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A MODEL FOR THE MOVEMENT

OF SELENIUM IN A CLOSED AQUATIC SYSTEM

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[illegible]

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CHAPTER I

INTRODUCTION AND LITERATURE SURVEY

Introduction

Selenium is widely distributed in the earth's crust. It is frequently found in industrial processes and occurs in our energy resources. It is an important trace element in the biological world, but may become a toxic substance through bio-magnification. It has been given quality criteria limitations in air and water. Despite this availability and potential hazard, the biochemistry of selenium is not well known and its movement and distribution in ecosystems has not been investigated to any significant extent.

The scope of this work, then is to develop the beginnings of a modeling effort which will ultimately lead to a predictive capability in the various trophic levels of natural systems. Completion of the model will be reserved for future works. The present effort will be limited to preliminary aspects of "system identification" (Patten 1969) rather than system analysis. An attempt will be made to hypothesize a model on biological grounds and to observe its ability to simulate a physical laboratory model.

Historical Background and Literature Survey

Historically, selenium poisoning was known to farmers and stockmen as "alkali disease." The symptoms of selenium poisoning were called, "blind staggers" (Franke, 1934). Enormous losses of livestock occurred in some of the areas of the midwest and southwest. The cattle and horses would become lame, lose hair and hooves and develope loss of control of voluntary muscles. Death eventually occurred from internal hemorrages. The woody aster (*Xyloriza*) and milk-vetch (*Astragalus*) involved in the historic selenium poisonings, were shown to accumulate selenium to 10,000 ppm. These plants have a growth requirement for selenium and can apparently accumulate it from the soil no matter what chemical form it is in (Rosenfeld & Beath 1964). This concentration was then passed trophically to the livestock and accumulated readily to toxic levels.

Robinson (1933) could reproduce this pathology with native forage that was shown to accumulate selenium. Shortly thereafter Franke (1934), using grains grown in areas where alkali disease occurred, demonstrated the toxic substance to be selenium. He subsequently demonstrated (Franke and Potter 1935) that selenium-containing feed would produce toxic effects in rats. Grains containing 25-30 ppm resulted in growth inhibition, jaundice, anemia, and hemorrage.

The role of selenium in biological systems is unclear and diverse. Its position in group VI of the periodic table reflects its chemical similarity to sulfur in living organisms (White, Handler, and Smith 1959). Painter, Edgar, and Page (1940), suggest the association of sulfur and selenium in soils and biologic materials in constant ratios. Franke showed an association of selenium with protein (1934). Schultz and Lewis (1940) observed the conversion of selenite to dimethylselenide in rats. The blue-green alga, <u>Anacystis nidulans</u> replaced sulfur compounds with the uptake of selenium analogues (Kumer and Prakash 1971).

Selenate toxicity was suggested by Shrift (1954) to be due to competitive inhibition of sulfur for metabolic enzymes. This inhibition occurred at membrane sites also.

Others suggest selenium to have antagonistic relationships with arsenic (Rhian and Moxon, 1943).

Selenium has been suggested to have a synergistic effect with Vitamin E and a relation to the reduction of lipids (O'Hara 1970, Schroeder 1970, Young 1970). It was found necessary in small amounts.

Irrespective of its biochemical role in the living system, selenium represents a potential hazard to man (Moxon and Rhian 1943). Clinton (1947) described the sequence of acute selenosis from selenium fume exposure. Smith and others (1938) described a high absorption through the intestine and subsequent elimination through the kidney. Franke (1936) demonstrated toxicity of selenium in rats. Lekin (1972) showed acute and chronic selenosis in animals feeding on vegetation containing selenium at levels less than 30 ppm.

In addition to toxic effects of selenium accumulation, Muth and others (1958) prevented White Muscle Disease (WMD) in lambs by the addition of selenium to feed. Glover (1967) described calves and lambs with muscular dystrophy, inhibition of growth, and reduced fertility on selenium deficient diets.

In general, the normal dietary levels of selenium for most species range from 0.1 to 0.5 ppm (Weswig 1972). Concentrations around five ppb produce the selenium defiency syndrome, and at higher concentrations of one to ten ppm can produce toxic effects. In addition, levels in the latter range are more likely to produce toxic effects through chronic trophic relation.

The U.S. Public Health Service has recognized a hazard to potable waters and recommended a safe upper limit to be 0.01 ppm. In addition, the American Conference of Governmental and Industrial Hygienists in 1962, documented a threshold limit value (TLV) of 0.1 mg/m^3 for a forty-hour week occupational exposure.

The distribution of selenium is widespread (Goldschmidt 1954). It occurs in minute concentrations in soil and sulfide minerals. The average earth's crust value is only 0.09 ppm. The widespread distribution and relationship to sulfur was suggested by Pillay and Sivasankara (1971) to be used as an indicator of sulfur dioxide pollution. They held that measurable selenium:sulfur ratios could be indicative of petroleum or other fossil fuel sources used for combustion. Mast and Ruch (1973) in a survey of Illinois crude oil wells found an association of selenium in the sulfur-containing wells ranging from 0.2 to 0.4 ppm. Johnson (1970) found that burning of coal released 0.7 ppm to 7.38 ppm selenium. Volcanic deposits have been found to contain as much as 120 ppm (Byers 1935), and values of 680 ppm have been reported from carbonaceous siltstone in western Wyoming (Beath, Hagner and Gilbert 1946).

Other sources and forms of input into the environment have been reported. Johnson (1970) reported nearly 20 ppm from the burning of solid waste such as newspapers, card-board and tissue. Olson (1970) measured 0.05 ppm in paper and 0.03 ppm to approximately 1 ppm to tobaccos. Selenium collected in air filters from United States cities was found to range from 0.05 to 10 ppm selenium. Hashimoto (1967) measured 0.21 ppb in rainwater.

In addition to levels and sources mentioned, there is a fairly significant industrial input into the environment (Lakin and Davidson 1967). Major industrial sources of selenium are from mining and refining of copper, lead, gold, nickel, and silver (Ledicotte, 1961). Selenium is also a waste product in the manufacture of sulfuric acid, pigments, insecticides, stainless steel, photo-electric cells, rubber, and glass.

Sources of selenium in the environment are widely distributed. The potential for greater input from man's energy use is becoming more prevalent. Mechanisms for the availability to the biotic system are present and bio-accumulation to high concentrations has been shown. Toxicity has been demonstrated. All of these facts suggest a potential hazard in the movement and accumulation of selenium in an ecosystem. Therefore, there is a need for ecosystem research.

CHAPTER II

DEVELOPMENT OF THE SELENIUM MODEL

Selenium Living Systems

There is little knowledge of the importance of selenium as a trace element in living systems (Wainerdi 1971). The classic studies of Franke (1934) demonstrated bioaccumulation and trophic movement. However, the data was not collected with an ecosystem view. Subsequent research often involved feeding animals specified levels of selenium as opposed to observing movement and accumulation of ambient levels in the natural forage. In other studies of terrestrial living systems, Allaway (1964) demonstrated bioaccumulation by detecting levels of selenium in various biological materials. Aquatic surveys by Kifer (1969) found natural levels of selenium in marine fish (See Table 1).

TABLE 1

KIFER DATA

East Canadian Herring	1.3-2.6 ppm
Tuna	3.4-6.2 ppm
Smelt	0.49-1.23 ppm
Menhaden	0.75-4.2 ppm

Wiersma and Lee (1971) sampled several Wisconsin lakes and found 0.5 ppm to 3.5 ppm in sediments. Work in trophic systems is lacking or absent. Where studies have been made, at least in earlier work, emphasis has been on health aspects or survey rather than characterization of ecological association and movement of the selenium.

Physical Model

The lack of data makes it difficult to observe movements and flows of selenium which might occur in natural situations. No postulates can be made based on field observations. Therefore, a model must be developed from basic ideas; synthesized from biological, chemical, and physical principles. The kind of model selected was based on these principles.

There are many types and categories of models depending on the criteria one uses to distinguish among them. The choice of models was narrowed somewhat by the nature of the system being studied. It seemed prudent (Patten 1969, St. Petersburg) to investigate both the physical and mathematical aspects of the selenium movement to approach a more realistic representation of what may occur in a natural system. A batch system was decided upon. A closed system such as an an aquarium would allow an added check on the model. The total amount of selenium is constant throughout the experimental period. (With a plug flow system or flume, one would have to be able to measure accurately the flows in and out of the system.) Thus, if projected to the natural environment, a batch system would represent an idealized lake rather than a stream.

A further decision was obvious from the nature of the problem. Little is known of the chemical transformations or even of the chemical forms that are biologically mediated in the movement of selenium into and out of organisms. Thus, the biological model or non-mechanistic model was chosen. Such a model could not account for mechanisms of uptake or for transformations within the living organism. It would, however, be a summarizing description of the mechanisms of flow among compartments. A mechanistic model would logically succeed the knowledge gained from a non-mechanistic model or biological type model. In addition, a continuous system type of mathematics was chosen. This would be more representative of selenium movement, growth, or bioaccumulation than a discrete or stochastic mathematical representation. Thus, the initial model chosen was a non-mechanistic, continuous, closed biological model representing a batch system.

At this point, decisions about the physical systems were made which would allow a more precise definition of the mathematical model. A system representing natural conditions was desired, so a sample of water from a natural source was chosen. Lake Thunderbird was in close proximity to the University of Oklahoma and represented a typical impounded water of the southwestern United States. The lake was selected for the source of water and sediment. It was undesirable to use a laboratory alga such as Chlorella sp. for want of indigenous biota. A diverse natural flora and fauna would enhance the meaning of any result that might be obtained.

A physical system was then envisioned in which a diverse biota in a closed aquatic bounded aquarium would interact with the bottom sediment in a natural manner (Figure 1). Continuous lighting was considered necessary for maintenance of algal growth for sufficient oxygen production. A rich growth was desired from the standpoint

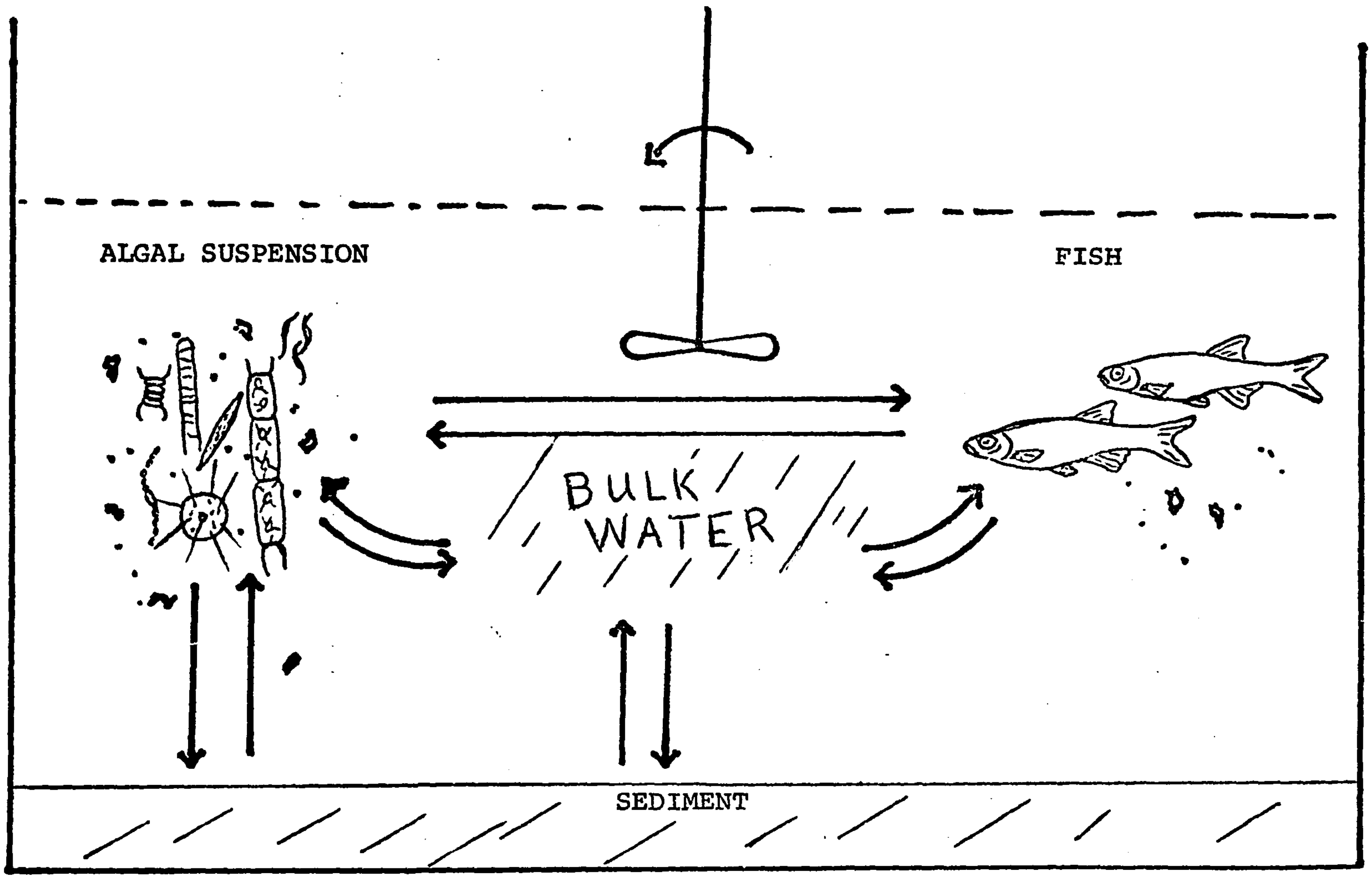


FIGURE 1

PHYSICAL BATCH SYSTEM OF SELENIUM MODEL

of measurement of selenium in the various suspended materials. A motorized propeller would be used to enhance the mixing of oxygen and exposure of algae to light. The control of pH could be affected by the addition of free carbon dioxide.

Minnows (Cyprinidae) were also selected for use in the system. A bottom feeder would complicate a model by an added variable, the changes in mass of the sediment. It would be more tractable to keep the masses of compartments discrete and constant. A strict algae-eating fish might be readily obtained, as an exotic species, but it was considered of value again to use an idigenous species.

In addition, it is documented information (Prosser 1945, Lovelace and Pololiak 1952, Rosenthal 1956, and Chipman 1956) that many chemical species may pass into fish through gills, skin and fins. Uptake does not necessarily infer feeding. Thus, a model may allow for predisposition to uptake through incidental feeding and membrane transfer without a strict trophic relationship. Also, the habit of constant gill ventillation was a desirable characteristic in the minnows for a system which may develop low oxygen levels.

Radiotracer methods were perhaps most attractive from the standpoint of continuous system data collection. A sensitive colorimetric method is reported in Rosenfeld and Beath (1964). This was a complex procedure for continuous sampling and could be considered only as an alternate check. The radiotracer method was the preferred choice for repeated sampling.

Selenium has a number of isotopes which are radioactive with short half-lives. There are no naturally occurring radioactive isotopes. All are produced synthetically. Selenium-75 is produced by activation analysis according to the following schemes in Table 2.

TABLE 2
SELENIUM-75 BY ACTIVATION ANALYSIS

$^{74}Se(n,\gamma)^{75}Se$
$^{75}As(d,2n)^{75}Se$
$^{75}As(p,n)^{75}Se$

Selenium-75 is suitable for experimental purposes because it has a reasonably long half-life (121.4 days).

The subsequent decisions were not so clear and were made through step-by-step process (Klehr 1972) obviated in in the remaining discussion.

A transfer matrix was constructed as an expression of the physical system. It could be written in terms of a mathematical matrix. This process of constructing the matrix must: (a). Summarize information in a comprehensive manner which would allow interaction of the various disciplines in an expeditious way. (b). Identify significant aspects of the chemistry and biology involved. (c). Recognize areas of lack of knowledge. (d). Help organize and expedite the research effort. The format can be summarized in the following steps:

1. Identify system and boundaries.
2. Identify selenium carriers and develop flow charts for them.
3. Identify chemical forms and chemical transforming mechanisms.
4. Relate and superimpose forms and transformations onto carrier flow charts.

The result is found to be a transfer matrix.

System Boundaries

The batch mix would be contained in an aquarium and the confines thereof considered to be the system boundaries. Flows into and out of the container, such as evaporation, would not be considered part of the system. Water would be added for evaporation loss. The container would be idealized and it would not be a part of the system. One must account for sorption onto the sides of the aquarium. The total selenium in the system should remain constant and radiotracer methods must correct for radioactive decay.

Carriers

The basic carriers include the biota, water, suspended material, and sediment. The carriers were listed at length considering each biologically and chemically. Simplifying decisions can be made if reasonable (Patten, 1969) by grouping carriers into functionally similar groups.

The selection of carriers was made with two important criteria in mind. The first was its biological correctness as a natural unit. The second was its ability to be discretely measured with techniques and instrumentation available.

There were numerous kinds of algae (Appendix B-24) including green and blue-green algae. It was considered that these would be discrete as a group of autotrophs and would make a reasonable biological entity. The differences of nutrient requirement between green and blue-green alga might suggest they be separate carriers. However, with mixing, constant lighting, addition of nutrients, and pH control, these differences might be resolved. This would unify the group for purposes of the model.

In addition to algae, the culture contained bacteria, minute fauna, such as protozoa and ashelminths, and other particles. The particles were made of reentrained sediment and a range of suspended and colloidal materials. To sample the water as a compartment carrier, a technique would have to be devised that would allow precise repeatable sampling, and make ecological sense.

A further investigation of sorption and uptake by bacteria and fine particles (Jones 1960) points out that uptake onto small organisms may be related to sorption onto fine particles associated closely with bacteria and algae. The discrete separation of these is not afforded by a simple technique. The 0.45 micron membrane filter was chosen to distinguish the water, colloids, and the dissolved solids from the particles in suspension greater than 0.45 microns. The suspended particulate compartment would contain all particles greater than 0.45 micron. Fish feces would also be included in the suspended particulate compartment. Fine colloids may be excluded.

The fish were seen to be discrete, well-defined entities except for fine particles that would closely adhere to the surface. Larger particles might be quickly rinsed off for repeatability of measurement. The finer particles that closely adhere would not readily be disturbed in a natural situation.

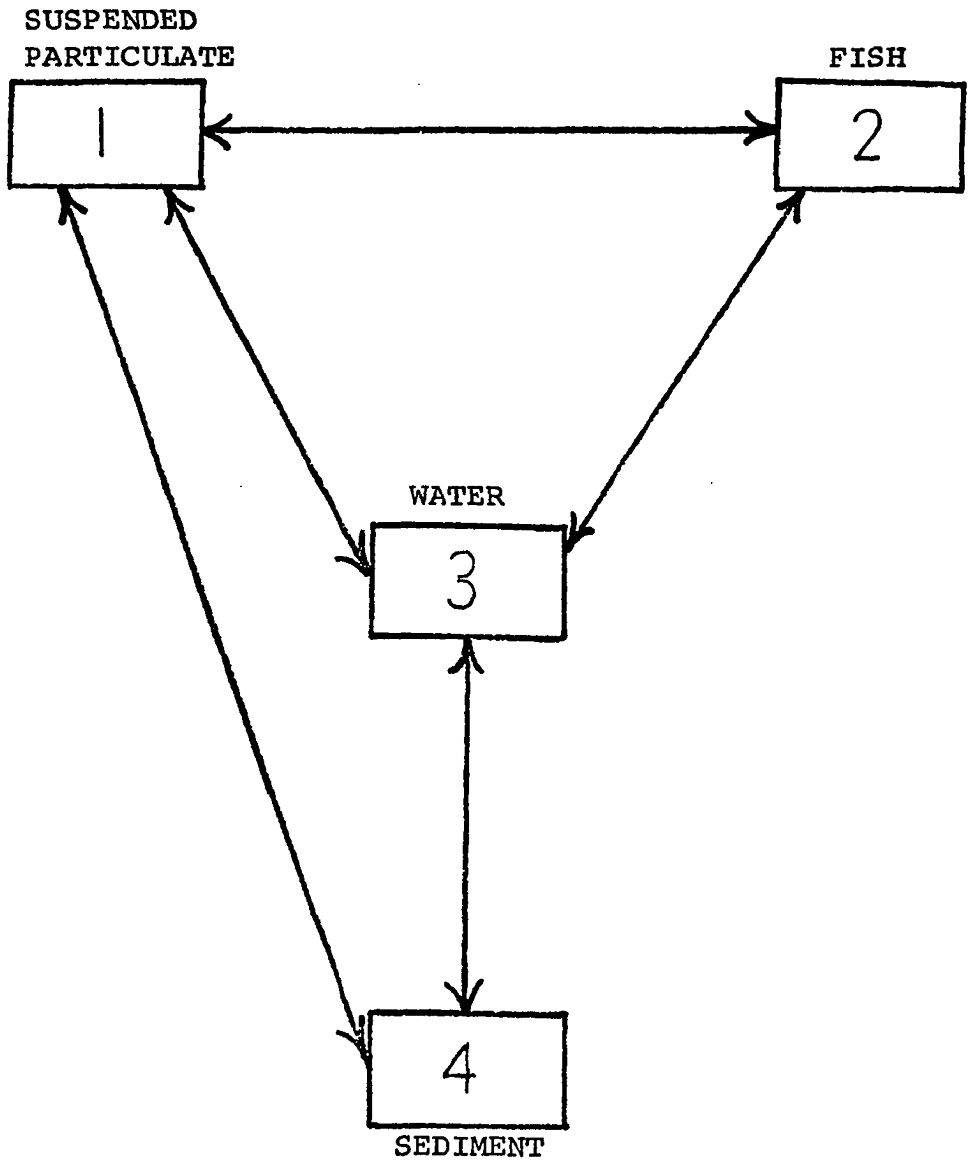
The sediment would be recognized as the unsuspended bulk. Settling and reentrainment were accepted as natural processes involved in selenium movement to be considered in the model.

The carriers then were simplified into four compartments called water, suspended particulate, fish, and sediment (Figure 2). Exchanges might occur among many of the compartments. For example, suspended particulate may have flows of selenium with fish, water, or sediment, that is, with compartment two, three, or four. The suspended particulate may release selenium to the water or may take it from the water. Flows occur in both directions between compartments. It will be noticed that no flows occur between compartments two and four.

To determine the nature of these flows, a carrier interaction table was constructed (Table 3). The selected carriers or compartments were listed such that the two-way interaction table was formed. The procedure was carefully carried out such that the list of carriers was written in sequence across the top of the table from left to right. They were then placed in the same sequence at

FIGURE 2

SIMPLIFIED FLOW DIAGRAM



the left of the table from top to bottom:

TABLE 3
CARRIER INTERACTION TABLE

	(1) Suspended Particulate	(2) Fish	(3) Water	(4) Sediment
(1) Suspended Particulate	--	X	X	X
(2) Fish	X	--	X	0
(3) Water	X	X	--	X
(4) Sediment	X	0	X	--

Decisions about interactions between any combination of carriers was made by focusing attention on a single interaction couple corresponding to a carrier on the left vs. a carrier on the top of the table. The question was asked, "Can selenium in this carrier (one selected from the left-hand column) become selenium in (or move into) a carrier at the top of a column?" An "X" indicating a positive decision was placed in the corresponding box. A negative decision was represented by an "O".

It was considered important that only <u>single step</u> processes be considered. Moreover, a judgement was made as to the significance of a particular flow or interaction movement. An interaction might have been indicated "O" if, even though it occurred, its action in the movement of selenium was insignificant.

The carriers were numbered for convenience, and reference to a decision about a flow was made by a coordinate pair (e.g. suspended particulate to fish would correspond to 1,2). In a discussion, use of the carrier names would be considered a less confusing means of communicating with another person.

One, one; 2,2; 3,3; and 4,4 represent flows and interactions within a carrier and, although interesting, were not important to a non-mechanistic model. These would be storage interactions from the standpoint of the model.

One, two would mean a movement of suspended particles directly to the fish in a phytophagous action, although not primarily a feeding response. This would be the case of incidental swallowing of material not a normal food substance. This was not considered insignificant to the model since even a small flow in this case might be the only flow in the considered direction between the two carriers. Thus, it may have a controlling effect on the movement of selenium.

The reverse flow, 2,1 would involve defecation and in one step would mean a biological flow from fish to suspended particulate. One, three and 3,1 are representative of chemical flows between the water and suspended particulate in one step.

One, four and 4,1 would result from the natural physical action of mixing and gravity.

Two, three and 3,2 are separate biological actions involved with transport of materials across membranes.

Two, four and 4,2 would involve death of the fish or would not occur in a one-step process. An attrition rate through death was not considered a desired research object in the early development of a selenium model. Thus, no provision was made for it and the assumption of no death was made. These were considered insignificant flows.

Three, four and 4,3 would represent chemical interactions in a one-step flow between the sediment and the water.

Chemical Forms and Transformation Mechanisms

The chemical forms were first selected, by investigation of natural forms and chemical reactions (Rosenfeld and Beath 1964, Subcommittee on Selenium 1971, Sienko and Plane 1961, Leddicotte 1961).

Positive oxidation states are +4 and +6 and only a few unstable compounds are in the +2 states. The binding in these states is primarily covalent. In the +4 state, the elements show both reducing and oxidizing properties but in the +6 state act as oxidants. In selenide, selenium assumes the oxidation state of -2. Polyselenides are known, but they are less stable than polysulfides.

Inorganic selenium compounds in natural water are oxides, acids, halides, sulfides, and selenides (Rosenfeld and Beath 1964). All selenium oxides are less stable than their sulfur analogues. The most stable state is SeO_2 rather than SeO_3. Selenium trioxide reacts vigorously with water producing selenic acid, H_2SeO_3. This form was chosen as the experimental source for the initial condition of selenium to be added to the water.

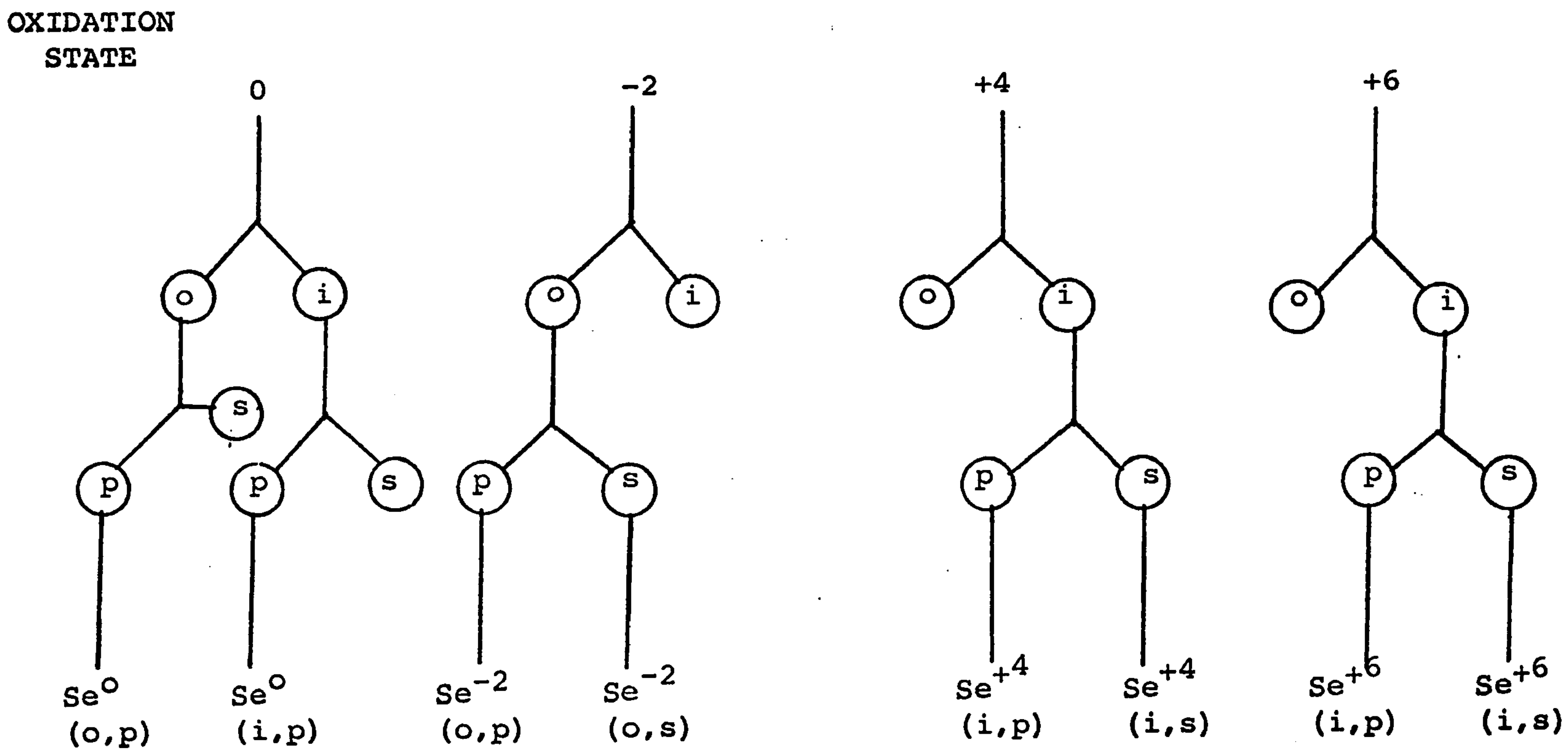
The acid formed from dissolution of selenium dioxide is selenious acid, a weak dibasic acid. Selenic acid is less stable and a stronger oxidizing agent. Selenic acid forms selenate and acid selenate salts. The halides are unstable in aqueous solutions and decompose. The sulfides, SeS and SeS_2, are insoluble in water. Hydrogen selenide is a colorless, very toxic gas resembling hydrogen sulfide in odor and properties. It is less stable. The selenide is a stronger acid than hydrogen sulfide and much more soluble.

Organic selenium compounds that may exist in biological systems and aquatic environments are as follows (Rosenfeld and Beath 1964): (1) Seleno-amino acids such as selenocysteine, selenomethionine, selenocystamine, selenohypotaurine, selenotaurine. (2) Homocyclic and heterocyclic seleno compounds such as selenoguanine, selenocystosine. (3) Selenopantethine. (4) Dimethyl selenide.

The selenium forms possible in water are summarized in Table 4. This list was subsequently reduced in preparation for the interaction table of forms and transformation mechanisms (Table 5). By consideration of chemical properties, various chemical forms of selenium were eliminated from consideration. This was done in sequence of oxidation states as they appear in Table 4, starting with selenium in the elemental state (Se^{o}). Elemental selenium is not soluble; thus, the possibility of soluble forms of free selenium were eliminated from consideration.

The oxidizing conditions of the system proposed would not allow formation of inorganic selenides of the -2 oxidation state. This reduction would occur in biological systems to form organic selenides, but selenious acid would not undergo the reduction in the system. Another possibility was the formation of sodium selenide. This is improbable

TABLE 4
FORMS OF SELENIUM IN NATURAL WATER



i = inorganic

o = organic

s = soluble

p = particulate

TABLE 5
SELENIUM FORMS AND THEIR TRANSFORMATION MECHANISMS
OUTPUT FORM

INPUT FORM	Se^{0} (o,p)	Se^{0} (i,p)	Se^{-2} (o,p)	Se^{-2} (o,s)	Se^{+4} (i,p)	Se^{+4} (i,s)	Se^{+6} (i,p)	Se^{+6} (i,s)
Se^{0} (o,p)	———	Desorption	Metabolism	Metabolism and Release	Multistep	Metabolism and Release	Multistep	Metabolism and Release
Se^{0} (i,p)	Adsorption	———	Metabolism	Metabolism and Release	Multistep	Multistep	Multistep	Multistep
Se^{-2} (o,p)	Oxidation and Adsorption	Oxidation	———	Decomposition	Multistep	Metabolism and Release	Multistep	Metabolism and Release
Se^{-2} (o,s)	Oxidation and Adsorption	Oxidation	Diffusion or Membrane Transport	———	Multistep	Multistep	Multistep	Multistep
Se^{+4} (i,p)	Multistep	Multistep	Multistep	Reduction by Metabolites	———	Dissolution or ion-exch. or Reduction	Oxidation	Oxidation and Dissolution
Se^{+4} (i,s)	Reduction and Adsorption	Bacterial Metabolism or Reduction	Reduction by metabolites or Metabolism	Reduction by metabolites or Metabolism	Precipitation or Ion-Exchange	———	Oxidation and Ion-Exchange	Oxidation
Se^{+6} (i,p)	Multistep	Multistep	Metabolism	Multistep	Reduction	Reduction	———	Ion-Exchange
Se^{+6} (i,s)	Reduction and Adsorption	Bacterial Metabolism Reduction	2-step Reduction or Metabolism	2-step Reduction or Metabolism	2-step Reduction or Metabolism	Reduction	Ion-Exchange	———

due to the instability of the compound. Anaerobic production of hydrogen selenide was not considered likely to be significant. Only the organic forms of the -2 oxidation state were considered.

Selenites and selenates were thought to be significant in inorganic forms. Organic forms exist only in the reduced state. The +4 and +6 oxidation states of inorganic selenium were thought to be important both as soluble and particulate forms.

This elimination process left eight chemical forms of importance. Table 5 was prepared to summarize the interaction possibilities of these forms. They were considered as one-step processes, but for convenience, sometimes more than one step was recorded. Each change of solubility, oxidation state, form, or carrier, would constitute a step.

The table was interpreted in the same manner as the previous interaction matrix, with the considered transformation going from row to column. For example, by row (the first input form), elemental selenium in the organic particulate form can be transformed into inorganic particulate by desorption, a single step process. It may transform itself into organic selenide particles by metabolic processes. This would be a single step in which proteins may be formed within the living organisms. The formation of soluble organic selenide requires an additional transfer of carrier by release after the metabolic process. This requires a two step process. The remaining selenites and selenates require more than a single step.

Continuing down to the second row, elemental selenium in the inorganic particulate form may transform to the organic particulate form by adsorption, a single step. It may also form organic selenide particles through the metabolic process. However, to form the soluble organic selenide, two processes are required; that of metabolic synthesis and release of a soluble form. The process is more than a single step since the formation of a product requires a change of carriers or compartments. The remaining oxidized forms all require processes in addition to metabolism and are therefore multi-step processes.

Continuing with the third and remaining rows, transfers of various kinds are suggested.

This table was thought to illustrate most of the significant kinds of chemical transformations that might occur in the proposed selenium model. These transformations are superimposed on the carrier flow diagram to identify the chemical, physical, and biological flows between the carrier couples. The following section explains the process in more detail.

The Superimposing of Chemical Forms and Transformations onto the Carrier Flow Table

Each of the chemical forms and transformation mechanisms was compared with a carrier flow interaction couple and the transforming chemical change was identified as a chemical, physical, or biological mechanism and recorded in the corresponding box (Table 6). Each carrier couple was treated in the same manner until all possibilities were recorded in the transfer matrix. For example, if Table 5 is observed for one-step processes, the first transfer is a desorption as described previously. Free selenium particulate is changed from organic to inorganic. Desorption would result in free, metallic selenium which is insoluble. This process is chemical, and would probably occur only within a given carrier and would not be represented as a flow in the final transfer matrix.

An additional example would occur with the metabolic change of free organic selenium particles to the organic selenide, particulate form. This reduction represents a complex process of oxidative deamination of proteins and the anabolic process of synthesis of biological material containing selenium. This would be identified on the final transfer matrix as feeding of the fish. This also occurs in the transformation of free inorganic particulate to organic

TABLE 6

TRANSFER MATRIX

	SUSPENDED PARTICULATE	FISH	WATER	SEDIMENT
SUPENDED PARTICU-LATE	———	FEEDING ADSORPTION	ION EXCHANGE OXIDATION REDUCTION DISSOLUTION DECOMPOSITION	SETTLING IMPINGEMENT
FISH	DEFECATION	———	URINATION	0
WATER	DIFFUSION ION EXCHANGE OXIDATION REDUCTION PRECIPITATION MEMBRANE TRANSPORT	MEMBRANE TRANSPORT DIFFUSION	———	ION EXCHANGE PRECIPITATION OXIDATION REDUCTION
SEDIMENT	REINTRAINMENT	0	DECOMPOSITION DISSOLUTION REDUCTION	———

selenide particles.

The next occurrence of a single step process in Table 5 is adsorption of inorganic free selenium particles to form organic particles of free selenium. This would be a flow in the transfer of suspended particulate by adsorption onto fish.

Additional single-step processes from Table 5 not already mentioned, are listed directly as a chemical process or included in a physical or biological process on the transfer matrix. Oxidation represents the transformation of soluble and particulate selenide to free, inorganic particles. The former would represent a flow from water to suspended particulate. The latter would cause no change of carrier. An additional oxidation of soluble selenite to soluble selenate would likewise result in no flow since this would occur without a change of carrier. The same is true with the particulate selenite to particulate selenate oxidation.

Decomposition would be a cause of flow of organic selenide particulate to soluble organic selenide. This flow would be found from suspended particulate to water and from sediment to water as bacteria decompose the organic material.

Diffusion or membrane transport is the biological uptake that would transform soluble, organic selenide into a particulate organic selenide. No other transformation of this type occurs as a single step. The flows which would result would be from water to fish and water to suspended particulate.

Reduction by metabolites is a transformation of particulate and soluble selenites to selenides. The particulate selenite becomes soluble selenide representing flows from suspended particulate and from sediment to water. Soluble selenite forms particulate selenide in the same way, representing a flow from water to suspended particulate or from water to sediment.

Dissolution is the process transforming particulate selenite to soluble form and represents a flow in the final transfer matrix of suspended particulate to water, and sediment to water.

Reduction is a chemical process which makes selenium more soluble when it has been precipitated with ferric ion flock formation. The reduction of the iron complex releases the selenium. An example of reduction is the transformation of particulate selenate to soluble selenite. This would be part of the flow of suspended particulate to water or sediment to water. The reverse case might occur in the reduction of soluble selenate to a particulate selenite such as an insoluble calcium selenium oxide or sulfide. This transformation would represent flow from water to suspended particulate or water to sediment. The transformation of particulate selenate to particulate selenite and the transformation of soluble selenate to soluble selenite represent no flows when superimposed on the carrier flow matrix.

Precipitation is the process transforming soluble selenite to particulate selenite and may be represented by the scavenging action of the ferric ion or the reaction of selenious acid with calcium ion. The flow represented on the transfer matrix would be from water to suspended particulate or from water to sediment.

Ion-exchange occurs as a single step when the oxidation state does not change. The ion-exchange in both directions between particulate selenite and soluble selenite would constitute flows of selenium between suspended particulate and water, and sediment and water. Similar flows would occur among the selenates.

The chemical, physical and biological actions were thus identified and are summarized as shown in the final transfer matrix (Table 6). Physical flows which were not recognized by identification of chemical and biological processes were due to the physical mixing of the system and were identified in the proper places. Settling and impingement would cause suspended particles to become sediment by definition. Likewise, reentrainment of sediment would define suspended particulate.

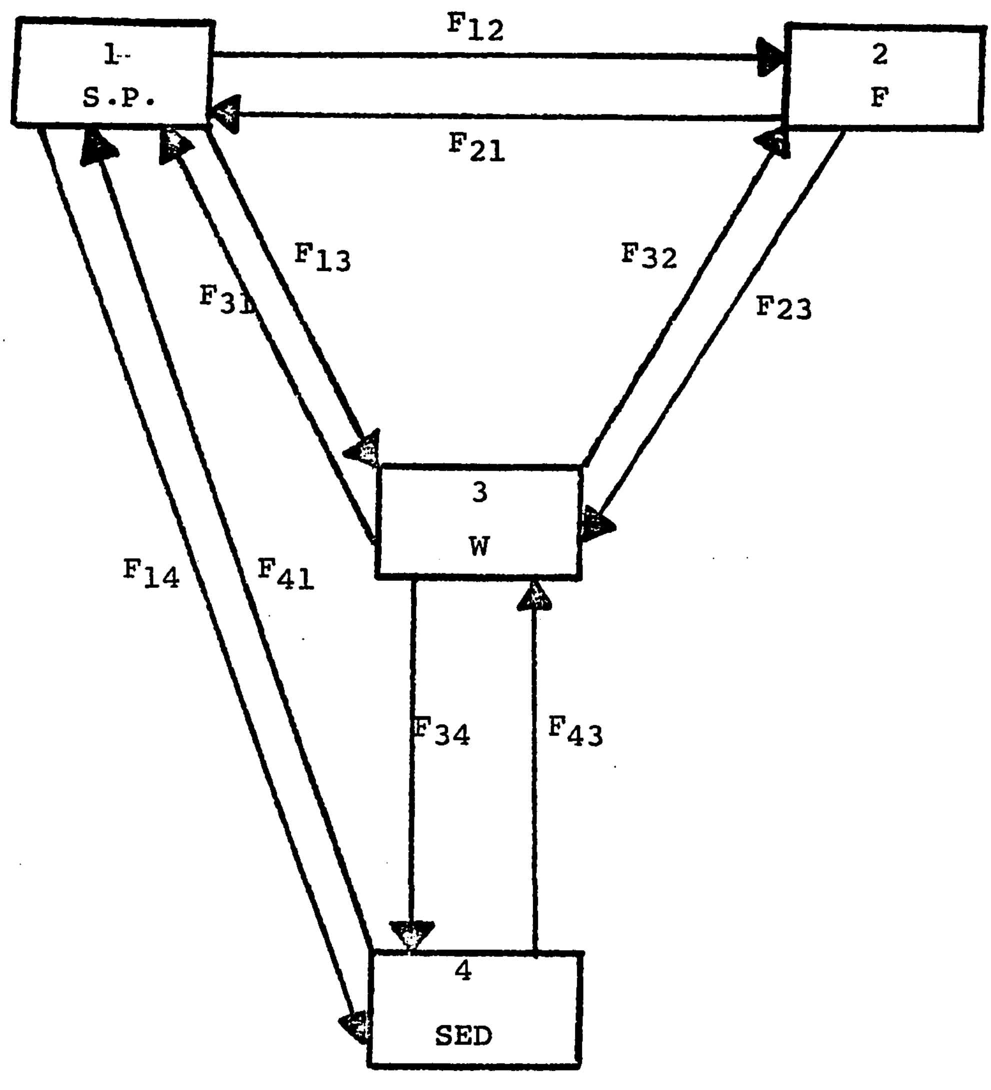
The Mathematical Expression of the Model

The transfer matrix represents a summary of the preceeding discussions and lends itself to mathematical expression. The transfer matrix was diagrammed in schematic form so that the flow relationships could more readily be visualized for mathematical expression (Figure 3). The arrows F_{i1}, F_{i2}, $F_{i3}, \ldots$ represent the sum of the flows out of a certain compartment (X_i)and are part of the sum of flows into other compartments. The boxes represent the chosen carriers and are frequently referred to as compartments in the model.

