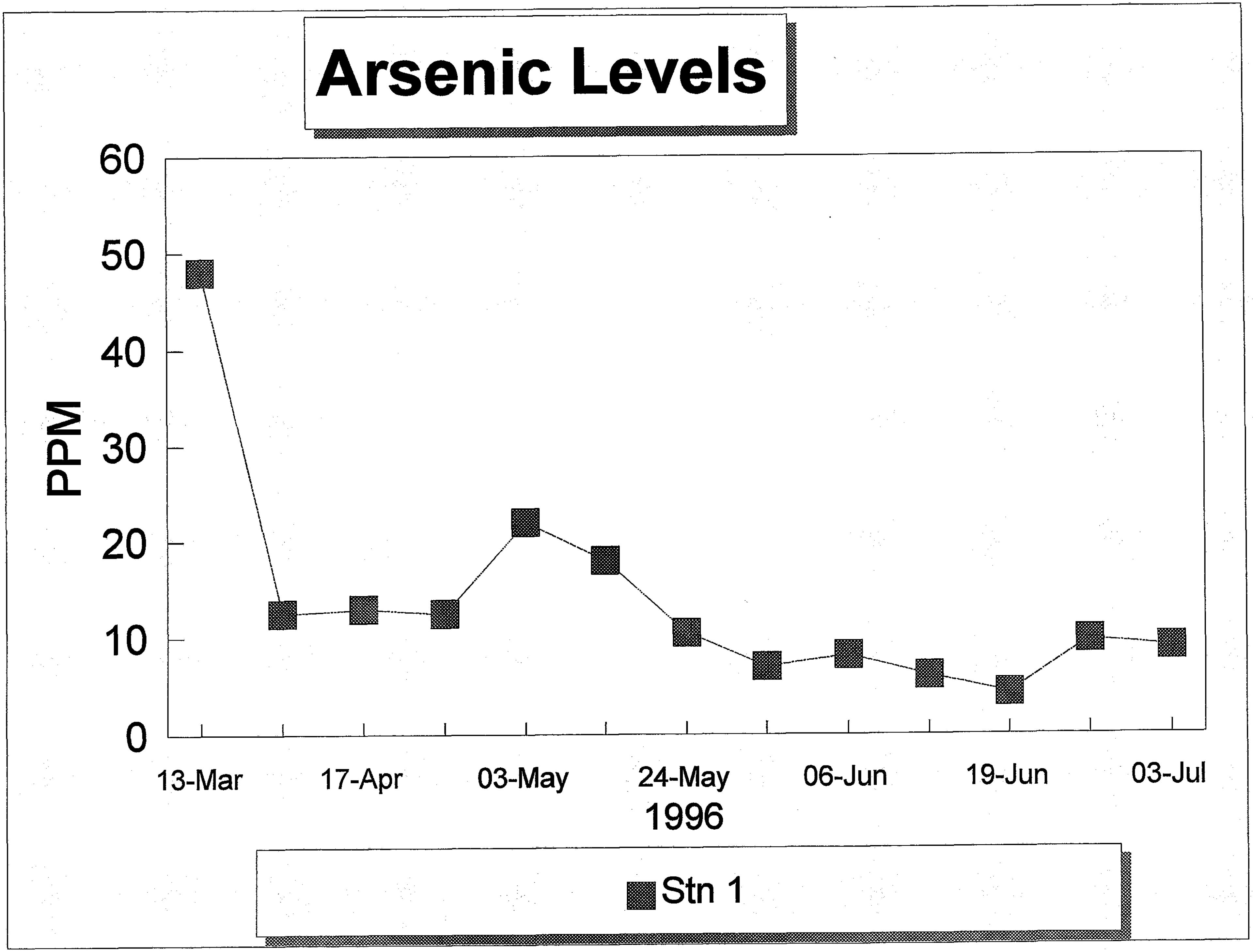

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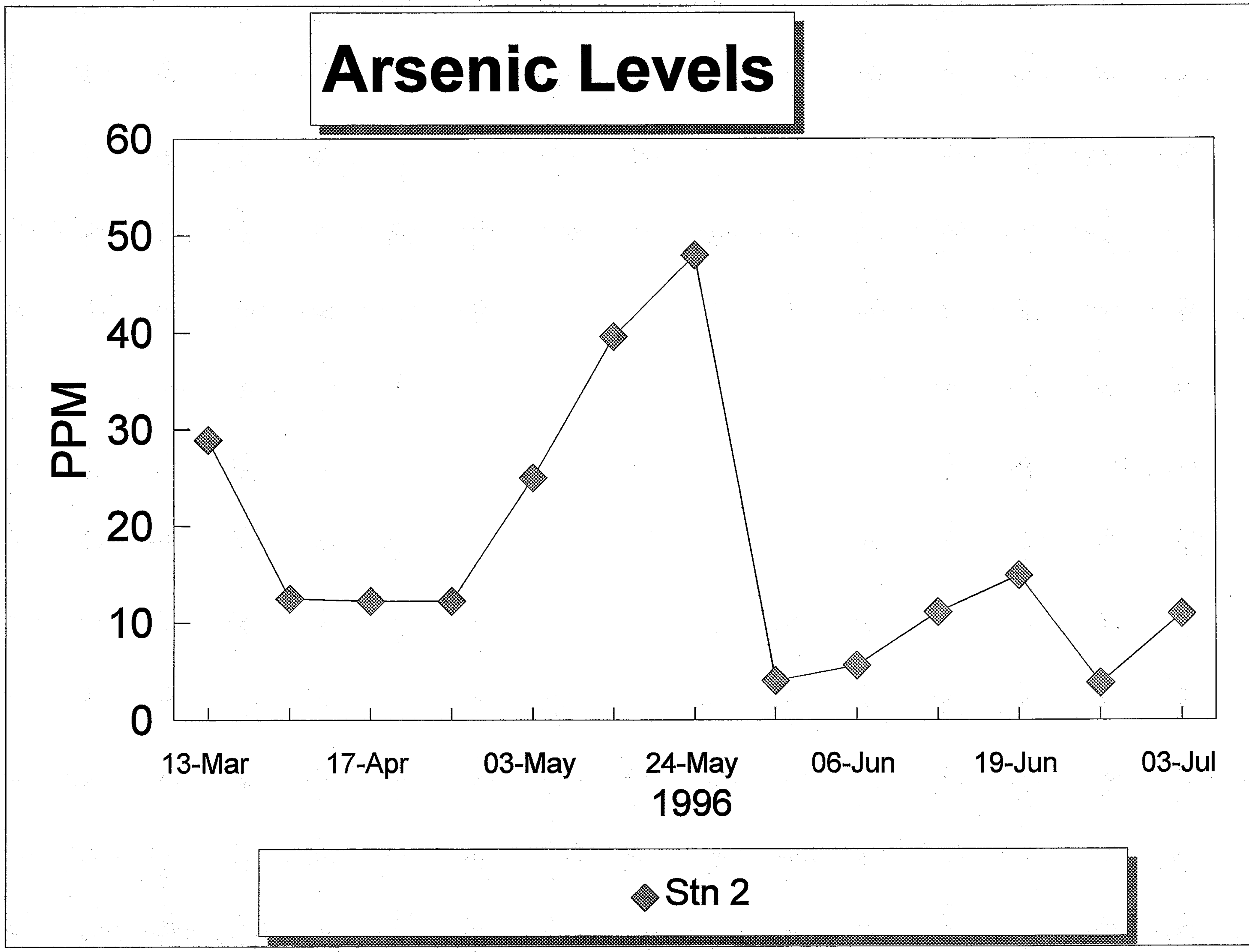

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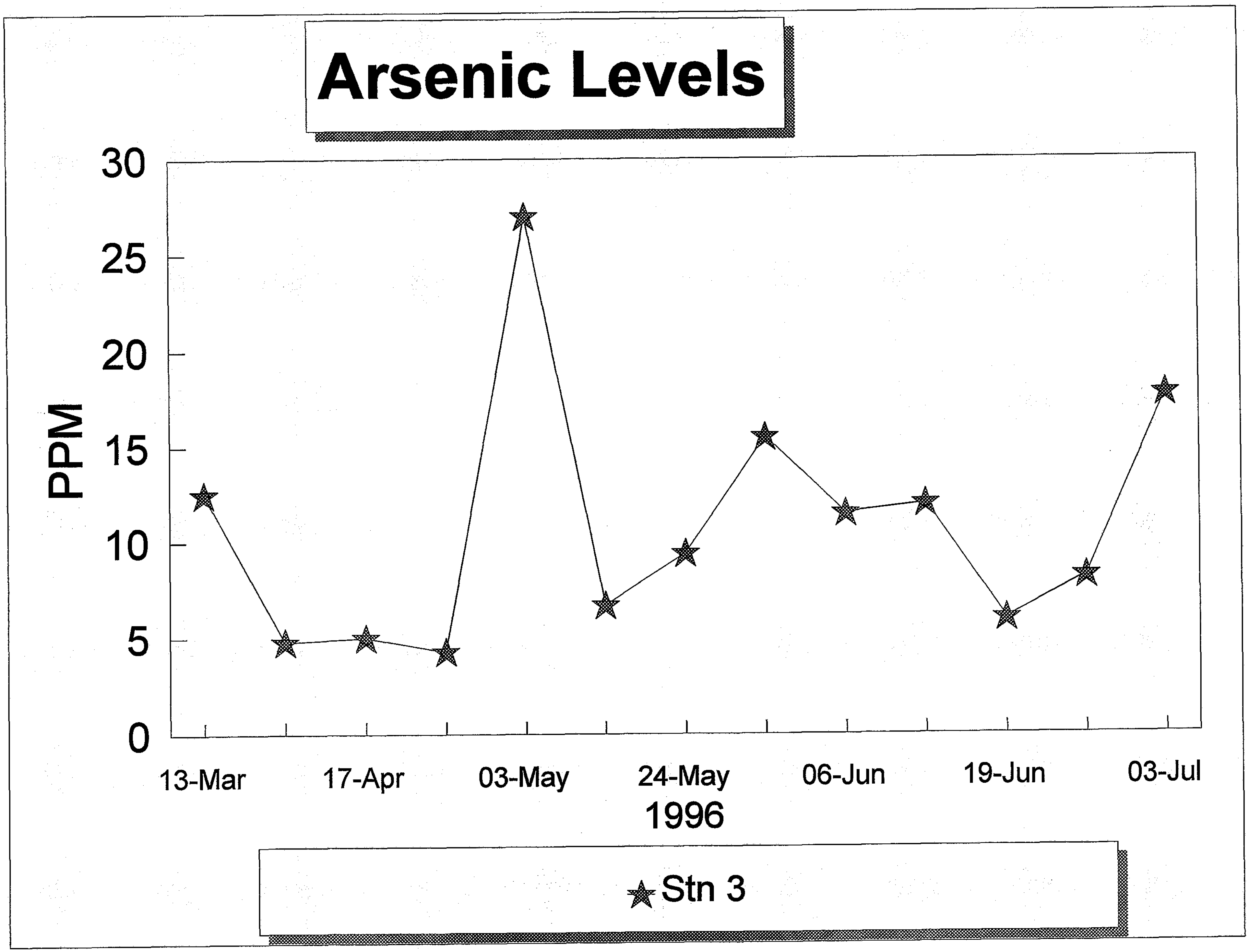
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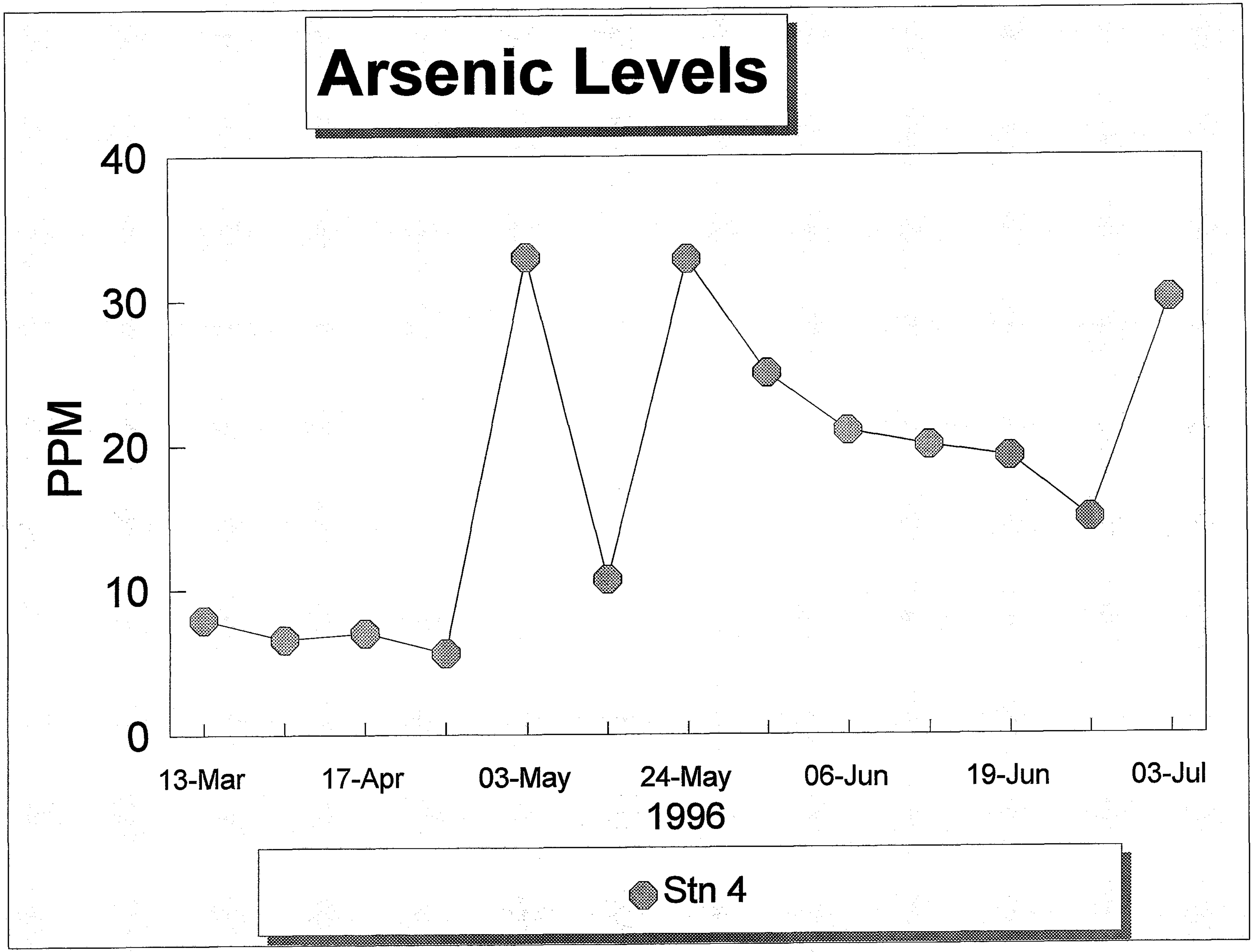
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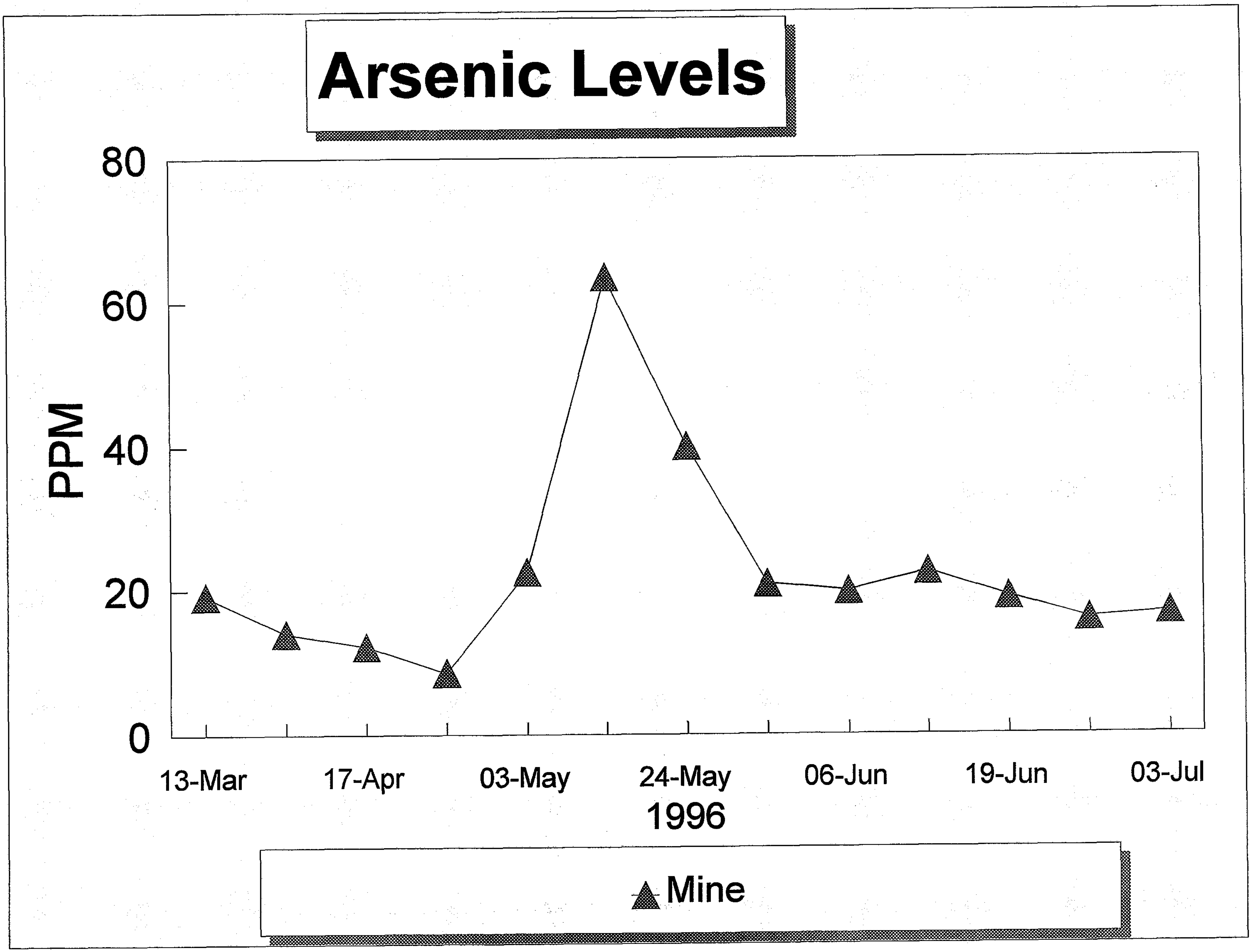