The model chosen was assumed to be linear as suggested by Patten (1969) when no clear knowledge of non-linear relationships occur. A classic model (Odum 1957) utilized completely the donor controlled model. That is, with a given variable X_i, and a time-related constant a_{ij}, consider the flow $F_{ij} = a_{ij}X_i$. This represents a donor controlled relationship. Other types of flows may be:

$$F_{ij} = a_{ij}X_j \quad \text{or} \quad F_{ij} = a_{ij} X_i X_j .$$

FIGURE 3
FLOW DIAGRAM



S.P. - Suspended Particulate
F - Fish
W - Water
SED - Sediment

The former is of the acceptor controlled type and the latter nonlinear, controlled by both the donating carrier and accepting carrier. An example of acceptor controlled flow would be a cow foraging on lush vegetation. The flow into the cow, F_{ij}, is related to the capacity of the cow to eat and not to some quality of the grass. If, on the other hand, the amount of grass were limited, the donor (grass) would control the flow of energy since the cow would not be eating to capacity. In ecosystem modeling the assumption is frequently made that the donor has nonlimiting amounts and therefore controls the flow. This assumption was made with each forward and reverse flow in the selenium model.

From this point, the complete model was readily expressed mathematically (Table 7) as a system of linear donor-controlled equations. The equations were expressed in matrix form (Figure 4) for convenient notation.

Related information was put in tabular form for concise expression of pertinent assumptions surrounding the model (Table 8).

With the completion of the theoretical aspects of the model, the experimental methods and procedures were next to be developed.

TABLE 7

EQUATIONS--LINEAR DONOR CONTROLLED

$$\dot{X}_1 = F_{21} + F_{31} + F_{41} - F_{12} - F_{13} - F_{14}$$

$$= a_{21}X_2 + a_{31}X_3 + a_{41}X_4 - a_{12}X_1 - a_{13}X_1 - a_{14}X_1$$

$$\dot{X}_2 = F_{12} + F_{32} - F_{21} - F_{23}$$

$$= a_{12}X_1 + a_{32}X_3 - a_{21}X_2 - a_{23}X_2$$

$$\dot{X}_3 = F_{13} + F_{23} + F_{43} - F_{31} - F_{32} - F_{34}$$

$$= a_{13}X_1 + a_{23}X_2 + a_{43}X_4 - a_{31}X_3 - a_{32}X_3 - a_{34}X_3$$

$$\dot{X}_4 = F_{14} + F_{34} - F_{41} - F_{43}$$

$$= a_{14}X_1 + a_{34}X_3 - a_{41}X_4 - a_{43}X_4$$

FIGURE 4

MATHEMATICAL MODEL

$$\begin{pmatrix} \dot{X}_1 \\ \dot{X}_2 \\ \dot{X}_3 \\ \dot{X}_4 \end{pmatrix} = \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} \\ b_{21} & b_{22} & b_{23} & 0 \\ b_{31} & b_{32} & b_{33} & b_{34} \\ b_{41} & 0 & b_{43} & b_{44} \end{bmatrix} \begin{pmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \end{pmatrix}$$

The notation b_{ij} represents uptake rate constants a_{ij} in matrix form.

TABLE 8
SUMMARIZING DEFINITIONS

OBJECTIVE - The objective of the study was to propose a model of the movement of selenium in a simplified, closed aquatic system.

CRITERIA - Experimentally determined parameters and estimated values would be substituted into the mathematical model and simulation would be made with analog computer programs.

COMPONENTS - X_1 = Suspended particulate-algal mixture, bacteria, other biota, feces, sorbed and suspended particles.

X_2 = Fish-Minnows, Hybognathus nuchalis

X_3 = Water-Lake water culture filterable through 0.45 micron filter.

X_4 = Sediment-Dredge sample lake sediment, unsuspended bulk.

INITIAL CONDITION - Spike selenium-75 and stable selenium in form of selenious acid into X_3.

VARIABLES - X_i = Milligrams selenium per compartment.

a_{ij} = Average uptake constants, fraction per hour.

F_{ij} = Flows between compartments representing physical, chemical, and biological activities describing the movement of selenium between compartments.

CHAPTER III

EXPERIMENTAL PROCEDURES AND METHODS

The flow diagram in Figure 3 summarizes the model. The objective is to obtain parameters which will lead to simulation of the model. The experimental procedures were designed with this objective in mind. The physical system was set up to allow flows of selenium from the water to the other three compartments as seen in Figure 3. Methods were devised to measure the amount of selenium in each compartment as a function of time. Statistical analyses of the data are used to determine flow rate constants which will ultimately develop the final simulation.

Experimental System Preparation

The laboratory container selected for use in the experimental system was a twenty gallon aquarium (one foot by two feet) with a depth of one foot. Precise dimensions can be seen in the diagram (Figure 5). The system was run with duplicate aquaria (Tanks I and II). The tanks were stirred continuously throughout the experimental period.

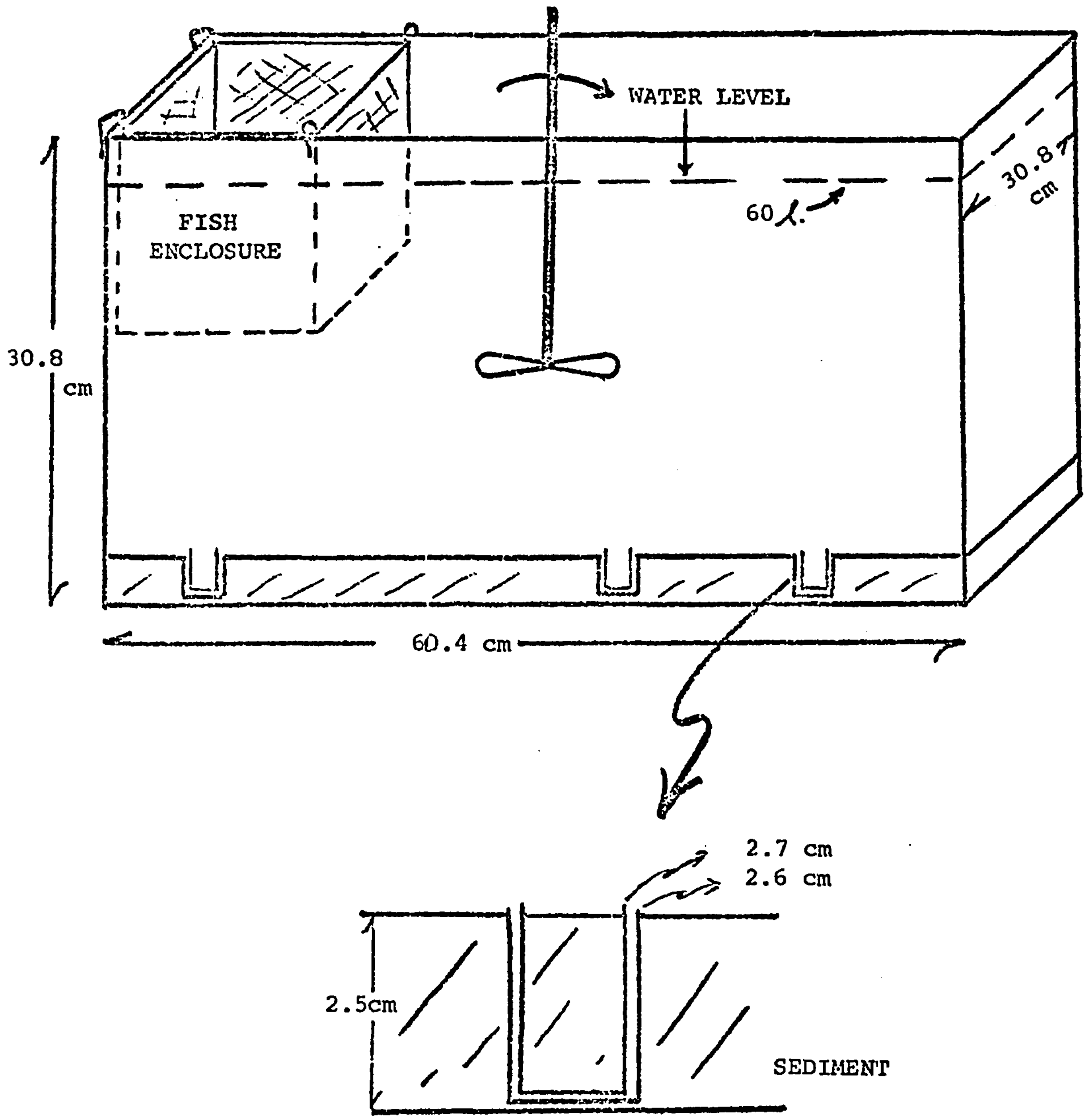


FIGURE 5. PHYSICAL MODEL,
CLOSEUP OF SEDIMENT CONTAINER <u>IN SITU</u>

The tanks were situated in front of identical banks of General Electric Cool White fluorescent bulbs. They were continuously illuminated with approximately 100-300 foot-candles light intensity as measured with a light meter through the tanks. The variation of light intensity was a result of changes of turbidity within the system during operation.

A fish enclosure 15cm. x 15cm. x 30cm. was hung over the edge of each of the tanks. A four millimeter nylon mesh was used (Figure 5).

Water

The water selected for the experimental tanks was taken locally from Lake Thunderbird, a Bureau of Reclamation impoundment at Norman, Oklahoma. The samples were taken in open water, filtered through cotton and used in the laboratory for preparation of the stock cultures. To the culture was added a modified Knop's nutrient media (Appendix A-1). The culture was stirred constantly and put under continuous lighting similar to the experimental tanks. This was the stock culture for the water and suspended particulate compartments.

Sediment

The sediment was also obtained from Lake Thunderbird by means of an Eckman dredge sampler. Three open water sites were selected at random and samples were combined. The sediment was air dried, ground and passed through a No. 10 sieve. A particle size analysis by sieve series was carried out (Appendix A-2).

The sediment thus prepared was spread in an even layer on large porcelain trays. It was sectioned into 16 regular sections and portions were drawn at random from the tray and combined to make up the sediment compartment to be put into the bottom of the experimental tanks. A small cup was used to procure the combined sediment by dipping it to overflowing and leveling it with a spatula. This technique was used to prevent discrimination against particles of a given size.

It was considered that free grab samples of the sediment would be disruptive and result in non-reproducible sampling. Therefore, a method was devised which would allow for standardized *in situ* sampling containers which would be retrievable for measurement and could be replaced without disturbing either the sample or the sediment. The sampling containers were prepared (Figure 5) in the following manner.

The sediment sample containers were made from the 19 mm. diameter plastic autoclavable caps for 16 x 160 mm. culture tubes. A band saw was used to cut from the open end until the desired height was reached. The 26 mm. vials thus produced were prepared to be recessed into the sediment.

Since removal of samples would allow selenium flow into the hole or cause its walls to collapse, a sleeve with a bottom was used to line the hole in which the sample container was placed. This lining sleeve was fashioned by cutting the top from a 15 ml. screwcap polyethylene bottle, resulting in a wide top cyclinder with a bottom. Thus, when the sample container was in place, it nested in the sleeve so that the top was protruding only enough to allow grasping by the sample retriever.

The sample containers were filled with sediment by weighing out particle size grades (Appendix A-3) of sediment that represented precisely the particle size distribution for the whole sediment as previously determined. Such a distribution totaling 10.8289 g. was carefully weighed into each container. This weight represented

$$\frac{10.82g}{7200g} = \frac{1}{664.887}$$

of the total sediment compartment. Eleven containers were saturated with water and put in place in the sediment in each tank (Figure 6).

In order to decide representative placement of the sediment sample containers, some sort of bottom profile of dynamic similarities was sought. Before putting sediment into the experimental tanks, a 30.8 x 60.4 cm. rectangle of blotting paper was saturated with water and placed on the bottom of each of the tanks. The tank was filled with water to the 60 l. mark and the propeller was then turned on. A representative sample of sediment was introduced around the center of the tanks above the propeller by graded particle size in sequence. The particles were allowed to impinge upon the paper at the bottom. In addition, a quantity of suspended particulate (algae, fish, feces, etc.) was treated in the same manner and allowed also to impinge onto the bottom paper. The resultant bottom profile (Figure 6) was removed carefully with the paper and allowed to dry. It was fixed with spray shellac, and photographed. The profile was then used as a rationale for the positioning of sediment sample containers.

The bottom profile was divided into four geometric areas (Figure 5), concentrically inscribed within each other as follows: an outside rectangle containing an elipse,

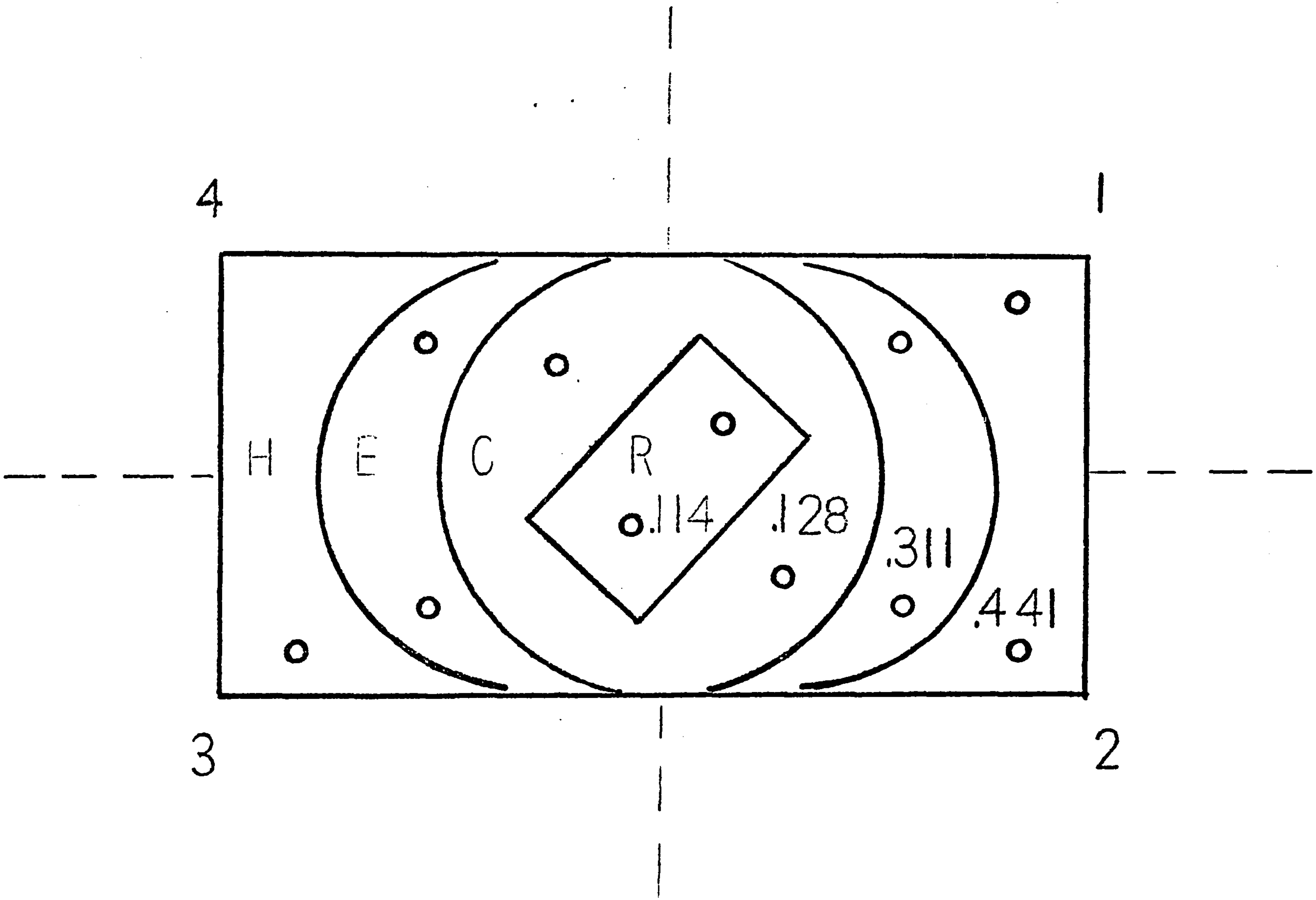


FIGURE 6, PLAN VIEW ACQUARIUM
GEOMETRIC AREAS, DISTRIBUTION
OF SEDIMENT SAMPLE CONTAINERS, QUADRANTS

a circle, and in turn, a small rectangle. The dimensions for these areas was determined by a combination of tracing on acetate overlay, inspection, and measurement with a metric ruler. The idealized areas were drawn more carefully to actual size. Placement of sampling containers was based on a combination of calculated centroid position, symmetrical placement of duplicate samples and wall reflection interference (Figure 6). The geometric areas were symbolized by letter for their mutually exclusive areas, starting with the inner rectangle, R, the circle, C, elipse, E, and the corners, H (from hyperbola). The areas of each of the regular geometric figures was calculated and the area of the mutually exclusive sampling regions was determined by subtraction. The total bottom area was calculated to be 1860.32 cm^2, and the described geometric mutually exclusive areas were determined to be fractions of the bottom area:

$$H=.4408,\ E=.3111\quad C=.1289,\ R=.1142.$$

Fish

The supply of fish was obtained from a local bait shop and the fish were sorted into a rough size range. Only those within the one to three gram range were used experimentally. Hybognathus nuchalis was used for the stock fish source. The fish were kept in the same tank used for the stock culture of water and of suspended particulate compartments.

The fish enclosures in the experimental tanks were suspended over quadrants 3 and 4 of Tank I and over quadrants 1 and 2 of Tank II (Figure 6).

The fish were fed at the rate of 0.11 g. food per g. fish per day using crushed pellets under the commercial name of SHRIMP-EL-ETTES. Both the lake water, lake sediment, and the fish food were analyzed for selenium by the aminobenzidine procedure taken from APHA, "Standard Methods for the Examination of Water and Waste Water." The fish food and sediment were crushed and homogenized in 0.1N. HCl and diluted in a volume of water before the standardized procedure was followed. The samples and standards were read in the Beckman D-B Spectrophotometer at 420 nanometers. Percent transmittance was recorded, and concentrations of selenium determined.

Suspended Particulate

The suspended particulate was that which developed naturally from the culture. The diverse biota which developed in the experimental tanks was examined occasionally for species and types, but no stringent attempt was made to characterize it (Appendix B-24).

The first run weights of suspended particulate were small enough so that it contributed in part to the lack of statistical precision in count rate data. Nutrients were added prior to the second run to stimulate a higher level of algal growth and improve the data obtained.

Experimental System Operation

To prepare for the experimental period, the sediment containers were filled as described previously. When wetted, the sediment sample containers had a depth the same as total sediment depth in the tank. The sediment and sample containers were left in place and the supply stock culture of suspended particulate and water was added carefully without disturbing the sediment. Time was allowed for the sand to be wetted and the voids filled with water. Then water was added up to a volume of sixty liters. The propellers were positioned and turned on. The light banks were lighted and the fish were introduced into the enclosure. The system was operated for a few days prior to addition of the radioselenium.

Sampling The Experimental System

Sampling

Sampling both experimental variables and stability parameters of the physical system were made on a daily or near daily basis. Parameters that were chosen to monitor the stability of the system were temperature, pH, dissolved oxygen, and filterable residue. Sampling of the compartment variables in the experimental tanks was done on a logarithmic time basis. Samples were taken at first by minutes, then increased to a daily interval. The sampling routine was as follows: The stability parameters were measured first as explained below. Then, the experimental variables were sampled in sequence: the water compartment, suspended particulate, fish, and sediment. With the completion of sampling, the sides of the tanks and other immersed structures (net, propeller) were scraped or brushed clean of deposition of suspended material. A microscope slide permanently fixed onto a glass rod was used as a scraper for the tank walls. The fish were fed, and the level of the tanks was returned to the 60 l. ± 3%. Evaporation loss accounted primarily for the approximately 250 ml. of water added per day.

The only water used in all experimental work or associated procedures, with the exception of the stock culture, was deionized water prepared by distillation and subsequent percolation through an ion exchange resin.

The stability parameters measured were temperature, dissolved oxygen, pH, and filterable residue. The temperature was measured to the nearest degree by suspending a thermometer in each tank. The thermometer was read through the glass wall without removal.

Dissolved oxygen was determined to the nearest 0.1 p.p.m. A membrane-type dissolved oxygen meter was used. It was calibrated and checked by the alkaline azide dissolved oxygen modification in Standard Methods.

A dip sample was taken for pH determination on a Photovolt digital pH meter to the nearest 0.1 pH unit. The sample was then returned to the tank. If the pH approached 9.0 units, it was lowered with the addition of carbon dioxide gas.

Filterable residue was determined with a total dissolved solids meter. The filtrate sample used to determine the water compartment counting rate was used for the determination. The reading was taken directly from the meter, adjusted for dilution, and recorded to the nearest part per million. The sample was returned to the tank.

Water Compartment, Suspended Particulate Compartment

The water and suspended particulate compartments were sampled together. In the first experimental run a 20.0 ml sample was freely drawn from a point approximately 10 cm. below the surface of the tank. A pipette was used which had been broken, fire-polished to a larger orifice, (Appendix A-5) and re-calibrated. The sample was pipetted into a 47 mm. diameter glass Millipore filter apparatus which was fitted to a 1,000 ml. suction flask operated off a water faucet aspirator. After the pipetting was complete, the sample was filtered through a 0.45 micron cellulose acetate Millipore filter and collected directly into a clean 25 X 250 mm Pyrex test tube. The tube was removed and the count rate determined. The value was recorded as the water compartment sample counting rate. The filtrate was used for filterable residue determination and then returned to the experimental tank. The filter was removed with the filter cake and dried in a planchet oven at 50° C. for 24 hours. The filter was placed in a 50 mm. petri dish, covered, removed from the oven, and allowed to cool for a short time before weighing to constant weight. The weight was recorded to the nearest 0.1 milligrams. The dried filter was rolled and inserted into the bottom of a 25 x 250 mm. Pyrex test tube and a count rate determined. This was recorded as the suspended particulate sample rate.

In the second experimental run, the water and suspended particulate sampling was done as 2 consecutive 20.0 ml. samples. The first 20.0 ml. pipetting was superimposed on top of the filter cake such that it was completely re-suspended by the additional 20.0 ml. Then the suction was turned on. The filtrate thus obtained was simply returned to the experimental tanks. The filter cake was treated as above, dried, weighed, and counted with the recording of weight and count rate to reflect a 40.0 ml. sample instead of a 20.0 ml sample.

In both experimental runs, the filter apparatus was rinsed 6 times with deionized water after each sample was filtered. Pipettes were likewise rinsed with dilute HCl and then acetone.

Fish

The fish were handled one at a time. Each was netted, clasped in gloved hand, and given a quick rinse in a beaker of deionized water. The purpose of this was to remove any loosely adhering particles properly belonging to the suspended particulate compartment. The fish was then put anterior end down into a 25 x 250 mm. clean test tube. Deionized water was used to bring the volume of fish and water to 20 ml. The tube containing the fish was put into the counting chamber and a counting rate was determined. This was recorded for each fish as a sampling of the fish compartment. The fish was placed in a waiting tank containing oxygenated, deionized water until all the fish in the tank were counted; and then they were all returned to the experimental tank. After counting each fish, the water in which the fish was counted was returned to the counting chamber for the detection of loss from the fish while being counted.

Sediment

The sediment was of constant depth and organized for the purpose of sampling into four geometric areas as described in a previous section. The samples were removed with the help of a retrieving device similar to those used in grasping objects that have fallen into small tubular orifices such as sink drains. The grasping device was used as a sample retriever by immersing the distal end to the bottom of the experimental tank. By squeezing the top, one could carefully grasp the container without disturbing the sediment or the sleeve in which it was sitting. If the visibility of the sample container was occluded by the turbidity of the suspended material, a depth-viewing device was employed. This allowed the experimenter to see the container with greater clarity. This was simply a 1000 ml. graduated cylinder with the projecting part of the base removed to allow juxtaposition of the viewer to the sample retriever. The viewing device was held by hand and the otherwise nonvisible samples could be seen clearly and retrieved with the necessary care.

When the sample containers were removed, each was drained of excess water and put into the counting chamber. A count rate was recorded for each sample container. During the time when the samples of sediment were removed, it was almost never necessary to turn off the propeller or to disturb the mixing dynamics of the experimental tanks.

There was a separate Roman Numeral designation for each tank (I, II) and numerals for the quadrant relative to a tank center origin (1, 2, 3, 4). Thus, a sample container in the lower left hand corner of tank II, would be designated II3H (Figure 6).

Radioisotope Tracer Procedures

Radioisotope Source Preparation

The radioisotope was received as selenium-75 in the chemical form H_2SeO_3 in 0.5N. HCl. The 1 mCi. source had a specific activity of 175 mCi. per mg., having a total of 0.0057 mg. solids in 0.1 ml. The isotope was removed from the container, checked for contamination and opened. The total volume was made up to 5.0 ml. by adding deionized water. This was the stock solution of radioselenium with a specific activity of 1 mCi per 5.0 ml.

Specific Activity for Run I

Several five lambda aliquots of radioselenium were removed and diluted 1:200,000. This was the same material as used for the efficiency calibration (see Appendix C-7, 8).

A total quantity of the 2.4316×10^6 cpm was added to a volume of water containing 1.200 mg. selenium. The selenium solution was prepared from H_2SeO_3 reagent and deionized water. The labeled selenium mixture was diluted to 400 ml, mixed for 15 minutes, and then divided into two aliquots for spiking the two experimental tanks for the first run.

The specific activity for the first run spike quantity was then:

$$\frac{2.4316 \times 10^6 \text{ cpm}}{1.200 \text{ mgSe}} = 2.0263 \times 10^6 \frac{\text{cpm}}{\text{mgSe}} .$$

Specific Activity for Run II

Approximately 50 lambda were removed from the stock radioselenium solution and diluted 1:200,000 as in the first run. Four aliquots were taken for readings in the standardized 20.0 ml. 25 x 250 mm. test tube. Count rates were as follows in TABLE 9.

TABLE 9

SPECIFIC ACTIVITY FOR EXPERIMENTAL RUN

Aliquot from Dilution of Radioselenium Solution	Count Rate Standard Geometry cpm per 20.0 ml
1	64,377
2	63,992
3	64,234
4	64,572
Average	64,294 cpm ± 508 cpm

A total quantity of the dilution containing 25,717,600 cpm was added to a volume of water containing 12.000 mgSe. The selenium was prepared from H_2SeO_3 reagent and deionized water. The labeled selenium mixture was diluted to 400 ml; mixed for 15 minutes, and divided into two aliquots for spiking the two tanks of experimental run II.

The specific activity for the second run spike quantity was then:

$$\frac{25.7.76 \times 10^6 \text{ cpm}}{12.000 \text{ mg Se}} = 2.1431 \times 10^6 \frac{\text{cpm}}{\text{mg Se}}.$$

Counting System

A gamma counting system was set up consisting of a 3 inch sodium iodide well crystal, a photomultiplier, and an Ortec Model 420 single channel analyzer. The detection unit was fixed upright in a counting chamber constructed of lead bricks which were precleaned to provide low background counting rates.

The following standard sources were used to calibrate the single channel analysis system. The linearity of the system was determined by using the same sources.

TABLE 10

CALIBRATION ENERGIES

^{57}Co---0.136 M.e.v.
^{133}Ba---0.080,0.276,0.302,0.356,0.382 M.e.v.
^{137}Cs---0.662 M.e.v.

A gamma spectrum of the selenium-75 was run to establish the proper operating voltage, baseline, and window width for the detection of the isotope. A source was placed in the counting chamber and the spectrum was obtained by recording count rate for the source at incremental increases in voltage. A plot was made of count rate vs. pulse height voltage (Appendix C-5).

Optimum operating parameters for the counting system were a baseline setting of 0.029 V. to eliminate noise, and a window width of 0.500 V. to allow greatest sensitivity for detection of the complete selenium-75 spectrum.

Counting Efficiency

Several 5 lambda aliquots were removed from the selenium-75 stock solution and placed into 25 x 250 mm. test tubes in a droplet at the bottom. The tubes were diluted by the addition of 20.0 ml. of deionized water. The count rate was determined after gentle swirling. A 100 lambda aliquot of the dilution was removed and put into a similar clean test tube. To this second tube were added 19.9 ml of the deionized water bringing the volume to 20.0 ml. The total dilution from the 1 mCi. stock bottle was then a factor of 2×10^{-5}. The machine efficiency was then calculated on the basis of this fraction of the source activity in a 20.0 ml. volume contained in a 25 x 250 mm. Pyrex test tube (Appendix C-7). The efficiency was determined to be 64.2%.

One lambda of radiolabeled H_2SeO_3 from the stock solution was pipetted into each of eight 25 x 250 mm. Pyrex test tubes. A series of concentrations of the same compound with stable selenium was prepared and 20.0 ml. of each respective concentration was added to the tubes containing the isotope. All dilution and rinse water was deionized water. Tubes were pre-cleaned in an acid bath of the same water. The pre-counted tubes were filled as described, allowed to set 15 minutes, and placed into the counting chamber. Counting rates were recorded before and after emptying and rinsing a series of times. The fraction of selenium sorption on glass test tubes was determined (Appendix C-9).

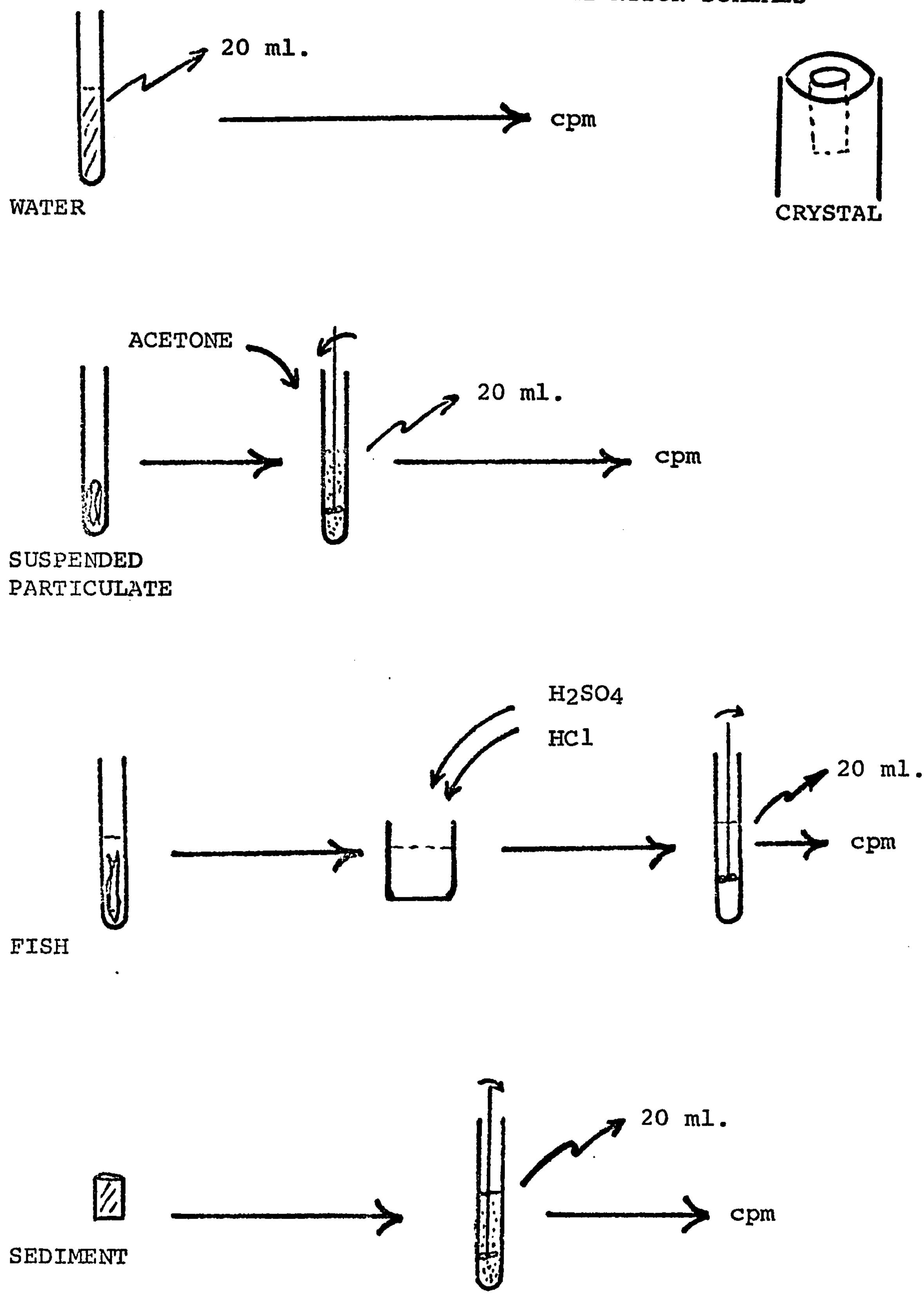
Calculation of amounts of selenium added with the tracer was made to see if the very dilute concentrations of stable selenium compound were significantly altered by the addition of the isotope (Appendix C-2).

Sorption was checked in the experimental tanks by daily scraping of the walls with a microscope slide fixed to a glass rod. As a check on this, another microscope slide was left in the tanks throughout the duration of the experiment. A second slide was put into each tank on occasion and left for a 24 hour period after which it was removed and scraped in a manner similar to the above tank walls, and placed on the crystal detector to be checked for remaining activity. At the end of the experimental period, the slide that had remained in each of the tanks for the duration of the experiment, was removed and counted, then scraped and again counted.

Normalization

Since the specific activity was determined in a standard 20.0 ml. volume, the water and other compartments must be normalized to this geometry (Figure 7). Count rates can then be converted to milligrams of selenium. The water compartment was normalized in the following manner: Five lambda were removed from the source stock bottle and diluted to 20.0 ml. A 100 lambda aliquot was removed and placed into each of several previously counted standard test tubes. A counting rate was determined and the tubes were filled with 20.0 ml. of 10^{-2} p.p.m. unlabeled selenium solution and again counted. A more complete set of paired data was obtained in a similar manner with the exception that counting rates were determined for 1.0 ml. increments up to 20.0 ml. (Appendix C-10).

FIGURE 7. COMPARTMENT NORMALIZATION SCHEMES



The effect of stirring was observed by preparing two series of test tubes as above, all with the same amounts of radioactive stock selenium solution and 20.0 ml. of 10^{-2} p.p.m. unlabeled selenium solution. Counting rates were determined on each of the tubes in both series, one series, while being stirred, the other not stirred at all (Appendix C-15).

The sediment compartment was normalized by washing the contents of the sediment sample containers into 25 x 250 mm. Pyrex tube and diluting to 20.0 ml. with the deionized water. The counting rate was determined while stirring (Appendix C-15).

The effect of attenuation by sand was observed by preparing two series of test tubes. Into all tubes was pipetted identical amounts of the radioactive selenium solution. One series had the subsequent addition of 20.0 ml. of 10^{-2} p.p.m. unlabeled selenium solution, and to the other series was added 10.82 g. of non-radioactive sand from the same source as used to prepare the experimental tanks. This second series was then diluted to a total volume of 20.0 ml. allowing time for the saturation of the void space in the sand. Stirred counting rates were determined on all tubes in both series (Appendix C-15).

Calculations were made of the theoretical attenuation by the sandy sediment assuming the sediment to be glass homogeniously distributed throughout the 20.0 ml. volume (Appendix C-16, 17).

The normalization of the fish compartment was determined by preparing a separate tank with uptake conditions similar to the experimental tanks and allowing the group of fish to build up in an activity to a reasonable level for detection significance. Radioselenium-75 of the same specific activity as that used in the experimental tanks was introduced. The fish were treated in the same manner as the experimental fish. A count rate was determined prior to wet ashing in a sequence of sulfuric and hydrochloric acids. Concentrated acids were used and the resulting solution was diluted to 20.0 ml. for an additional count rate determination for each fish (Appendix C-12).

The suspended particulate compartment was normalized by dissolving the previously counted dried filters containing the samples of suspended material in a 20.0 ml. quantity of acetone. The suspension was stirred while a count rate was determined (Appendix C-11).

Counting Statistics and Data Analysis

Background counting rates were kept to near 100 c.p.m. by detector shielding and by frequent wiping of the inside of the counting chamber and well crystal. All glassware was washed and rinsed when re-used so that its counting rate fell within 95% confidence limits of the background counting rates. When practical, a thin food wrap was used to line the well crystal to avoid contamination of the counting chamber.

When repeated daily sample counting rates fell within 95% confidence limits of the average value, the system was considered to have reached steady state or completion of uptake for the experimental sampling.

Regression analyses were made on the uptake data to determine the parameters for the selenium model.

Post Experimental Procedure

At the end of the experimental period the tanks were drained and the sediment removed with a spatula. Each of the geometric areas was separated and kept in a separate container. Each area was mixed in a blender to homogeneity with the aid of deionized water. The sample areas were air dried and a 10.82 g. aliquot was put into a clean sediment sample container, re-saturated with the deionized water and placed in the counting chamber as a representative of its respective geometric area. The counting rate was recorded as such.

Samples of these areas were treated in a blender with hot methanol and homogenized in volumes of deionized water. The samples were analyzed for selenium using the diaminobenzidine procedure as in the APHA "Standard Methods for the Treatment of Water and Waste Water." Standard solutions were prepared and samples and standards were read in a Beckman D-B Spectrophotometer. Recordings were made of % transmittance and concentrations were determined.

CHAPTER IV

DATA AND DISCUSSION

Organization

The analysis of the data will be divided into four parts. The first part will be a discussion of the stability parameters. How stable was the system in terms of the design of the model?

The second part will be an analysis of the uptake data by compartments. Pre and post-experimental work will be included in the discussion. The primary objective will be the determination of uptake constants for the simulation of the model in Chapter V. This will be done through the use of regression analysis.

The third part will assess the validity of radiotracer methods and selenium concentrations obtained.

The last part will be a projection of the data to determine other parameters related to the data. These are not germain to the simulation of the model, but are important for suggesting additional research.

Stability Parameters

The stability parameters were sampled as a part of experimental data to determine the stability of the system. All of this data is located in Appendix B-17, 18. Significant changes in these parameters might cause changes in the physiological function of the living organisms. They may produce flows or rates of uptake which were not considered in the design of the model.

Changes in pH (Appendix B-17, 18) occurred with a relatively small variation. The highest and lowest values from either tank in both runs varied no more than a pH unit. This relatively small deviation would not likely result in any physiological stress for the fish. The algae were able to maintain a relatively constant pH after approximately one week of acclimation by addition of carbon dioxide. The tendency of the algal culture to drive the pH up was moderated and very little addition of carbon dioxide was necessary after the first week.

Since the pH change was so small, there was likely no important change in the driving force influencing chemical reactions.

Dissolved oxygen fluctuated a considerable amount, but the variations of both runs was approximately the same.

The only generalization that might be made is that perhaps the values were slightly higher during the first week of each run. It is possible that the algae were still in the log phase of growth and liberating oxygen at a maximum rate. During the remaining weeks, there was a cycling of decomposition and growth at a relatively constant and stable rate. This hypothesis is somewhat verified by the suspended particulate weight data (Appendix B-19, 20) which indicates a mass increase and weight fluctuations after an initial period.

The primary concern for dissolved oxygen is not for fluctuation, but for a minimum level for support of life. The minnows have the habit of constant gill ventillation and seemed not to be under any physiological stress when the dissolved oxygen dropped below four parts per million. This habit and the mixing action of the propeller probably maintained the oxygen transfer across the gill membrane well within normal values.

The only other concern, then, was for maintenance of an oxidizing state for chemical reactions which may have occurred. As long as any oxygen tension remained, this state was maintained. Only until oxygen is depleted completely, would the redox potential begin to change.

The total dissolved solids changed very little within runs; but the second run was significantly higher in TDS (Appendix B-17, B-18). This may be attributed in part to added nutrients in establishing the culture for the second run. The TDS was constant for each run and was therefore controlled for any experimental run. No effects were observable with this change in dissolved ions. The most significant factor was probably the tenfold increase in selenium concentration in the system. This may have made a significant contribution to the increase of dissolved material; however, the loss of selenium from the water was not accompanied by a drop in TDS throughout the course of the experiment. The additional selenious acid may have increased the solubility product for compounds which allowed more to be dissolved. The increased dissolved materials, then, may not have precipitated upon removal of selenium from solution. They may have super-saturated without precipitating and maintained a constant TDS. Calcium ions, for instance, may have increased in solubility with the increase of selenious acid. The trophic loss of selenium from the water was not accompanied by a precipitation of selenium because of a shift in the bicarbonate equilibrium to more acid conditions. The pH would not shift due to a loss of free CO_2. This type of equilibrium, however, could not account for the doubling of TDS alone. The limits of dissolved materials were not excessive, and normal physiology and constant chemistry within any run were maintained.

Temperature changes of a degree up or down were the maximum limits of variation. The slight changes would not be considered significant to change the physiology or chemistry of the system. The first run averaged a degree or two lower than the second run. This was due to an increase in room temperatures. This difference would not be significant for purposes of the model.

The suspended particulate weights remained relatively constant throughout the experimental period. Fluctuations were due to sampling error. This was primarily a function of the mixing, since the pipetting error was considered to be less than 5 per cent, and the weighing error a maximum range of 0.4 mg. (See Figures 8 and 9.) Outside the bounds of the sampling error there seemed to be a slightly cyclic variation of weight. This was found to be true in both experimental runs. This cyclic nature might be explained as alternating growth and decomposition release periods. Changes in free nutrient levels could cause this to occur.

Figure 8.-SUSPENDED PARTICULATE WEIGHT
First Run—Tanks I, II
20 ml Sample

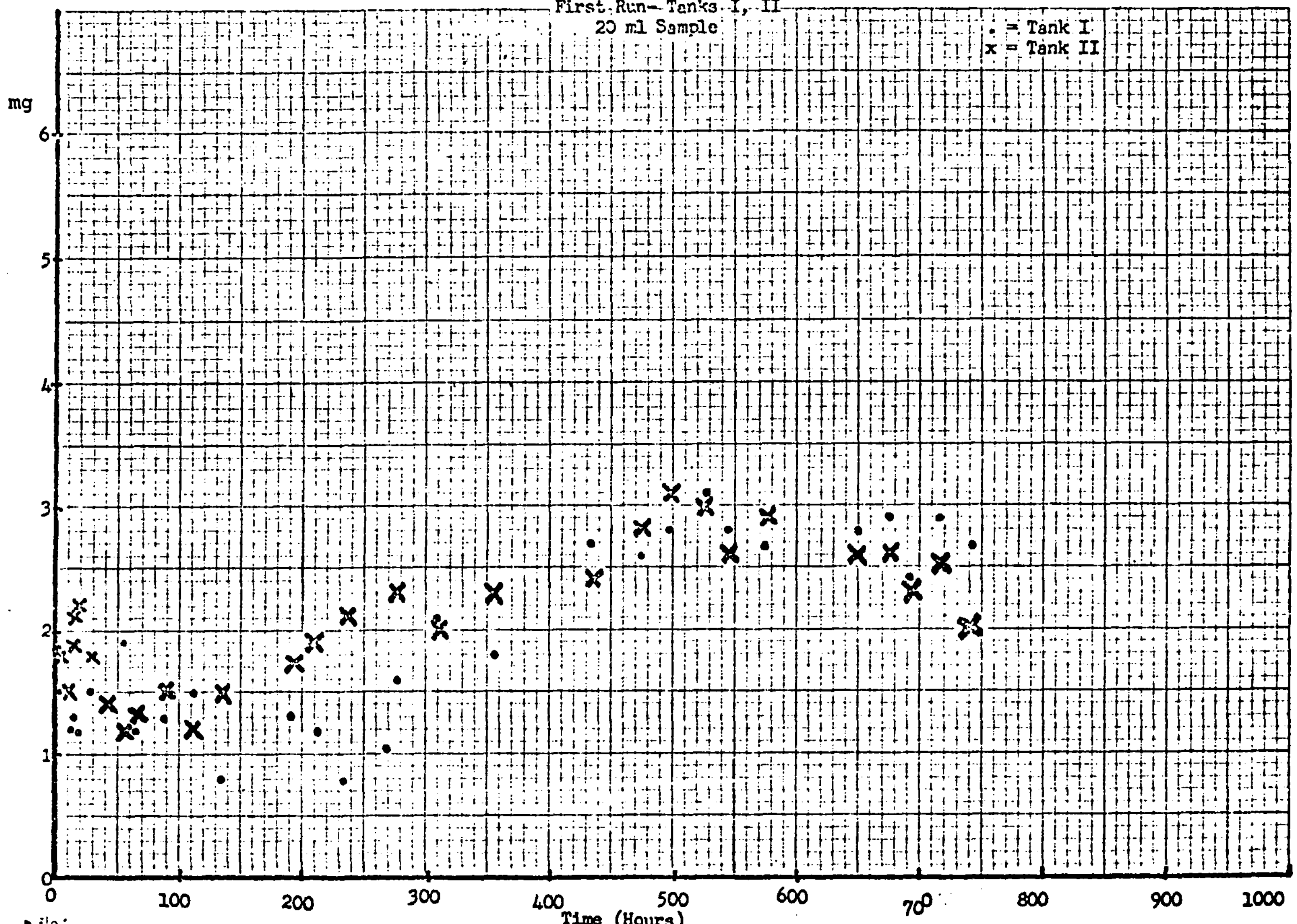
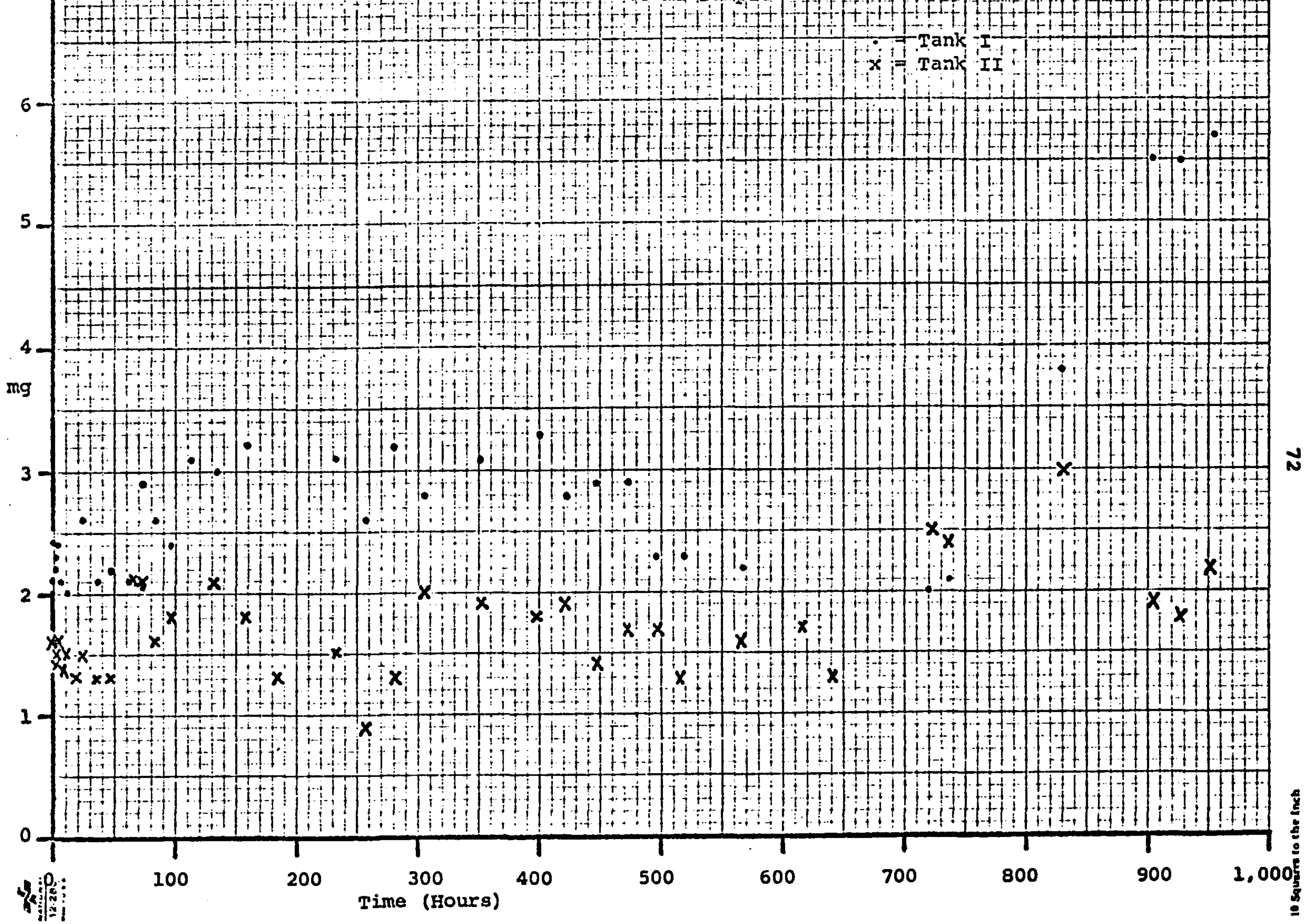


Figure 9. Suspended Particulate Weight, Second Run, Tanks I and II
40 ml Sample



This fluctuation might be related to variation in levels of dissolved oxygen. No statistical correlation was made, but a visual scanning of the data would reveal relationships of this kind. In general, this cycling would seem to have no significant effect on the movement of selenium in the total system. This will be discussed later in this chapter.

Other biota in the system would indicate stability of the system (Appendix B-24). Diversity of types and small numbers would indicate a stability. Stalked protozoans and rotifers would indicate the more advanced successional stages. The adundance of an alga such as Ankistro desmus sp. and Scenedemus sp. is common for ponds and aquaria. They are considered planktonic algae when mixing action occurs. Blue-green forms were not abundant. Thus the algal forms also represent species established for periods of time in pools and ponds.

The non-experimental parameters and biota in general represent a system that is established for a period of time and relatively constant.

Experimental Runs and Associated Data

The two experimental runs represent four similar systems which responded with repeatable similarity at two different levels of selenium concentration (Figures 10-13).

Figure 10--UPTAKE OF SELENIUM
First Run--Tank I

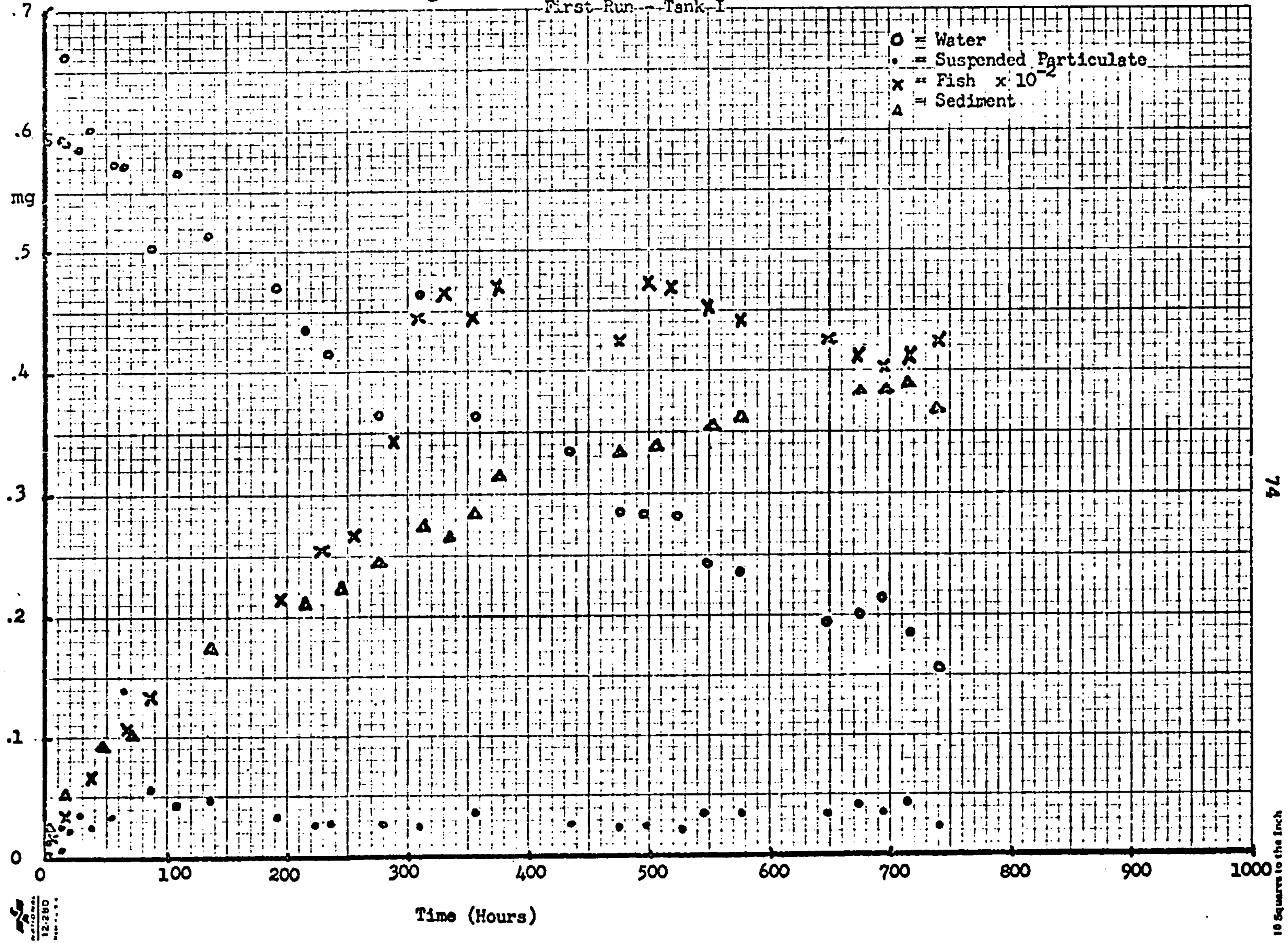


Figure 11 .-- UPTAKE OF SELENIUM
First Run- Tank II

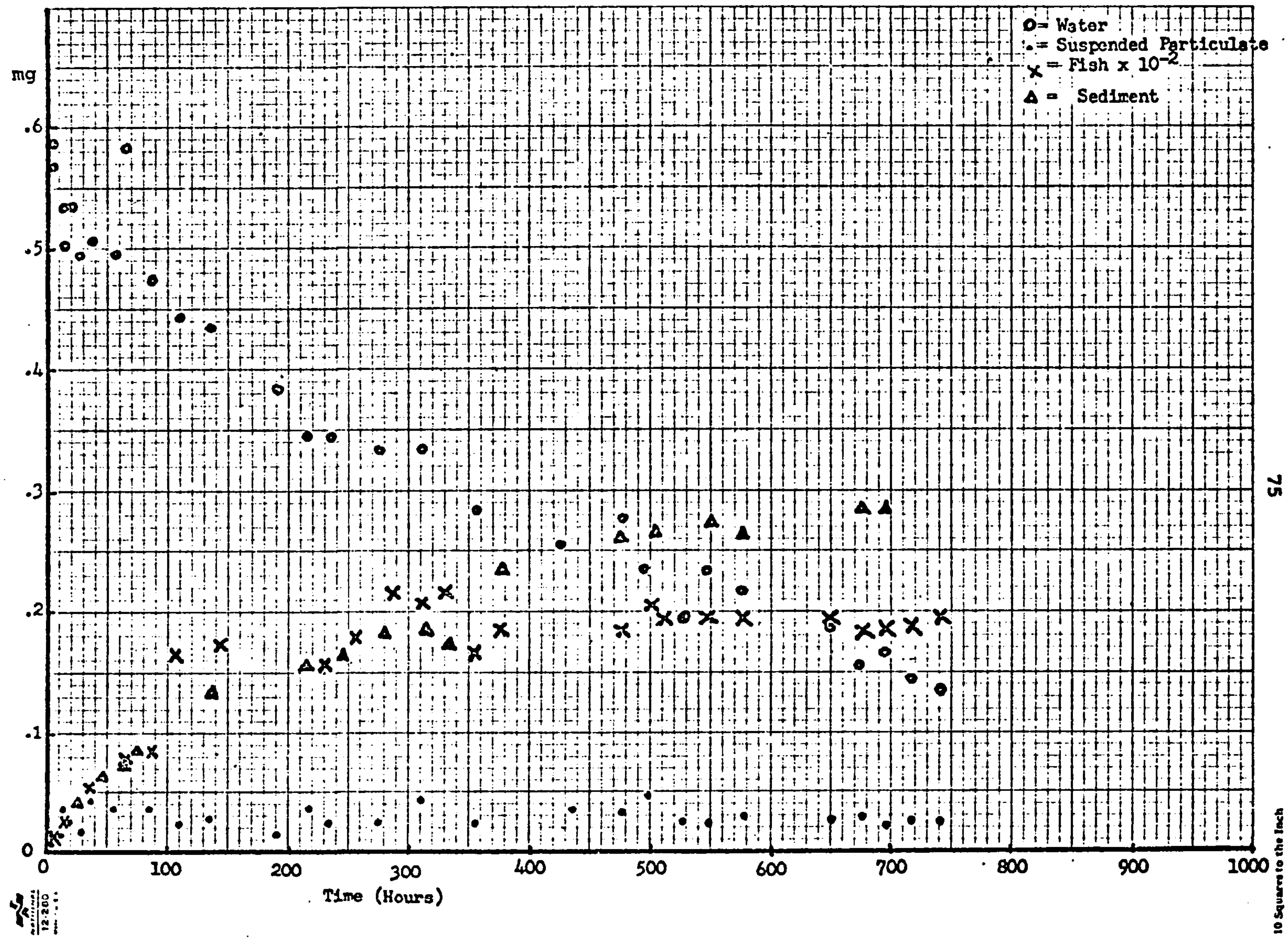


Figure 12. Uptake of Selenium (Second Run, Tank I)

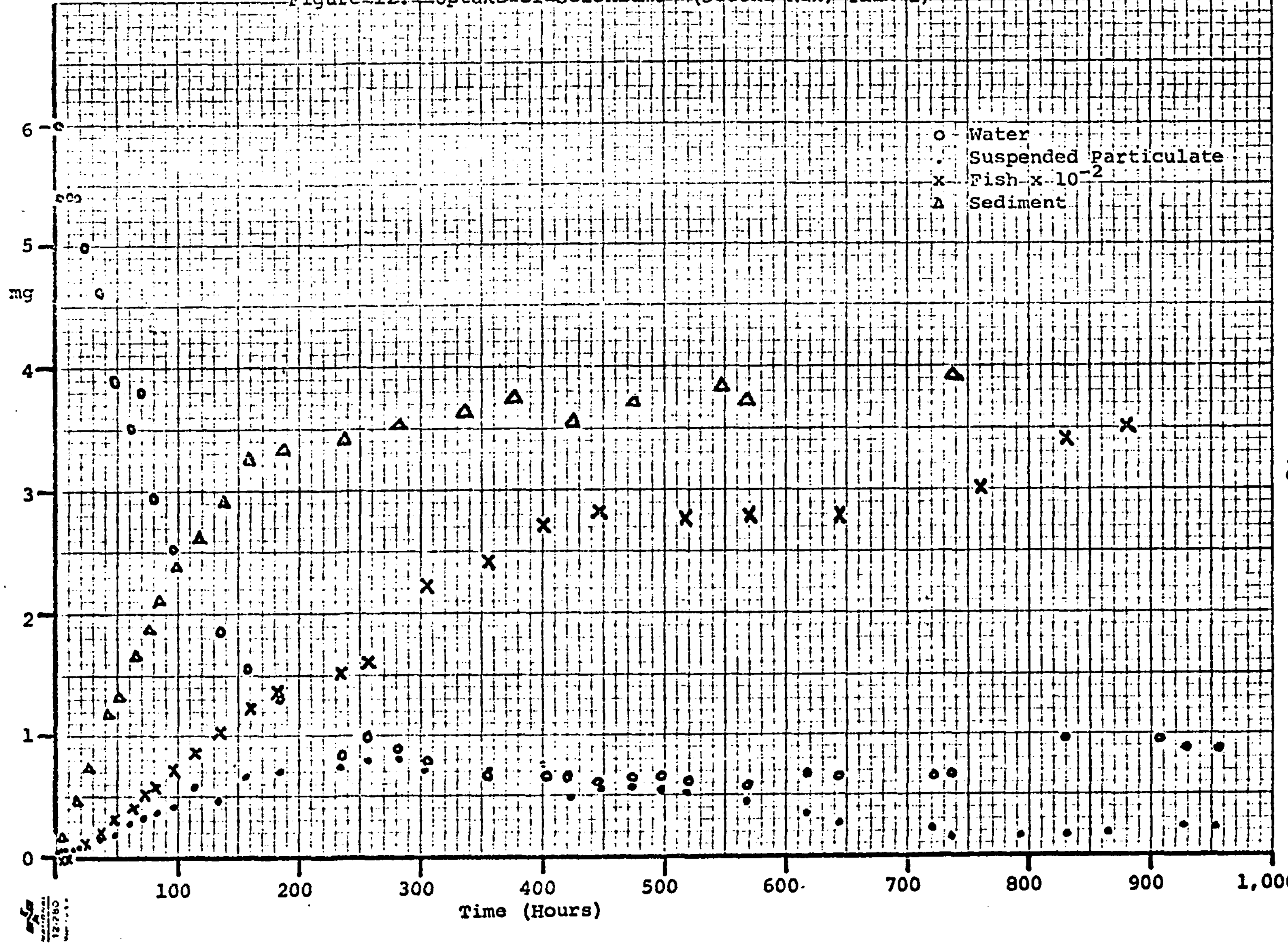
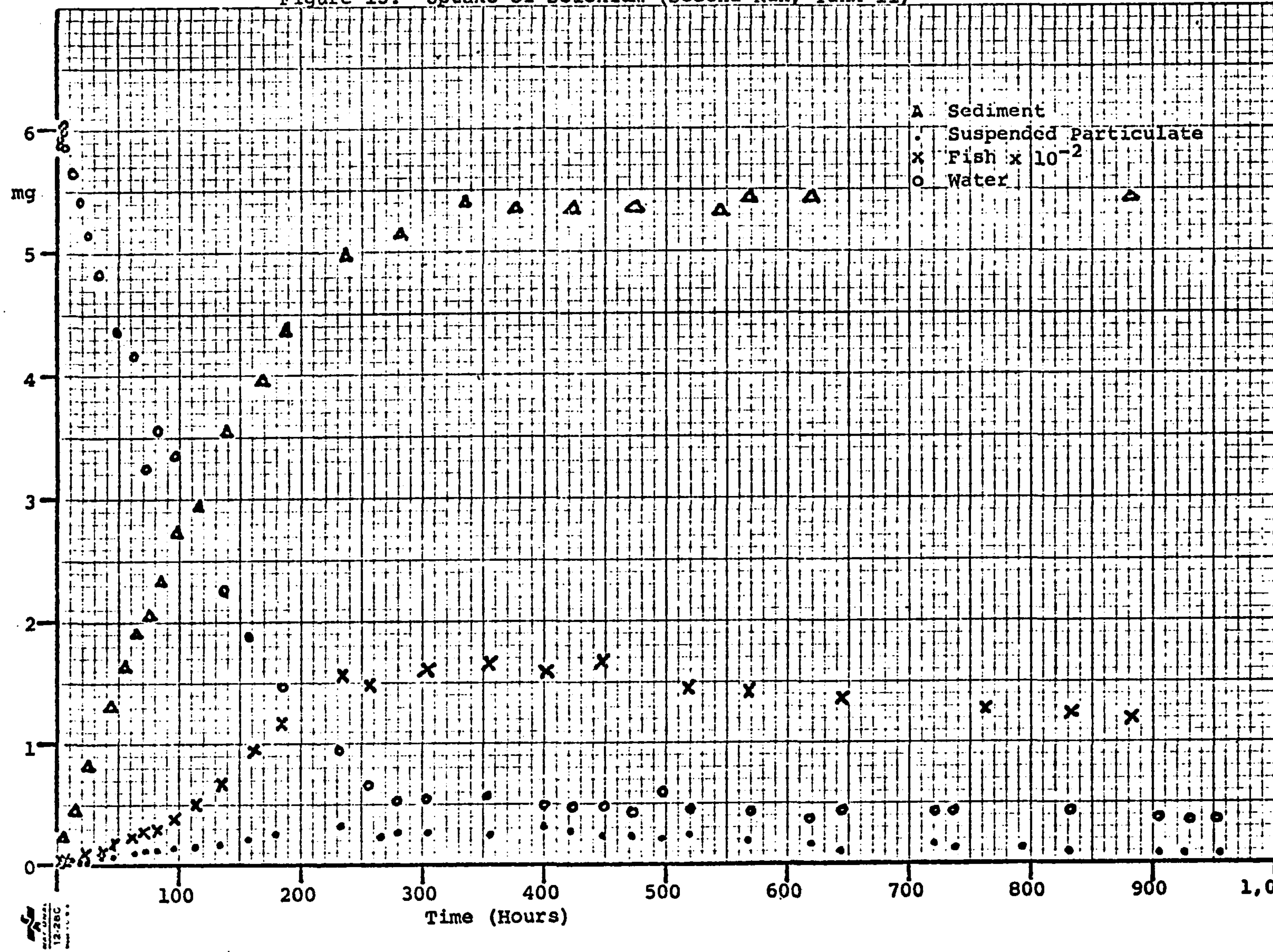


Figure 13. Uptake of Selenium (Second Run, Tank II)



The first run was more truly experimental. Techniques were untried and the precision of sampling was not developed by the experimenter as well as in the second run. Reliability of equilibrium values is not quite as good in the first run. The specific activity of selenium-75 in stable selenium was such that the random fluctuation of the count rate was greater than the variation in selenium amounts. This occurred particularly when the water became somewhat devoid of selenium, near the equilibrium value (or steady state).

The equilibrium time in general was suggested by consecutive variations of sampling data which were within a 95% confidence interval. This was the judgement used for completion of experimental data.

The increase or loss of selenium over a period of time is related to the unique character of each compartment and must be examined compartment by compartment.

Water

The water compartment is by logic the first to be discussed since the selenium is introduced into the system in a completely soluble form and becomes immediately a part of the water compartment. The remaining three compartments are initially devoid of selenium and the flow begins out of the water to the remaining three compartments. Since the total amount of selenium is contained in the system, the other compartments take up the selenium as the water loses it.

The loss of selenium by water in the first run (Figure 10, 11) did not obtain as low a value as in the second run. The reliability of the data in the first run was not as good as that in the second run (Appendix B-1, 5, 9, 13). The two tanks in the first run showed values at 700 hours to be about 0.2 mg loss from 0.6 mg. The count rate for the first run ranges from approximately 2500 counts per ten minutes to 1900 counts per ten minutes for the last 200 hours of run time. This final value with correction for decay falls nearly within the 95% confidence interval for approximately a week run time. This is close enough to suggest steady state or equilibrium time is approaching. The value can be looked at more carefully with regression analysis as will be discussed later in this chapter.

The water compartment in the second run (Figures 12, 13) shows a lower value on approach of steady state. This would be expected since the 95% confidence interval about the 400 hour counting rate contains the curve for more than a week (Appendix B-9, 13).

Within the second run, the final values compare very well for the two tanks. A variation of 0.3 mg or less than 5% for more than a week occurs. The tanks are then identical for the water compartment within the sampling error.

The water is a massive compartment (60,000g.) which reached equilibrium in about 400 hours. The data from the second run suggests the most reliable values but is not contradicted by the values from the first run.

There would appear to be no complication in the geometry or normalization of the sample data, since the standardization of counting rate to mg. of selenium was identical to the sampling of the water compartment. Sorption loss was insignificant (Appendix C-9). In concentration ranges from 10^{-4} ppm. to 10 ppm., glass sorption was linear and amounted to only about 2%.

Suspended Particulate

The accumulation of selenium in the suspended particulate was related to the mass of suspended particulate. The mass of the algae was very small compared to the water or sediment mass, and smaller uptake values were apparent.

It is difficult to determine the equilibrium value from the first experimental run (Figures 10-11). The count rate is so low that the significance of selenium amounts cannot be detected above background (Appendix C-18). The 62 hour counting rate of 1,618 counts per ten minutes is significantly above background at the 95% confidence interval. The value reached by the suspended particulate appears to be 0.05 mg or about 8% of the total amount.

After the initial sample in the second run, the count rates were significant throughout the experimental period. In both tanks of the second run, there was an overgrowth of selenium uptake and subsequent drop to the equilibrium value. Tank II did not reach as high a value and was lower during the latter part of the run. An examination of the suspended particulate weights (Appendix B-19, 20), show that Tank I averaged 1.46 times the weight of Tank II. The selenium uptake in the suspended particulate (Figures 12, 13), are in agreement with this factor.

The rich culture was produced by a Knopp's modified media (Appendix A-1). This provided micro nutrients and trace materials necessary to stimulate a rich growth. This was probably more rich than most natural waters, but provided large enough samples for statistical meaning with the count rates obtained.

Standardization and normalization procedures were verified by data found in Appendix C-11. Ten samples of suspended particulate were counted at a standard geometry and found to average a slightly lower count rate than those obtained with the experimental sampling procedure. The variance of the samples was relatively small and supports the validity of only a small correction factor (0.9055). In the sampling procedure, the rolled filter was placed directly into the test tube and counted. With this method, the center of density of particulate would go slightly deeper into the well of the detecting crystal as compared to the standard geometry. This would allow fewer of the gamma emissions to escape detection and thus result in a counting rate higher than with standard geometry. A large difference would not be expected.

The buildup and continued drop, or latent depression of compartment uptake in suspended particulate is not unusual. When flow occurs into a compartment and a subsequent flow out, an overshoot sometimes occurs. There is a lag time before the loss rate equilibrates with the inflow. It may exceed the inflow for a period of time in which the amount in the compartment is decreasing to a final equilibration.

An experiment was done, however, which provides some contradictory data (Appendix A-5). A comparison of pipettes was made in which a broken-end pipette was compared to the normal-end pipette used in sampling. The broken-end pipette was calibrated to an identical volume, but had a larger orifice for the sample to enter. The broken-end pipette seemed to be collecting a different statistical population than the normal pipette. The broken-end pipette was collecting 1.62 times the weight of suspended material than the normal pipette was obtaining. The standard deviation of this pipette was also more than two times the normal pipette. This strongly suggests that the experimenter was not obtaining the larger aggregates of suspended particulate in the sampling technique. The obvious particles excluded would be fish feces, but no other data substantiates this suggestion. If this were so, the selenium concentration of the excluded portion may be at variance with the concentration in the remaining portion. Results would lower uptake values in proportion to the amounts excluded.

The growth of selenium in the suspended particulate is not surprising and may be considered consistent from first to second run. The differences within the second run can be explained such that they are considered identical in response to the modeling effort.

Fish

The uptake into fish was relatively small (Appendix B-3, 7, 11, 15). Their physiology appeared normal. They suffered no apparent stress from dissolved oxygen, temperature, pH, or salinity (Appendix B-17, 18). It may be concluded that the results obtained are representative of normal biological activities of the minnows and represent a consistent pattern in all four situations. Weight data (Appendix B-23), showed some growth for most fish. This was apparently continuous and did not cause perterbations in the uptake values obtained. Although normal fluctuations might be expected with living organisms, these were for the most part smooth and continuous. In the first run, Tank II fish weight, there was a loss amounting to nearly 2 grams through the death of two fish. The accompanying data (Appendix B-7) and Figure 11 show this. The equilibrium value approached by Tank II is a lower value than that in Tank I. The final mass of the fish compartment is lower in Tank II also. This weight difference was continued into the second run using the same fish and the uptake response reflected the mass difference in a very similar way. The final values for Tank I in the first and second runs were about 0.006 total selenium. Tank II had a similar response and it was lower, reflecting the mass difference as before.

The curve of Tank I in the first run showed more erratic values at the final portion of the curve, which made judgement of an equilibrium time more difficult without the use of statistical analysis. A 95% confidence interval was exceeded occasionally from the 300 hour time to the completion of sampling. These differences might be accounted for in the physiology of the fish itself. Living organisms may deviate from what may be considered normal activity on an individual basis without being under stress. This is a variable that is difficult to control without large populations of the living organisms.

A further observation might be made on fish number 2 from the first run, Tank I (Appendix B-3). The notation "up" indicates the fish was counted with its anterior end up. This was a habitual response of certain fish, that when placed anterior end down to determine the count rate, they reversed themselves in the tube. Some fish were so difficult as to make it impractical to keep them in the proper position. They were simply counted anterior end up. This produced a difference in their counting geometry so that a correction was needed.

In an attempt to determine this correction factor, 20 samplings of 10 different fish were obtained with count rates normal and inverted. The results may be seen in Appendix B. The fish inversions are compared and an adjustment fraction determined. Therefore, if a fish was counted anterior-end up, the count rate could be adjusted by this factor to make up for the undetected counts.

If fish number 2, as referred to above, was normally uptaking at a low rate, then the adjustment would cause values to be erratically high on the uptake curve. If the reverse were true, the values would be low.

In addition to this fact, the count rate depended on the fish to remain straight. If it curved its body, it could increase the count rate by settling deeper into the well crystal. On the other hand, it could decrease its count rate by remaining high in the tube. The water volume was little enough (20 ml. total volume) so that the latter was not likely.

Another variability that could occur was due to the inability of the investigator to observe the position of the fish while in the counting chamber. The fish was observed before and after counting. If the duplicate counts were similar, it was assumed that the fish had maintained the proper position throughout the counting time. It would be possible, however, for a fish with a tendency to invert, to do so while in the chamber and resume its proper position just prior to removal. The counting rate could be lessened significantly. If the fish remained inverted for most of both duplicate counts, they would show no difference and would be recorded as counts taken in the proper position.

The greatest amount of uptake in the fish must be due to membrane uptake (gills, etc.). This would be expected since minnows do not normally feed upon algae or suspended materials of this nature. The trophic relation is more incidental.

The normalization of fish data was attempted two ways (Appendix C-12). Both a wet and dry ashing procedure was attempted. The dry ashing procedure resulted in poorest recovery of counting rate. The values were erratic. The best yield was obtained by the wet ash technique and resulted in data which was consistent with little variation. For this reason, the wet ash correction factor was used (0.706). The liberation of heat during the solubilizing action may be cause for loss of activity from volatilization. Since the total amount of selenium in the system is constant, losses should be conspicuous when summing up the values of all compartments. The fraction of total selenium in fish is in the order of a few thousandths and would never be observed by such a procedure since it would be so small. The consistency of the wet ash data is supportive of its correctness. It would be expected that differences in addition of acids would show up in more variation of data if this kind of loss were significant.

Sediment

The sediment compartment was a massive compartment consisting of 7,200 g. The major portion of selenium moved to the sediment. The sediment is made up of inorganic particles and living material. The forces moving selenium into the sediment are thus physical and biological. The final observations of the sediment showed a well developed green surface layer composed of algae and organic material. Settled particulates could function as sediment to uptake selenium in addition to the original inorganic particles.

Sieve analysis showed the sediment to be of a sandy nature with a distribution of particle size about a mean of the hundred mesh size (Appendix A-2). The distribution was skewed slightly to the fine particle size since the size greater than ten mesh was excluded in an initial screening.

The fine particles were any particle less than 200 mesh or 74 microns. The fine particles were a relatively small fraction of the total distribution constituting 7.6% of the weight. Jones (1960) suggests the importance of fine particles on uptake due to the large surface area. Ten identical sediment sampling containers were filled with sediment by an impartial procedure and a sieve analysis done on each. The results were consistent and the averages accepted for the amounts to be placed in the sediment samplers. The samplers were assumed to be identical units which could be retrieved as such and returned without disturbance. The amount contained in each sampler was calculated to be a known fraction of the total sediment mass. This was done by area ratio of the container to total bottom (Appendix A-3). The largest error would be in the measurement of the diameter of the sampling container. This measurement would be consistent in both Tank I and Tank II.

The distribution of particle size on the bottom (Appendix A-4), was consistent with the choice of geometric areas for sampler placement. The observation of falling particles by size showed them to fall in the distinct areas which were hypothesized from a look at the bottom. If particles would grade themselves into separate areas, then these areas might have different uptake rates and should be sampled likewise. The calculation of these areas was shown in Figure 6. The fractions of bottom area represented were used to adjust the respective sample data so that the total selenium in the sediment compartment could be determined (Appendix B-4, 8, 12, 16). Each of the areas showed continuous increase in selenium as did the sediment compartment. It is interesting to note that raw data shows certain areas to uptake at faster rates. The pattern in general follows the qualitative particle size distribution (Appendix A-4). The area predisposed to smaller particle sizes had higher uptake values in terms of count rates. Areas E and H in general seemed to have higher values than C or R. This was true for both tanks in both runs. This would seem to support the contention that smaller particles have a greater uptake for a given mass as compared to larger particles. An important factor, however, must be the settling of living particles in the same areas that fine particles are collected. This would add significantly to the uptake of these areas since small masses of algal material uptake selenium well from solution. In addition, if the fecal material from the fish contains a large amount of selenium, these areas would uptake at a faster rate.

Since the fish do not accumulate very much selenium, one might ignore this suggestion. But if fish uptake rates were high, their loss rates could be very high so as to result in little accumulation in the fish. The result would be to add large amounts of selenium in the form of feces to the suspended particulate. This is possible since accumulation in the fish is very low. It would seem reasonable that large volumes of water ventilate the gills and could allow intake rates that would be high. The late depression of suspended particulate noted earlier in this chapter could support this hypothesis. If by the comparison of pipettes data (Appendix A-5), one accepts the sampling method to be excluding feces, this hypothesis is supported. That is, the high loss rate via fish feces does not show up as suspended particulate, but is settled to the bottom and shows up as additional sediment uptake. An additional perspective can be gained by careful comparison of the values of raw counting rate in the E and H areas in Tanks I and II of both runs. A higher uptake rate is in most cases associated with quadrants three and four in Tank I, but with 1 and 2 in Tank II. This is meaningful since the fish enclosure is above these quadrants in the respective tanks as mentioned. All of this discussion strongly supports a possibility of a high uptake and loss by the fish which is not accounted for by the model, and shows up as sediment uptake. In this case, a balance of total selenium would still occur. The balance of total selenium in all cases supports the area correction for sediment samplers.

In general, the approach of sediment uptake to a steady state value could be assessed by the same means as done previously with other compartments. Ninety-five percent confidence limits could contain the uptake curves for a week in most cases. The stability of this massive compartment was greater than others. Higher count rates near equilibrium allows better statistical fit.

An additional correction used on the sediment samplers was a geometry normalization and attenuation factor. Normalization factors can be observed on data from both tanks (Appendix C-13). The stirring was used to maintain homogeneity while a counting rate was determined on sediment sampling containers. A normalization factor was determined from averages taken on both tanks and used to modify the sample counting rates for the sediment uptake data. This factor was supported by sediment transmission and stirring data (Appendix C-14). This demonstrated that the effect of stirring did not change the count rate by observing the mean and approximated standard deviation. They indicated the same statistical population. For example, proper stirring would not allow formation of a vortex that would produce a different counting geometry. The sediment however produced different count rates when stirred. This indicated there was some attenuation by the sediment distribution. Sediment transmission calculations from the data (Appendix C-15) shows the attenuation to be 4.5%.

If an additional study is made of the theoretical calculation of transmission (Appendix C-16), a comparison can be made of the probable limits of attenuation by the sediment. Since the sediment was essentially sand, the maximum and minimum mass attenuation coefficents could be referenced in a handbook (Bureau of Radiological Health 1970). The two values represent the range of gamma energies of selenium-75 in silicon dioxide. Subsequent calculations suggest a theoretical attenuation by the sediment to be from 5% to about 19%. The significance of the attenuation calculation (Appendix C-17) shows by examination of per cent emissions the 5% value to be the most probable attenuation! This fits the data precisely and supports the factors of attenuation and geometry used to modify the sample data.

Radiotracer Methods and Selenium Amounts

The selenium-75 decay scheme (Appendix C-I) shows four energy ranges of gamma to be important in detection. These constitute the significantly large percentages that will be detectable. Optimum detection efficiency was obtained with a window width corresponding to the spectrum energy range. Standard energy sources were used to verify the spectrum energies (Table 10). The determined spectrum corresponded to published data (Appendix C-6) throughout the energy range.

Calculations of amount of selenium showed the weight of selenium-75 to be insignificant chemically when added to stable selenium (Appendix C-2).

The efficiency calibration data and calculations (Appendix C-7, 8), are verified by the fact that the total selenium was equal to the sum of the four compartment amounts.

Sorption of selenium-75 experiments (Appendix C-9) showed a linear relationship of sorption on glass to all concentrations of selenium. The approximately 2% value was insignificant and would not be observed in any of the compartment values for selenium uptake. It was observed that sorption occurred within 15 minutes. The data collected demonstrates a stability of sorption within 4 hours.

Sorption on a microscope slide (Appendix B-21) gives *in situ* indication of greater percentages remaining on the glass. However, standard geometry could not be used and the statistical confidence in the value is not nearly so good as the sorption experiment. At a count rate of approximately 130 cpm, the fluctuation of 2 to 16% is still within a 95% confidence interval for that low count rate. The *in situ* data was considered to support the 2% value. The sorption was accepted as insignificant on the experimental tanks.

The background counting rates were relatively constant throughout the period of experimentation. Clean, heavy shielding would account for this. One-hundred-minute counting times were used daily. The 95% confidence interval of the background counting rate was never more than plus or minus four counts per minute. Due to a longer counting time, this was always a smaller value than the confidence limits around any of the sample data.