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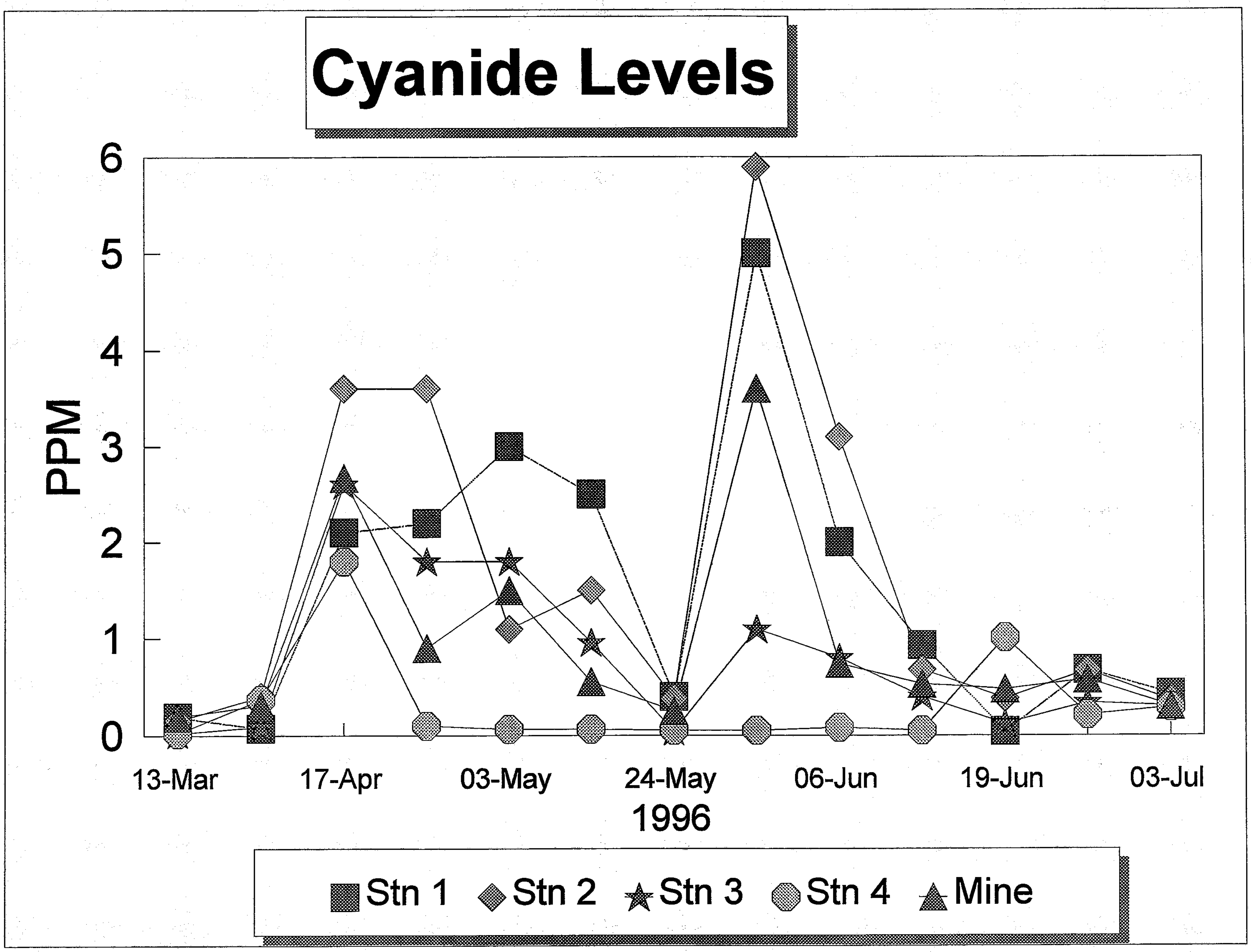

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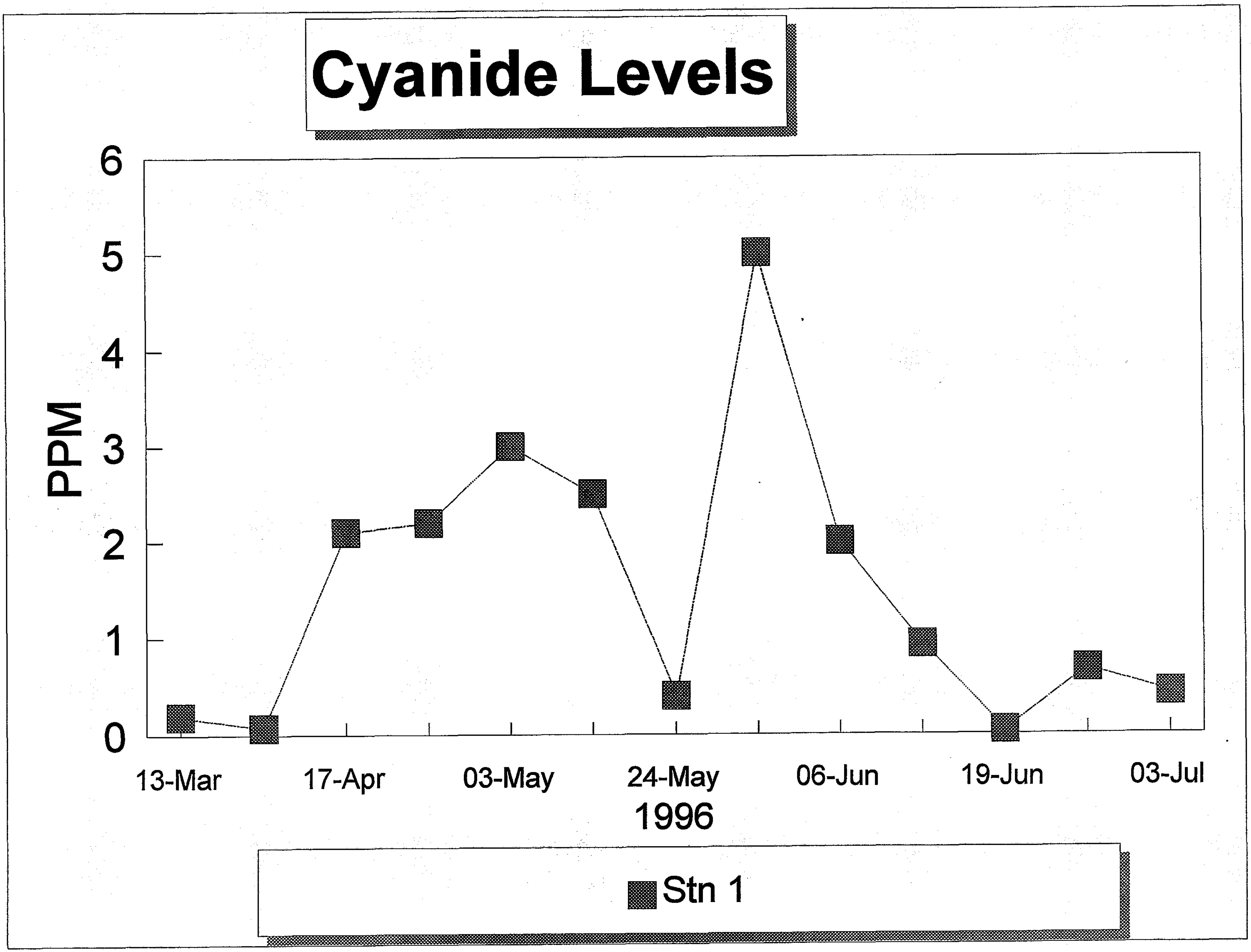
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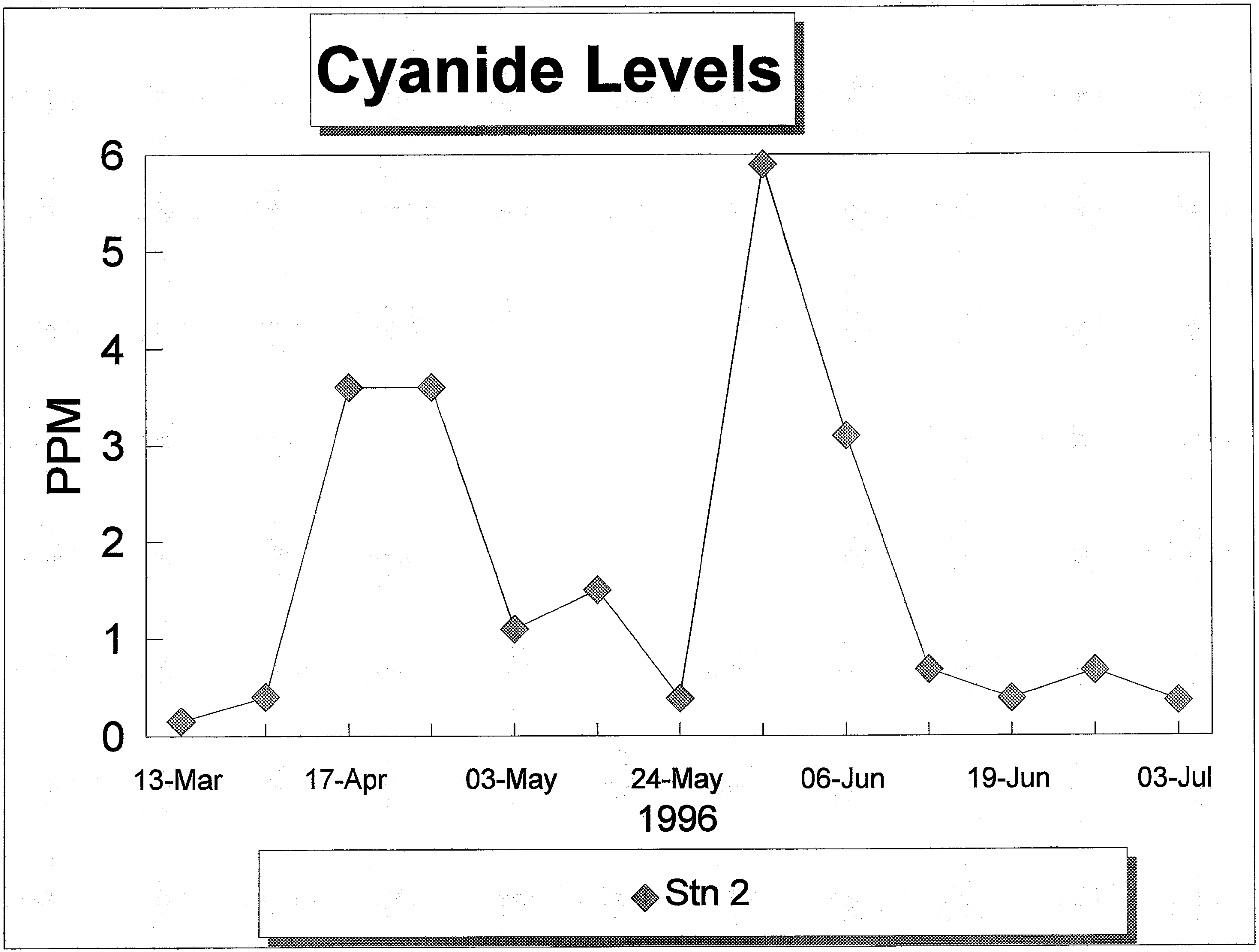
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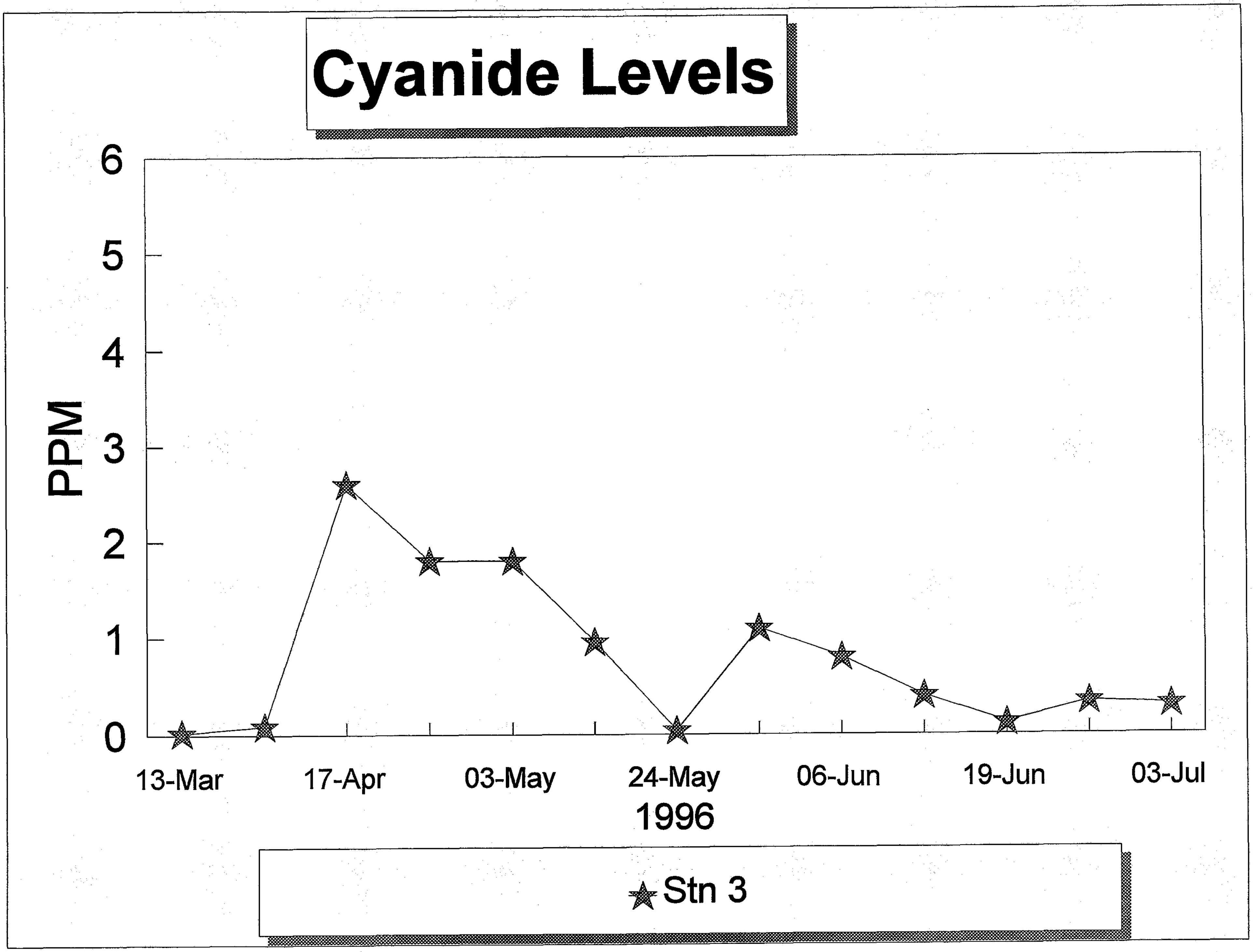