A complication in background occurred with the use of the same tanks for the second run. This meant that the total concentrations of the second run would have to be considerably higher than that of the first run. Also, the specific activities of the first and second run spike amounts was made similar. Similar specific activities would allow residual counting rates to be subtracted in the same manner as background. The residual counting rates could be subtracted directly from the raw counting rates of the second run data. For example, the residual selenium was measured in all compartments possible. Background was subtracted and the remainder was taken as the residual value from the first run. This value was used to construct a schedule of decay of residual selenium for each of the compartments (Appendix C-19). This schedule was prepared by calculation according to the laws of radioactive decay.

Thus, the total background in the second run was different from the normal background of the first run. In addition to normal background, it contained a residual selenium-75 background from the first run. In order to adjust the raw counting rates for the second run, two subtractions were necessary. The raw counting rate was determined, normal background was subtracted, and then residual selenium was subtracted according to the schedule of decay (Appendix C-19) for that compartment and tank.

The calculations from measured values of residual selenium was accepted as the true value and used to adjust the raw counting rates for the second run. In most cases, the residual amount was insignificant.

The spectrophotometric method to determine selenium amounts did not achieve a 100 per cent yield (Appendix D-1). The standard curve and samples corresponded in linearity however and all were consistently lacking in yield. The loss is not surprising since the hot methanol would only lyse cells. Soluble selenium would be most readily released. Any refractory organic material would not likely be degraded to release selenium. As a consequence, it was lost to the preliminary oxidation of the standard method used.

Water and fish food samples lacked selenium to the limits of detection. Assuming maximum interference and best technique, the value found in the samples was probably less than 0.001 parts per million.

Parameters Projected from Data

The basic technique of data reduction used was the linear regression analyses of all uptake curves (Figures 14-21). This technique was used to determine the initial uptake constants and is based on the data approaching equilibrium. For this reason, the regression analysis was done on the initial data. The initial data was chosen by an approximation of the 68% confidence interval, two

Figure 14. Water Compartment
Second Run, Tank I (Linear Regression)

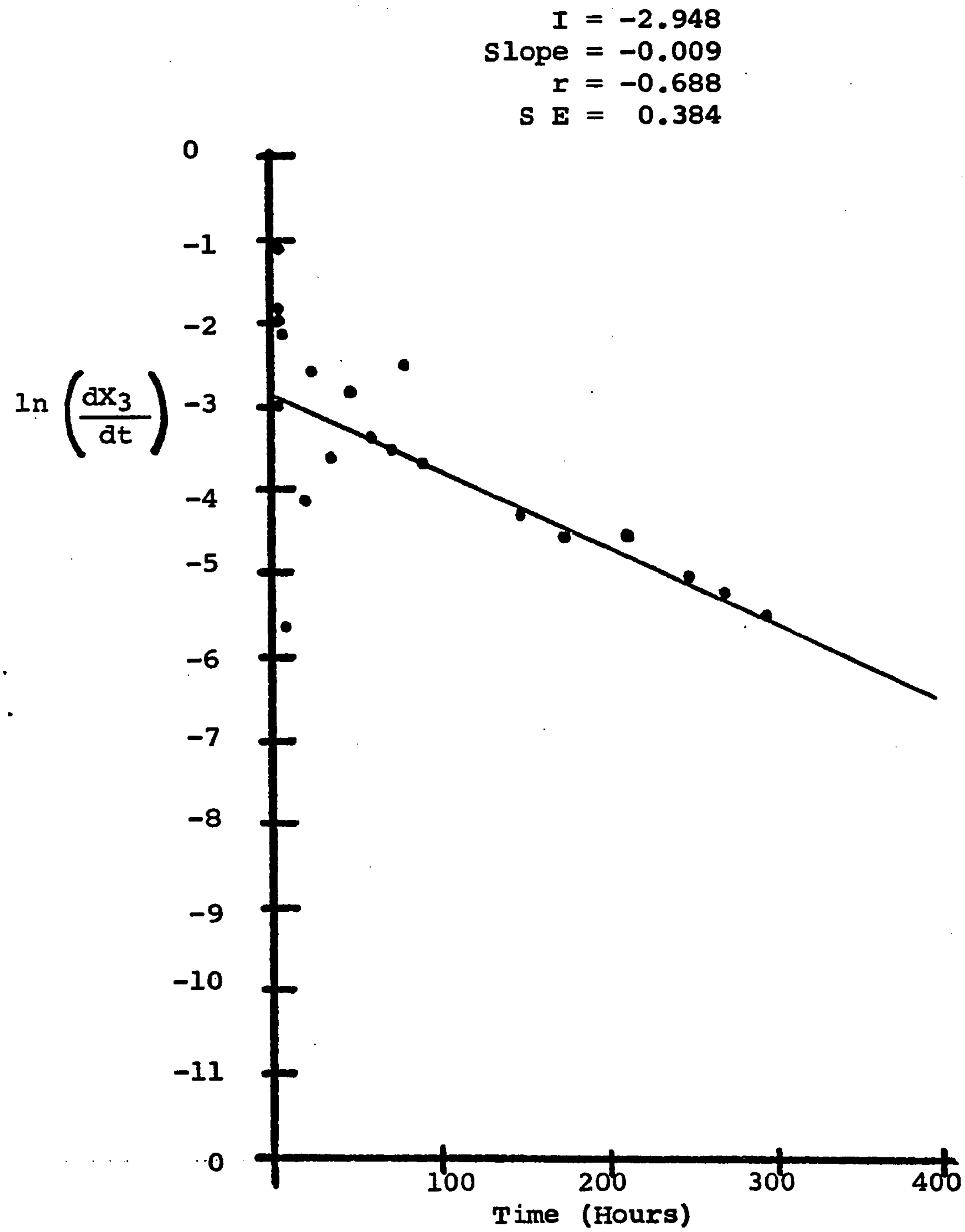


Figure 15. Suspended Particulate Compartment
Second Run, Tank I (Linear Regression)

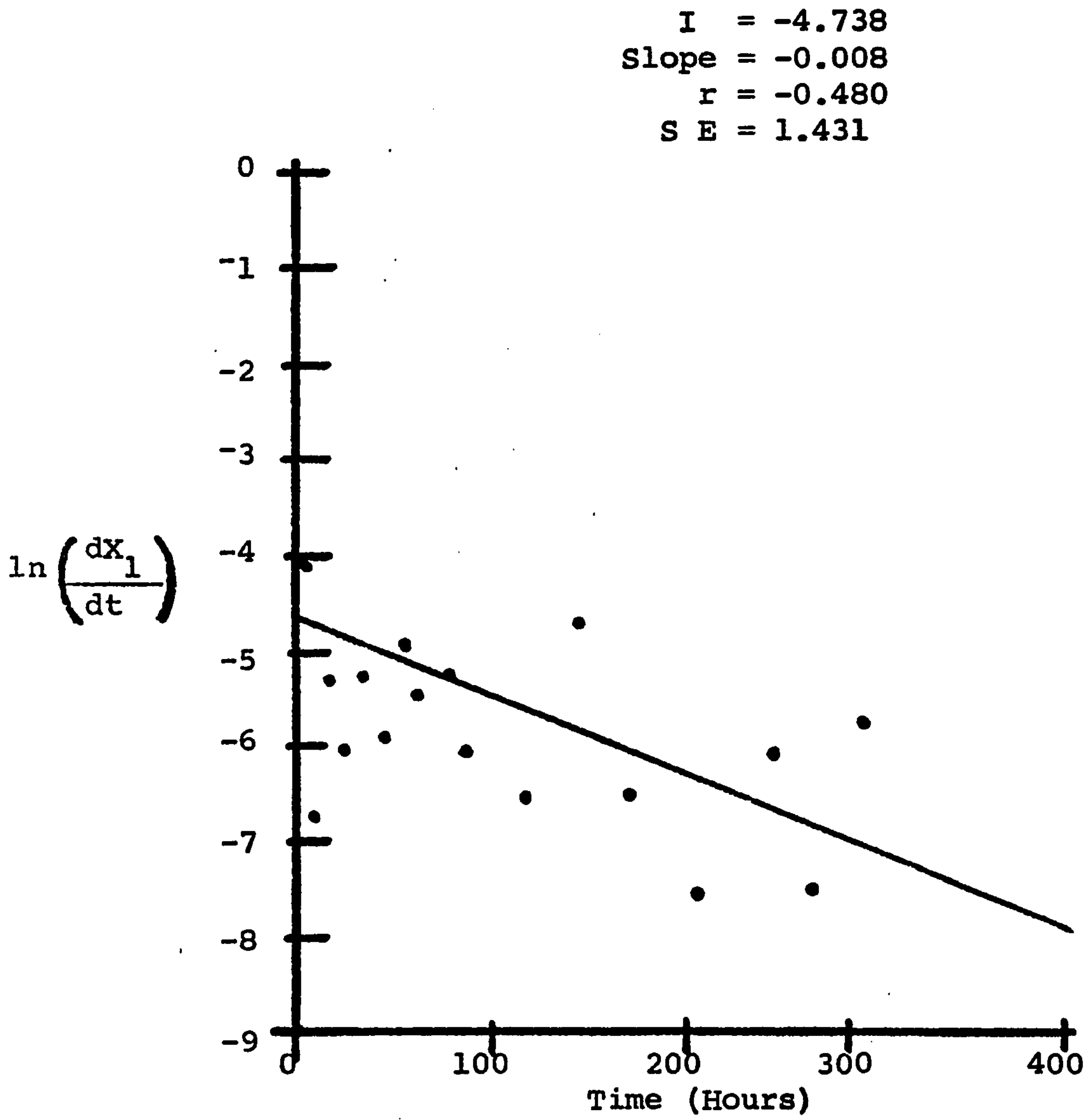


Figure 16. Fish Compartment
Second Run, Tank I (Linear Regression)

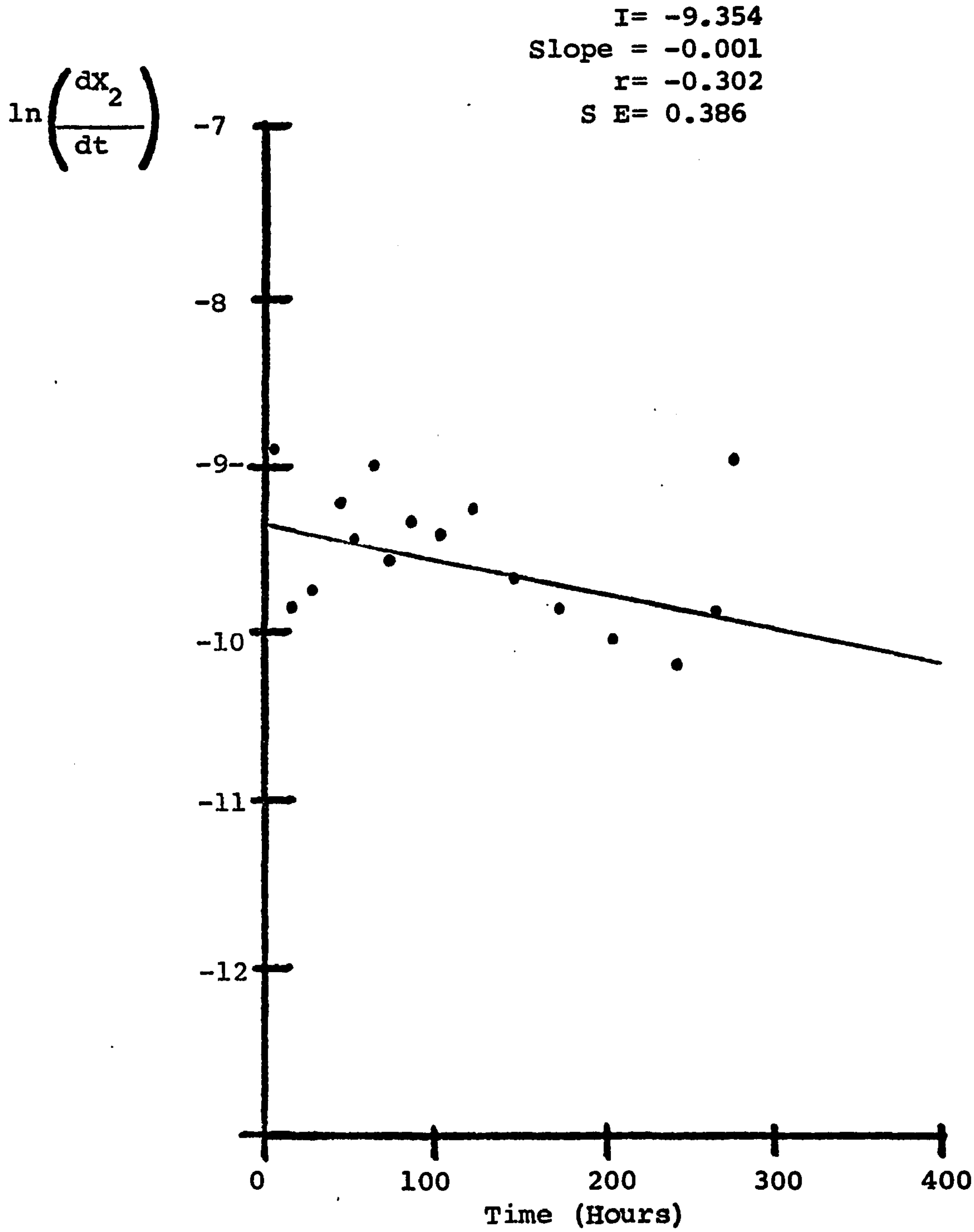


Figure 17. Sediment Compartment
Second Run, Tank I (Linear Regression)

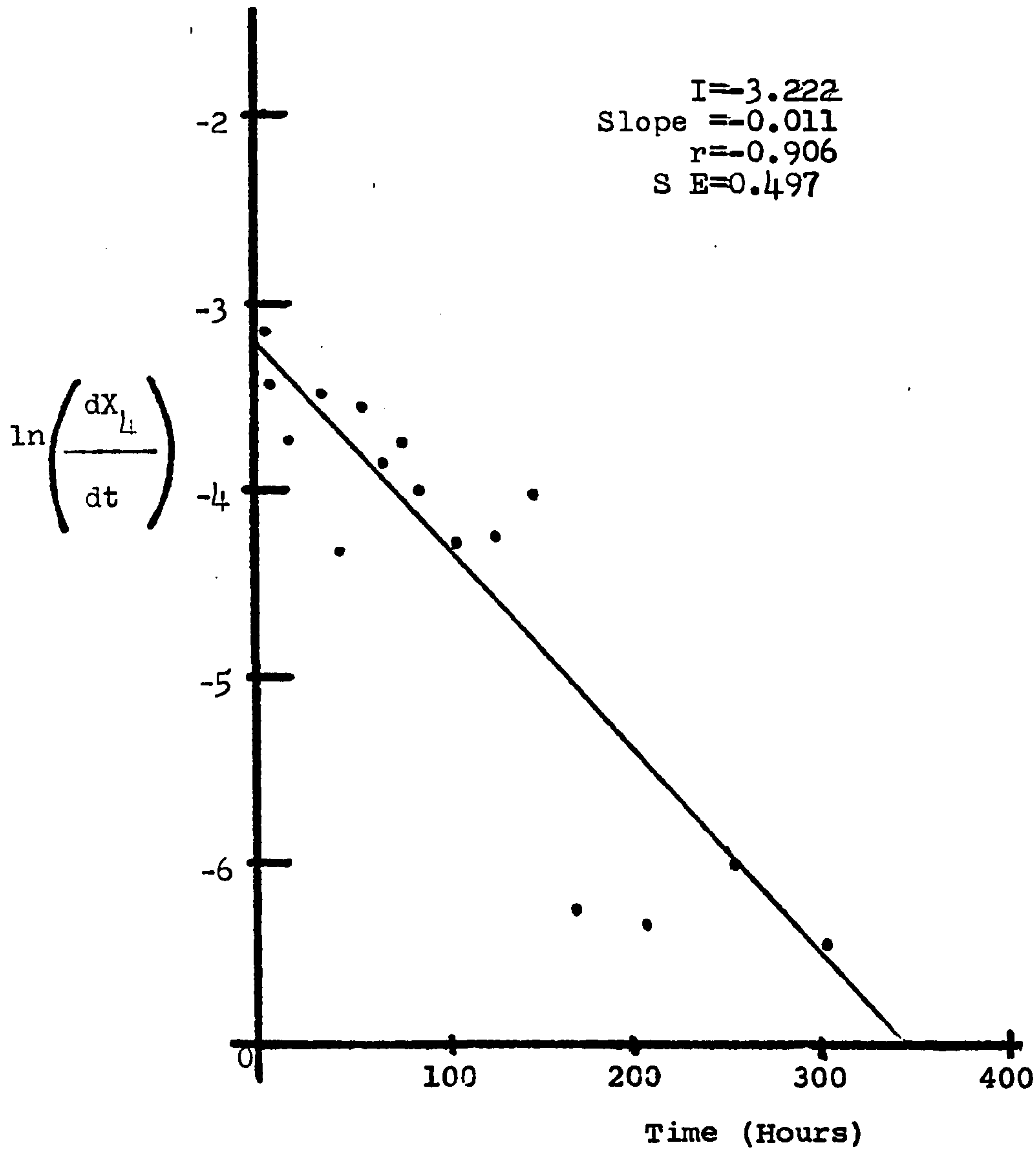


Figure 18. Water Compartment
Second Run, Tank II (Linear Regression)

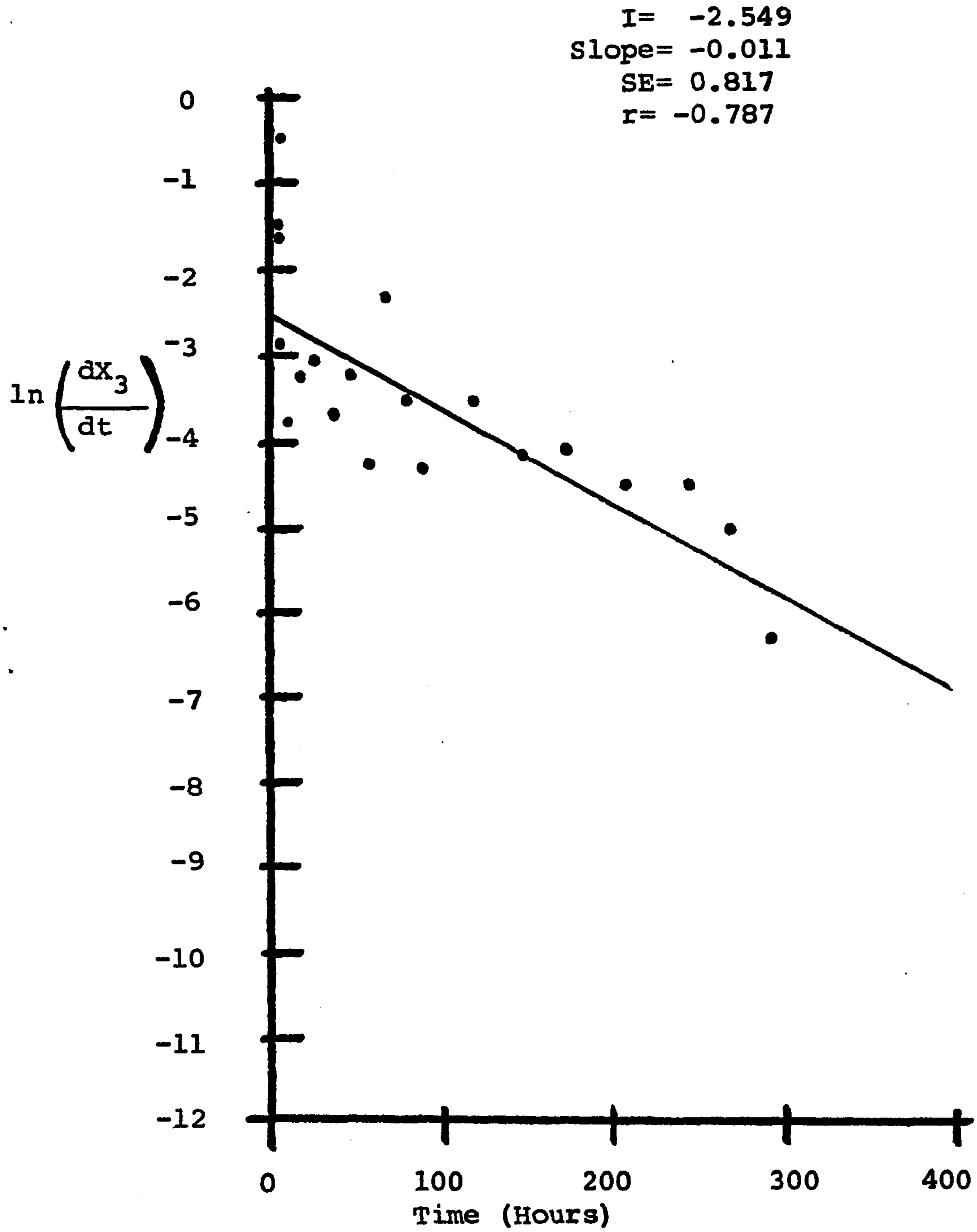


Figure 19. Suspended Particulate Compartment Second Run, Tank II (Linear Regression)

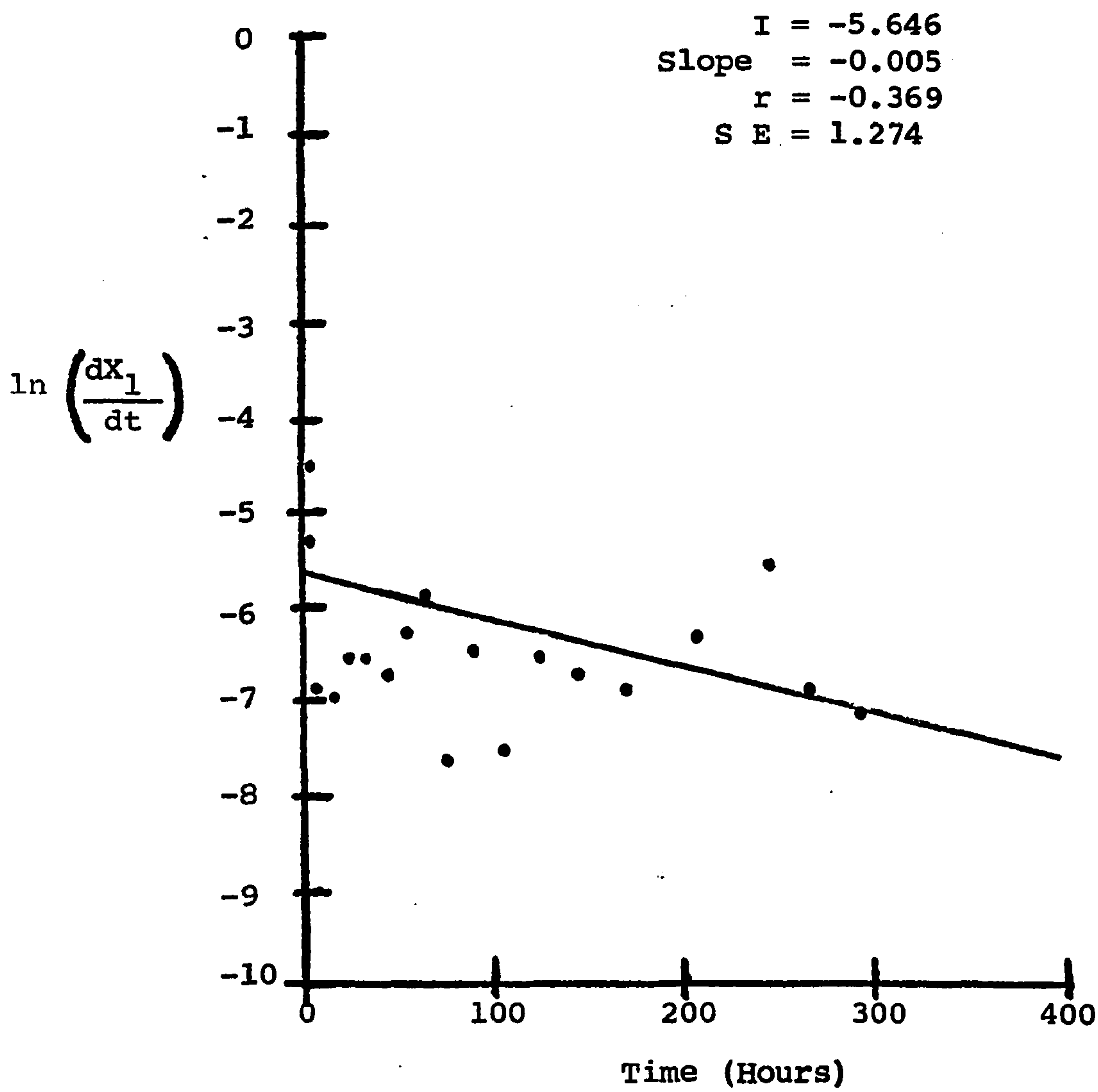


Figure 20. Fish Compartment
Second Run, Tank II (Linear Regression)

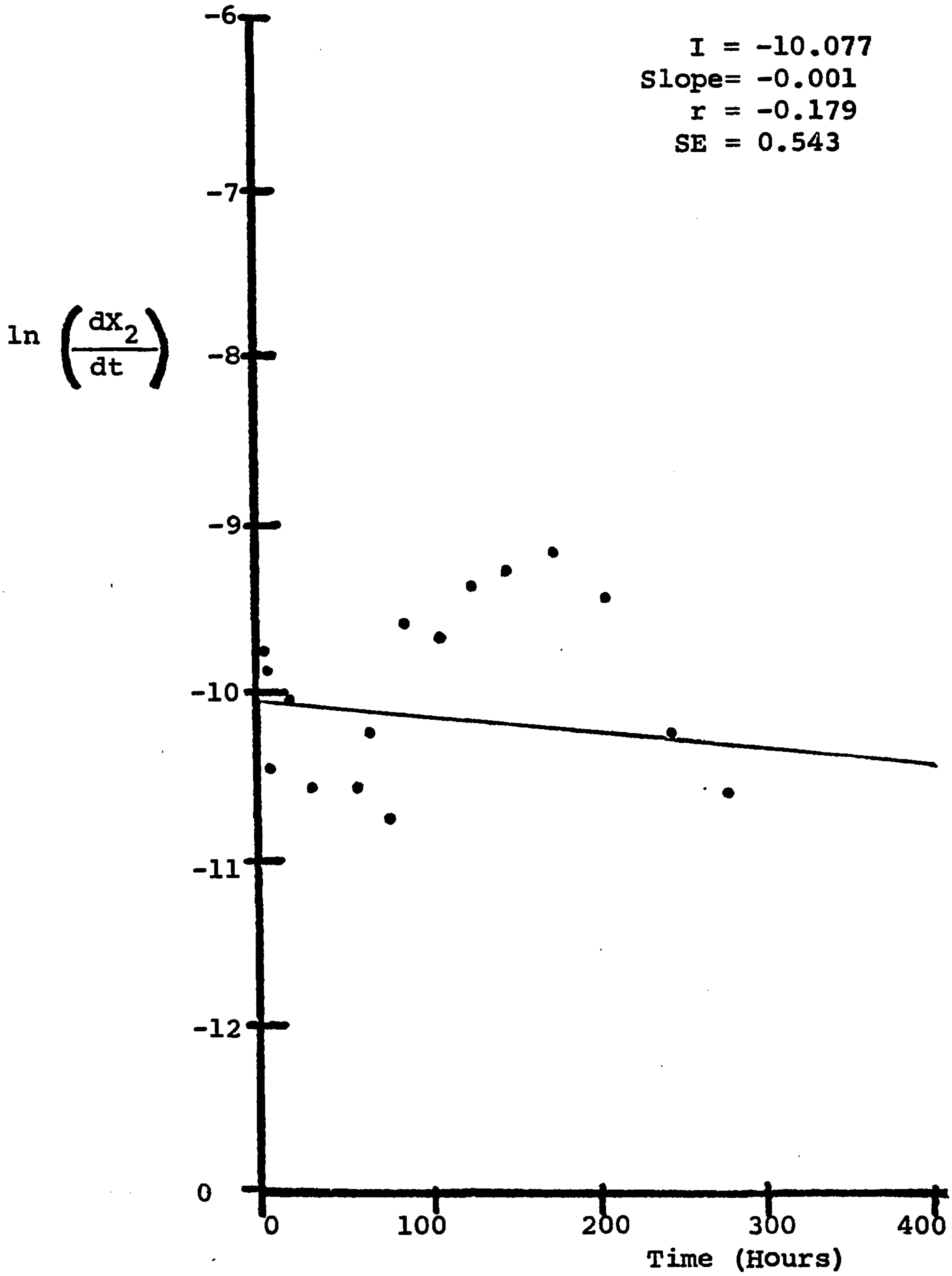
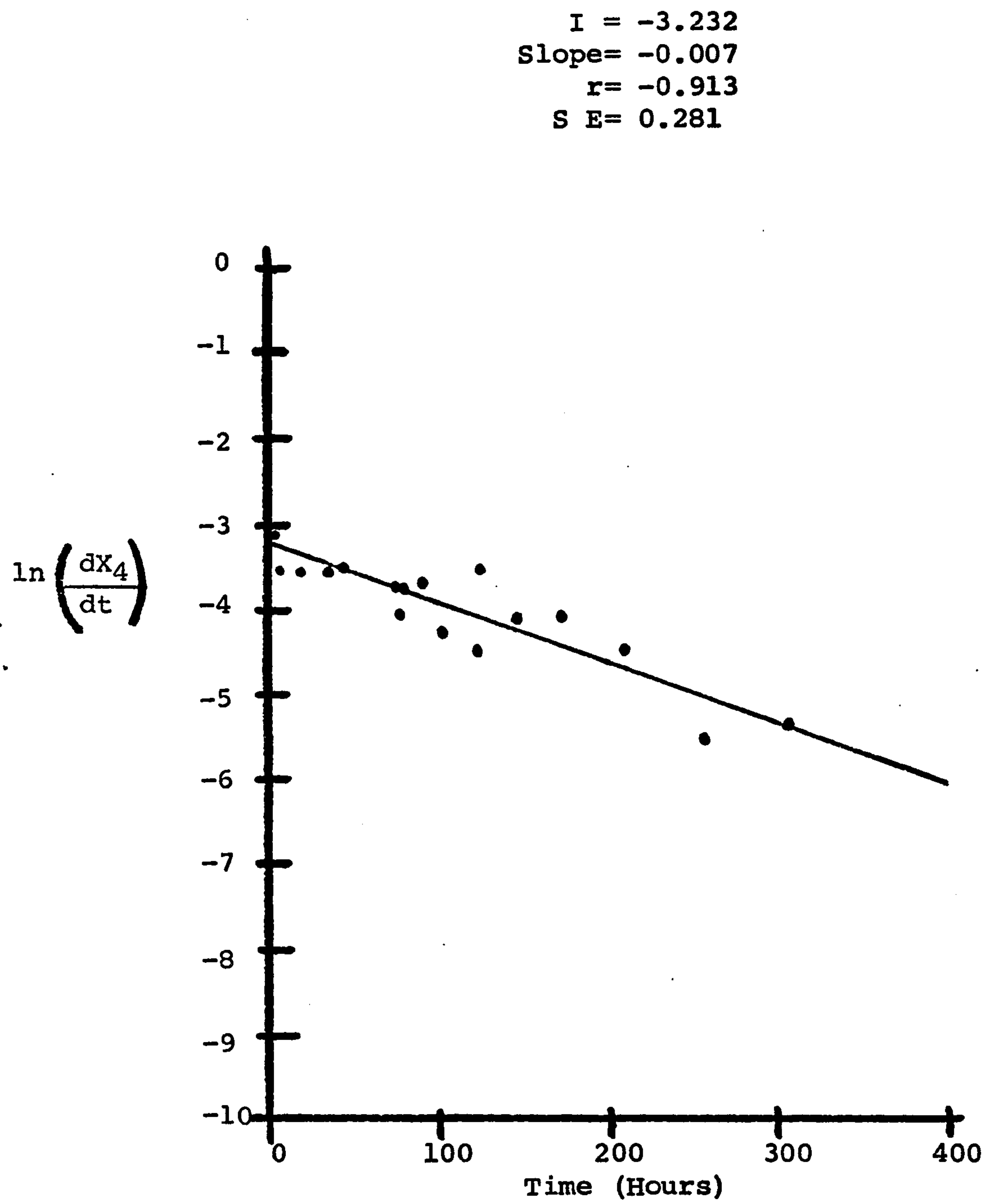


Figure 21. Sediment Compartment
Second Run, Tank II (Linear Regression)



times the square root of a mean value, as will be described. When the time occurred in which the data first came near equilibrium, the mean value was determined for the data of an additional equivalent length of time. The confidence interval was constructed about this mean. The initial data for the regression analysis was considered to be that data collected prior to the interval.

This method for logarithmic growth and decay curves was based on the principle of developing a linear relationship. The differentials, ΔX_i and Δt, were calculated for each sample interval. A linear regression analysis was made on the natural logarithm of the differential quotient as a function of time. The relationship is shown by the mathematical expression in Table 11. The initial uptake rate (a_{ij}) is obtained from the value projected to zero time. The antilog to base 10 is needed to determine equilibrium values. This equilibrium value represented a best fit value for a linear uptake relationship.

The initial uptake rate (a_{ij}) is the primary objective of the analysis. These values for each compartment will be used directly as necessary parameters in the simulation of the model. This will be discussed more fully in Chapter V.

The calculations derive values which are consistent with the previous discussions of uptake curves. The first run has a larger error, and was not analysed by this method. The second run shows a precise fit in both tanks and conforms well to a total selenium balance. This in general would support the model design as being a reasonable representative of the flows between compartments.

The greatest source of contradiction is the calculated values for suspended particulate found in the second run (Table 11). This would add validity to the alternate hypothesis concerning the latent depression in suspended particulate uptake.

Further analyses are helpful for projecting new meaning into the data obtained. The following types of calculations are useful for adding perspective or suggesting research efforts needed (Table 12). The table lists uptake constants, turnover times, and equilibrium values to steady states. Biological half lives are also calculated.

This determination of equilibrium times and calculation of steady state values is shown in Tables 13 and 14.

Additional parameters (Table 15) are calculated. Concentration factors and parts per million selenium show the bio-accumulation of selenium and suggest potential hazard.

TABLE 11

CALCULATION OF EQUILIBRIUM VALUES (x_i) BY INITIAL SLOPE
(Second Run, Tanks I, and II)

RELATIONSHIP: $X_i = x_i\ (1 - e^{-a_{ij}t})$

DIFFERENTIAL: $\ln \dfrac{dX_i}{dt} = \ln(a_{ij}x_i) - a_{ij}t$

At to...........Intercept = $\ln\ (a_{ij}x_i) - a_{ij}(0)$

TANK I

-WATER... $2.948 = \ln(-.009\ x_3)$

$x_3 = \dfrac{5.24 \times 10^{-2}}{.009} = 5.82$ mg (lost)

-SUSPENDED PARTICULATE... $-4.738 = \ln(-.008\ x_1)$

$x_1 = \dfrac{8.730}{.008} = 1.09$ mg

-FISH... $-9.354 = \ln\ (-.001\ x_2)$

$x_2 = \dfrac{8.64 \times 10^{-5}}{.001} = .086$ mg

-SEDIMENT... $-3.222 = \ln(-.011\ x_4)$

$x_4 = \dfrac{4.00 \times 10^{-2}}{.011} = 3.63$ mg

TABLE 11 (CONTINUED)

CALCULATION OF EQUILIBRIUM VALUES (x_1) BY INITIAL SLOPE
(Second Run, Tanks I, and II)

TANK II

-WATER... $-2.549 = \ln(-.011\ x_3)$

$$x_3 = \frac{.078}{.011} = 7.09 \text{ mg (lost)}$$

-SUSPENDED PARTICULATE...

$$-5.646 = \ln(-.005\ x_1)$$

$$x_1 = \frac{3.52 \times 10^{-3}}{.005} = .704 \text{ mg}$$

-FISH... $-10.077 = \ln(-.001\ x_2)$

$$x_2 = \frac{4.19 \times 10^{-5}}{.001} = .0419 \text{ mg}$$

-SEDIMENT... $-3.232 = \ln(-.007\ x_4)$

$$\frac{-3.94 \times 10^{-2}}{.007} = 5.62 \text{ mg}$$

TABLE 12
PARAMETERS FROM UPTAKE DATA

	UPTAKE CONSTANT a_{ij} (hr^{-1})	TURNOVER TIME T^{-1} (hr)	EQUILIBRIUM VALUE x_i (mgSe)	EQUILIBRIUM TIME t_{ss} (hr)	EFFECTIVE HALF TIME t_{eff} (hr)	BIOLOGICAL HALF TIME t_B (hr)
WATER	0.010	100	5.15 loss	230	69	71
SUSPENDED PARTICULATE	0.006	166	0.212	383	115	120
FISH	0.001	1000	0.034	230	693	71
SEDIMENT	0.009	111	3.93	256	77	79

TABLE 13

DETERMINATION OF EQUILIBRIUM TIME

t_{ss} = time to steady state

x_i = equilibrium value X_i

Equation for Regression Line:

$$\ln \left[\frac{\Delta X_i}{\Delta t}\right] = \ln (a_{ij}x) - a_{ij}t$$

If: $\ln \left[\frac{\Delta X_i}{\Delta t}\right] = 0$, then $t = t_{ss}$

And: $\frac{-\ln 0.1}{a_{ij}} = t_{ss}$

TABLE 14

CALCULATION OF BIOLOGICAL HALF TIMES

$$\frac{x_i}{x_i} = 1-e^{-a_{ij}t}$$

Since true equilibrium is reached at infinite time, 0.9 x_i is practical equilibrium. (Davis and Foster 1958).

$$0.9 = 1-e^{-a_{ij}t_{ss}}$$

$$0.1 = e^{-a_{ij}t_{ss}}$$

$$-\ln (0.1) = a_{ij}\ t_{ss}$$

Since.... $\left[a_{ij} = \frac{.693}{t_{eff}} \right]$

$$-\ln (0.1) = \frac{.693}{t_{eff}}\ t_{ss}$$

$$t_{ss} = t_{eff}\ \frac{(-\ln 0.1)}{.693}$$

And $\frac{1}{t_{eff}} = \frac{1}{t_B} + \frac{1}{t_R}$

Then at 90% Equilibrium:

$$t_{ss} = \frac{2.302}{\frac{.693}{t_B} + \frac{.693}{t_R}}$$

And $t_B = \dfrac{.693\ t_{ss}}{2.302 - \frac{.693}{2889.6}\ t_{ss}}$

TABLE 15

CONCENTRATION FACTORS AND FINAL
SELENIUM CONCENTRATION
SECOND RUN

	TANK I			TANK II		
	mg / g Compartment	C.F.*	Selenium ppm	mg / g Compartment	C.F.*	Selenium ppm
WATER	0.848 / 60,000	1	0.014	0.379 / 60,000	1	0.0063
SUSPENDED PARTICULATE	0.212 / 4.62	3,248	45.8	0.065 / 2.65	3,883	24.5
FISH	0.034 / 14.3	168	2.37	0.0108 / 10.8	158	1.00
SEDIMENT	3.934 / 7,200	38	0.546	5.454 / 7,200	120	0.757

*(mg/g Compartment) / (mg/g Water)

Summary

In summary, the four compartments uptake as expected. The separate tanks of both runs compare favorably and the four sets of data can be considered similar systems. The summing of compartments to a constant value of total selenium is good and supportive of the model.

The objective was continued in determination of rate constants for simulation in Chapter V.

The late depression of uptake in suspended particulate is probably due to slow equilibration of intake with losses.

Good supportive data has been obtained for the correction factors used and the model itself substantiates them by a good fit.

An hypothesis has been suggested which would account for the depression of the suspended particulate uptake by a failure of sampling design which caused added sediment uptake. It would propose that the low uptake amounts in the fish compartment is due to high intake and high loss rates.

In general,the data are statistically good, internally consistent and fitting to the proposed model. Radiotracer methods are sound and analytical methods substantiate the amounts of selenium detected.

Summary (Continued)

Regression analyses add validity to steady state values, and parameters determined by calculation should support the model and suggest new research.

CHAPTER V

SIMULATION OF THE MODEL AND CONCLUSIONS

It will be the objective in this final chapter to adapt the selenium model in a meaningful way to an analog computer program. An attempt will be made to simulate the data collected in the laboratory.

The outcome of this simulation will be productive in substantiating the value of the modeling effort for verification and for raising research questions.

The initial uptake constants obtained from the linear regression analyses are important in developing the model. The diagonal of the matrix of the selenium model represents the sum of the flows out of the respective compartments. The remaining entries in each column $b_{i1} \ldots b_{i4}$ represent the flows into each of the respective compartments, X_i . At steady state $\frac{dx_i}{dt} = 0$ and $\sum_{i=1}^{4} b_{ij} = 0$ for all columns (See Table 16).

TABLE 16

DIAGONAL MATRIX

$$\begin{bmatrix} b_{11} & -- & -- & -- \\ -- & b_{22} & -- & -- \\ -- & -- & b_{33} & -- \\ -- & -- & -- & b_{44} \end{bmatrix}$$

The solution to the matrix is affected by obtaining uptake constants in sufficient number to solve the set of simultaneous equations. Table 17 represents the incomplete solution in which there are four equations in ten unknowns.