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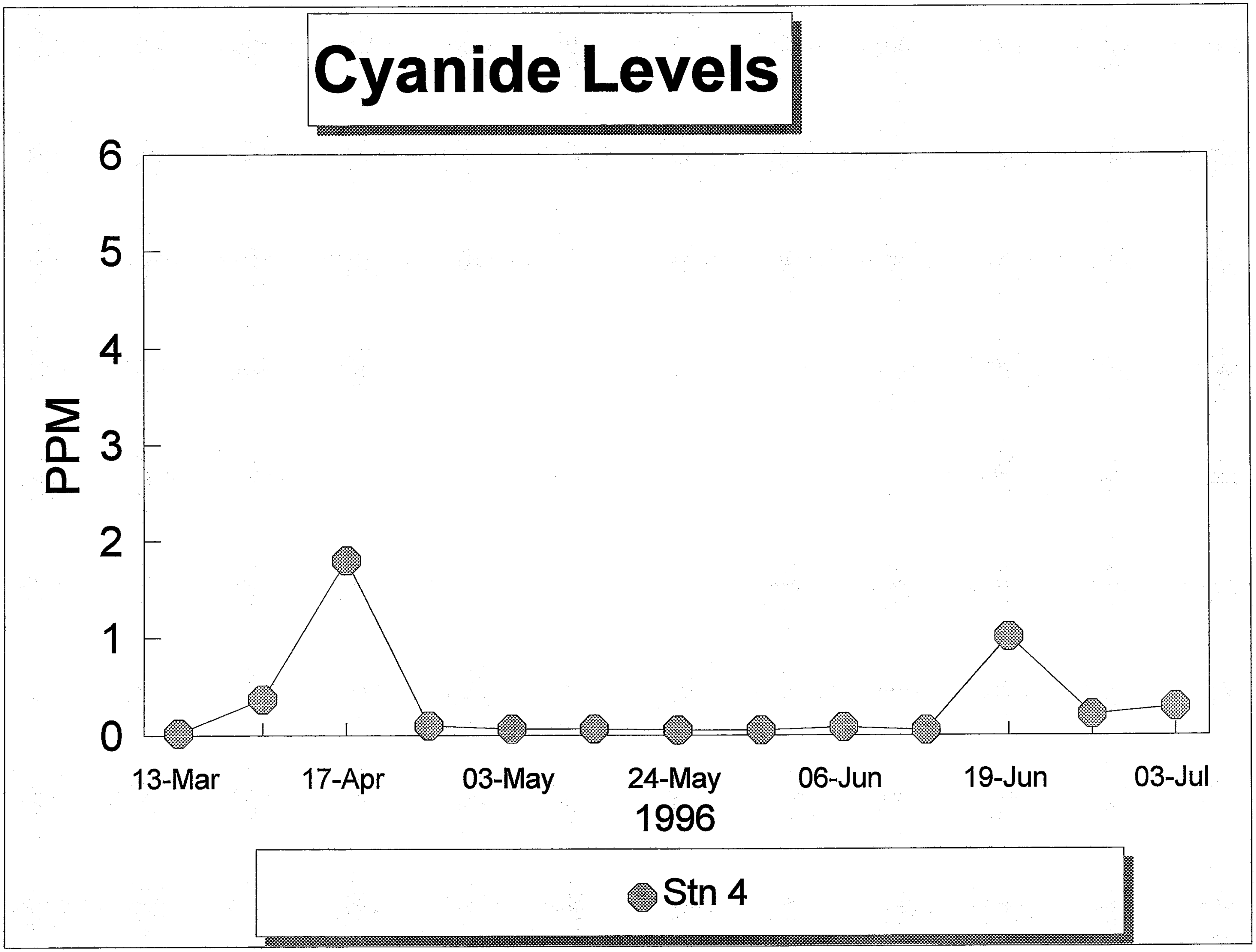
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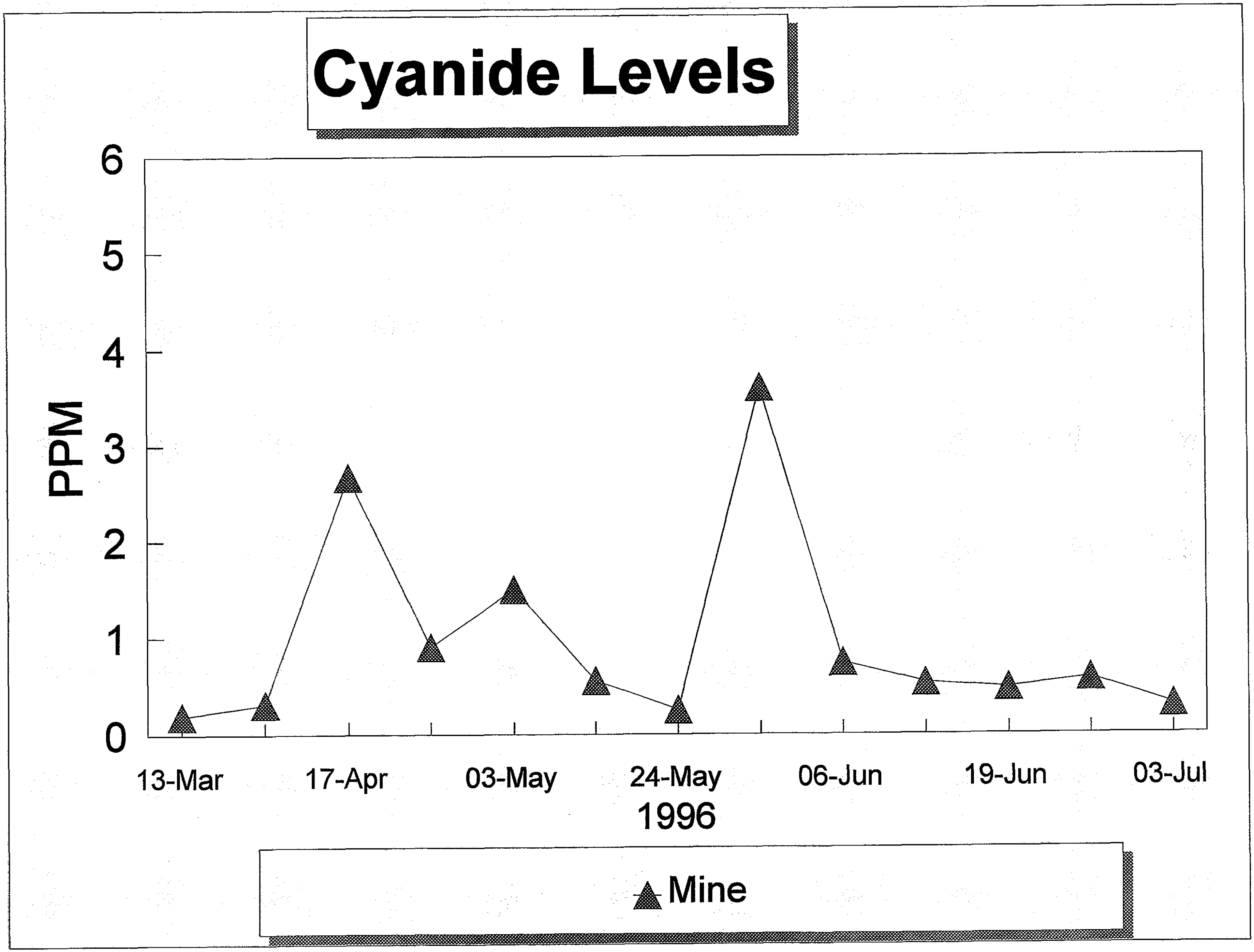
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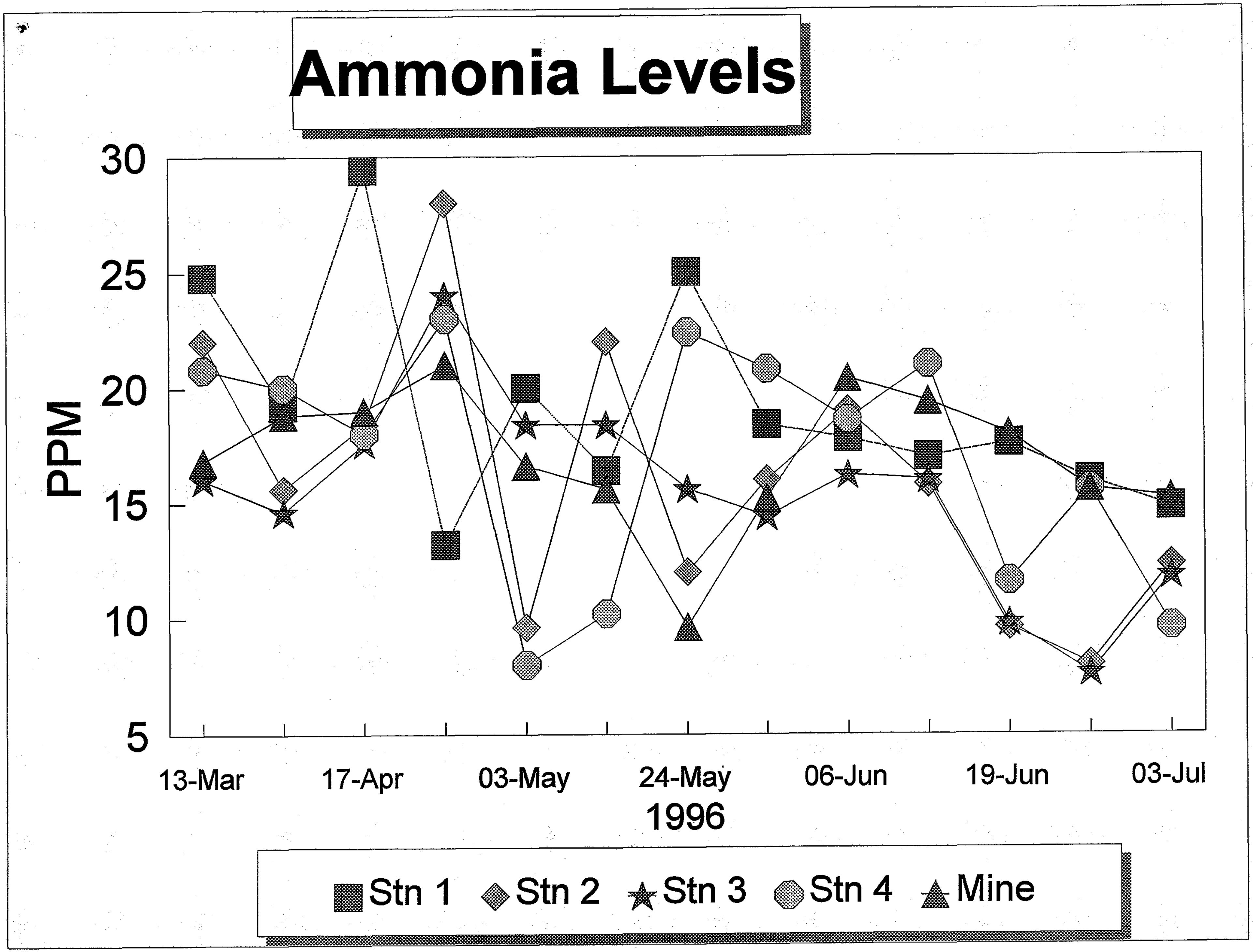

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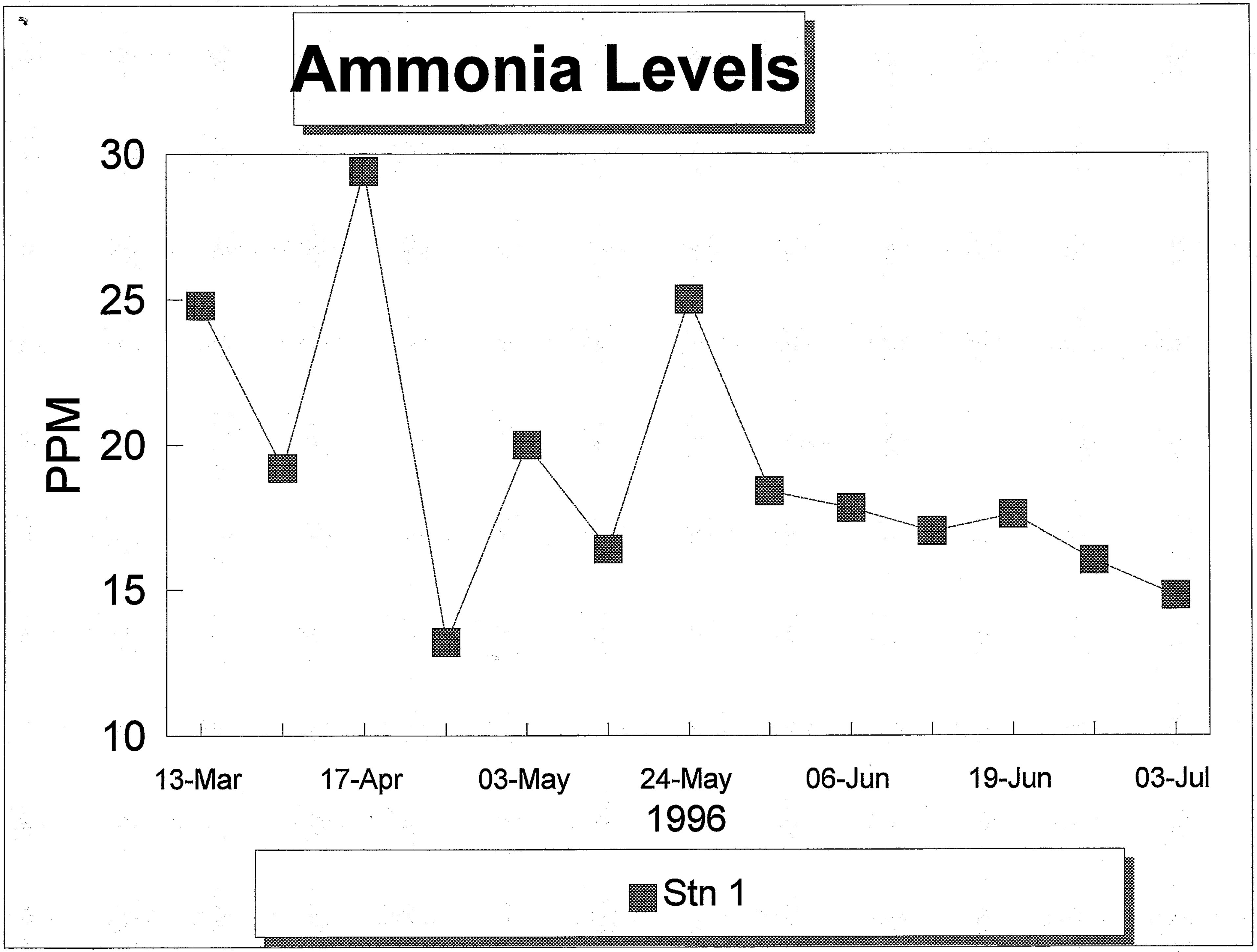