TABLE 17

MATRIX FORM WITH INCOMPLETE SOLUTION

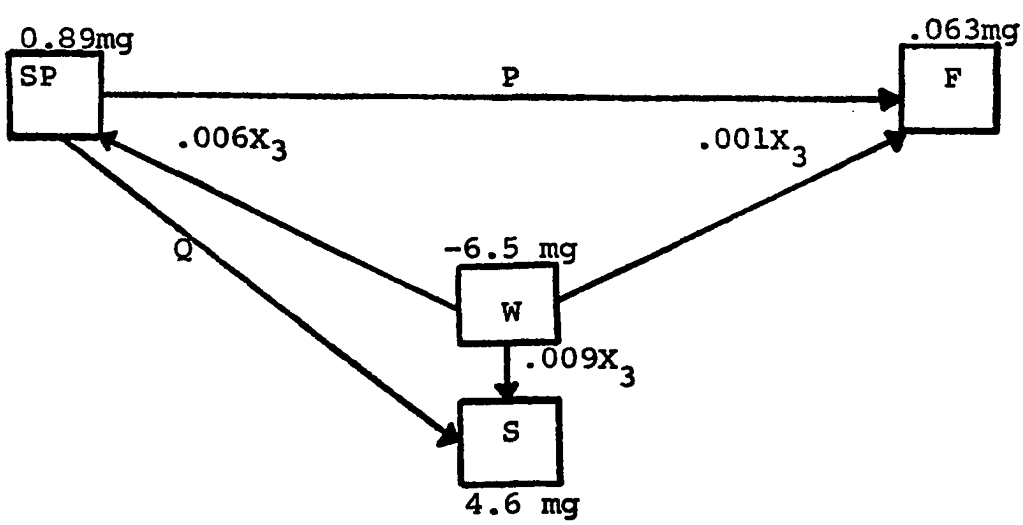
$$\begin{bmatrix} .006 & b_{12} & b_{13} & b_{14} \\ b_{21} & .001 & b_{23} & 0 \\ b_{31} & b_{32} & .010 & b_{34} \\ b_{41} & 0 & b_{43} & .009 \end{bmatrix} \begin{pmatrix} 0.89 \\ 0.063 \\ -6.5 \\ 4.6 \end{pmatrix} \cong \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

Average values from the second run were used, therefore, a precise materials balance of 6.0 mg. total is not possible. A solution is impossible without the use of analog simulation. Knowing the columns add to zero yields eight equations. Simulation of two additional unknowns would allow solution.

A simpler model is conceived in which the initial flows are assumed as unidirectional (Figure 22).

FIGURE 22

SIMPLIFIED FLOW DIAGRAM WITH INITIAL FLOWS



An analog computer program can be written to fit this simpler model (Figure 23). With this simple model, a search can be made to find flows P and Q between suspended particulate and fish and suspended particulate and sediment (Figure 22). These are assumed as initial flows and would represent the initial flows and would represent the initial uptake rates.

The simulation occurred with the flow P $\cong$ 0.001 and Q $\cong$ 0.010.

The matrix can be completed (Figure 24) with the simulation of the original data on the complete model.

Figure 24. Completed Matrix.

$$\begin{bmatrix} .006 & .0005 & .001 & .008 \\ .001 & .001 & .008 & 0 \\ .001 & .0005 & .010 & .001 \\ .004 & 0 & .001 & .009 \end{bmatrix}$$

The complete analog computer program that produced this simulation is shown in Figure 25. The analog simulation obtained from this matrix is shown in Figure 26.

Figure 23. Simplified Analog Computer Program

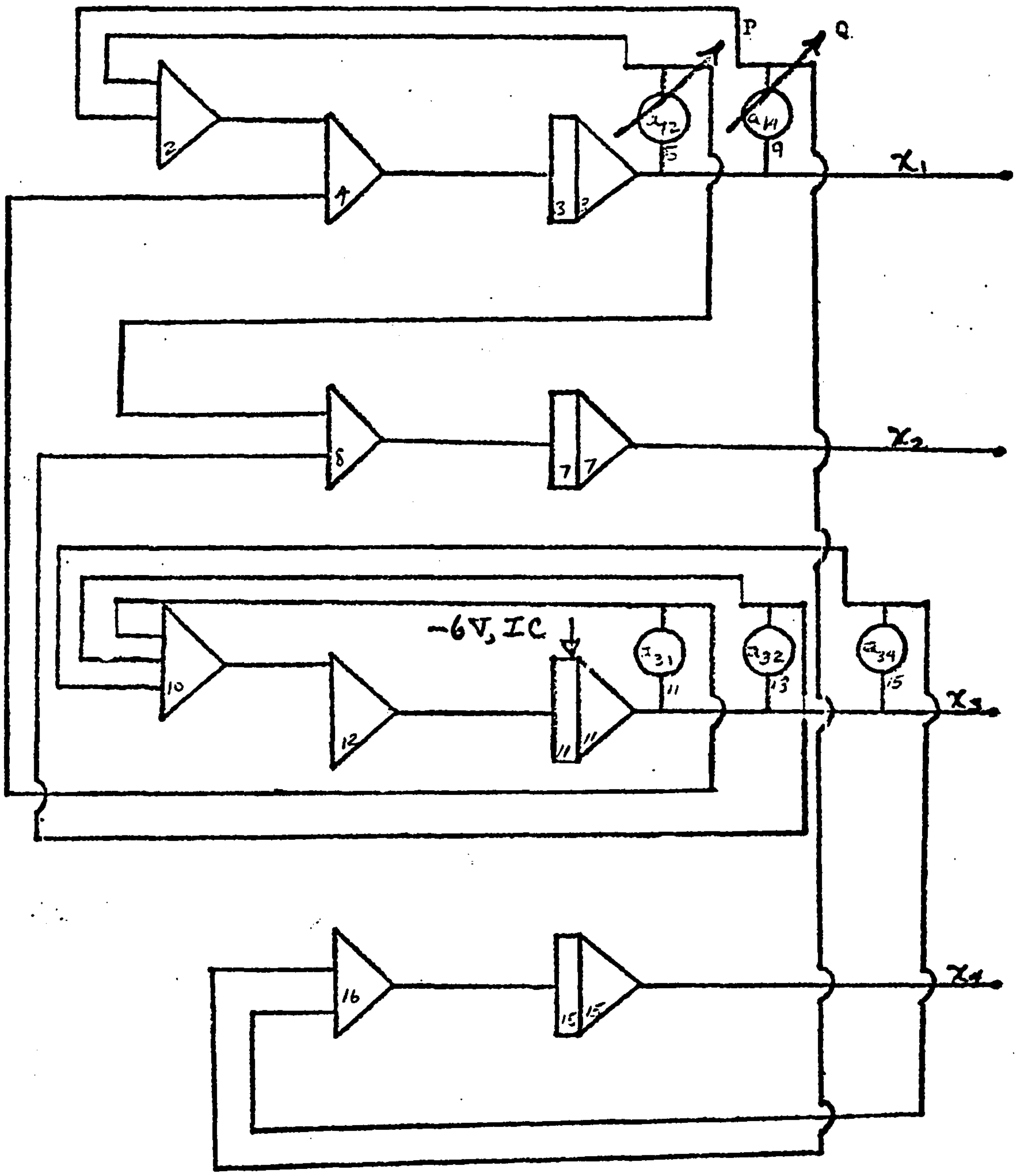


Figure 25. Complete Analog Computer Program

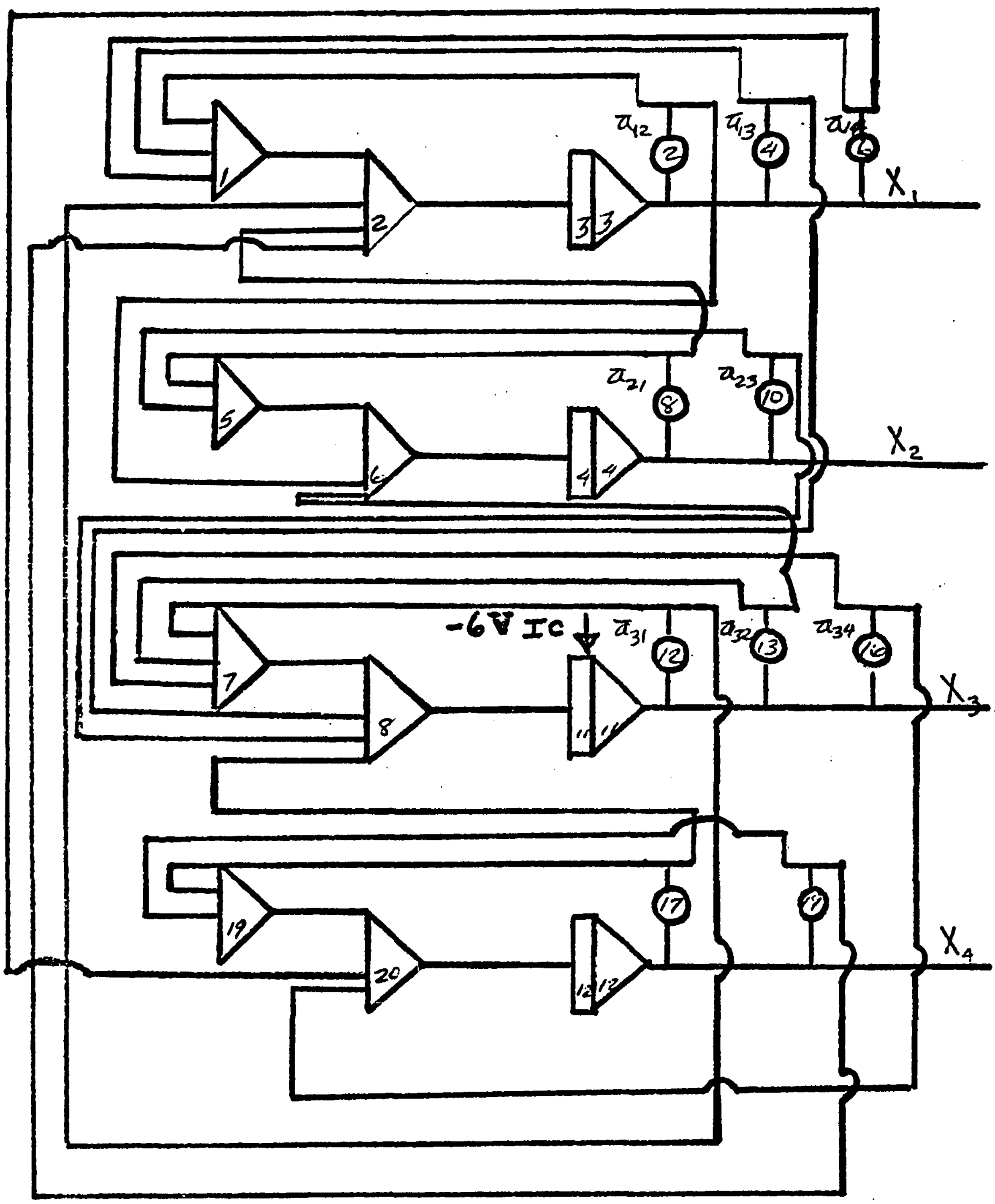
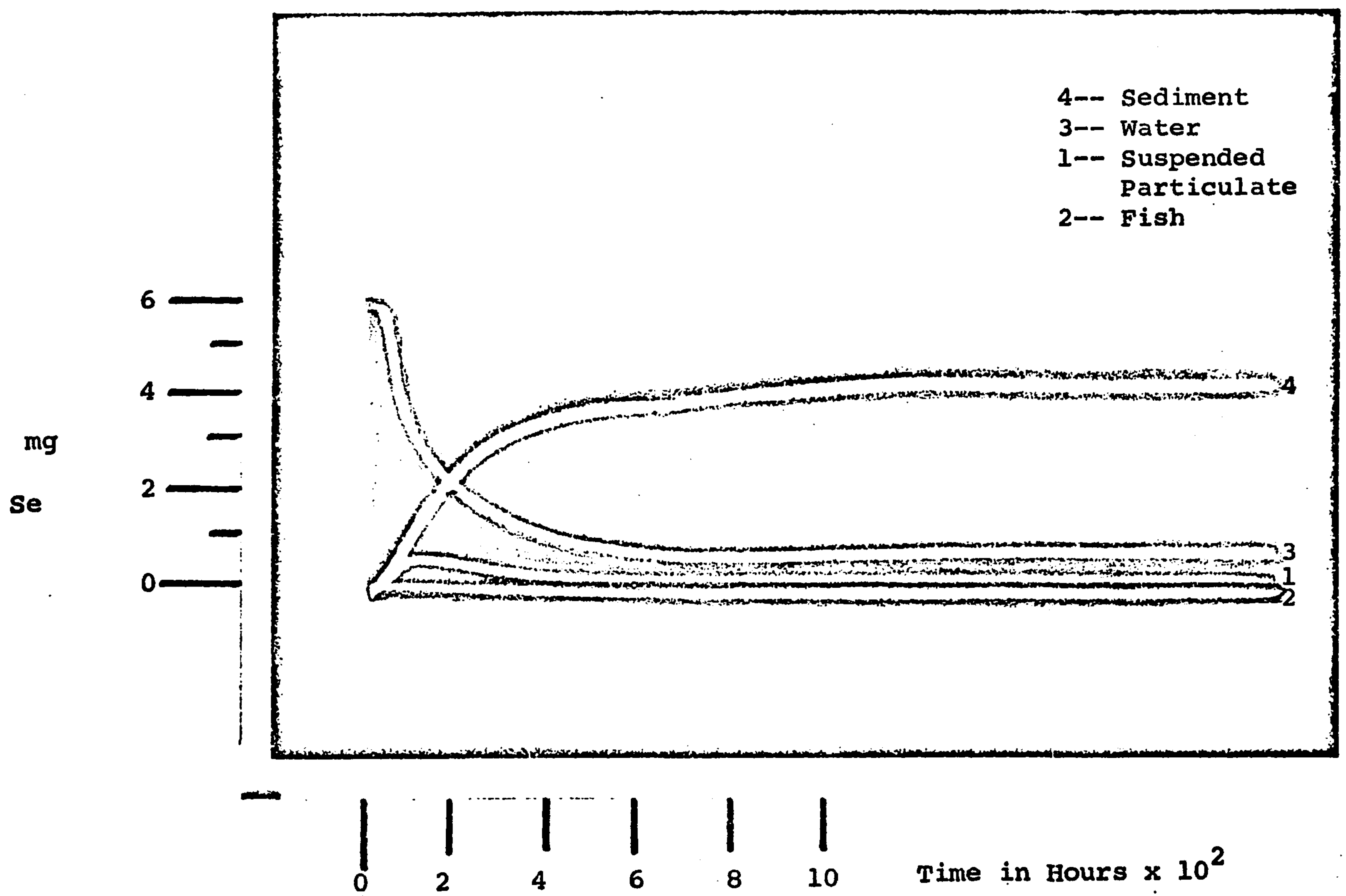


Figure 26. Analog Simulation of Selenium Model



An examination of the solution matrix (Figure 24) can summarize the thinking that went into the development of the selenium model.

The suspended particulate shows almost equal flows in and out of the fish. This fits our knowledge that the fish is not accumulating selenium by feeding on algae. Its rate of uptake from water is equal to its loss rate. One would expect sorption and metabolic uptake to produce accumulation. The transfer rate to sediment is double the reverse rate. Settling is going on at a higher rate than re-entrainment.

The fish compartment shows a much lower rate of uptake from water than loss and again no trophic gain appears from the suspended particulate. Apparently what is eaten is passed through without much absorption in the gut wall. This is supported by the observation of green fecal material which appears to have been passed by the fish without damage to the algal cells.

As expected, the water compartment shows rates to the other compartments greater than the incoming rates.

The sediment shows an uptake rate from the water no greater than the reverse flow. Both chemical and physical actions are greater for flow into the sediment than out. Sorption would occur more likely than desorption, and apparently precipitation or ion exchange reactions tend to move selenium to the sediment. The rate from the suspended particulate is greater than the loss by sediment to that compartment.

A brief reiteration would allow that the primary interaction of suspended particulate is a water uptake and a settling loss to sediment. The water is donating to all compartments, and the fish is accumulating mostly by membrane uptake with relatively little loss through the kidney. The sediment is gaining selenium both from the water and suspended particulate at favorably large rates.

From the conclusions, certain other relationships are evident from Tables 12 and 15 (Chapter IV). The suspended particulate has a small mass, rapid loss to sediment, and good uptake from water. This results in a high concentration factor and fairly rapid turnover rate with a short equilibrium time and biological half life. The fish has only one uptake source and a relatively large mass. Its concentration factor is thus low. It has a longer turnover time and biological half life because of a possible low excretion rate. The water loses to all compartments and would have a short turnover time. The large mass of sediment and relative rates of uptake from two compartments give it a relatively low concentration factor and large accumulation. Since it contains settled suspended particulate it might be expected to have shorter turnover rates than fish.

The simulation fits the data and the uptake constants generated make good biological sense. The model seems to have no obvious contradiction. However, it would still allow for the alternate hypothesis suggested in the previous chapter by the latent depression of the suspended particulate uptake. It is possible that the large settling rate of the suspended particulate is due to the swallowing, concentration, and defecating action of the fish. The fecal pellets, being larger, settle at a high rate. The function of the fish would be to advance the settling rate of the suspended particulate with a very low absorption such that the fish receives no significant build up of selenium. The biological half life of the fish that has been calculated, then is essentially due to kidney excretion vs. membrane uptake.

The important value of the model must be to stimulate meaningful questions which can verify or contradict various aspects of the model. For instance, questions arise: Is the high concentration factor of suspended particulate associated with the bacteria or other flora or is it associated with fine particles? It would be interesting to find the biological half life of the fish in a feeding relationship compared to membrane uptake alone. The fraction absorbed in the gut should be investigated. Questions about migration rates in the sediment would be valuable studies. In addition, further trophic studies should be undertaken to elucidate a more complete food chain.

The ultimate modeling effort should be related to field observations. For example, if field observations show a different equilibrium time than is measured in the laboratory, then $a_{ij} = \frac{-\ln 0.1}{\text{time}}$ assuming 90% equilibrium. Selenium could be measured in the lake and converted to laboratory values with the assumptions of equilibrium.

Additional modeling efforts will become more mechanistic. Better analytical chemistry is needed to help this kind of modeling.

As all of these kinds of studies continue, the model will change. A model represents only a fabrication of the methods used to investigate the problem. As new techniques are developed, the model must change also. In doing so, it improves predictability and stimulates new questions.

APPENDIX A

APPENDIX A-1

CULTURE MEDIA

(Fogg 1965, P. 35)

NUTRIENT	%
KNO_3	0.1
$Ca(NO_3)_2$	0.01
K_2HPO_4	0.02
$MgSO_4 \cdot 7\ H_2O$	0.01
$FeCl_3$	0.0001
Vitamins	Trace
Difco-Peptone	Excess

APPENDIX A-2

SEDIMENT SIEVE SIZE ANALYSIS

SAMPLE NUMBER	MESH SIZE	WEIGHT(g) PLANCHET & SEDIMENT	WEIGHT(g) PLANCHET		WEIGHT(g) SEDIMENT	% TOTAL
#1	>40	10.0780	9.4320		0.6460	4.4
	>60	11.6203	9.5509		2.0694	14.1
	>100	15.4725	9.2750		6.1975	42.4
	>140	12.5833	9.4950		3.0883	21.2
	>200	10.9557	9.4049		1.5508	10.6
	Fines	10.2210	9.1760		1.0450	7.1
				TOTAL	14.5970	100.00%
#2	>40	10.0758	9.4377		0.6381	4.5
	>60	11.4850	9.5504		1.9346	13.8
	>100	15.2162	9.3772		5.8390	41.7
	>140	12.4495	9.4119		3.0376	21.7
	>200	10.8245	9.2923		1.5322	10.9
	Fines	10.4691	9.4581		1.0110	7.2
				TOTAL	13.9925	100.00%
#3	>40	9.9476	9.3388		0.6088	4.3
	>60	11.3613	9.3753		1.9860	14.1
	>100	15.2750	9.4605		5.8145	41.4
	>140	12.3570	9.3501		3.0069	21.4
	>200	11.1528	9.6052		1.5476	11.0
	Fines	10.7743	9.7019		1.0724	7.6
				TOTAL	14.0362	100.00%

APPENDIX A-2 (CONTINUED)

SEDIMENT SIEVE SIZE ANALYSIS

SAMPLE NUMBER	MESH SIZE	WEIGHT(g) PLANCHET & SEDIMENT	WEIGHT(g) PLANCHET		WEIGHT(g) SEDIMENT	% TOTAL
#4	> 40	10.0132	9.3427		0.6705	4.6
	> 60	11.6136	9.5000		2.1136	14.7
	> 100	15.3995	9.3816		6.0179	42.0
	> 140	12.2059	9.1738		3.0321	21.1
	> 200	10.5961	9.1038		1.4923	10.4
	Fines	10.3237	9.3264		0.9973	6.9
				TOTAL	14.3237	100.00%
#5	> 40	10.1666	9.6166		0.5500	3.9
	> 60	11.3345	9.5847		1.7498	12.5
	> 100	15.0418	9.3282		5.7136	41.0
	> 140	12.7642	9.6089		3.1553	22.6
	> 200	10.8727	9.2262		1.6465	11.8
	Fines	10.7669	9.6500		1.1169	8.0
				TOTAL	13.9321	100.00%
#6	> 40	10.0830	9.5992		0.4838	3.3
	> 60	11.2306	9.5064		1.7242	12.0
	> 100	15.3916	9.5718		5.8698	41.1
	> 140	12.8586	9.6185		3.2401	22.6
	> 200	11.0693	9.3479		1.7214	12.0
	Fines	10.6684	9.4270		1.2414	8.6
				TOTAL	14.2807	100.00%

APPENDIX A-2 (CONTINUED)

SEDIMENT SIEVE SIZE ANALYSIS

SAMPLE NUMBER	MESH SIZE	WEIGHT(g) PLANCHET & SEDIMENT	WEIGHT(g) PLANCHET		WEIGHT(g) SEDIMENT	% TOTAL
#7	> 40	10.0152	9.3847		0.6305	4.4
	> 60	11.3121	9.4318		1.8803	13.1
	> 100	15.6200	9.5346		6.0854	42.6
	> 140	12.5013	9.3975		3.1038	21.8
	> 200	11.1506	9.6288		1.5218	10.6
	Fines	10.4720	9.4094		1.0626	7.4
				TOTAL	14.2844	100.00%
#8	> 40	9.8383	9.2390		0.5993	4.8
	> 60	11.5137	9.5793		1.9344	13.2
	> 100	15.3616	9.2600		6.1016	41.8
	> 140	12.5747	9.4327		3.1420	21.3
	> 200	11.1962	9.6048		1.5914	10.9
	Fines	10.6371	9.5397		1.0974	7.7
				TOTAL	14.4661	100.00%
#9	> 40	9.9803	9.2920		0.6883	4.8
	> 60	11.5579	9.6962		1.8617	13.2
	> 100	15.5643	9.6754		5.8889	41.8
	> 140	12.6444	9.6463		2.9981	21.3
	> 200	11.1283	9.5867		1.5416	10.9
					1.0865	7.7

APPENDIX A-3

DISTRIBUTION OF SEDIMENT IN SAMPLING CONTAINERS ACCORDING TO SIEVE ANALYSIS

- Area of Experimental Tanks = 1860.32 cm^2
- Area of 1 sampling container $= \pi\left(\frac{D}{2}\right)^2$

$$= \underline{(3.1416)\ (1.89/2)^2}\ cm^2$$

$$= 2.805\ cm^2$$

where container diameter = 1.89 cm.

- Fraction of sediment in one container by area ratio =

$$\frac{2.805\ cm^2}{1860.32\ cm^2} = .001508$$

- Total weight sediment in tank = 7200g

and

- Weight of Sediment to be placed in one container =

(.001508) 7200g = 10.857 g/container.

- Weight by particle size required for container to be representative.

PARTICLE SIZE DISTRIBUTION

SIZE	%	WEIGHT(g)
> 40	(4.3%)	0.4668g
> 60	(13.42%)	1.4578g
> 100	(41.81%)	4.5361g
> 140	(21.63%)	2.3483g
> 200	(11.03%)	1.1975g
Fines	(7.6 %)	0.8251g
TOTAL	99.99%	10.8289g

APPENDIX A-4

QUALITATIVE DISTRIBUTION OF PARTICLE SIZE ON BOTTOM

The blotter paper was positioned on the bottom of the tanks and a particle size distribution was introduced in the center by the propeller sequentially by size.

The following visual observations were made. Water was in the tank. See FIGURE VI for letter code.

	MESH SIZE	DISTRIBUTION
FINES	< 200	General, primarily H
	< 140	C and E
	< 100	C
	< 60	R and C
	< 40	R

APPENDIX A-5

COMPARISON OF PIPETTES

Normal Pipette: 20.0 ml

Broken End Pipette: Tip broken off and recalibrated to 20.0 ml to allow larger orifice.

	SAMPLE NUMBER	WEIGHT SUSPENDED PARTICULATE MILLIGRAMS	STATISTICAL ANALYSIS
	1	1.7	
	2	1.8	
	3	1.7	
	4	1.7	
NORMAL	5	1.9	mean = 1.83 mg
	6	1.9	
	7	1.8	$\sqrt{n}$ = 0.105 mg
	8	1.9	
	9	2.0	1.96 $\sqrt{n}$ = 0.207 mg
	10	1.9	
	11	3.1	
	12	2.9	
	13	2.6	mean = 2.98 mg
	14	3.1	
BROKEN	15	2.7	$\sqrt{n}$ = 0.253 mg
END	16	3.0	
	17	2.8	1.96 $\sqrt{n}$ = 0.495 mg
	18	3.3	
	19	2.9	
	20	3.4	

APPENDIX B

APPENDIX B-1

WATER COMPARTMENT (FIRST RUN, TANK I)

HOURS ELAPSED TIME	FILTER NUMBER	RAW 10 MIN. COUNT 20 ml SAMPLE	cpm CORRECTED FOR BACKGROUND	cpm CORRECTED FOR DECAY	mg Se 20 ml SAMPLE x 10^{-3}	mg Se 60 l TANK
0						
1.5	19	536-476 *	401	401	.1978	.5936
2.0	17	602-559 *	476	476	.2349	.7047
12	5	512-500 *	401	401	.1978	.5936
13	7	4,941	389	389	.1919	.5759
19	9	5,510	446	446	.2201	.6603
29	11	5,035	398	398	.1966	.5899
37	13	5,164	411	411	.2030	.6090
55	15	4,900	385	389	.1922	.5766
62	2	4,891	384	388	.1917	.5751
87	3	4,417	336	340	.1680	.5042
110	21	4,797	375	383	.1892	.5676
134	23	4,429	338	346	.1711	.5134
190	25	4,078	304	318	.1569	.4709
212	27	3,855	282	295	.1454	.4364
232	29	3,685	266	281	.1387	.4163
278	31	3,342	231	248	.1222	.3667
310	33	3,976	294	315	.1552	.4657
354	35	3,235	220	241	.1187	.3562
432	37	3,095	206	228	.1124	.3374
476	39	2,801	174	195	.0963	.2889

* one minute count

APPENDIX B-1 (CONTINUED)

WATER COMPARTMENT (FIRST RUN, TANK I)

HOURS ELAPSED TIME	FILTER NUMBER	RAW 10 MIN. COUNT 20 ml SAMPLE	cpm CORRECTED FOR BACKGROUND	cpm CORRECTED FOR DECAY	mg Se 20 ml SAMPLE x 10^{-3}	mg Se 60 l TANK
498	41	2,750	171	192	.0945	.2837
526	43	2,695	169	190	.0939	.2818
549	45	2,474	145	164	.0810	.2432
573	47	2,415	141	161	.0796	.2388
650	49	2,170	115	134	.0659	.1977
672	51	2,180	117	137	.0678	.2035
692	53	2,242	124	146	.0720	.2160
716	55	2,065	105	124	.0612	.1838
740	57	1,913	90	108	.0532	.1596

APPENDIX B-2

SUSPENDED PARTICULATE (First Run, Tank I)

ELAPSED TIME IN HOURS	FILTER NUMBER	RAW cpm ROLLED FILTER 20 ml SAMPLE	cpm CORRECTED FOR BACKGROUND	cpm DECAY CORRECTED	NORMALIZED cpm (x .9055)	10^{-6} mg Se ** 20 ml SAMPLE	mg Se COMPARTMENT (x 3,000)
0	00	987*	0	0	0	0	0
1.5	19	1,032*	4	5	5	3	.007
2.0	17	99, 114 107	8	10	9	4	.013
12	5	126, 106 108	14	18	16	8	.024
13	7	102, 94, 119	6	7	7	3	.009
19	9	118, 94, 122	12	15	14	7	.021
29	11	126, 123, 116	23	28	25	12	.038
37	13	113, 115, 117	16	20	18	9	.027
55	15	1,187*	20	25	22	11	.033
62	even 2	1,618*	63	78	71	35	.105
87	3	1,327*	34	42	38	18	.056

* ten minute count   ** mg per cpm = 0.4935

APPENDIX B-2 (CONTINUED)

SUSPENDED PARTICULATE (First Run, Tank I)

ELAPSED TIME IN HOURS	FILTER NUMBER	RAW cpm ROLLED FILTER 20 ml SAMPLE	cpm CORRECTED FOR BACKGROUND	cpm DECAY CORRECTED	NORMALIZED cpm (x .9055)	10^{-6} mg Se ** 20 ml SAMPLE	mg Se COMPARTMENT (x 3,000)
110	21	142, 101, 129	25	31	28	14	.042
134	23	1,280*	29	36	33	16	.049
190	25	114, 120, 115, 126	20	25	22	11	.033
212	27	116, 103, 120	14	17	16	8	.024
232	29	1,168*	18	22	20	10	.030
278	31	106, 108, 134	17	21	19	9	.029
310	33	115, 113, 115	15	19	17	8	.026
354	35	116, 113, 137	23	29	26	13	.039
432	37	1,150*	16	20	18	9	.027

* ten minute count   ** mg per cpm = 0.4935

APPENDIX B-2 (CONTINUED)

SUSPENDED PARTICULATE (First Run, Tank I)

ELAPSED TIME IN HOURS	FILTER NUMBER	RAW cpm ROLLED FILTER 20 ml SAMPLE	cpm CORRECTED FOR BACKGROUND	cpm DECAY CORRECTED	NORMALIZED cpm (x .9055)	10^{-6} mg Se ** 20 ml SAMPLE	mg Se COMPARTMENT (x 3,000)
476	39	121, 111, 109	15	18	16	8	.025
498	41	117, 128, 96	15	18	16	8	.025
526	43	134, 91	13	17	15	7	.023
549	45	125, 118	22	28	25	12	.038
573	47	114, 128	22	27	25	12	.037
650	49	1,204*	21	27	24	12	.036
672	51	123, 124	24	30	28	13	.041
692	53	119, 125	23	29	26	13	.039
716	55	109, 140	25	32	29	14	.043
740	57	117, 121	20	25	22	11	.034

* ten minute count ** mg per cpm = 0.4935

APPENDIX B-3

FISH COMPARTMENT (First Run, Tank I)

ELAPSED TIME IN HRS.	FISH NUMBER 1	2	3	4	5	6
0	121-105	111-106	111-98	105-108	113-104	109-110
2.75	139	158	160	165	-	-
13	262-250	255-287	274-273	302	332	-
38	337-394 357	403-366	412	465-450	545-551 545	-
63	446-430	478-484	514-561	649-645	659-639	756-727
88	568-596	631-617	714-725	722-713	785-793	906-849
191	284-151	722-703	1,080-1,031	1,079-1,100	1,512-1,623	1,784-1,817
230	879-788	863-893	1,047-1,054	1,147-1,208	1,625-1,734	1,939-1,933
254	733-734	859-882	1,015-970	1,228-1,276	2,001-2,010	1,996-2,031
287	746-839	1,172 940 up	1,495-1,430	1,697-1,738	1,845-1,897	2,333-2,366
310	1,248-1,192	1,171 1,388 up	1,752-1,733	1,901-1,878	2,694-2,630	2,980-3,003 2,985-3,031
330	1,091-1,073	1,040 1,126 up	1,284 1,303 up	1,675-1,657	2,784-2,908	3,146-3,042
354	1,045-1,099	1,250 1,167 up	1,597-1,617	1,869-1,914	2,927-2,823	2,826-2,931
374	1,109-1,051	1,436 1,177 up	1,671-1,718	1,950-1,958	2,913-3,090	3,129-2,955

APPENDIX B-3 (CONTINUED)

FISH COMPARTMENT (First Run, Tank I)

ELAPSED TIME IN HRS.	FISH NUMBER 1	2	3	4	5	6
476	1,095-1,025	1,083-1,182	1,219 1,208 up	1,666-1,670	2,960-2,792	2,943-2,919
500	1,008-1,043 995	1,037 1,035 up	1,577-1,576	1,661-1,903 1,749	2,861-2,929 2,830-2,787	2,964-3,063
518	1,028-1,129	1,164 1,158 up	1,183 1,180 up	1,637-1,654	2,756-2,779	2,995-2,892 2,905
549	985-990	1,087-1,149	1,135-1,150 1,156	1,564-1,570	2,087-2,683 1,984 up 2,680	2,788-2,774
574	950 down 1,051	1,096 1,083 up	1,518-1,543	1,643-1,685	2,765-2,686	2,876-2,707
650	926-882	1,056-1,094up	1,388-1,449 1,452	1,700-1,685	2,630-2,608	2,606-2,689
672	881-871	1,090-1,007 1,003 up	1,410-1,411	1,591-1,589	2,409-2,371	2,612-2,724
694	889-895 up	1,348-1,270	1,451-1,385	1,561-1,550	2,609-2,621	2,682-2,589 2,652
716	931-886	1,200-1,109	1,159-1,208 1,231	1,610-1,594	2,528-2,470	2,660-2,597
740	942-886	1,135 1,105 up	1,138 up 1,105-1,108	1,135-1,193	2,466-2,558	2,626-2,643

APPENDIX B-3 (CONTINUED)

FISH COMPARTMENT (First Run, Tank I)

ELAPSED TIME IN HOURS	BACKGROUND CORRECTED SUM COMPARTMENT	COMPARTMENT cpm DECAY CORRECTED	10^{-6} COMPARTMENT mg Se*	10^{-6} COMPARTMENT mg Se NORMALIZED**
0	0	0	0	0
2.75	303	303	149	105
13	1,090	1,090	538	379
38	1,961	1,961	967	683
63	2,864	2,897	1,429	1,009
88	3,705	3,748	1,849	1,306
191	5,816	6,090	3,005	2,122
230	6,933	7,260	3,583	2,529
254	7,246	7,675	3,787	2,674
287	9,210	9,869	4,870	3,438
310	11,994	12,851	6,342	4,477
330	12,252	13,278	6,553	4,626
354	11,760	12,745	6,289	4,440
374	12,304	13,492	6,658	4,701
476	10,966	12,164	6,003	4,237
500	12,063	13,536	6,679	4,716
518	12,020	13,488	6,656	4,699
549	11,420	12,963	6,397	4,517
574	11,051	12,688	6,261	4,420
650	10,541	12,242	6,042	4,265
672	10,116	11,885	5,865	4,140
694	9,831	11,550	5,700	4,024
716	9,941	11,814	5,830	4,116
740	10,232	12,160	6,001	4,236

* (0.49350×10^{-6}) mg/cpm

** Normalization Factor = .706

APPENDIX B-4

SEDIMENT COMPARTMENT (First Run, Tank I, Raw cpm)

ELAPSED TIME IN HRS.	I 3 H	I 2 H	I 1 H	I 3 R	I 1 R	I 4 C
0	1,045*	1,032*	1,029*	1,052*	1,055*	1,035*
3	147	190	-	215	-	233
19	1,959*	2,960*	2,855*	3,366*	3,403*	4,104*
44	3,153*	4,363*	4,205*	4,654*	5,154*	5,755*
70	306-322	516-481	497-574	539-554	563-566	699-735
133	6,997*	7,775*	6,752*	6,360*	8,355*	9,513*
212	8,313*	8,919*	7,523*	7,202*	8,564*	9,217*
242	898-848	847-874	865-896	743-747	931-949	947-1,009
278	1,268-1,248	814-736	889-946	801-776	802-823	1,031-984
311	1,515	751-790	1,024-1,051	833-839	931-929	1,017-984
332	1,459-1,484	786-815	945-1,002	870-855	771-794	975-1,004
355	1,485-1,471	905-932	1,066	839-876	907-920	1,047-1,096
375	1,497-1,550	950-1,003	1,171-1,148	968-919	1,125-1,055	1,298-1,321
477	1,625-1,556	1,016-1,058	1,176-1,198	955-952	1,098-1,084	1,294-1,284
502	15,380*	10,264*	1,166-1,223	9,665*	1,039-1,090	13,219*
550	15,985*	10,613*	1,277-1,253	9,810*	1,125-1,133	13,227*
574	16,490*	10,463*	1,209-1,306	10,274*	1,084-1,126	13,402*
673	18,623*	10,818*	1,308-1,346	10,310*	1,100-1,094	13,503*
693	17,902*	10,586*	1,352-1,325	9,938*	1,058-1,158	13,544*
717	17,761*	10,556*	1,346-1,282	9,539*	1,130-1,108	13,076*
735	1,699-1,697	999-1,063	1,290-1,304	8,802*	1,044-1,038	1,308-1,360

* ten minute count

APPENDIX B-4 (CONTINUED)

SEDIMENT COMPARTMENT (First Run, Tank I, Raw cpm)

ELAPSED TIME IN HRS.	I 2 C	I 4 E	I 2 E	I 3 E	I 1 E
0	1,045*	1,059*	1,039*	1,022*	1,063*
3	-	230	-	209	-
19	4,001*	3,878*	3,536*	3,744*	2,991*
44	5,880*	5,484*	5,111	5,447*	489-437
70	662-653	587-631	667-657	551-562	470-476
133	9,402*	8,898*	7,912*	7,727*	5,758*
212	11,195*	10,567*	10,326*	9,224*	7,234*
242	1,073-1,094	1,004-1,036	970-942	968-955	755-703
278	1,083-1,044	1,028-1,006	878-929	952-898	743-705
311	1,149-1,198	991-1,034	949-947	1,014-1,038	714-720
332	1,148-1,078	972-980	930-911	994-940	850-813
355	1,178-1,315	1,105-1,125	996-1,041	1,037-1,039	747-890
375	1,411-1,400	1,168-1,057	1,048	1,161-1,128	948-927
477	1,470-1,482	1,279-1,223	1,127-1,101	1,268-1,251	978-928
502	1,398-1,431	1,249-1,266	11,781*	12,553*	930-942
550	1,433-1,434	1,376-1,261	12,363*	12,937*	975-977
574	1,413-1,419	1,264-1,299	12,444*	13,323*	975-1,002
					939-996
673	1,453-1,394	1,264-1,255	12,460*	13,421*	997-1,005
693	1,460-1,361	1,280-1,222	12,416*	12,968*	1,013-964
717	1,420-1,416	1,309-1,255	12,137*	12,949*	969-965
735	1,327-1,362	1,249-1,287	1,211-1,216	1,268-1,237	967-974

* ten minute count

APPENDIX B-4 (CONTINUED)

SEDIMENT COMPARTMENT (First Run, Tank I, Corrected*
for Background, Normalized+ for Attenuation, Geometry)

ELAPSED TIME IN HRS.	I 3 H	I 2 H	I 1 H	I 3 R	I 1 R	I 4 C
0	0	0	0	0	0	0
3	42-34	85-68	-	110-88	-	128-103
19	91-73	191-153	180-144	232-186	235-189	305-245
44	210-169	331-266	315-253	360-289	410-330	471-378
70	209-168	394-316	430-346	441-355	460-369	612-491
133	595-478	673-541	570-458	532-427	731-587	847-680
212	727-584	788-632	648-521	616-495	752-604	817-656
242	770-618	758-609	778-624	642-516	837-672	875-703
278	1,154-926	671-538	813-653	684-550	709-569	903-726
311	1,411-1,133	667-535	934-950	732-587	826-663	896-720
332	1,367-1,098	697-560	870-698	759-609	678-544	886-711
355	1,374-1,103	814-654	962-773	753-605	809-650	968-777
375	1,417-1,138	870-699	1,053-846	838-673	984-790	1,203-966
477	1,486-1,193	933-749	1,187-953	849-682	987-792	1,185-952
502	1,437-1,154	925-743	1,093-878	865-695	963-774	1,220-980
550	1,498-1,202	960-770	1,164-934	880-707	1,028-825	1,221-981
574	1,547-1,242	945-759	1,156-929	926-744	1,004-806	1,238-994
673	1,761-1,414	980-787	1,226-985	930-747	996-800	1,249-1,003
693	1,689-1,356	957-769	1,237-993	892-717	1,007-809	1,253-1,006
717	1,675-1,345	954-767	1,213-974	852-685	1,018-817	1,206-969
735	1,597-1,282	930-747	1,196-960	779-626	940-755	1,233-990

*Left Entry +Right Entry

APPENDIX B-4 (CONTINUED)

SEDIMENT COMPARTMENT (First Run, Tank I, Corrected* for Background, Normalized+for Attenuation, Geometry)