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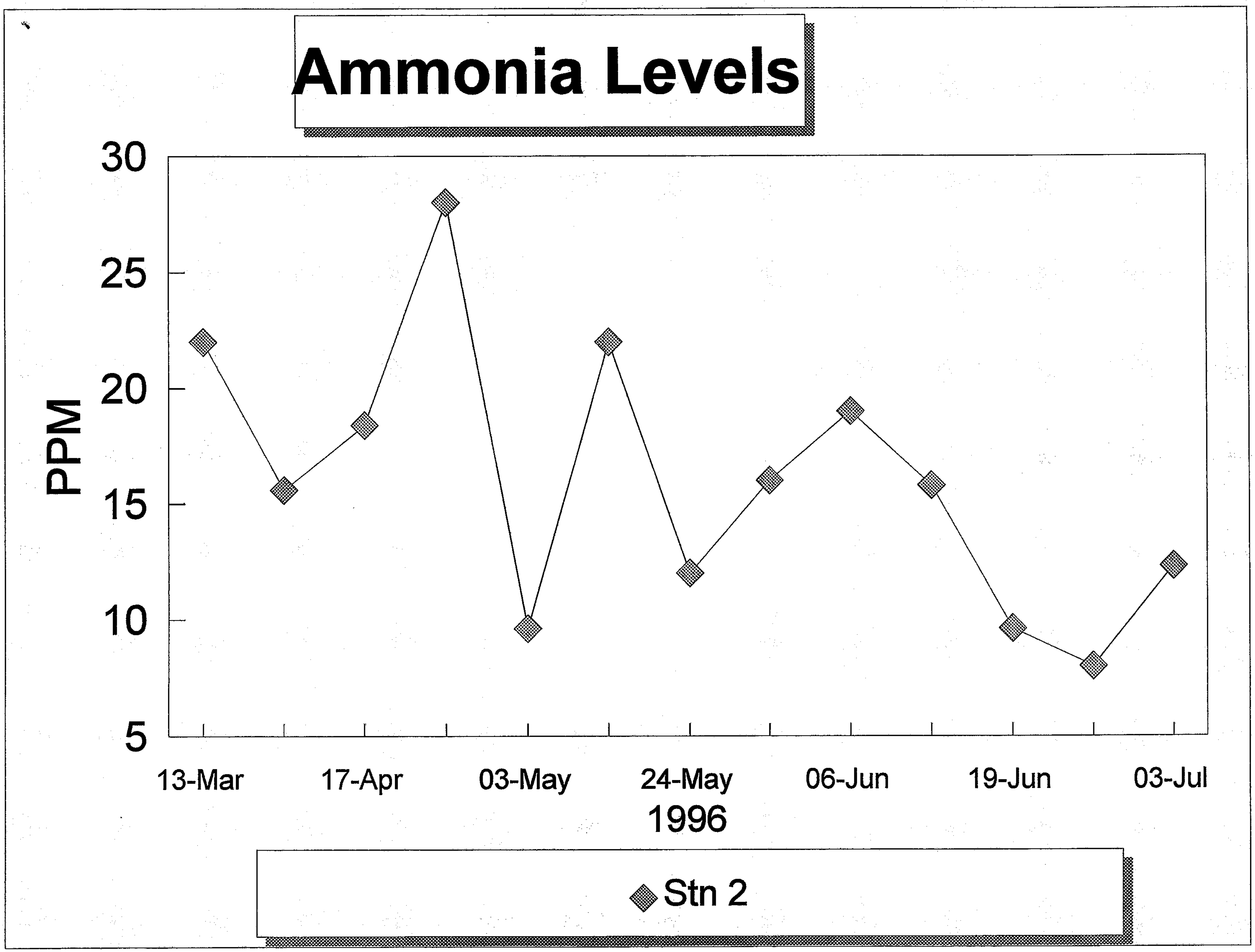
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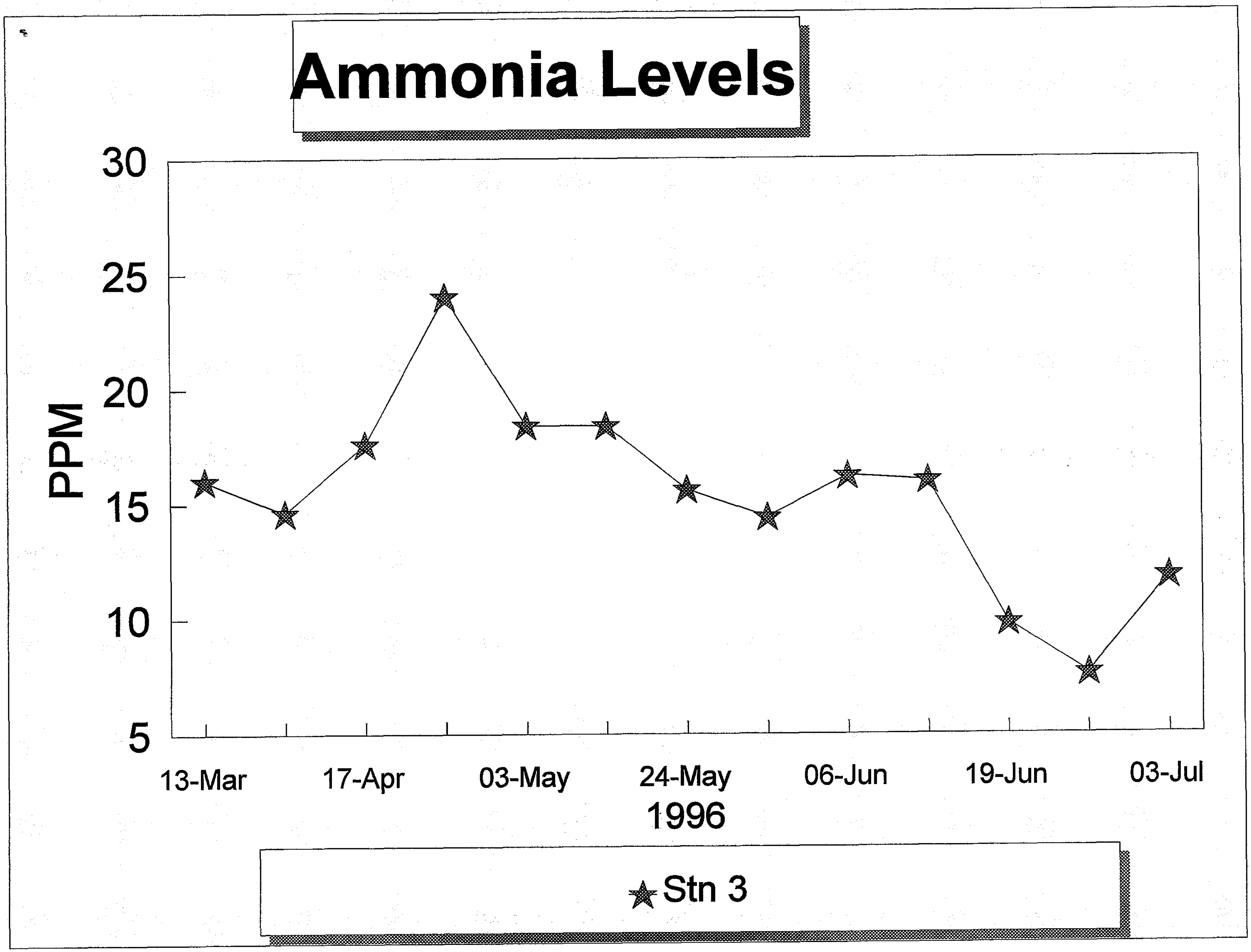
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