ELAPSED TIME IN HRS.	I 2 C	I 4 E	I 2 E	I 3 E	I 1 E
0	0	0	0	0	0
3	-	125-100	-	107-86	-
19	295-237	283-227	249-200	269-216	194-156
44	483-388	443-356	406-326	440-353	358-287
70	552-444	504-405	557-447	451-363	368-296
133	836-672	785-631	687-552	669-537	471-379
212	1,015-816	953-765	929-746	819-657	619-497
242	981-787	916-736	853-685	858-689	626-503
278	960-771	913-733	800-642	821-659	620-498
311	1,069-859	908-730	844-678	922-740	613-492
332	1,009-810	872-700	817-656	863-693	728-584
355	1,143-917	1,011-812	915-734	934-750	714-573
375	1,300-1,044	1,006-808	942-756	1,039-834	831-667
477	1,372-1,102	1,147-921	1,010-811	1,156-928	849-681
502	1,314-1,055	1,156-929	1,077-864	1,154-926	835-670
550	1,333-1,070	1,217-978	1,135-912	1,193-958	875-703
574	1,315-1,056	1,180-947	1,143-918	1,231-988	877-704
673	1,322-1,062	1,158-930	1,145-919	1,241-996	900-722
693	1,314-1,055	1,150-923	1,140-916	1,196-960	887-712
717	1,317-1,058	1,181-948	1,112-893	1,194-959	866-695
735	1,244-999	1,167-937	1,112-893	1,151-925	869-698

*Left Entry +Right Entry

APPENDIX B-4 (CONTINUED)

SEDIMENT COMPARTMENT (First Run, Tank I, Decay Correction, Geometric Average, Mg Selenium)

HOURS ELAPSED TIME	H AVERAGE cpm	H FRACTION cpm	R AVERAGE cpm	R FRACTION cpm	C AVERAGE cpm	C FRACTION cpm	E AVERAGE cpm	E FRACTION cpm
0	-	-	-	-	-	-	-	-
3	51	22	88	10	-	-	93	29
19	111	49	188	21	241	31	200	62
44	214	94	310	35	383	49	331	103
70	249	110	362	41	468	60	378	118
133	489	215	507	58	676	87	525	163
212	580	256	550	63	736	95	666	207
242	617	272	594	68	745	96	653	203
278	760	335	560	64	749	97	633	197
311	938	413	625	71	790	102	660	205
332	864	381	576	66	761	98	658	205
355	908	400	628	72	847	109	717	223
375	955	421	732	84	1,005	130	766	238
477	1,022	451	737	84	1,027	132	835	260
502	982	433	735	84	1,018	131	847	264
550	1,027	453	766	87	1,026	132	888	276
574	1,043	460	775	89	1,025	132	889	277
673	1,150	507	774	88	1,033	133	892	277
693	1,118	493	763	87	1,031	133	878	273
717	1,107	488	751	86	1,014	131	874	272
735	1,068	471	690	79	995	128	863	269

APPENDIX B-4 (CONTINUED)

SEDIMENT COMPARTMENT (First Run, Tank I,
Decay Correction, Geometric Average, Mg Selenium)

HOURS ELAPSED TIME	IDEALIZED CONTAINER SUM OF FRACTIONS	10^6 cpm COMPARTMENT*	10^6 cpm DECAY CORRECTED	mg Se ** COMPARTMENT
0	0	0	0	0
3	70	.0465	.0465	.0229
19	163	.1083	.1083	.0534
44	281	.1868	.1889	.0932
70	329	.2187	.2212	.1092
133	523	.3477	.3558	.1756
212	621	.4128	.4323	.2133
242	639	.4248	.4500	.2221
278	693	.4607	.4880	.2408
311	791	.5259	.5635	.2781
332	750	.4986	.5435	.2682
355	804	.5345	.5826	.2875
375	873	.5804	.6328	.3123
477	927	.6163	.6875	.3393
502	912	.6063	.6842	.3377
550	948	.6303	.7176	.3541
574	958	.6369	.7313	.3609
673	1,005	.6682	.7851	.3874
693	986	.6555	.7741	.3820
717	977	.6495	.7719	.3809
735	947	.6296	.7483	.3693

* (Idealized) x (664.88747)

** $(0.49350 \times 10^{-6} \frac{mg}{cpm})$

APPENDIX B-5

WATER COMPARTMENT (FIRST RUN, TANK II)

HOURS ELAPSED TIME	FILTER NUMBER	RAW 10 MIN. COUNT 20 ml SAMPLE	cpm CORRECTED FOR BACKGROUND	cpm CORRECTED FOR DECAY	mg Se 20 ml SAMPLE x 10^{-3}	mg Se 60 l TANK
0						
1.5	20	510-496 *	398	398	.1964	.5892
2.0	18	523-449 *	381	381	.1880	.5690
12	6	494-436 *	360	360	.1776	.5329
13	8	459-437 *	343	343	.1692	.5078
19	10	4,677	363	363	.1789	.5369
29	12	4,404	335	335	.1655	.4965
37	14	4,493	344	344	.1699	.5097
55	16	4,364	331	335	.1654	.4963
62	1	4,931	389	394	.1942	.5827
87	4	4,201	316	320	.1578	.4734
110	22	3,983	294	301	.1486	.4458
134	24	3,903	286	293	.1445	.4337
190	26	3,501	246	258	.1271	.3815
212	28	3,296	225	236	.1165	.3497
232	30	3,240	221	234	.1155	.3465
278	32	3,137	210	225	.1108	.3326
310	34	3,026	198	212	.1044	.3134

* one minute count

APPENDIX B-5 (CONTINUED)

WATER COMPARTMENT (FIRST RUN, TANK II)

HOURS ELAPSED TIME	FILTER NUMBER	RAW 10 MIN. COUNT 20 ml SAMPLE	cpm CORRECTED FOR BACKGROUND	cpm CORRECTED FOR DECAY	mg Se 20 ml SAMPLE x 10^{-3}	mg Se 60 1 TANK
354	36	2,802	176	193	.0953	.2859
432	38	2,593	155	172	.0849	.2549
476	40	2,443	138	155	.0765	.2295
498	42	2,470	143	160	.0791	.2373
526	44	2,199	114	130	.0643	.1930
549	46	2,410	139	158	.0777	.2333
573	48	2,308	129	148	.0731	.2192
650	50	2,066	105	121	.0599	.1798
672	52	1,918	91	106	.0526	.1578
692	54	1,960	90	113	.0556	.1668
716	56	1,866	84	101	.0496	.1488
740	58	1,785	78	93	.0459	.1378

APPENDIX B-6

SUSPENDED PARTICULATE (First Run, Tank II)

ELAPSED TIME IN HOURS	FILTER NUMBER	RAW cpm ROLLED FILTER	cpm CORRECTED FOR BACK-GROUND	cpm DECAY CORRECTED	NORMALIZED cpm (x .9055)	10^{-6} mg Se ** 20 ml SAMPLE	mg Se COMPARTMENT (x 3,000)
0	0	974*	0	0	0	0	0
1.5	20	108, 105, 112	9	12	10	5	.016
2	18	108, 112, 93	5	7	6	3	.009
12	6	111, 101, 109	8	10	9	4	.014
13	8	124, 116, 131	25	31	28	13	.041
19	10	114, 120, 109	15	19	17	8	.026
29	12	117, 117, 97	11	14	13	6	.019
37	14	1,265*	27	34	31	15	.046
55	16	1,219*	23	28	26	12	.038
62	1	1,431*	44	55	50	24	.074
87	4	1,215*	22	28	25	12	.038
110	22	107, 116, 113	13	16	15	7	.022

* ten minute count   ** mg per cpm = 0.4935 x 10^{-6}

APPENDIX B-6 (CONTINUED)

SUSPENDED PARTICULATE (First Run, Tank II)

ELAPSED TIME IN HOURS	FILTER NUMBER	RAW cpm ROLLED FILTER	cpm CORRECTED FOR BACK-GROUND	cpm DECAY CORRECTED	NORMALIZED cpm (x .9055)	10^{-6} mg Se ** 20 ml SAMPLE	mg Se COMPARTMENT (x 3,000)
134	24	1,152*	16	20	18	9	.027
190	26	107, 98, 114	7	9	8	4	.012
212	28	1,221*	23	29	26	13	.039
232	30	1,153*	16	20	18	9	.027
278	32	103, 131, 113	17	21	19	9	.028
310	34	118, 115, 147	28	34	31	15	.046
354	36	118, 113, 112	15	19	17	8	.026
432	38	112, 129, 123	22	28	25	12	.037
476	40	137, 117, 108	22	27	24	12	.036
498	42	125, 121, 135	28	35	32	15	.047

* ten minute count ** mg per cpm = 0.4935 x 10^{-6}

APPENDIX B-6 (CONTINUED)

SUSPENDED PARTICULATE (First Run, Tank II)

ELAPSED TIME IN HOURS	FILTER NUMBER	RAW cpm ROLLED FILTER	cpm CORRECTED FOR BACK-GROUND	cpm DECAY CORRECTED	NORMALIZED cpm (x .9055)	10^{-6} mg Se ** 20 ml SAMPLE	mg Se COMPARTMENT (x 3,000)
526	44	113 115	15	19	17	8	.025
549	46	108 117	13	17	15	7	.023
573	48	108 126	18	22	20	10	.030
650	50	1,164*	17	22	20	9	.029
672	52	1,170*	18	22	20	10	.030
692	54	1,120*	13	16	15	7	.022
716	56	1,157*	17	21	19	9	.028
740	58	1,129*	14	17	16	7	.024

* ten minute count   ** mg per cpm = 0.4935 $\times 10^{-6}$

APPENDIX B-7

FISH COMPARTMENT (First Run, Tank II)

ELAPSED TIME IN HRS.	FISH NUMBER					
	1	2	3	4	5	6
0	117-103	98-103	104-112	100-93	105-101	112-101
3	162	165	171	172	176	-
14	134-145	167-205	221-218	209-228	271-278	350-308
38	222-224	339-340	358-354	360-378	405-427	507-517
63	233-229	315-364	356-379	467-515	565-642	756-778
88	232-232	428-457	464	553-546	792-767	
118	267 up 280 up	549-485	691-703	1,049-1,077	1,205-1,224	1,393-1,366
191	531-588	774-855	1,198-1,265	1,226-1,248	1,400-1,350	
230	673-669	882-879	983-995	1,147-1,148	1,205-1,144	dead
254	810-716	934-978	973-984	1,256-1,304	1,397-1,413	
287	959-912	1,138-1,190	1,175-1,317	1,445-1,462	1,491-1,424	
310	979-931	1,059-943	1,241	1,478-1,396	1,511-1,445	
330	997-995	920-923 up	1,383-1,349	1,388-1,347	1,320-1,428	
354	968-1,078	1,042-1,005	1,296-1,265	1,426-1,444	dead	
374	1,013-1,042	1,008-1,010up	1,389-1,496	1,510-1,579		
476	754-828	1,354-1,337	1,457-1,442	1,155-1,115 up		
500	859-891 up	1,441-1,583	1,082-1,046up	1,143-1,179 up		
518	807-1,026 1,011	1,281-1,353	1,506-1,560	1,176-1,087 up		
549	1,020-996	1,257-1,357	1,052-1,101up	1,562-1,506		

APPENDIX B-7 (CONTINUED)

FISH COMPARTMENT (First Run, Tank II)

ELAPSED TIME IN HRS.	FISH NUMBER					
	1	2	3	4	5	6
574	951-1,010	1,355-1,251	1,100 1,048 up	1,460-1,512		
650	817-723 up	1,216-1,265	1,037-1,070up	1,053-1,112 up		
672	791-726 up	820-850 up	979-1,015up	1,523		
694	919-979	1,122-1,127	953-1,005up	1,191-1,154 up		
716	967-972	1,188-1,103	1,435-1,327	1,082-1,098 up		
740	1,062-958	1,210-1,224 1,087-1,241	1,043-972 up	1,063-1,088 up		

APPENDIX B-7 (CONTINUED)

FISH COMPARTMENT (First Run - Tank II)

ELAPSED TIME IN HOURS	BACKGROUND CORRECTED SUM COMPARTMENT	COMPARTMENT cpm DECAY CORRECTED	10^{-6} COMPARTMENT mg Se*	10^{-6} COMPARTMENT mg Se NORMALIZED**
0	0	0	0	0
3	385	385	189	134
14	740	740	365	257
38	1,585	1,585	782	552
63	2,215	2,240	1,105	780
88	2,318	2,344	1,157	817
118	4,610	4,717	2,328	1,643
191	4,691	4,912	2,424	1,711
230	4,338	4,542	2,241	1,582
254	4,857	5,144	2,538	1,792
287	5,730	6,139	3,029	2,139
310	5,587	5,986	2,954	2,085
330	5,826	6,314	3,116	2,199
354	4,371	4,737	2,337	1,650
374	4,960	5,438	2,683	1,894
476	4,704	5,217	2,574	1,817
500	5,297	5,943	2,933	2,070
518	4,912	5,511	2,720	1,920
549	4,968	5,639	2,782	1,964
574	4,805	5,516	2,722	1,922
650	4,793	5,566	2,747	1,939
672	4,526	5,317	2,624	1,852
694	4,576	5,376	2,653	1,873
716	4,553	5,411	2,670	1,885
740	4,604	5,471	2,700	1,906

* (0.49350×10^{-6}) mg/cpm

** Normalization Factor .706

APPENDIX B-8

SEDIMENT COMPARTMENT (First Run, Tank II, Raw Data)

ELAPSED TIME IN HRS.	II 3 H	II 2 H	II 1 H	II 3 R	II 1 R	II 4 C
0	1,059*	1,032*	1,051*	1,043*	1,057*	1,029*
3	-	143	-	-	-	-
23	2,457*	2,484*	2,432*	2,238*	2,032*	2,457*
47	349	3,755*	3,082*	2,886*	2,451*	3,043*
71	427-412	427-454	466-464	304-312	302-286	332-338
137	5,077*	6,144*	6,701*	5,258*	3,735*	4,329*
214	523-558	834-877	999-1,112	551-560	346-374	522-546
243	561-540	900-952	1,076-1,080	505-527	464-473	484-490
280	647-684	1,007-1,113	1,089-1,041	568-550 583-607	413-435	455 eroded 536
312	605-543	979-1,008 1,027	1,212-1,189	538-539	409-403	504-545
333	582-630	1,084-1,138	1,219-1,244	608-599	436-474	494 eroded 511
376	728-708	1,520-1,467	1,703-1,652	695-672	515-525	643-704
478	766-686	1,600-1,699	1,875-1,872	761-726	559-568	633-693
503	746-698	1,611-1,568	1,609-1,656	668-730	562-537	675-687
550	766-762	1,784-1,726	1,826-1,773	720-733	523-520	692-697
575	788-787	1,769-1,743	1,336 feces washed 1,430 out	769-800	542-579	691-686
674	792-800	1,807-1,912	1,673 eroded 1,533	793-782	548-567 633	741-741
695	819-769	1,918-1,806	1,725-1,691	723-786	591-592	686-736 714
736	791-816	1,914-1,800				

* ten minute count

APPENDIX B-8 (CONTINUED)

SEDIMENT COMPARTMENT (First Run, Tank II, Raw Data)

ELAPSED TIME IN HRS.	II 2 C	II 4 E	II 2 E	II 3 E	II 1 E
0	1,060*	1,049*	1,044*	1,037*	1,050*
3	-	-	155 one	-	-
23	3,610*	2,752*	2,900*	294	3,295*
47	5,239*	398	412	375	446 420
71	486-516 558-506	500-471	402-425	460-485	531-529
137	6,749*	7,108*	5,763*	8,045*	8,239*
214	678-729	619-637	692-709	731-689	834-810
243	741-750	665-717	636-621	645-706	872-911
280	769-800	549 eroded 573	666-612	740 erosion 826	918-951
312	769-789	421-454	701-696	640-678	954-913
333	708-696	457 eroded 464	615-642	602-604	896-916
376	956-905	610-585	817-840	782 dumped & 813 eroded	1,178-1,090 1,082-1,134
478	892-890	669-593	859-860	768-804	1,067-1,027
503	959-991	634-624	873-821	810-799	1,192-1,174
550	915-965	654-658	841-900	859-816	1,186-1,133 1,186
575	1,019-959	663-642	868-896	845-822	1,179-1,164
674	943-1,006	721, 697 675	817-911	868-833	1,214-1,254
695	954-944	678-673	843-853	865-801	1,132-1,209

APPENDIX B-8 (CONTINUED)

SEDIMENT COMPARTMENT (First Run, Tank II, Corrected for Background, Normalized for Attenuation, Geometry) *

ELAPSED TIME IN HRS.	II 2 C	II 4 E	II 2 E	II 3 E	II 1 E
0	0	0	0	0	0
3	-	-	50-40	-	-
23	256-205	170-136	185-148	189-151	224-180
47	418-336	293-235	307-246	270-216	328-263
71	411-330	380-305	308-247	367-295	425-341
137	569-457	605-486	471-378	699-561	718-577
214	598-480	523-419	595-478	605-485	717-575
243	640-514	586-470	521-418	570-458	786-631
280	679-545	456-366	534-428	678-544	829-666
312	674-541	378-303	593-476	554-444	828-665
333	597-479	355-285	523-420	498-399	801-643
376	825-662	492-395	723-580	692-556	1,016-815
478	786-631	526-422	754-605	681-546	942-756
503	870-698	524-420	742-595	699-561	1,078-865
550	835-670	551-442	765-614	732-588	1,063-853
575	884-709	547-439	777-623	728-584	1,066-856
674	869-698	592-475	759-609	745-598	1,129-906
695	844-677	570-458	743-596	728-584	1,065-855
736					
1,912					

* Left entry corrected for background. Right entry normalized for attenuation and geometry.

APPENDIX B-8 (CONTINUED)

SEDIMENT COMPARTMENT (First Run, Tank II, Corrected for Background, Normalized for Attenuation, Geometry) *

ELAPSED TIME IN HRS.	II 3 H	II 2 H	II 1 H	II 3 R	II 1 R	II 4 C
0	0	0	0	0	0	0
3	-	38-30	-	-	-	-
23	140-112	143-115	138-110	118-95	98-78	140-112
47	244-195	270-217	203-163	183-147	140-112	199-160
71	314-252	335-269	360-289	203-163	189-151	230-184
137	402-323	509-409	565-453	420-337	268-215	327-269
214	435-349	750-602	950-763	450-361	255-205	429-344
243	445-357	821-659	973-781	411-330	363-291	382-306
280	560-450	955-766	960-770	470-377	319-256	390-313
312	469-376	903-725	1,095-879	434-348	301-241	419-336
333	501-402	1,006-807	1,126-904	498-400	350-281	397-319
376	613-492	1,388-1,114	1,572-1,262	578-464	415-333	568-456
478	621-498	1,544-1,240	1,768-1,420	638-512	458-368	558-448
503	617-495	1,484-1,192	1,527-1,656	594-476	444-356	576-462
550	659-529	1,650-1,324	1,694-1,360	621-499	416-334	589-473
575	682-548	1,651-1,325	1,278-1,026	679-545	455-365	583-468
674	691-554	1,754-1,408	1,498-1,202	682-548	477-383	636-510
695	689-553	1,757-1,410	1,603-1,287	649-521	486-390	607-487
736	698-560	1,752-1,406				
1,912	506-406	1,522-1,222				

* Left entry corrected for background. Right entry normalized for attenuation and geometry.

APPENDIX B-8 (CONTINUED)

SEDIMENT COMPARTMENT (First Run, Tank II, Decay Correction, Geometric Average Mg Selenium)

HOURS ELAPSED TIME	H AVERAGE cpm	H FRACTION cpm	R AVERAGE cpm	R FRACTION cpm	C AVERAGE cpm	C FRACTION cpm	E AVERAGE cpm	E FRACTION cpm
0	0	0	0	0	0	0	0	0
3	30	13	-	-	-	-	40	12
23	112	49	86	9	158	20	153	47
47	192	84	129	14	248	31	240	74
71	265	117	157	17	257	33	297	92
137	377	166	276	31	363	46	500	155
214	515	227	283	32	412	53	489	152
243	538	237	310	35	412	53	494	153
280	609	268	316	36	429	55	501	155
312	589	259	294	33	438	56	472	146
333	628	277	340	38	399	51	436	135
376	840	370	398	45	559	72	586	182
478	914	402	440	50	539	69	582	181
503	959	422	416	47	580	74	610	189
550	935	412	416	47	571	73	624	194
575	861	379	455	51	588	75	625	194
674	929	409	465	53	604	77	647	201
695	950	419	455	52	582	75	623	193

APPENDIX B-8 (CONTINUED)

SEDIMENT COMPARTMENT (First Run, Tank II, Decay Correction, Geometric Average Mg Selenium)

HOURS ELAPSED TIME	IDEALIZED CONTAINER SUM OF FRACTIONS	10^6 cpm COMPARTMENT*	10^6 cpm DECAY CORRECTED	mg Se ** COMPARTMENT
0	0	0	0	0
3	-	-	-	-
23	125	.0831	.0831	.0410
47	203	.1350	.1366	.0674
71	259	.1722	.1742	.0860
137	398	.2646	.2739	.1352
214	464	.3085	.3230	.1594
243	478	.3178	.3366	.1661
280	514	.3418	.3662	.1807
312	494	.3285	.3520	.1737
333	501	.3331	.3610	.1782
376	669	.4448	.4821	.2379
478	702	.4668	.5238	.2585
503	732	.4867	.5461	.2695
550	726	.4827	.5479	.2704
575	699	.4648	.5337	.2634
674	740	.4920	.5781	.2853
695	739	.4914	.5773	.2849

* (Idealized Container) x (664.88747)
** (0.49350 x 10^{-6} mg/cpm)

APPENDIX B-9

WATER COMPARTMENT (Second Run, Tank I)

Elapsed Time in Hours	Filter Number	Raw cpm 20 ml Sample	cpm Corrected Background	cpm Corrected Decay	mg Se 20 ml Sample x 10^{-3}	mg Se Tank
0	1	1,556*	0	0	0	0
.083	3	44,467*	4,291	4,291	2.002	6.006
.25	5	44,202*	4,264	4,264	1.989	5.968
.5	7	44,407*	4,285	4,285	1.999	5.997
1.0	9	45,000*	4,344	4,344	2.026	6.080
3	11	40,581*	3,902	3,902	1.820	5.462
12	13	4,110	3,922	3,922	1.830	5.890
		4,046				
18	15	3,935	3,853	3,853	1.797	5.393
		4,082				
23.5	17	3,702	3,562	3,562	1.662	4.986
		3,733				
37	19	3,456	3,300	3,300	1.539	4.619
48	21	2,977	2,797	2,830	1.320	3.961
		2,994				
		2,889				
61	23	2,682	2,500	2,529	1.180	3.540
		2,630				
70.5	25	2,794	2,691	2,722	1.270	3,810
		2,899				
81	27	2,244	2,074	2,098	0.978	2.936
		2,216				

* Ten minute count

APPENDIX B-9 (CONTINUED)

WATER COMPARTMENT (Second Run, Tank I)

Elapsed Time in Hours	Filter Number	Raw cpm 20 ml Sample	cpm Corrected Background	cpm Corrected Decay	mg Se 20 ml Sample $x 10^{-3}$	mg Se Tank
96	29	1,898	1,782	1,824	0.8510	2.553
		1,989				
134	33	1,490	1,297	1,343	0.6266	1.879
		1,428				
157	35	1,239	1,082	1,120	0.5225	1.567
		1,249				
183	37	1,066	894	936	0.4367	1.310
		1,062				
232	39	719	556	587	0.2748	0.8244
		713				
256	41	7,895*	662	701	0.3270	0.9812
280	43	757	567	608	0.2836	0.8510
		695				
303	45	667	503	539	0.2514	0.7544
		654				
353	47	5,940*	436	475	0.2216	0.6649
400	49	5,873*	429	473	0.2207	0.6621
421	55	5,883*	430	475	0.2216	0.6649
447	57	591	390	435	0.2029	0.6089
		505				

* Ten minute count

APPENDIX B-9 (CONTINUED)

WATER COMPARTMENT (Second Run, Tank I)

Elapsed Time in Hours	Filter Number	Raw cpm 20 ml Sample	cpm Corrected Background	cpm Corrected Decay	mg Se 20 ml Sample x 10^{-3}	mg Se Tank
472	59	5,190*	411	459	0.2141	0.6425
496	61	501	408	460	0.2146	0.6439
		501				
518	63	515	383	432	0.2015	0.6047
		515				
568	65	504	359	412	0.1922	0.5767
		520				
617	67	542	413	480	0.2239	0.6719
		577				
641	69	527	386	448	0.2090	0.6271
		538				
720	71	552	380	452	0.2109	0.6327
		497				
736	73	532	397	472	0.2202	0.6607
		554				
830	77	726	560	685	0.3196	0.9588
		687				
904	81	6,732*	527	656	0.3061	0.9182

* Ten minute count

APPENDIX B-9 (CONTINUED)

WATER COMPARTMENT (Second Run, Tank I)

Elapsed Time in Hours	Filter Number	Raw cpm 20 ml Sample	cpm Corrected Background	cpm Corrected Decay	mg Se 20 ml Sample x 10^{-3}	mg Se Tank
928	83	680	494	615	0.2869	0.8608
		612				
952	85	639	494	622	0.2902	0.8706
		644				
1,024	87	635	472	605	0.2822	0.8468
		603				

APPENDIX B-10

SUSPENDED PARTICULATE COMPARTMENT (Second Run, Tank I)

Elapsed Time in Hours	Filter Number	Raw Ten Minute Count Rate 40 ml	Background Corrected cpm	Decay Corrected cpm	Normalization (x .9055)	mg Se 40 ml Sample x 10^{-6}	mg Se Compartment
0.0	1	1,305	10	11	10	0	0
.083	3	1,697	48	52	47	21.93	0.03289
.25	5	1,782	57	63	57	26.59	0.03975
.5	7	1,636	43	47	42	19.59	0.02938
1	9	1,758	55	61	55	25.66	0.03849
3	11	1,779	57	63	57	26.59	0.03988
12	13	1,925	72	79	72	33.59	0.05038
18	15	2,326	112	124	112	52.26	0.07839
23.5	17	2,506	130	143	130	60.66	0.09099
37	19	3,440	223	246	222	103.59	0.15538
48	21	3,903	269	297	269	125.48	0.18822
61	23	5,168	396	438	397	185.05	0.27758
70.5	25	5,794	458	505	457	213.24	0.31986
81	27	6,602	539	594	538	251.03	0.37654
96	29	7,081	588	648	587	273.89	0.41083
113	31	9,449	825	910	824	384.48	0.57672
134	33	9,835	864	953	863	309.36	0.46404
157	35	10,777	958	1,056	956	446.07	0.66910
183	37	11,410	1,014	1,118	1,012	472.20	0.70880
232	39	11,772	1,052	1,160	1,050	489.93	0.73489
256	41	12,571	1,126	1,242	1,125	524.93	0.78739
280	43	12,465	1,116	1,231	1,145	534.26	0.80139

APPENDIX B-10 (CONTINUED)

SUSPENDED PARTICULATE COMPARTMENT (Second Run, Tank I)

Elapsed Time in Hours	Filter Number	Raw Ten Minute Count Rate 40 ml	Background Corrected cpm	Decay Corrected cpm	Normalization (x .9055)	mg Se 40 ml Sample x 10^{-6}	mg Se Compartment
303	45	11,959	1,034	1,140	1,032	481.53	0.72229
353	51	11,239	1,003	1,106	1,002	467.53	0.70129
400	53	12,237	1,103	1,216	1,102	514.19	0.77128
421	55	7,923	671	740	670	312.62	0.46893
447	57	9,020	781	861	780	363.95	0.54592
472	59	9,432	822	906	820	382.61	0.57391
496	61	9,071	787	868	785	366.28	0.54942
518	63	8,572	718	792	717	334.55	0.50182
568	65	6,888	549	637	577	269.22	0.40384
617	67	5,809	462	537	486	226.76	0.34015
641	69	5,032	384	446	404	188.50	0.28275
720	71	3,617	235	321	291	135.78	0.20367
736	73	2,705	144	197	178	83.05	0.12458
792	75	2,829	156	213	193	90.05	0.13508
830	77	3,161	199	248	225	104.78	0.15717
904	81	4,015	281	366	332	170.88	0.25633
928	83	3,905	273	355	322	150.31	0.22547
952	85	3,928	273	355	322	150.31	0.22547
1,024	87	3,774	257	334	303	141.50	0.21225

APPENDIX B-11

FISH COMPARTMENT (Second Run, Tank I)

ELAPSED TIME	FISH NUMBER 1	2	3	4	5
0	731	431	956	1,509	1,363
	750	892	1,005	1,566	1,451
1.5	628	711	1,037	1,317	1,417
	586	703	1,015	1,378	1,368
6	1,029	1,064	1,198	1,430	1,602
	995	1,048	1,196	1,495	1,714
22.5	1,588	1,583	1,760	1,763	2,363
	1,556	1,666	1,750	1,824	2,345
37	1,973	2,115	2,205	2,351	3,230
	2,010	1,978	2,159	2,310	3,123
		2,018		2,322	
				2,326	
47.5	1,993	2,766	2,880	3,237	3,975
	2,002	2,807	2,822	3,207	3,750
					3,792
62	2,914	3,180	3,741	3,773	4,581
	3,067	3,215	3,626	3,601	4,462
71	3,616	3,915	3,955	4,260	5,262
	3,708	4,065	4,181	4,081	5,358
81	3,904	4,123	4,283	4,746	6,304
	3,962	4,119	4,243	4,570	6,262
96	4,555	4,658	5,327	5,452	6,944
	4,628	4,556	5,163	5,594	6,768
113	5,254	5,392	6,355	6,601	7,396
	5,233	5,672	6,346	6,436	7,369
134	6,163	7,307	7,264	7,349	8,839
	6,305	7,018	7,320	7,478	8,691
160	8,068	8,282	8,184	8,355	8,145
	8,231	8,075	8,383	8,221	8,538
183	8,087	8,108	8,985	9,570	9,895
	8,038	8,198	8,843	10,025	9,908
	8,106			9,641	
232	8,363	10,355	10,407	10,722	10,875
	8,281	10,225	10,287	10,729	10,745
256	8,098	10,691	10,822	10,884	11,886
	8,057	10,825	10,839		11,573
303	8,447	11,626	12,223	14,039	22,341
	8,516	11,776	12,221	14,051	22,105
353	9,376	12,324	13,595	15,020	22,830
	9,292		14,162	15,149	22,325

APPENDIX B-11 (CONTINUED)

FISH COMPARTMENT (Second Run, Tank I)

ELAPSED TIME	FISH NUMBER 1	2	3	4	5
400	9,767	13,833	16,244	16,579	24,245
	9,565	14,251	15,209	16,336	23,681
447	10,454	15,441	15,770	17,549	23,607
	10,372	15,167	15,420	17,727	23,802
518	9,336	14,961	15,457	17,262	22,957
	9,464	15,034	14,889	17,114	22,970
568	10,351	14,064	16,044	16,915	22,714
	10,207	13,799	16,821	16,518	22,731
641	9,452	13,134	15,494	17,395	22,175
	9,490	13,005	15,600	17,600	22,032
760	11,141	14,608	16,537	20,169	23,790
	11,331	14,388	16,732	20,270	23,532
				20,078	
				21,287	
830	12,353	16,295	17,828	19,754	24,451
	12,354	16,146	18,247	20,274	24,424
880	12,617	16,600	18,439	19,192	24,770
	12,763	16,619	18,488	19,393	24,758
1,024	11,595	15,893	17,079	19,278	23,273
	11,591	16,163	16,817	19,078	23,095

APPENDIX B-11 (CONTINUED)

FISH COMPARTMENT (Second Run, Tank I)

ELAPSED TIME	Total Compartment cpm	Compartment Corrected for Background cpm	Compartment Corrected for Decay cpm	Compartment (x .46660 x 10^{-6}) mg Se	Compartment Normalized (x .706) Mg Se
0	5,577	0	0	0	0
1.5	5,050	0	0	0	0
6	6,386	809	809	.0003	.00026
22.5	9,100	3,523	3,523	.0016	.00115
37	11,714	6,142	6,142	.0028	.00202
47.5	14,696	9,182	9,289	.0043	.00305
62	18,080	12,566	12,712	.0059	.00418
71	21,201	15,687	15,869	.0074	.00522
81	23,258	17,744	17,950	.0083	.00591
96	26,873	21,416	21,915	.0102	.00721
113	31,027	25,570	26,167	.0122	.00861
134	36,867	31,410	32,142	.0149	.0105
160	41,241	35,800	37,058	.0172	.0122
183	44,766	39,335	40,718	.0189	.0134
232	50,495	45,120	47,247	.0220	.0155
256	52,280	46,975	49,757	.0232	.0163
303	68,673	63,368	67,899	.0316	.0223
353	73,199	68,003	74,137	.0345	.0244
400	79,855	74,717	82,400	.0384	.0271
447	82,655	77,565	85,541	.0399	.0281
518	79,722	74,684	84,279	.0393	.0277
568	80,082	75,089	86,202	.0402	.0283
641	77,553	72,672	84,400	.0393	.0278
760	86,626	81,854	91,676	.0427	.0301
830	91,064	86,363	105,621	.0492	.0347
880	91,820	87,177	108,099	.0504	.0356
1,024	84,931	82,382	104,611	.0488	.0344

APPENDIX B-12

SEDIMENT COMPARTMENT (Second Run, Tank I, Raw cpm)

HOURS ELAPSED TIME	I3H	I2H	I1H	I3R	I1R
0					
4.25	2,309	1,232	1,516	1,556	1,483
			1,591		1,477
13	3,504	2,050	2,314	3,160	2,716
	3,894	1,934	2,280	3,018	2,718
	4,010				
25	5,175	2,376	3,522	4,541	3,955
	5,208	2,490	3,470	4,523	3,862
40	7,939	3,335	4,816	7,229	5,731
	8,085	3,373	4,829	7,136	5,543
50	7,554	3,678	5,844	8,929	6,889
	7,632	3,718	5,914	8,779	6,818
63	9,274	4,794	7,370	10,884	7,890
	9,457	4,765	7,436	10,900	7,951
72	9,693	5,684	8,694	12,025	8,400
	9,640	5,714	8,534	11,909	8,626
82	10,455	6,678	9,547	13,093	9,688
	10,309	6,500	9,381	12,830	9,542
97	10,909	7,364	10,992	14,457	10,989
	10,847	7,355	10,937	14,491	10,902
114	11,601	8,481	11,932	14,893	11,891
	11,355	8,634	11,849	15,189	11,751
136		9,833	13,045	15,473	12,791
		9,744	13,125	15,301	12,987

APPENDIX B-12 (CONTINUED)

SEDIMENT COMPARTMENT (Second Run, Tank I, Raw cpm)

HOURS ELAPSED TIME	I4C	I2C	I4E	I2E	I3E	I1E
0						
4.25	1,574	2,038	1,508	1,508	2,272	1,741
		2,135			2,260	1,724
13	2,054	2,832	2,450	2,236	3,845	2,542
	2,031	2,785	2,474	2,221	3,818	2,522
25	2,759	4,054	3,468	3,098	5,489	3,579
	2,733	4,196	3,537	3,072	5,630	3,561
40	3,587	5,623	4,795	4,245	7,626	4,875
	3,640	5,690	4,809		7,636	4,985
50	4,144	6,573	5,541	4,994	9,238	6,223
	4,039	6,580	5,702	5,139	9,200	6,499
63	4,454	7,937	6,426	6,274	10,372	7,654
	4,489	8,003	6,459	6,490	10,177	
72	4,873	8,509	7,246	7,340	11,496	8,437
	4,773	8,463	7,229	7,308	11,495	8,542
82	5,157	9,627	8,194	8,387	12,506	9,777
	5,121	9,730	8,021	8,476	12,547	9,671
97	5,683	10,816	8,889	9,673	13,712	10,965
	5,365	10,566	8,954	9,672	13,576	11,052
114	5,597	11,761	8,841	10,600	13,578	11,835
	5,618	12,053	9,013	10,476	13,876	11,849
136	6,030	13,172	10,097	11,517	14,359	13,115
	6,089	13,173	10,430	11,373	14,193	13,209

APPENDIX B-12 (CONTINUED)

SEDIMENT COMPARTMENT (Second Run, Tank I, Raw cpm)

HOURS ELAPSED TIME	I3H	I2H	I1H	I3R	I1R
158	17,938	10,527	14,023	14,935	13,729
	18,255	10,531	14,064	14,934	13,544
184	16,305	10,693	14,739	15,304	13,925
	16,818	10,757	14,616	15,159	14,128
233	15,299	11,113	15,545	15,546	14,995
	15,544	11,439	15,454	15,592	15,026
280	15,271	11,510	15,685	15,974	15,337
	15,452	11,585	15,836	15,957	15,258
332	15,482	10,766	15,311	16,406	15,575
	15,723	10,850	15,436	16,354	15,684
375	16,841	11,195	15,449	16,349	15,204
	16,684	11,221	15,500	16,111	15,063
421	13,978	11,121	15,386	15,972	15,184
	13,862	11,264	15,457	15,854	15,256
472	14,015	11,749	15,810	15,280	15,875
	14,078	11,574	16,018	15,232	15,872
543	15,562	11,595	15,791	16,161	15,435
	15,751	11,519	15,646	15,928	15,210
568	12,853	11,616	15,324	15,720	15,313
	12,772	11,935	15,804	15,927	15,445
736	14,041	11,928	16,409	16,124	15,868
	14,180	12,267	16,199	15,988	15,717

APPENDIX B-12 (CONTINUED)

SEDIMENT COMPARTMENT (Second Run, Tank I, Raw cpm)

HOURS ELAPSED TIME	I4C	I2C	I4E	I2E	I3E	I1E
158	6,743	13,574	11,413	12,000	14,191	13,481
	6,698	13,470	11,428	11,906	14,534	13,563
184	7,059	14,241	12,814	12,492	14,420	13,132
	6,940	14,647	12,633	12,574	14,677	13,468
233	8,142	15,109	13,313	13,306	14,292	14,046
	7,949	15,114	13,265	13,337	14,337	13,915
280	8,227	15,506	14,140	13,513	13,942	15,196
	8,043	15,702	14,190	13,481	14,143	15,171
332	9,119	16,299	14,482	14,061	14,669	15,369
	9,248	16,061	14,479	14,123	14,868	15,369
375	8,780	15,794	15,107	13,874	14,906	14,875
	8,798	15,721	15,436	13,438	14,263	14,981
			15,334			
421	9,440	15,263	15,208	14,044	14,151	15,251
	9,337	15,272	15,557	14,128	14,358	15,110
472	9,385	15,965	15,696	13,632	14,716	15,357
	9,587	15,796	15,737	13,717	14,817	15,328
543	9,667	15,810	15,812	13,710	14,306	15,132
	9,542	15,982	15,703	13,979	14,443	15,174
568	9,511	15,885	15,513	14,202	14,738	14,978
	9,270	16,055	15,299	14,392	14,574	15,204
736	10,033	16,018	15,955	13,825	13,765	15,692
	9,932	16,465	16,141	13,613	13,699	15,670

APPENDIX B-12 (CONTINUED)

SEDIMENT COMPARTMENT (Second Run, Tank I, Correction for Background, Normalization, Attenuation)

HOURS ELAPSED TIME	I3H	I2H	I1H	I3R	I1R
0	0	0	0	0	0
4.25	909	494	588	750	699
	730	396	472	602	561
13	2,402	1,254	1,332	2,283	1,936
	1,928	1,006	1,069	1,833	1,554
25	3,806	1,702	2,541	3,734	3,135
	3,056	1,366	2,040	2,998	2,517
40	6,627	2,629	3,867	6,384	4,916
	5,321	2,111	3,105	5,126	3,947
50	6,208	2,967	4,924	5,056	6,080
	4,985	2,382	3,953	4,059	4,882
63	7,980	4,048	6,448	10,094	7,147
	6,407	3,750	5,177	8,105	5,739
72	8,296	4,976	7,669	11,207	7,748
	6,661	3,995	6,158	8,999	6,221
82	9,012	5,866	8,519	12,171	8,850
	7,236	4,710	6,840	9,773	7,106
97	9,508	6,636	10,019	13,684	10,180
	7,634	5,328	8,045	10,988	8,174

LEGEND: Above Number - cpm corrected for background
Below Number - cpm with additional correction for normalization and attenuation.

APPENDIX B-12 (CONTINUED)

SEDIMENT COMPARTMENT (Second Run, Tank I, Correction for Background, Normalization, Attenuation)

HOURS ELAPSED TIME	I3H	I2H	I1H	I3R	I1R
114	10,123	7,841	10,955	14,259	11,064
	8,128	6,296	8,796	11,449	8,884
136	13,000	9,072	12,150	14,605	13,132
	9,636	7,284	9,756	11,727	10,544
158	16,741	9,813	13,108	14,152	12,879
	13,443	7,879	10,525	11,364	10,341
184	15,220	10,015	13,752	14,457	13,282
	12,221	8,042	11,042	11,608	10,665
233	14,095	10,580	14,583	14,803	14,269
	11,318	8,495	11,710	11,886	11,458
280	14,049	10,858	14,854	15,207	14,564
	11,281	8,718	11,927	12,211	11,694
332	14,226	10,227	14,477	15,297	14,612
	11,423	8,209	11,600	12,283	11,773
375	15,478	10,533	14,587	15,488	14,416
	12,428	8,457	11,713	12,436	11,576
421	12,150	10,523	14,533	15,179	14,510
	9,756	8,449	11,669	12,188	11,651

LEGEND: Above Number - cpm corrected for background
Below Number - cpm with additional correction for normalization and attenuation.

APPENDIX B-12 (CONTINUED)

SEDIMENT COMPARTMENT (Second Run, Tank I, Correction for Background, Normalization, Attenuation)

HOURS ELAPSED TIME	I3H	I2H	I1H	I3R	I1R
472	12,790	10,999	15,045	14,530	15,170
	10,270	8,832	12,081	11,667	12,181
543	14,414	10,901	14,858	15,325	14,626
	11,574	8,753	11,930	12,305	11,744
568	11,695	11,126	14,713	15,111	14,690
	9,391	8,929	11,828	12,134	11,796
736	12,376	11,466	15,480	15,407	15,124
	9,937	9,207	12,430	12,371	12,144

LEGEND: Above Number - cpm corrected for background
Below Number - cpm with additional correction for normalization and attenuation.

APPENDIX B-12 (CONTINUED)

SEDIMENT COMPARTMENT (Second Run, Tank I, Correction for Background, Normalization, Attenuation)

HOURS ELAPSED TIME	I4C	I2C	I4E	I2E	I3E	I1E
0	0	0	0	0	0	0
4.25	733	1,271	657	743	1,197	1,085
	588	1,020	527	596	961	871
13	1,201	1,992	1,611	1,463	2,762	1,885
	964	1,599	1,293	1,174	2,217	1,513
25	1,914	3,319	2,661	2,328	4,501	2,930
	1,536	2,665	2,136	1,869	3,614	2,352
40	2,893	4,906	3,961	3,488	6,573	4,290
	2,323	3,939	3,180	2,800	5,278	3,444
50	3,259	5,876	4,780	4,309	8,161	5,721
	2,616	4,718	3,838	3,460	6,553	4,593
63	3,639	7,164	5,598	5,625	9,216	7,014
	2,922	5,752	4,495	4,516	7,400	5,632
72	4,000	7,688	6,406	6,575	10,448	7,856
	3,212	6,173	5,144	5,279	8,389	6,308
82	4,316	8,880	7,275	7,682	11,479	9,091
	3,465	7,130	5,841	6,168	9,217	7,300
97	4,701	9,893	8,089	8,923	12,597	10,390
	3,774	7,944	6,495	7,165	10,115	8,343

LEGEND: Above Number - cpm corrected for background
Below Number - cpm with additional correction for normalization and attenuation.

APPENDIX B-12 (CONTINUED)

SEDIMENT COMPARTMENT (Second Run, Tank I, Correction for Background, Normalization, Attenuation)

HOURS ELAPSED TIME	I4C	I2C	I4E	I2E	I3E	I1E
114	4,793	11,113	8,104	9,797	12,691	11,215
	3,848	8,923	6,507	7,866	10,190	9,005
136	5,245	12,374	9,440	11,212	13,240	12,535
	4,211	9,936	7,580	9,003	10,631	10,065
158	5,906	12,732	10,597	11,792	13,326	12,882
	4,742	10,223	8,509	9,468	10,700	10,344
184	6,194	13,654	11,909	12,588	13,523	12,679
	4,973	10,964	9,562	10,108	10,858	10,181
233	7,248	14,337	12,484	12,772	13,300	13,365
	5,820	11,512	10,024	10,255	10,679	10,732
280	7,346	14,838	13,368	12,780	13,039	14,574
	5,898	11,914	10,734	10,262	10,470	11,702
332	8,141	15,403	13,808	13,452	13,654	14,531
	6,537	12,368	11,087	10,801	10,964	11,668
375	8,016	15,007	17,511	12,953	13,603	14,331
	6,436	12,050	14,061	10,401	10,923	11,507
421	8,623	14,525	14,609	13,390	13,283	14,589
	6,924	11,663	11,731	10,752	10,666	11,714

LEGEND: Above Number - cpm corrected for background
Below Number - cpm with additional correction for normalization and attenuation.

APPENDIX B-12 (CONTINUED)

SEDIMENT COMPARTMENT (Second Run, Tank I, Correction for Background, Normalization, Attenuation)

HOURS ELAPSED TIME	I4C	I2C	I4E	I2E	I3E	I1E
472	8,729	15,146	14,951	12,985	13,805	14,757
	7,009	12,162	12,005	10,426	11,085	11,849
543	8,789	15,170	15,000	13,162	13,423	14,574
	7,057	12,181	12,045	10,569	10,778	11,702
568	8,649	15,252	14,657	13,622	13,595	14,518
	6,945	12,247	11,769	10,938	10,916	11,657
736	8,935	15,221	15,113	12,960	12,069	15,126
	7,174	12,222	12,135	10,406	9,691	12,146

LEGEND: Above Number - cpm corrected for background
Below Number - cpm with additional correction for normalization and attenuation.

APPENDIX B-12 (CONTINUED)

SEDIMENT COMPARTMENT (Second Run, Tank I, Decay Correction, Geometric Average of Area, Milligrams Selenium)

HOURS ELAPSED TIME	H		R		C		E	
	AVERAGE cpm	FRACTION cpm	AVERAGE cpm	FRACTION cpm	AVERAGE cpm	FRACTION cpm	AVERAGE cpm	FRACTION cpm
0	0	0	0	0	0	0	0	0
4.25	533	235	581	66	804	103	739	230
13	1,483	654	1,693	193	1,281	165	1,549	482
25	2,379	1,049	2,757	314	2,101	270	2,493	775
40	3,964	1,747	4,536	518	3,131	403	3,676	1,143
50	4,076	1,796	4,471	510	3,667	472	4,611	1,434
63	5,311	2,341	6,922	790	4,337	559	5,511	1,714
72	5,869	2,587	7,610	869	4,692	604	6,280	1,953
82	6,506	2,867	8,439	963	5,298	682	7,132	2,218
97	7,160	3,156	9,581	1,094	5,859	755	8,029	2,498
114	7,837	3,454	10,167	1,161	6,386	823	8,942	2,780
136	9,078	4,001	11,136	1,271	7,074	911	9,320	2,899
158	11,322	4,991	10,852	1,239	7,483	964	9,755	3,035
184	10,882	4,796	11,137	1,271	7,968	1,027	10,177	3,166
233	10,710	4,721	11,672	1,332	8,666	1,117	10,423	3,242
280	10,802	4,761	11,453	1,365	8,906	1,148	10,792	3,357
332	10,664	4,700	12,008	1,371	9,452	1,218	11,130	3,462
375	11,257	4,962	12,006	1,371	9,243	1,191	11,723	3,647
421	9,908	4,367	11,920	1,361	9,293	1,197	11,216	3,489
472	10,363	4,568	11,924	1,361	9,585	1,235	11,341	3,528
543	10,958	4,830	12,025	1,373	9,619	1,239	11,273	3,507
568	9,885	4,357	11,965	1,366	9,596	1,236	11,320	3,521
736	10,378	4,574	12,258	1,399	9,698	1,250	11,095	3,451

APPENDIX B-12 (CONTINUED)

SEDIMENT COMPARTMENT (Second Run, Tank I, Decay Correction, Geometric Average of Area, Milligrams Selenium)

HOURS ELAPSED TIME	IDEALIZED CONTAINER SUM OF FRACTIONS	COMPARTMENT cpm*	COMPARTMENT mg Se	DECAY CORRECTED mg
0	0	0	0	0
4.25	634	421,538	.1966	.1966
13	1,494	993,341	.4634	.4634
25	2,408	1,601,049	.7469	.7469
40	3,811	2,533,886	1.1821	1.195
50	4,212	2,800,506	1.306	1.321
63	5,404	3,593,051	1.676	1.695
72	6,013	3,997,968	1.865	1.886
82	6,730	4,474,692	2.087	2.111
97	7,503	4,988,650	2.327	2.381
114	8,218	5,464,045	2.549	2.608
136	9,082	6,038,508	2.817	2.916
158	10,229	6,801,133	3.172	3.283
184	10,260	6,821,745	3.182	3.332
233	10,412	6,922,808	3.229	3.420
280	10,631	7,068,418	3.297	3.533
332	10,751	7,148,205	3.334	3.617
375	11,171	7,427,457	3.465	3.797
421	10,414	6,924,138	3.230	3.578
472	10,692	7,108,976	3.316	3.717
543	10,949	7,279,852	3.396	3.864
568	10,480	6,968,020	3.250	3.731
736	10,674	7,097,008	3.311	3.934

* = (664.88747) x (Idealized Container)

APPENDIX B-13

WATER COMPARTMENT (Second Run, Tank II)

HOURS ELAPSED TIME	FILTER NUMBER	RAW COUNT cpm 20 ml SAMPLE	BACKGROUND CORRECTED cpm	DECAY CORRECTED cpm	(x .4666 x 10^{-6}) mg Se 20 ml SAMPLE	COMPARTMENT mg Se (SAMPLE x 3,000)
0	2	1,418 ten*	-	-	-	-
.083	4	43,684 ten*	4,225	4,225	1,971	5.91
.25	6	4,357	4,201	4,201	1,960	5.88
		4,331				
.5	8	44,591 ten*	4,316	4,316	2,013	6.04
1	10	44,035 ten*	4,260	4,260	1,987	5.96
3	12	43,260 ten*	4,183	4,183	1,951	5.85
12	14	41,847 ten*	4,041	4,041	1,885	5.65
18	16	4,005	3,863	3,863	1,802	5.41
		4,006				
23.5	18	3,733	3,680	3,680	1,717	5.15
		3,913				
37	20	3,601	3,439	3,439	1,604	4.81
		3,564				
48	22	3,229	3,091	3,126	1,459	4.37
		3,239				
61	24	3,115	2,948	2,982	1,391	4.18
		3,068				
70.5	26	2,466	2,299	2,326	1,085	3.26
		2,419				
81	28	2,672	2,510	2,539	1,185	3.56
		2,635				

* ten minute count

APPENDIX B-13 (CONTINUED)

WATER COMPARTMENT (Second Run, Tank II)

HOURS ELAPSED TIME	FILTER NUMBER	RAW COUNT cpm 20 ml SAMPLE	BACKGROUND CORRECTED cpm	DECAY CORRECTED cpm	(x .4666 x 10^{-6}) mg Se 20 ml SAMPLE	COMPARTMENT mg Se (SAMPLE x 3,000)
96	30	2,440	2,333	2,387	1,114	3.34
		2,421				
		2,565				
134	34	1,721	1,562	1,598	746	2.24
		1,688				
157	36	1,472	1,305	1,351	630	1.89
		1,423				
183	38	1,192	1,026	1,062	495	1.49
		1,145				
232	40	789	652	683	318	0.956
		798				
256	42	600	459	486	226	0.681
280	44	464	351	371	173	0.520
		520				
303	46	488	374	401	187	0.562
		543				
353	48	5,236 ten*	383	418	195	0.585
400	50	4,651 ten*	325	358	167	0.501
421	56	4,633	323	356	166	0.499

* ten minute count

APPENDIX B-13 (CONTINUED)

WATER COMPARTMENT (Second Run, Tank II)

HOURS ELAPSED TIME	FILTER NUMBER	RAW COUNT cpm 20 ml SAMPLE	BACKGROUND CORRECTED cpm	DECAY CORRECTED cpm	(x .4666 x 10^{-6}) mg Se 20 ml SAMPLE	COMPARTMENT mg Se (SAMPLE x 3,000)
447	58	422	307	339	158	0.475
		473				
472	60	4,556 *	314	350	163	0.491
496	62	458	323	364	170	0.510
		439				
520	64	432	282	318	148	0.446
		411				
568	66	418	268	308	143	0.431
		397				
617	68	380	239	274	128	0.384
		376				
641	70	400	254	295	137	0.413
		371				
		409				
720	72	384	249	295	138	0.414
		390				
736	74	397	255	303	141	0.424
		389				

* Ten minute count

APPENDIX B-13 (CONTINUED)

WATER COMPARTMENT (Second Run, Tank II)

HOURS ELAPSED TIME	FILTER NUMBER	RAW COUNT cpm 20 ml SAMPLE	BACKGROUND CORRECTED cpm	DECAY CORRECTED cpm	(x .4666 x 10^{-6}) mg Se 20 ml SAMPLE	COMPARTMENT mg Se (SAMPLE x 3,000)
830	78	396	260	318	148	0.445
		398				
904	82	3,652 ten*	228	283	132	0.397
928	84	364	223	277	129	0.388
		354				
952	86	390	222	277	129	0.387
		344				
1,024	88	346	215	270	126	0.379
		356				

* ten minute count

APPENDIX B-14

SUSPENDED PARTICULATE COMPARTMENT (Second Run, Tank II)

HOURS ELAPSED TIME	FILTER NUMBER	RAW 10 MIN. COUNT RATE 40 ml	BACKGROUND CORRECTED cpm	DECAY CORRECTED cpm	cpm NORMALIZED (x .9055)	mg Se PER 40 ml SAMPLE	COMPART-MENT mg Se
0	2	1,274	0	0	0	0	0
.083	4	1,745	16	18	16	8	.0114
.25	6	1,665	8	9	8	4	.0057
.5	8	1,685	10	11	10	5	.0069
1	10	1,611	2	2	2	1	.0012
3	12	1,670	8	9	8	4	.0057
12	14	1,795	21	23	21	10	.0145
18	16	1,723	13	14	13	6	.0088
23.5	18	1,826	24	26	24	11	.0164
37	20	2,081	49	54	49	23	.0342
48	22	2,272	68	75	68	32	.0475
61	24	2,627	104	115	104	49	.0728
70.5	26	3,033	144	159	144	67	.1007
81	28	3,096	151	167	151	71	.1058
96	30	3,438	185	204	185	86	.1292
113	32	3,581	199	219	198	93	.1387
134	34	3,999	241	266	241	112	.1685
157	36	4,394	280	309	280	131	.1958
183	38	4,767	318	351	318	148	.2224
232	40	6,135	455	502	455	212	.3181
256	42	4,717	313	345	312	146	.2186
280	44	5,099	351	387	350	164	.2452

APPENDIX B-14 (CONTINUED)

SUSPENDED PARTICULATE COMPARTMENT (Second Run, Tank II)

HOURS ELAPSED TIME	FILTER NUMBER	RAW 10 MIN. COUNT RATE 40 ml	BACKGROUND CORRECTED cpm	DECAY CORRECTED cpm	cpm NORMALIZED (x .9055)	mg Se PER 40 ml SAMPLE	COMPART-MENT mg Se
303	46	5,359	377	416	377	176	.2636
353	48	5,147	356	393	356	166	.2490
400	50	6,146	456	503	455	212	.3187
421	56	5,265	368	415	376	175	.2630
447	58	4,721	317	358	324	151	.2268
472	60	4,778	323	365	331	154	.2313
496	62	4,394	286	325	294	137	.2059
520	64	4,608	307	351	318	148	.2224
568	66	4,192	266	310	281	131	.1964
617	68	3,516	198	231	209	98	.1463
641	70	2,891	136	158	143	67	.1001
720	72	3,635	211	258	234	109	.1635
736	74	3,259	173	212	192	90	.1343
792	76	2,958	143	175	158	74	.1109
830	78	2,681	120	149	135	63	.0944
904	82	2,561	108	141	128	60	.0893
928	84	2,517	104	136	123	58	.0862
952	86	2,432	95	124	112	52	.0785
1,024	88	2,343	80	104	94	44	.0659

APPENDIX B-15

DATA FISH COMPARTMENT (Second Run, Tank II)

HOURS ELAPSED TIME	FISH NUMBER 1	2	3	4
0	617	696	681	857
	542	679	777	753
2	634	766	778	915
	654	761	791	921
6.5	799	794	880	1,023
	781	790	911	1,017
23	1,023	1,278	1,275	1,645
	1,024	1,199	1,274	1,700
37	1,330	1,485	1,533	2,041
	1,332	1,447	1,491	1,959
			1,546	
47.5	1,705	1,808	2,179	2,836
	1,745	1,758	2,038	2,755
62	1,889	2,234	2,533	2,857
	1,957	2,102	2,617	2,942
71	2,295	2,316	2,555	3,377
	2,285	2,385	2,696	3,193
81	2,448	2,668	2,773	3,321
	2,408	2,715	2,717	3,315
96	2,975	3,476	3,550	4,117
	2,940	3,563	3,613	3,958
113	3,763	4,303	4,714	5,483
	3,737	4,461	4,562	4,808
134	4,839	5,439	5,688	7,389
	4,749	5,326	5,580	7,442
			5,628	
160	6,186	6,741	8,365	8,975
	6,194	6,763	8,483	9,033
183	7,911	7,877	9,841	11,952
	7,780	7,937	9,601	11,507
232	10,863	11,558	11,842	14,071
	10,782	11,517	11,909	14,046
256	9,915	10,394	11,010	14,238
	9,845	10,436	10,903	13,843
				13,903

APPENDIX B-15 (CONTINUED)

DATA FISH COMPARTMENT (Second Run, Tank II)

HOURS ELAPSED TIME	FISH NUMBER			
	1	2	3	4
303	10,536	10,569	11,615	14,607
	10,665	11,004	12,004	14,607
		11,064	12,100	
		10,764		
353	11,018	10,894	11,322	15,344
	10,874	11,059	11,363	15,156
400	10,266	16,482	11,238	14,668
	10,339	10,375	11,186	14,146
447	10,437	11,380	11,315	15,466
	10,407	11,177	11,346	15,469
518	8,637	9,851	10,036	13,438
	8,476	10,035	10,410	13,246
568	8,299	9,138	10,082	12,392
	8,267	9,070	10,303	12,270
641	7,584	8,263	10,005	12,120
	7,854	8,029	9,996	11,856
760	7,176	7,834	9,371	11,091
		7,769		10,683
830	6,521	7,186	9,217	9,948
	6,464	7,109	9,438	10,039
880	6,262	6,508	9,474	9,700
	6,450	6,514	9,495	9,603
1,024	5,146	5,539	8,126	9,264
	5,287	5,374	8,265	9,239

APPENDIX B-15 (CONTINUED)

DATA FISH COMPARTMENT (Second Run, Tank II)

HOURS ELAPSED TIME	cpm Compartment Corrected for Background	cpm Compartment Corrected for Decay	Compartment Mg Se (x .4666 x 10^{-6})	Compartment Mg Se Normalized
0	0	0	0	0
2	308	308	143	.00010
6.5	696	696	324	.00022
23	2,408	2,408	1,123	.00079
37	3,519	3,519	1,642	.00115
47.5	5,638	5,703	2,661	.00187
62	6,791	6,870	3,205	.00226
71	7,777	7,867	3,670	.00259
81	8,408	8,506	3,968	.00280
96	11,349	11,613	5,418	.00382
113	15,168	15,522	7,242	.00511
134	20,477	20,954	9,777	.00690
160	27,649	28,621	13,354	.00942
183	34,482	35,694	16,655	.01175
232	45,649	47,800	22,303	.01574
256	42,577	45,099	21,043	.01485
303	45,322	48,562	22,659	.01599
353	45,898	50,028	23,343	.01648
400	43,738	47,958	22,377	.01579
447	45,930	50,945	23,771	.01678
518	39,521	44,599	20,809	.01469
568	37,391	42,562	19,859	.01402
641	35,381	41,091	19,173	.01353
760	32,832	39,020	18,207	.01285
830	30,581	37,299	17,404	.01228
880	29,675	36,614	17,084	.01206
1,024	25,827	32,796	15,302	.01080

APPENDIX B-16

SEDIMENT COMPARTMENT RAW DATA CPM (Second Run, Tank II)

HOURS ELAPSED TIME	II3H	II2H	II1H	II3R	II1R
0	0	0	0	0	0
5.5	1,338	2,860	3,204	1,354	1,176
	1,308	2,990	3,262	1,442	1,144
13.5	2,000	4,756	5,065	2,200	1,612
	2,076	4,903	5,040	2,213	1,571
	2,059				
26	3,077	7,886	7,758	3,577	2,212
	2,984	7,858	7,858	3,605	2,201
41	4,699	12,848	10,811	5,353	2,912
	4,804	13,010	11,110	3,250	2,974
	4,804				
51	5,674	15,724	12,705	6,292	3,220
	5,679	15,903	12,598	6,315	3,237
64	6,584	17,780	15,101	7,549	3,865
	6,554	17,861	14,886	7,668	3,873
73	7,450	18,393	16,170	8,454	4,127
	7,451	18,668	16,345	8,441	4,225
83	8,096	19,713	18,281	9,316	4,703
	8,380	19,311	18,534	9,402	4,795
	8,490				
98	9,851	20,073	21,322	10,634	5,312
	9,943	20,426	21,732	10,554	5,205
115	11,290	21,509	21,777	11,527	5,517
	11,329	21,549	21,551	11,764	5,681

APPENDIX B-16 (CONTINUED)

SEDIMENT COMPARTMENT RAW DATA CPM (Second Run, Tank II)

HOURS ELAPSED TIME	II3H	II2H	II1H	II3R	II1R
136	14,514	23,157	26,763	13,649	6,583
	14,659	23,071	27,034	13,795	6,620
159	16,707	23,269	29,339	15,287	7,473
	16,704	23,448	29,326	15,190	7,315
185	18,847	23,550	30,441	16,824	7,327
	19,050	23,793	30,242	16,802	7,214
234	21,806	23,976	36,478	19,295	8,413
	21,878	23,791	36,480	19,534	8,397
280	22,634	22,662	31,466	19,859	8,344
	22,665	22,627	32,010	19,989	8,306
332	23,325	24,241	39,981	20,045	8,669
	23,338	24,419	40,304	20,560	8,696
375	23,048	25,565	37,105	20,053	8,329
	23,313	25,640	37,502	20,249	8,508
421	23,347	25,898	37,559	20,037	8,400
	23,242	26,162	37,540	20,154	8,296
472	23,383	25,206	37,758	19,981	8,348
	23,108	25,347	37,634	19,917	8,375
543	22,582	24,137	37,386	19,648	8,193
	22,902	23,952	37,189	19,781	7,948
					8,140

APPENDIX B-16 (CONTINUED)

SEDIMENT COMPARTMENT RAW DATA CPM (Second Run, Tank II)

HOURS ELAPSED TIME	II3H	II2H	II1H	II3R	II1R
568	22,332	24,246	37,508	19,870	8,054
	22,666	24,102	37,303	19,768	8,155
617	22,185	24,592	35,918	19,437	8,147
	22,142	24,461	36,057	19,442	8,042
880	22,269	23,285	32,637	18,543	7,928
	22,298	23,322	32,799	18,674	7,899
1,024					

APPENDIX B-16 (CONTINUED)

SEDIMENT COMPARTMENT RAW DATA CPM (Second Run, Tank II)

HOURS ELAPSED TIME	II4C	II2C	II4E	II2E	II3E	II1E
0	0	0	0	0	0	0
5.5	13,670 ten*	1,563	1,380	1,452	1,562	1,699
		1,497	1,378	1,436	1,507	1,620
13.5	1,772	2,187	2,083	2,268	2,206	2,426
	1,904	2,171	2,160	2,227	2,163	2,466
26	2,441	3,075	3,000	3,294	3,211	3,561
	2,446	3,069	3,128	3,344	3,040	3,553
41	3,241	4,224	4,005	5,254	4,550	5,285
	3,322	4,285	4,095	5,076	4,614	5,368
51	3,581	5,159	5,055	6,649	5,565	6,185
	3,520	5,198	4,862	6,671	5,625	6,128
64	3,945	5,087	6,056	6,715	6,463	7,303
	3,825	5,258	5,940	6,721	6,634	7,397
73	4,235	5,981	6,766	6,933	7,248	8,590
	4,058	6,117	6,771	6,948	7,166	8,434
				6,823		
				7,035		
83	4,803	6,701	7,499	7,878	8,019	8,736
	4,735	6,810	7,555	7,974	8,047	9,772
						9,798

* ten minute count

APPENDIX B-16 (CONTINUED)

SEDIMENT COMPARTMENT RAW DATA CPM (Second Run, Tank II)

HOURS ELAPSED TIME	II4C	II2C	II4E	II2E	II3E	II1E
98	4,739	7,566	8,668	9,343	9,369	11,328
	4,754	7,829	8,662	9,364	9,355	11,044
115	5,407	8,638	9,431	11,078	9,841	12,338
	5,272	8,646	9,492	11,076	10,100	12,698
136	6,264	10,427	10,338	13,330	11,859	14,290
	6,948	10,567	10,516	13,519	11,548	14,510
159	6,845	12,367	11,182	16,036	13,328	15,933
	6,727	12,296	11,138	15,930	13,302	15,801
185	7,689	13,507	12,494	18,160	14,883	17,813
	7,606	13,622		18,090	14,676	18,139
234	8,472	15,574	12,912	21,724	16,526	19,682
	8,566	15,770	13,336	22,279	16,355	19,664
280	8,659	15,790	14,379	22,164	17,214	19,789
	8,346	15,614	14,285	22,340	17,148	19,880
332	8,250	14,684	15,009	22,791	16,894	19,391
	8,213	14,604	14,809	22,824	16,511	19,487
375	8,229	14,388	13,887	21,925	16,501	18,890
	8,272	14,028	13,864	22,102	16,548	19,188
421	8,143	13,820	14,285	22,201	16,390	18,655
	8,102	13,942	13,893	22,344	16,324	18,855

APPENDIX B-16 (CONTINUED)

SEDIMENT COMPARTMENT RAW DATA CPM (Second Run, Tank II)

HOURS ELAPSED TIME	II4C	II2C	II4E	II2E	II3E	II1E
472	8,147	13,314	13,735	21,717	16,198	18,565
	8,092	13,520	13,935	21,820	16,147	18,623
543	8,092	13,247	13,303	21,228	15,064	18,275
	8,124	13,350	13,215	21,498	15,712	17,866
568	7,936	12,927	14,666	21,238	15,570	17,618
	8,017	13,007	14,443	21,256	15,565	17,514
617	7,945	12,805	14,622	20,837	15,514	17,674
	8,065	12,810	14,777	20,819	15,543	17,747
880	7,738	12,695	14,748	19,755	14,957	17,000
	7,898	12,764	14,642	19,986	14,739	17,165

APPENDIX B-16 (CONTINUED)

SEDIMENT COMPARTMENT CPM (Second Run, Tank II)
(Corrected for Background, Normalized for Attenuation, Geometry)

HOURS ELAPSED TIME	II3H	II2H	II1H	II3R	II1R
0	0	0	0	0	0
5.5	712	1,298	1,639	853	666
	571	1,042	1,316	684	534
13.5	1,434	3,202	3,458	1,661	1,097
	1,151	2,571	2,777	1,334	881
26	2,419	6,245	6,214	3,046	1,712
	1,942	5,014	4,989	2,445	1,375
41	4,172	11,302	9,366	4,756	2,449
	3,350	9,075	7,521	3,819	1,966
51	5,071	14,204	11,075	5,763	2,739
	4,072	11,406	8,893	4,628	2,199
64	5,964	16,211	13,417	7,068	3,380
	4,789	13,017	10,774	5,676	2,714
73	6,845	16,921	14,681	7,907	3,687
	5,496	13,587	11,789	6,349	2,960
83	7,717	17,903	16,831	8,819	4,260
	6,196	14,376	13,515	7,081	3,420

LEGEND: Above Number - cpm corrected for all background.
Below Number - cpm normalized, corrected for geometry.

APPENDIX B-16 (CONTINUED)

SEDIMENT COMPARTMENT CPM (Second Run, Tank II)
(Corrected for Background, Normalized for Attenuation, Geometry)

HOURS ELAPSED TIME	II3H	II2H	II1H	II3R	II1R
98	9,298	18,657	19,967	10,059	4,773
	7,466	14,981	16,033	8,077	3,833
115	10,710	19,937	20,104	11,110	5,114
	8,600	16,009	16,143	8,921	4,106
136	13,992	21,539	25,355	13,192	6,121
	11,235	17,295	20,360	10,593	4,915
159	16,111	21,781	27,789	14,708	6,914
	12,937	17,490	22,314	11,810	5,551
185	18,360	22,113	28,814	16,288	6,794
	14,743	17,757	23,138	13,079	5,455
234	21,254	22,325	34,952	18,889	7,929
	17,066	17,927	28,066	15,168	6,366
280	22,067	21,103	36,800	19,404	7,853
	17,720	16,946	29,551	15,581	6,305
332	22,754	22,805	38,648	19,787	8,214
	18,271	18,312	31,034	15,889	6,596
375	22,608	24,093	35,825	19,640	7,954
	18,154	19,347	28,767	15,770	6,387

LEGEND: Above Number - cpm corrected for all background.
Below Number - cpm normalized, corrected for geometry.

APPENDIX B-16 (CONTINUED)

SEDIMENT COMPARTMENT CPM (Second Run, Tank II)
(Corrected for Background, Normalized for Attenuation, Geometry)

HOURS ELAPSED TIME	II3H	II2H	II1H	II3R	II1R
421	22,722	24,521	36,071	19,584	7,884
	18,246	19,690	28,965	15,726	6,330
472	22,678	23,783	36,233	19,443	7,901
	18,210	19,098	29,095	15,612	6,344
543	22,185	22,583	35,855	19,217	7,641
	17,814	18,134	28,791	15,431	6,136
568	21,948	22,728	35,988	19,326	7,656
	17,624	18,250	28,898	15,518	6,148
617	21,617	23,096	34,585	18,951	7,650
	17,358	18,546	27,772	15,218	6,143
880	21,762	21,947	31,389	18,141	7,488
	17,475	17,623	25,205	14,567	6,013

LEGEND: Above Number - cpm corrected for all background.
Below Number - cpm normalized, corrected for geometry.

APPENDIX B-16 (CONTINUED)

SEDIMENT COMPARTMENT CPM (Second Run, Tank II)
(Corrected for Background, Normalized for Attenuation, Geometry)

HOURS ELAPSED TIME	II4C	II2C	II4E	II2E	II3E	II1E
0	0	0	0	0	0	0
5.5	827	904	865	790	993	679
	664	725	694	634	797	545
13.5	1,298	1,553	1,607	1,593	1,643	1,466
	1,042	1,247	1,290	1,279	1,319	1,177
26	1,903	2,446	2,550	2,665	2,584	2,577
	1,528	1,964	2,047	2,139	2,075	2,069
41	2,741	3,628	3,536	4,511	4,041	4,346
	2,201	2,913	2,839	3,622	3,244	3,490
51	3,015	4,558	4,449	6,013	5,059	5,186
	2,421	3,660	3,572	4,828	4,062	4,164
64	3,350	4,552	5,489	6,071	6,012	6,380
	2,690	3,655	4,407	4,875	6,671	5,123
73	3,611	5,429	6,259	6,300	6,671	7,542
	2,900	4,359	5,026	5,059	5,356	6,056
83	4,234	6,135	7,008	7,279	7,497	8,465
	3,399	4,926	5,627	5,845	6,020	6,797

LEGEND: Above Number - cpm corrected for all background
Below Number - cpm normalized, corrected for geometry.

APPENDIX B-16 (CONTINUED)

SEDIMENT COMPARTMENT CPM (Second Run, Tank II)
(Corrected for Background, Normalized for Attenuation, Geometry)

HOURS ELAPSED TIME	II4C	II2C	II4E	II2E	II3E	II1E
98	4,216	7,083	8,161	8,712	8,831	10,226
	3,385	5,688	6,553	6,996	7,091	8,211
115	4,809	8,028	8,957	10,436	9,439	11,558
	3,862	6,446	7,192	8,380	7,579	9,281
136	6,081	9,889	9,927	12,789	11,177	13,450
	4,883	7,940	7,971	10,269	8,975	10,800
159	6,261	11,723	10,660	15,348	12,789	14,917
	5,027	9,413	8,559	12,324	10,269	11,978
185	7,127	12,952	11,999	17,496	14,258	17,036
	5,723	10,400	9,635	14,049	11,449	13,679
234	7,999	15,070	12,629	21,372	15,919	18,733
	6,423	12,101	10,141	17,162	12,783	15,042
280	7,987	15,105	13,841	21,629	16,665	18,903
	6,413	12,129	11,114	17,368	13,381	15,179
332	7,720	14,053	14,422	22,190	16,190	18,518
	6,199	11,284	11,580	17,818	13,000	14,869
375	7,744	13,622	13,393	21,402	16,017	18,127
	6,218	10,938	10,754	17,186	12,862	14,555

LEGEND: Above Number - cpm corrected for all background.
Below Number - cpm normalized, corrected for geometry.

APPENDIX B-16 (CONTINUED)

SEDIMENT COMPARTMENT CPM (Second Run, Tank II)
(Corrected for Background, Normalized for Attenuation, Geometry)

HOURS ELAPSED TIME	II4C	II2C	II4E	II2E	II3E	II1E
421	7,616	13,295	13,607	21,661	15,850	17,843
	6,116	10,675	10,926	17,394	12,727	14,327
472	7,617	12,837	13,357	21,162	15,669	17,691
	6,116	10,308	10,725	16,993	12,582	14,205
543	7,615	12,729	12,789	20,769	14,894	17,185
	6,114	10,221	10,269	16,677	11,959	13,799
568	7,488	12,403	14,088	20,658	15,078	16,690
	6,013	9,959	11,313	16,588	12,108	13,402
617	7,521	12,248	14,238	20,245	15,043	16,843
	6,039	9,835	11,433	16,256	12,079	13,525
880	7,355	12,195	14,253	19,313	14,384	16,257
	5,906	9,792	11,445	15,508	11,550	13,054

LEGEND: Above Number - cpm corrected for all background.
Below Number - cpm normalized, corrected for geometry.

APPENDIX B-16 (CONTINUED)

SEDIMENT (Second Run, Tank II, cpm)
Decay Correction, Geometric Average, Mg Selenium

HOURS ELAPSED TIME	H		R		C		E	
	AVERAGE cpm	FRACTION cpm	AVERAGE cpm	FRACTION cpm	AVERAGE cpm	FRACTION cpm	AVERAGE cpm	FRACTION cpm
0	0	0	0	0	0	0	0	0
5.5	875	385	609	69	694	89	667	207
13.5	1,912	842	1,107	126	1,144	147	1,266	393
26	3,471	1,530	1,910	217	1,746	224	2,082	647
41	5,824	2,566	2,892	329	2,557	329	3,298	1,026
51	7,110	3,133	3,413	389	3,040	391	4,156	1,292
64	8,342	3,676	4,195	478	3,172	408	5,269	1,638
73	9,092	4,006	4,654	530	3,629	467	5,374	1,671
83	10,070	4,438	5,250	598	4,162	536	6,072	1,888
98	11,486	5,062	5,955	678	4,536	584	7,212	2,243
115	12,338	5,437	6,513	742	5,154	664	8,108	2,522
136	15,031	6,624	7,754	883	6,411	826	9,503	2,956
159	16,419	7,236	8,680	989	7,220	930	10,782	3,354
185	17,595	7,754	9,267	1,056	8,061	1,038	12,200	3,795
234	20,031	8,827	10,767	1,227	9,262	1,193	13,782	4,287
280	20,484	9,027	10,943	1,247	9,271	1,194	14,260	4,435
332	21,472	9,462	11,242	1,281	8,741	1,126	14,316	4,453
375	21,105	9,301	11,078	1,262	8,578	1,105	13,839	4,304
421	21,286	9,381	11,028	1,257	8,395	1,081	13,843	4,306
472	21,153	9,322	10,978	1,251	8,212	1,058	13,626	4,238
543	20,638	9,095	10,783	1,229	8,167	1,052	13,176	4,098
568	20,599	9,077	10,833	1,234	7,986	1,028	13,352	4,153
617	20,258	8,927	10,680	1,217	7,937	1,022	13,323	4,144
880	19,444	8,569	10,290	1,173	7,849	1,011	12,889	4,009

APPENDIX B-16 (CONTINUED)

SEDIMENT (Second Run, Tank II, cpm)
Decay Correction, Geometric Average, Mg Selenium

HOURS ELAPSED TIME	IDEALIZED CONTAINER SUM OF FRACTIONS	Cpm COMPARTMENT	mg Se COMPARTMENT	DECAY CORRECTED mg Se
0	0	0	0	0
5.5	750	498,665	.2326	.2326
13.5	1,508	1,002,650	.4678	.4678
26	2,618	1,740,675	.8121	.8121
41	4,250	2,825,771	1.318	1.318
51	5,205	3,460,739	1.614	1.631
64	6,200	4,122,302	1.923	1.944
73	6,674	4,437,458	2.070	2.092
83	7,460	4,960,060	2.314	2.339
98	8,567	5,696,090	2.657	2.715
115	9,365	6,226,671	2.905	2.969
136	11,289	7,505,914	3.502	3.579
159	12,509	8,317,077	3.880	3.965
185	13,643	9,071,059	4.232	4.373
234	15,534	10,328,361	4.819	4.979
280	15,903	10,573,705	4.933	5.153
332	16,322	10,852,293	5.063	5.406
375	15,972	10,619,582	4.954	5.348
421	16,025	10,654,821	4.971	5.366
472	15,869	10,551,099	4.923	5.373
543	15,474	10,288,468	4.772	5.323
568	15,492	10,300,436	4.806	5.420
617	15,310	10,179,427	4.749	5.415
880	14,762	9,815,068	4.579	5.454

APPENDIX B-17

STABILITY PARAMETERS FIRST RUN
(Data of Non-Experimental Parameters, Tanks I, II)

	pH		DO		TDS		TEMPERATURE	
DAY	I	II	I	II	I	II	I	II
1	8.4	8.3	9.8	8.4	410	460	21	21
2	8.5	8.4			420	440	21	22
3	8.5	8.4	9.0	8.2				
4	8.5	8.4	8.3	7.6	400	450	22	22
5	8.5	8.5	8.0	8.3	430	450	21	22
6	8.3	8.4					21	22
7	8.5	8.4	7.8	9.1	410	465		
8	8.4	8.3					22	22
9	8.5	8.3	7.2	8.3	400	480	22	23
10	8.4	8.3	7.8	8.0			22	23
11					450	470	21	23
12	8.6	8.5	8.2	7.5			22	23
13	8.5	8.4	7.8	7.2	435	470	21	22
14	8.5	8.6	8.1	7.5			21	22
15	8.5	8.4	6.2	7.4	410	480	21	22
16	8.3	8.6	6.8	6.6			22	22
17	8.4	8.5	7.2	6.2	430	450	21	22
18	8.3	8.4			440	460	21	22
19	8.5	8.5	6.5	7.1			21	22
20					420	475	22	23
21	8.5	8.4	6.6	6.8	420	470	22	23
22	8.4	8.6	5.4	7.3	430	465	21	22
23	8.5	8.6	5.8	6.4			21	22
24					425	485		
25	8.5	8.4	6.1	5.9	430	480	22	22
26								
27							21	22
28	8.4	8.5	6.2	5.8	430	485	21	22
29	8.5	8.4	5.9	6.2	440	490		
30	8.5	8.5	6.4	6.5			21	22
31	8.4	8.5	5.9	6.7			21	23

APPENDIX B-18

STABILITY PARAMETERS SECOND RUN

(Data of Non-Experimental Parameters, Second Run, Tanks I, II)

	pH		DO		TDS		TEMP.	
DAY	I	II	I	II	I	II	I	II
0	8.9	8.5	7.3	6.2	800	790	24	24
1	8.7	8.4	9.0	8.4	800	780	24	25
2	8.9	8.5	8.2	6.5	800	780	24	24
3	8.5	8.4	7.9	7.3	820	800	23	24
4			8.1	7.9			23	24
5			9.2	7.5	840	800	24	25
6	8.5	8.5			860	800	24	25
7			8.3	8.0			24	25
8	8.5	8.5	7.9	7.6	840	800	23	24
9					840	800	24	25
10			6.4	5.9	840	800	29	25
11			5.8	5.8	830	810	24	24
12	8.4	8.3	5.5	6.0	850	840	25	26
13			7.2	6.5	780	820	25	26
14							25	26
15	8.4	8.3	8.5	7.9	830	800	25	26
16			8.3	8.1	825	810	24	26
17	8.5	8.4	7.6	7.7	830	830	24	26
18			6.5	6.0	835	810	24	26
19	8.4	8.4			800	790	24	25
20			5.0	4.8	840	805	23	24
21			4.2	5.1	810	780	23	25
22	8.3	8.2	3.9	3.5	830	820	24	25
23			4.5	4.5	770	780	24	25
24	8.3	8.3	4.2	3.8	800	790	24	25
25			4.5	4.3	860	800	23	24
	8.4	8.3	3.2	3.9				
29			3.0	4.5	850	805	24	25
30	8.3	8.5	4.2	6.1	875	820	24	26
34			3.4	5.6	800	800	25	25
37	8.3	8.4	4.7	6.0	780	810	25	25
38			3.7	3.5	800	790	24	25
39			5.2	4.1	800	780	24	24
42	8.3	8.5	4.8	4.0	800	780	24	25

APPENDIX B-19

SUSPENDED PARTICULATE

FILTER WEIGHTS (First Run, Tank I, 20 ml Sample)

FILTER NUMBER		FILTER WEIGHT GRAMS	SUSPENDED PARTICULATE + FILTER GRAMS	DIFFERENCE mg
00		.0781	.0796	1.6
19		.0717	.0732	1.5
17		.0688	.0696	0.8
5		.0953	.0965	1.2
7		.0861	.0874	1.3
9		.0856	.0868	1.2
11		.0565	.0580	1.5
13		.0707	.0721	1.4
15		.0708	.0727	1.9
2	even	.0818	.0830	1.2
3		.0836	.0849	1.3
21		.0586	.0871	1.5
23		.0625	.0633	0.8
25		.0659	.0672	1.3
27		.0707	.0719	1.2
29		.0663	.0671	0.8
31		.0665	.0681	1.6
33		.0830	.0851	2.1
35		.1012	.1030	1.8
37		.1082	.1109	2.7
39		.1006	.1032	2.6
41		.1013	.1041	2.8
43		.1025	.1056	3.1
45		.1010	.1038	2.8
47		.0987	.1014	2.7
49		.0989	.1017	2.8
51		.1029	.1058	2.9
53		.1033	.1057	2.4
55		.1022	.1051	2.9
57		.1061	.1068	2.7
AVERAGE				1.88

APPENDEX B-19 (CONTINUED)

SUSPENDED PARTICULATE

FILTER WEIGHTS (First Run, Tank II, 20 ml Sample)

FILTER NUMBER	FILTER WEIGHT GRAMS	SUSPENDED PARTICULATE + FILTER GRAMS	DIFFERENCE mg
0	.0672	.0690	1.8
20	.0649	.0665	1.6
18	.0681	.0699	1.8
6	.0878	.0899	2.1
8	.0858	.0877	1.9
10	.0566	.0588	2.2
12	.0605	.0623	1.8
14	.0702	.0716	1.4
16	.0706	.0718	1.2
1	.0855	.0868	1.3
4	.0859	.0874	1.5
22	.0639	.0651	1.2
24	.0592	.0607	1.5
26	.0660	.0677	1.7
28	.0701	.0720	1.9
30	.0658	.0679	2.1
32	.1003	.1026	2.3
34	.0810	.0830	2.0
36	.1038	.1061	2.3
38	.1124	.1148	2.4
40	.0941	.0969	2.8
42	.1003	.1034	3.1
44	.1016	.1046	3.0
46	.0976	.1002	2.6
48	.0990	.1019	2.9
50	.1029	.1055	2.6
52	.1034	.1060	2.6
54	.1014	.1037	2.3
56	.1016	.1041	2.5
58	.1047	.1067	2.0
AVERAGE			2.08

APPENDIX B-20

SUSPENDED PARTICULATE FILTER WEIGHTS
(Second Run, Tank I, 40 ml Sample)

FILTER NO.	TIME ELAPSED	FILTER WT. G.	FILTER & SAMPLE G.	WEIGHT SAMPLE mg
1	0	.1011	.1035	2.4
3	0.083	.0937	.0958	2.1
5	0.25	.1079	.1101	2.2
7	0.5	.0949	.0972	2.3
9	1	.0931	.0955	2.4
11	3	.0882	.0903	2.1
13	12	.0860	.0880	2.0
15	18			
17	23.5	.0870	.0896	2.6
19	37	.1011	.1032	2.1
21	48	.0860	.0882	2.2
23	61	.0856	.0877	2.1
25	70.5	.1015	.1044	2.9
27	81	.1006	.1032	2.6
29	96	.0998	.1022	2.4
31	113	.0995	.1026	3.1
33	134	.0982	.1012	3.0
35	157	.1025	.1057	3.2
39	232	.1213	.1244	3.1
41	256	.1097	.1123	2.6
43	280	.0997	.1029	3.2
45	303	.0870	.0898	2.8
51	353	.0993	.1024	3.1
53	400	.0992	.1025	3.3
55	421	.1008	.1036	2.8
57	447	.1059	.1088	2.9
59	472	.1026	.1055	2.9
61	496	.0971	.0994	2.3
63	518	.1021	.1044	2.3
65	568	.1055	.1077	2.2
71	720	.1013	.1033	2.0
73	736	.0994	.1015	2.1
75	792	.1008	.1028	2.0
77	830	.1039	.1082	4.3
81	904	.1001	.1056	5.5
83	928	.1000	.1055	5.5
85	952	.1014	.1071	5.7
87	1,024	.1005	.1076	7.1
89		.1002	.1081	7.9
AVERAGE				3.08

APPENDIX B-20 (CONTINUED)

SUSPENDED PARTICULATE FILTER WEIGHTS
(Second Run, Tank II, 40 ml Sample)

FILTER NO.	TIME ELAPSED	FILTER WT. G.	FILTER & SAMPLE	WEIGHT SAMPLE mg
2	0	.0936	.0952	1.6
4	0.033	.1038	.1054	1.6
6	0.25	.0957	.0971	1.4
8	0.5	.0960	.0978	1.8
10	1	.0927	.0942	1.5
12	3	.0852	.0866	1.4
14	12	.0862	.0877	1.5
16	18	.0873	.0886	1.3
18	23.5	.1007	.1022	1.5
20	37	.1007	.1020	1.3
22	48	.0861	.0874	1.3
24	61	.1000	.1021	2.1
26	70.5	.1038	.1059	2.1
28	81	.1030	.1046	1.6
30	96	.1042	.1060	1.8
34	134	.1010	.1031	2.1
36	157	.0970	.0988	1.8
38	183	.1047	.1060	1.3
40	232	.1076	.1091	1.5
42	256	.1101	.1110	.9
44	280	.1064	.1077	1.3
46	303	.1092	.1112	2.0
48	353	.1023	.1042	1.9
50	400	.1037	.1055	1.8
56	421	.1080	.1099	1.9
58	447	.1061	.1075	1.4
60	472	.0949	.0966	1.7
62	496	.1067	.1084	1.7
64	518	.1067	.1080	1.3
66	568	.1009	.1025	1.6
68	617	.1044	.1061	1.7
70	641	.1033	.1046	1.3
72	712	.1002	.1027	2.5
74	736	.1000	.1024	2.4
76	792	.1027	.1046	1.9
78	830	.1048	.1078	3.0
82	904	.1001	.1020	1.9

APPENDIX B-20 (CONTINUED)

SUSPENDED PARTICULATE FILTER WEIGHTS
(Second Run, Tank II, 40 ml Sample)

FILTER NO.	TIME ELAPSED	FILTER WT. G.	FILTER & SAMPLE	WEIGHT SAMPLE mg
84	928	.0993	.1011	1.8
86	952	.1011	.1033	2.2
88	1,024	.0996	.1026	3.0
90		.1000	.1029	2.9
AVERAGE				1.77

APPENDIX B-21

SORPTION ON MICROSCOPE SLIDE

SECOND RUN

A microscope slide was in situ for the duration of the experiment.