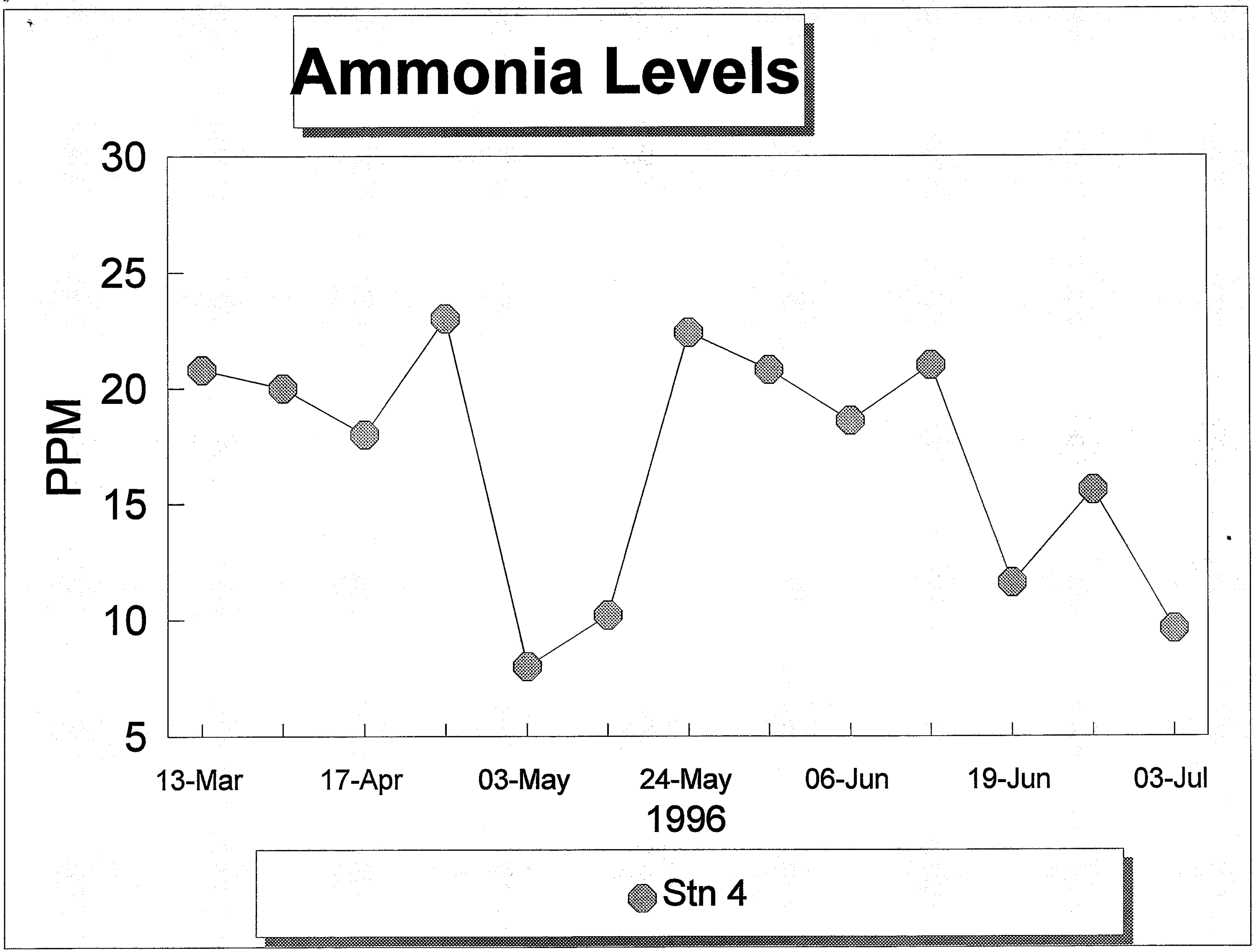

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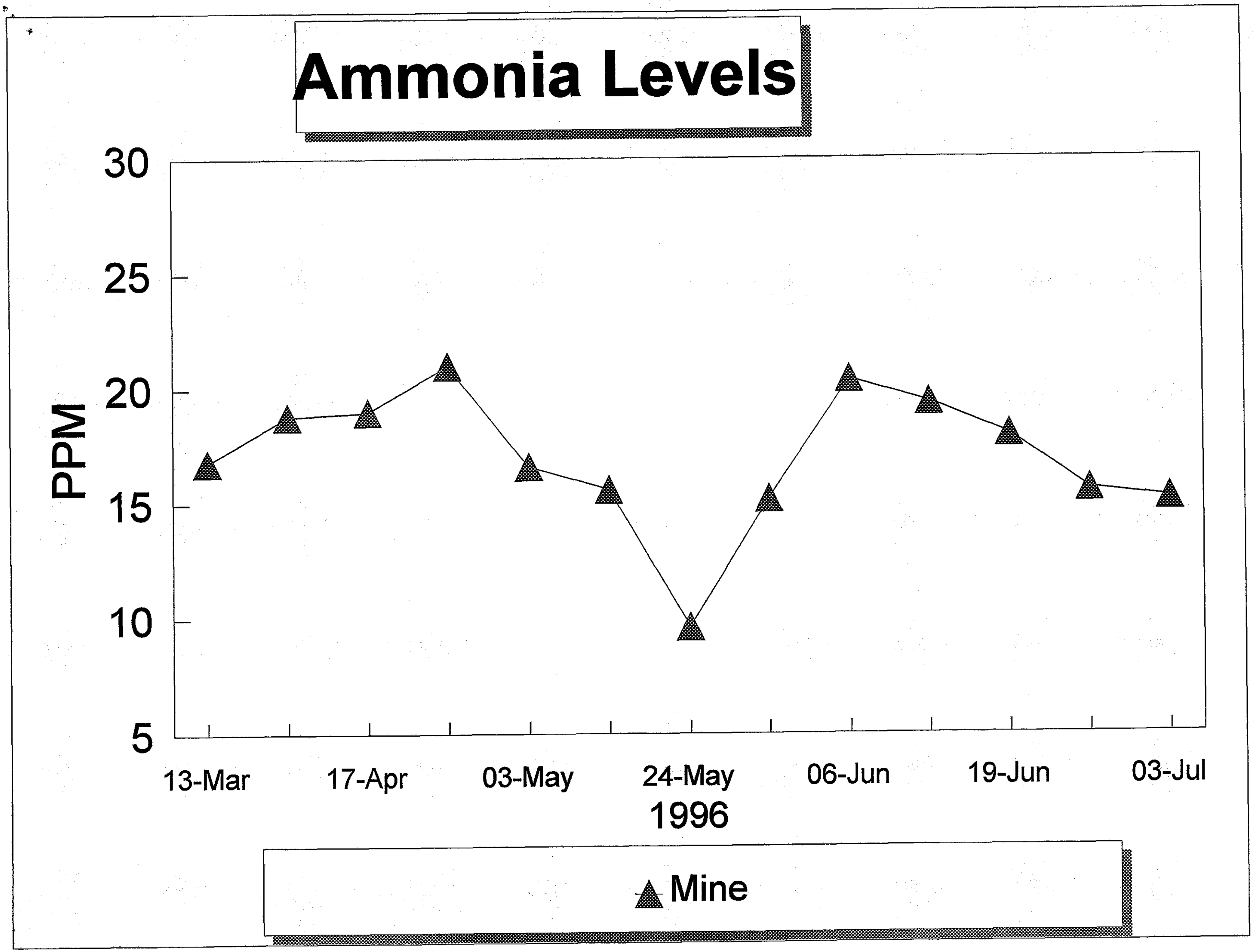
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