It was counted and then scraped clean and counted again.

A second slide was immersed for 15 minutes and allowed to drip dry and then counted.

	RAW COUNT PER TEN MINUTES		CORRECTED cpm	
	TANK I	TANK II	TANK I	TANK II
Duration Slide	2,442	2,371	132	125
Scraped	1,226	1,562	10.6	44
15 minute slide	1,212	1,327	9.2	20.7
% Remaining on Glass (Duration Slide)			8%	16%

Background = 11,212 per 100 minutes.

APPENDIX B-22

FISH ORIENTATION COMPARISON
(Count Rates Anterior End Up Compared) (Down/Up)

INVERSION OCCURENCE	ANTERIOR UP cpm	AVE.	ANTERIOR DOWN cpm	AVE.	ADJUSTMENT FRACTION
1	968	999	1,389	1,442	1.44
	1,030		1,496		
2	1,349	1,349	1,441	1,512	1.12
			1,583		
3	1,089	1,148	1,562	1,534	1.33
	1,207		1,506		
4	820	825	1,062	1,010	1.22
	830		958		
5	940	925	1,172	1,172	1.26
	911				
6	1,177	1,177	1,436	1,436	1.22
7	2,087	2,035	2,683	2,684	1.31
	1,984		2,686		
8	1,096	1,102	1,603	1,622	1.47
	1,109		1,641		
9	754	754	931	911	1.20
			892		
10	1,505	1,484	1,973	1,991	1.34
	1,464		2,010		
11	1,974	1,959	2,857	2,899	1.48
	1,944		2,942		
12	2,798	2,790	4,123	4,121	1.47
	2,783		4,119		
13	5,644	5,644	7,349	7,413	1.31
			7,478		
14	5,358	5,467	8,282	8,178	1.49
	5,576		8,075		
15	9,593	9,593	12,324	12,324	1.28
16	11,506	11,507	16,579	16,457	1.43
	11,509		16,336		
17	12,140	12,228	16,915	16,716	1.36
	12,316		16,518		
18	7,504	7,515	12,353	12,353	1.64
	7,526		12,354		
19	7,261	7,187	9,948	9,993	1.39
	7,114		10,039		
20	6,892	6,971	9,474	9,484	1.36
	7,050		9,495		
AVERAGE					1.356

APPENDIX B-23

FISH COMPARTMENT WEIGHTS
(Weight in Grams)

First Run	Tank I							Tank II					
	Fish Number*						Total g	Fish Number*					Total g.
Beginning	1	2	3	4	5	6		1	2	3	4	5	6	
Weight	1.8	1.6	1.9	2.3	2.3	2.4	= 12.3g	1.7	1.9	2.0	2.3	2.2	2.5	= 12.65 g
End Weight	-	-	-	-	-	-	= 13.6g	-	-	-	-	-	-	= 10.80 g
Second Run	Tank I							Tank II						
	Fish Number						Total g.							Total g.
Beginning	1	2	3	4	5	6		1	2	3	4			
Weight	1.7	2.2	2.4	2.9	3.7		= 11.95 g.	2.4	3.0	3.0	3.4			= 11.8 g
End Weight	2.4	2.4	2.4	2.5	3.5	3.7	= 14.3 g.	2.2	2.4	2.9	3.3			= 10.8 g

* Numbers do not correspond to the same fish from first to second runs but do within the second run.

APPENDIX B-24

SPECIES LIST

ALGAE

MYXOPHYCEAE
- Phormidium (abundant in bottom)
- Oscillatoria

SCENEDESMACEAE
- Scenedesmus (Predominant Plankton First Run)

OOCYSTACEAE
- Ankistrodesmus (Predominant Plankton Second Run)

CHLOROCOCCACEAE
- Golenkinia (Abundant First Run)

ULOTRICHACEAE
- Ulothrix

DESMIDACEAE
- Tetmemorus

BACILLARIOPHYCEAE
- Navicula (common)
- Stauroneis

PROTOZOA

- Vorticella
- Stylonychia
- Amoeba

ASHELMINTHES

- Philodina
- Nematode

APPENDIX C

APPENDIX C-1

SELENIUM-75 DECAY SCHEME

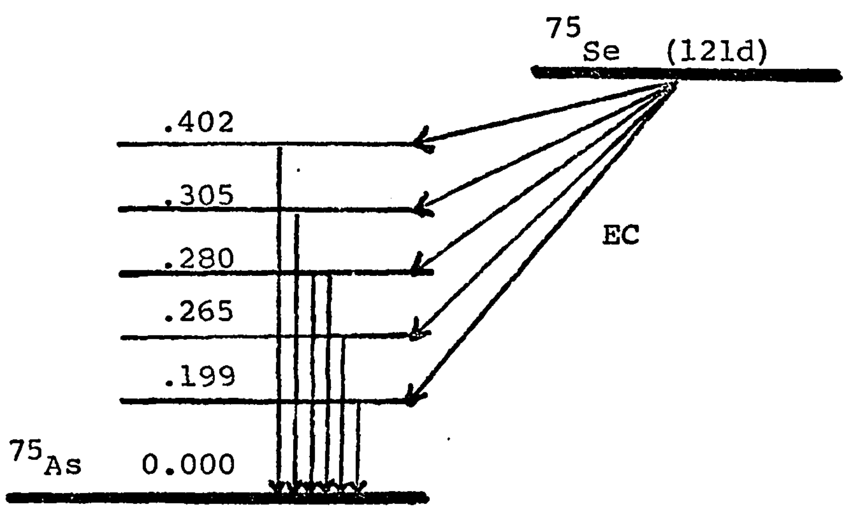
The mode of decay is by electron capture and gamma emission of various energies ranging from 0.402 Mev to 0.199 Mev:

0.136 Mev...57%

0.265 Mev...60%

0.280 Mev...25%

0.402 Mev...12%



APPENDIX C-2

PARTS PER MILLION SELENIUM IN ASSAY AMOUNT

Assay: $\left[0.0057 \text{ mg}/0.1 \text{ ml}\right]$ H_2SeO_3

then $0.0057 \text{ mg}/0.1 \text{ ml} = \left[\frac{0.057 \text{ mg}}{\text{ml}}\right]$ H_2SeO_3

and $\frac{0.057 \text{ mg } H_2SeO_3}{\text{ml}} \quad \frac{(0.612 \text{ Se-79})}{H_2SeO_3}$

$= \left[0.0348 \text{ mg/ml}\right]$ Se = .0348 grams per liter

$= 34.8 \text{ mg/l} = 34.8$ ppm Se

If use whole 0.1 ml Assay amount

$= 0.00348 \text{ mg}/60$ liter

$= 5.8 \times 10^{-5}$ mg/l = ppm insignificant

to levels in experimental tanks 0.01 ppm

If use 5 lambda from whole Assay amounts then order

of 10^{-3} less significant.

APPENDIX C-3

SPIKE QUANTITY FOR EXPERIMENTAL SYSTEM

Stock Solution:

5.0 ml = 0.0057 mg H_2SeO_3 in 0.5 N. NCL

= 1 mCi April 2, 1973

= 175 mCi/mg.

Remove: 1 lambda from stock:

Contains $\frac{1}{5000}$ mCi

and $\frac{0.0057}{5 \times 10^3}$

$= 1.14 \times 10^{-6}$ mg H_2SeO_3

and 1.14×10^{-6} (.612) = 0.697×10^{-6} mg Se

Remove: 5 lambda from stock:

Contains $\frac{1}{1000}$ mCi

and 5.7×10^{-6} mg H_2SeO_3

and 5.7×10^{-6} (.612) $\frac{\text{Se a. m. u.}}{H_2SeO_3 \text{ a. m. u.}}$

$= 3.48 \times 10^{-6}$ mg Se

APPENDIX C-4

SELENIUM-75 SPECTRUM (ΔE=.050V)

PULSE HEIGHT VOLTAGE	COUNTS PER MINUTE	PULSE HEIGHT VOLTAGE	COUNTS PER MINUTE	PULSE HEIGHT VOLTAGE	COUNTS PER MINUTE
0.010	8,178	0.166	2,742	0.268	9,012
0.028	8,201	0.168	2,863	0.270	8,637
0.030	8,568	0.170	2,856	0.272	8,175
0.040	9,706	0.172	2,874	0.274	7,818
0.050	10,523	0.174	2,878	0.276	7,013
0.060	10,864	0.176	2,857	0.278	6,248
0.070	11,057	0.178	2,990	0.280	5,653
0.080	11,821	0.180	2,967	0.282	5,416
0.090	14,668	0.182	2,896	0.284	4,764
0.100	20,049	0.184	2,875	0.286	4,458
0.102	22,193	0.186	2,911	0.288	3,986
0.104	23,593	0.188	2,946	0.290	3,544
0.106	25,273	0.190	2,999	0.300	2,327
0.108	26,226	0.192	2,848	0.310	1,575
0.110	27,114	0.194	2,829	0.320	1,431
0.112	27,731	0.196	2,893	0.330	1,438
0.114	27,618	0.198	2,794	0.340	1,409
0.116	27,712	0.200	2,867	0.350	1,608
0.118	26,889	0.208	2,949	0.360	1,759
0.120	25,851	0.216	3,725	0.370	2,172
0.122	24,343	0.224	4,433	0.380	2,759
0.124	22,226	0.226	4,899	0.390	3,380
0.126	20,263	0.228	5,453	0.392	3,386
0.128	18,077	0.230	6,033	0.394	3,474
0.130	16,263	0.232	6,726	0.396	3,568
0.132	14,197	0.234	7,203	0.398	3,601
0.134	11,670	0.236	7,438	0.400	3,701
0.136	8,194	0.238	7,901	0.402	3,544
0.138	6,547	0.240	8,362	0.404	3,648
0.140	5,770	0.243	9,103	0.406	3,652
0.142	4,736	0.244	9,583	0.408	3,563
0.144	4,135	0.246	10,127	0.410	3,343
0.146	3,627	0.248	10,768	0.412	3,315
0.148	3,262	0.250	11,040	0.414	2,973
0.150	3,059	0.252	11,345	0.416	2,824
0.152	2,863	0.254	11,818	0.418	2,736
0.154	2,880	0.256	11,559	0.420	2,388

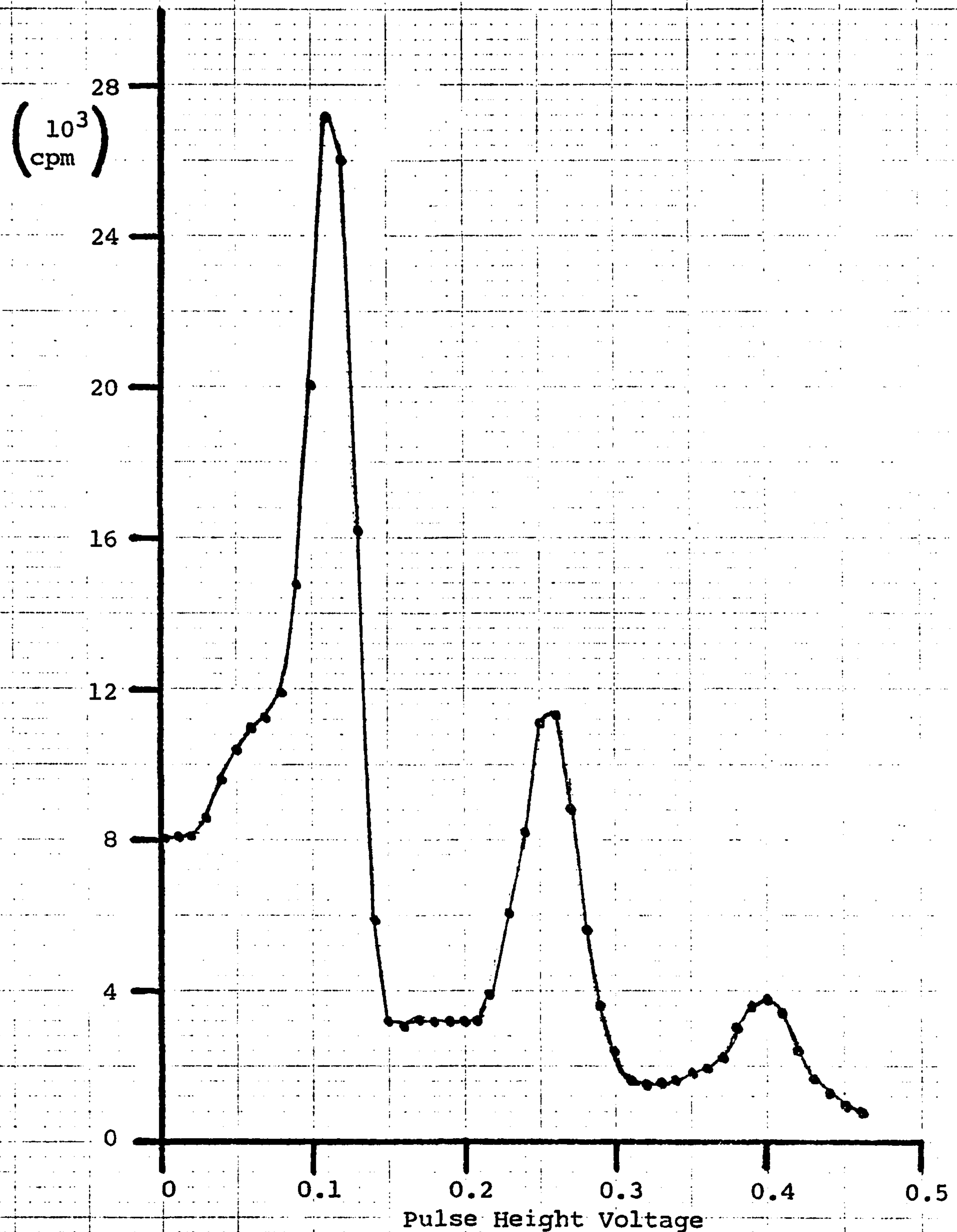
APPENDIX C-4 (CONTINUED)

SELENIUM-75 SPECTRUM (ΔE=.050V)

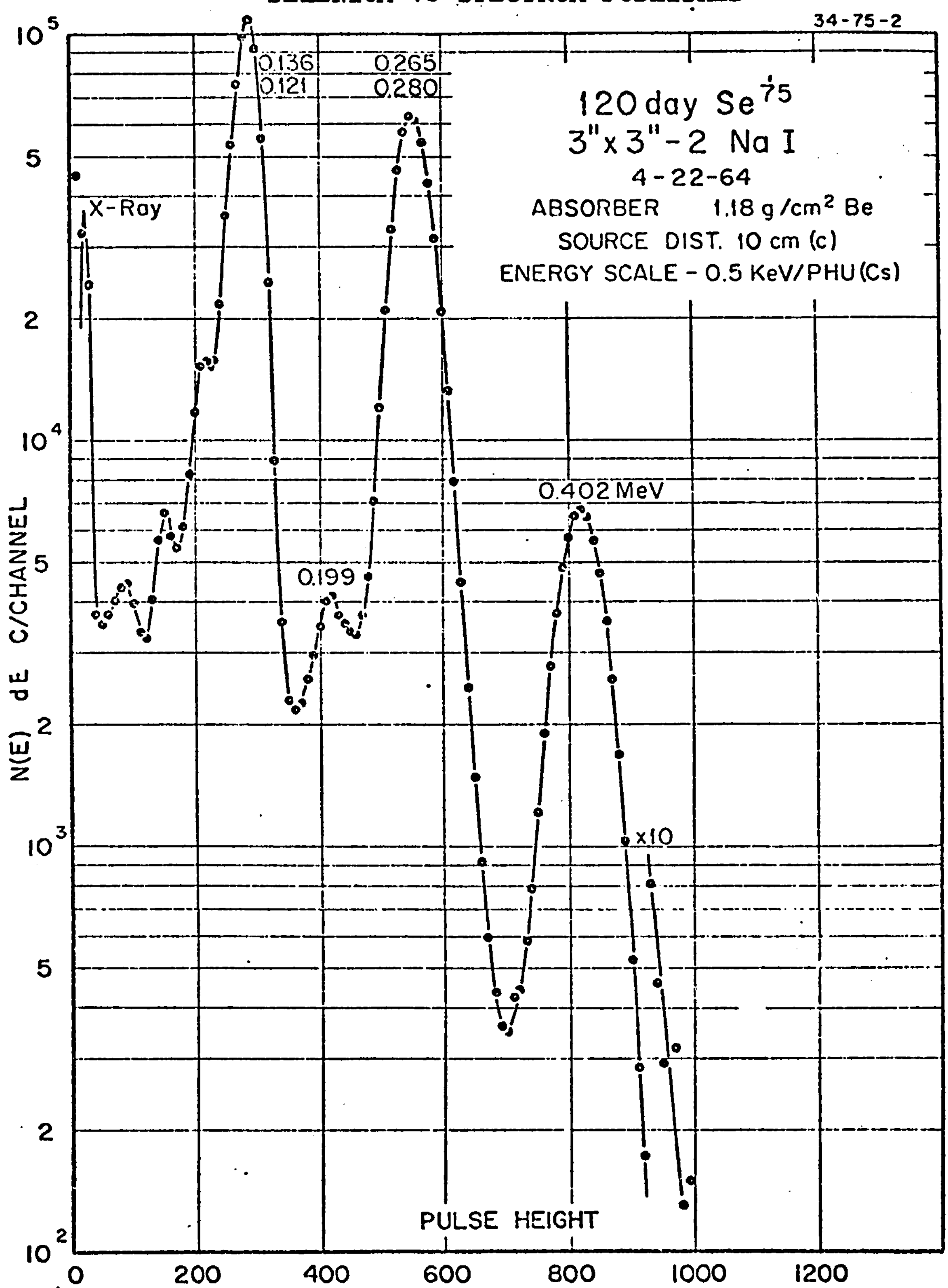
PULSE HEIGHT VOLTAGE	COUNTS PER MINUTE	PULSE HEIGHT VOLTAGE	COUNTS PER MINUTE	PULSE HEIGHT VOLTAGE	COUNTS PER MINUTE
0.156	2,748	0.258	11,341	0.430	1,567
0.158	2,753	0.260	11,379	0.440	1,071
0.160	2,749	0.262	10,715	0.450	678
0.162	2,759	0.264	10,286	0.460	536
0.164	2,846	0.266	9,084		

APPENDIX C-5

SELENIUM-75 SPECTRUM PLOT



APPENDIX C-6
SELENIUM-75 SPECTRUM PUBLISHED



Heath, R. L. USAEC. Scintillation Spectrometry Gamma-Ray Spectrum Catalogue, 2nd Edition, Volume.II, August 1964.

APPENDIX C-7

COUNTING EFFICIENCY CALIBRATION

May 1, 1973

A five lambda aliquot was taken from stock solution of 1 mCi. in 5 ml. and diluted to 20.0 ml. as a standard counting volume. The 100 lambda aliquot of such dilution was taken and diluted to 20.0 ml standard volume.

Activity and Calibration Solution=

$$\frac{5\lambda \text{ aliquot} \quad 1\text{mCi} \quad 100\lambda \quad \text{ml} \quad \text{ml}}{20 \text{ ml.} \quad 5 \text{ ml.} \quad 20 \text{ ml.} \quad 1000\lambda \quad 1000\lambda} =$$

$$\frac{1 \text{ mCi}}{4{,}000{,}000 \text{ ml.}}, \text{ or } \frac{1}{200{,}000} \text{ mCi in 20 ml.}$$

Count Rate

Test Tube Sample	Counts / m/ 20.0 ml
1	6096
2	6086
3	6033
4	6101
5	6081
6	6037
7	6153
8	6053
9	6121
10	6192
11	5916
Average	6079

APPENDIX C-8
CALCULATION OF EFFICIENCY

Assay Amount:

1 mCi H_2SeO_3 in 0.1 ml
containing 0.0057 mg H_2SeO_3

Stock Solution of Radioselenium:

Upon arrival of the above source, 4.9 ml distilled ion exchange water was added to dilute to a 5.0 ml stock solution.

Efficiency:

Use calibration data previously determined with $\frac{1}{200,000}$ dilution to calculate efficiency.

Efficiency= $\frac{\text{cpm}}{\text{dpm}}$, where decay correction is 1.173

$$= \frac{(1.173)(6.079 \text{ counts})(\text{min})(\text{s})(\text{mCi})(2 \times 10^5)}{(\text{min})(60)(\text{s})(3.7 \times 10^7)(\text{d})(\text{mCi})}$$

= 0.642

=64.2% Efficiency

APPENDIX C-9

SORPTION OF SELENIUM-75 ON TEST TUBES

Total Selenium ppm	Time to Reading	cpm in 20 ml	cpm after decanting	cpm after 3 rinses	cpm after 3 added rinses	cpm washed tube / cpm in 20 ml (Sorbed Fraction)	ppm sorbed
	Immediate	225569			(Repeated count)	(Average of 8 hour,	
10	8 hours	149522	7298	2018	1777-1721	4 days)	
	4 days	149408			Average 1749	1.17×10^{-2}	1.17×10^{-1}
	Immediate	196348					
1	8 hours	174569	8079	3832	3553-3558		
	4 days	172858			Average 3555	2.40×10^{-2}	2.40×10^{-2}
	Immediate	245049					
10^{-1}	8 hours	179328	9389	4681	4324-4239	2.47×10^{-2}	2.47×10^{-3}
	4 days	166483			Average4281		
	Immediate	245217					
10^{-2}	8 hours	175241	8100	5407	5114-5131	2.99×10^{-2}	2.99×10^{-4}
	4 days	166929			Average 5122		
	Immediate	209772					
10^{-3}	8 hours	175676	9625	6548	6002-5985	3.48×10^{-2}	3.48×10^{-5}
	4 days	168699			Average 5993		
	Immediate	198180					
10^{-4}	8 hours	169917	12809	4538	4155-4241	2.50×10^{-2}	2.50×10^{-6}
	4 days	165173			Average 4198		

APPENDIX C-10

NORMALIZATION OF WATER

Five λ from Stock Selenium Solution was diluted to 20.0 ml. A 100 λ aliquot was removed and diluted stepwise as follows:

100 λ ml	Corrected cpm	Corrected cpm
1.0	7776	7700
2.0	7682	7734
3.0	7644	7596
4.0	7496	7638
5.0	7578	7499
6.0	7456	7380
7.0	7435	7520
8.0	7478	7421
9.0	7331	7245
10.0	7281	7168
11.0	7120	7135
12.0	6940	6893
13.0	6750	6965
14.0	6711	6744
15.0	6755	6576
16.0	6630	6456
17.0	6601	6235
18.0	6574	6130
19.0	6356	5963
20.0	6154	5809

APPENDIX C-11

NORMALIZATION OF SUSPENDED PARTICULATE

The filter containing suspended particulate was dissolved in 20 ml. acetone and stirred while a counting rate was determined. This was the standardized geometry.

FILTER NO.	cpm ROLLED FILTER AND SUSPENDED PARTICULATE	cpm DISSOLVED FILTER AND SUSPENDED PARTICULATE	cpm CORRECTED FOR DECAY	GEOMETRY CORRECTION FRACTION
50	6,146	4,796	5,051	.823
51	11,239	9,422	9,923	.883
52	5,067	4,166	4,388	.866
53	12,237	10,808	11,383	.930
54	5,760	5,171	5,446	.945
55	7,923	7,010	7,383	.932
56	5,265	4,514	4,754	.903
57	9,020	7,430	7,825	.868
58	4,721	4,231	4,456	.944
59	9,432	8,025	8,452	.896
60	4,778	4,406	4,640	.971
AVE.				.9055
RANGE				.148

APPENDIX C-12

NORMALIZATION OF FISH

Individual fish were wet or dry ashed then dissolved to 20.0 ml and counting rate determined while stirring.

Wet Ash: H_2SO_4 + HCl   Dry Ash: 250°C Muffle furnace + HCl

	FISH NUMBER	FISH WHOLE cpm	BACKGROUND CORRECTED cpm	FISH SOLUABILIZED cpm	BACKGROUND CORRECTED cpm	DECAY CORRECTED cpm	FRACTION COUNT RECOVERED	AVE.
	1	357	246	201	89	99	.40	
	2	2,240	2,130	2001	1,888	2,109	.99	
Dry	3	712	601	321	209	234	.38	0.46
Ash	4	754-712	623	404	292	326	.52	
	5	1,018-1,023	911	590	478	534	.58	
	6	767-745	646	401	289	323	.50	
	7	1,027-1,016	912	697	584	653	.71	
Wet	8	694-692	583	477	365	408	.69	
Ash	9	926-892	799	651	539	602	.75	0.706
	10	1,163-1,126	1,034	765	653	730	.70	
	11	1,229-1,166	1,088	812	700	782	.71	
	12	1,454	1,344	927	815	912	.68	

APPENDIX C-13

NORMALIZATION OF SEDIMENT

TANK I CONTAINER NUMBER	SAMPLE CONTAINER RAW COUNT cpm	SAMPLE CONTAINER BACKGROUND CORRECTED cpm	STIRRED IN 20 ml RAW COUNT cpm	STIRRED IN 20 ml BACKGROUND CORRECTED cpm
3 H	6,511-6,388	6,341	4,606-4,601	4,490
			4,621	
2 H	7,987-7,924	7,797	5,951-5,402	5,405
			5,383-5,360	
1 H	9,781-9,780	9,672	7,416-7,490	7,334
3 R	15,043-15,316	15,071	12,075-12,713	12,394
1 R	11,669-11,614	11,533	8,529-8,688	8,587
			8,836-8,722	
4 C	7,141-7,341	7,133	5,466-5,551	5,525
			5,856-5,703	
2 C	11,300-11,481	11,282	8,238-8,380	8,190
4 E	11,651-11,668	11,551	9,212	9,118
			9,386-9,115	
2 E	9,761-9,907	9,726	7,298-7,174	7,104
3 E	10,088-10,096	9,984	8,058-8,098	7,959
1 E	8,818-8,939	8,770	7,091-7,154	7,003

APPENDIX C-13 (Continued)

NORMALIZATION OF SEDIMENT

TANK II CONTAINER NUMBER	SAMPLE CONTAINER cpm	SAMPLE CONTAINER BACKGROUND CORRECTED cpm	STIRRED IN 20 ml cpm	STIRRED IN 20 ml BACKGROUND CORRECTED cpm
3 H	16,178-16,021	15,991	11,001-11,361	11,181
2 H	8,467-8,576	8,413	6,444	6,325
1 H	22,423-22,540	22,373	17,741-18,399	17,951
3 R	14,984-14,769	14,768	11,195-11,294	11,125
1 R	6,304-6,135	6,111	4,837-4,573	4,502
			4,454	
4 C	5,471-5,318	5,286	4,044-4,072	3,939
2 C	9,442-9,218	9,222	7,016-7,126	6,952
4 E	9,629-9,574	9,493	7,034-7,079	6,937
2 E	12,806-12,608	12,599	9,698-10,331	10,235
			10,755-10,632	
3 E	11,147-11,104	11,017	8,196-8,263	8,110
1 E	15,300-15,315	15,199	13,624	13,158
			13,147	
			13,025	
			13,388	
			13,201	
AVERAGE OF TANKS I AND II		10,878		8,342

NORMALIZATION FACTOR: $\frac{8,342}{10,878} = .766$

APPENDIX C-14

SEDIMENT TRANSMISSION AND STIRRING DATA

(All tubes 20.0 ml volumes total)
(All tubes identical aliquots of stock radioselenium)

	TUBE NO.	REPEATED COUNTS CPM	AVE. CPM	MEAN CPM	$\sqrt{n}$
NOT STIRRED	1	9,120	8,945	9,009	94.92
		8,770			
	2	9,009	8,937		
		8,865			
	3	9,023	8,993		
		8,962			
	4	8,926	9,014		
		9,101			
	5	9,158	9,155		
		9,152			
STIRRED	1	9,058	9,032	9,023	94.99
		9,005			
	2	9,092	9,024		
		8,955			
	3	8,954	9,006		
		9,058			
	4	9,024	8,987		
		8,950			
	5	9,219	9,064		
		8,909			
10.82g SEDIMENT + STIRRING	1	8,723	8,651	8,610	92.79
		8,579			
	2	8,618	8,606		
		8,597			
	3	8,458	8,498		
		8,538			
	4	8,574	8,727		
		8,880			
	5	8,497	8,569		
		8,640			

APPENDIX C-15

SEDIMENT TRANSMISSION CALCULATIONS

Attenuation Calculated from Data

-Average unattenuated counting rate=

$$\frac{(9{,}009) + (9{,}023)}{2} = 9{,}016 \text{ c.p.m.}$$

-Variation of attenuated from unattenuated counting rates=

$$\frac{(9{,}016) - (8{,}610)}{9{,}016} = 4.5\% \text{ Attenuation}$$

-Transmission =

$$\frac{8{,}610}{9{,}016} = 95.4\%$$

APPENDIX C-16
THEORETICAL CALCULATION OF TRANSMISSION

Range for SiO_2

MINIMUM	MAXIMUM
- 100 Kev	500 Kev
.087 cm^2/g	.169 cm^2/g

- Linear Attenuation Coefficient: $= (\mu/\rho)\,\rho$

(.087) (1.9) = .165	(.169) (1.9) = .32

- Relaxation Length = $(-\mu x)$

(.165) (.675) = .1114	(.321) (.675) = .2167

Use x = 0.675 cm, S.G. silicon dioxide=1.86
Since 10.85 g Sand in 20 cm^2 volume
when stirred = $\frac{10.85\text{g}}{1.86\text{g/cm}^3} = 5.84\ \text{cm}^3$
This volume spread the length of 20.0 ml
in a test tube would have a radius of
.675 cm solid sand.

-Transmission $\frac{I}{I_\circ} = e^{-\mu x}$

.950	.816

APPENDIX C-17

SIGNIFICANCE OF TRANSMISSION CALCULATION

Since Se-75

0.136 Mev= 57%
0.265 Mev= 60%
0.280 Mev= 25%
0.402 Mev= 12%

154%

.136 Mev plus .265 Mev spectra

$$= \begin{array}{r} 57 \\ 60 \\ \hline 117\ \% \end{array}$$

and $\frac{117\ \%}{154\ \%} \cong .76$

thus ~ 3/4 of spectra occurs in lower half of energy range making attenuation less significant.

APPENDIX C-18
BACKGROUND COUNT RATES (FIRST AND SECOND RUN)

FIRST RUN		SECOND RUN	
ELAPSED TIME IN HRS.	BACKGROUND COUNT 100 MINUTES	ELAPSED TIME IN HRS.	BACKGROUND COUNT 100 MINUTES
0	10,576		
		0	11,022
62	10,503		
87	10,410	72	11,094
117	10,402	96	10,977
134	10,398		
191	10,421	168	11,735
230	10,356	192	11,506
254	10,430	216	12,100
287	10,525	264	11,248
311	10,498	312	11,292
330	10,410		
354	10,404	384	11,202
374	10,684	408	11,154
470	10,447	456	11,286
494	10,150		
518	10,246	552	11,319
549	10,191		
573	10,228	576	11,203
638	10,171	600	11,106
662	10,015	624	11,106
692	10,228	648	11,128
710	10,103	696	10,985
734	10,010	720	10,910
762	10,131	840	11,441
800	10,193	864	12,214
900	10,002	888	11,464
950	10,136	936	11,111
1,000	10,079	960	12,125
1,032	10,023	1,008	11,212
		1,032	11,206

APPENDIX C-19

WATER COMPARTMENT

SCHEDULE OF DECAY RESIDUAL SELENIUM BACKGROUND FROM FIRST RUN

ELAPSED TIME IN HRS.	CALCULATED RESIDUAL SELENIUM CPM	
	TANK I	TANK II
0	45	31
48	44	31
96	43	30
144	43	30
192	43	29
240	42	29
288	42	29
336	42	28
384	41	28
432	41	28
480	40	27
528	40	27
576	39	27
624	38	27
672	38	26
720	38	26
768	37	26
816	37	25
864	37	25
912	36	25
960	36	24
1,008	35	24
1,056	35	24

TANK I: (Residual Selenium from First Run)
1,428 counts per 10 minutes per 20 ml sample

TANK II: (Residual Selenium from First Run)
1,289 counts per 10 minutes per 20 ml sample

BACKGROUND: 9,789 counts per 100 minutes.

TIME: zero hours elapsed.

APPENDIX C-19 (Continued)
SUSPENDED PARTICULATE COMPARTMENT
SCHEDULE OF DECAY RESIDUAL SELENIUM BACKGROUND FROM FIRST RUN

ELAPSED TIME DAYS	CALCULATED cpm RESIDUAL SELENIUM (-) BACKGROUND 40 ml SAMPLE TANK I	TANK II
0	9.1	47.2
17	8.2	42.8
21	8.0	41.8
22	8.0	41.5
23	7.9	41.3
27	7.8	40.5
35	7.4	38.6
38	7.3	37.9
46	6.9	36.2
89	5.4	28.4
96	5.2	27.1

TANK I: Zero Time: (Residual Selenium from First Run)
8,410 counts per ten minutes per 0.1999 g suspended particulate.
Background = 11,202 counts per 100 minutes and

$$\frac{728.1 \text{ cpm}}{0.1999\text{g}} = \frac{9.1 \text{ cpm}}{40 \text{ ml sample}}$$

(Based on 792 hour ave. 2.5 mg per 40 ml sample, Appendix B-20)

TANK II: Zero Time: (Residual Selenium from First Run)
42,280 counts per 10 minutes per 0.1543 g suspended particulate.
Background = 11,202 counts per 100 minutes, and

$$\frac{411.6 \text{ cpm}}{.1543\text{g suspended particulate}} = \frac{47.2 \text{ cpm}}{40 \text{ ml sample}}$$

(Based on Ave. of 1.7 mg per 40 ml sample, Appendix B-20)

APPENDIX C-19 (Continued)

FISH COMPARTMENT

SCHEDULE OF DECAY RESIDUAL SELENIUM BACKGROUND FROM FIRST RUN

ELAPSED TIME IN HRS.	RESIDUAL Se (-) BACKGROUND COMPARTMENT cpm TANK I	TANK II
0	5,027	2,353
48	4,969	2,326
96	4,912	2,299
144	4,856	2,273
192	4,800	2,247
240	4,745	2,221
288	4,690	2,195
336	4,636	2,169
384	4,583	2,144
432	4,530	2,120
480	4,478	2,095
528	4,427	2,071
576	4,375	2,047
624	4,326	2,024
672	4,276	2,001
720	4,227	1,978
768	4,178	1,955
816	4,130	1,932
864	4,083	1,910
912	4,036	1,888
960	3,990	1,867
1,008	3,944	1,845
1,056	3,813	1,824

	FISH NUMBER 1	2	3	4	5
TANK I (Zero Time) cpm	731	931	956	1,363	1,509
	750	892	1,005	1,451	1,566
TANK II (Zero Time) cpm	617	696	681	857	
	542	679	777	753	

BACKGROUND = 11,006 counts per 100 minutes.

APPENDIX C-19 (Continued)

SEDIMENT COMPARTMENT

SCHEDULE OF DECAY RESIDUAL SELENIUM BACKGROUND FROM FIRST RUN*

HOURS ELAPSED	COUNTS PER MINUTE										
TIME	II3H	II2H	II1H	II3R	II1R	II4C	II2C	II4E	II2E	II3E	II1E
0	499	1,515	1,482	433	382	428	514	402	542	429	868
51	493	1,497	1,464	428	377	423	508	397	535	424	858
98	487	1,480	1,448	423	373	418	502	392	529	419	848
136	482	1,463	1,431	418	368	413	496	388	523	414	838
185	476	1,446	1,415	413	364	408	490	383	517	409	828
280	470	1,429	1,398	408	360	403	485	379	511	404	819
332	465	1,413	1,382	403	356	399	479	375	505	400	809
375	460	1,397	1,366	399	352	394	474	370	499	395	800
472	455	1,381	1,351	394	348	390	468	366	494	391	791
543	445	1,349	1,320	385	340	381	457	358	482	382	773
568	439	1,334	1,305	381	336	376	452	354	477	377	764
617	434	1,318	1,290	376	332	372	447	349	471	373	755
880	409	1,244	1,217	355	313	351	422	330	445	352	713
1,024	396	1,202	1,176	343	303	339	407	319	430	340	688

* Corrected for Background = 11,200 counts per 100 minutes

Appendix C-19 (Continued)

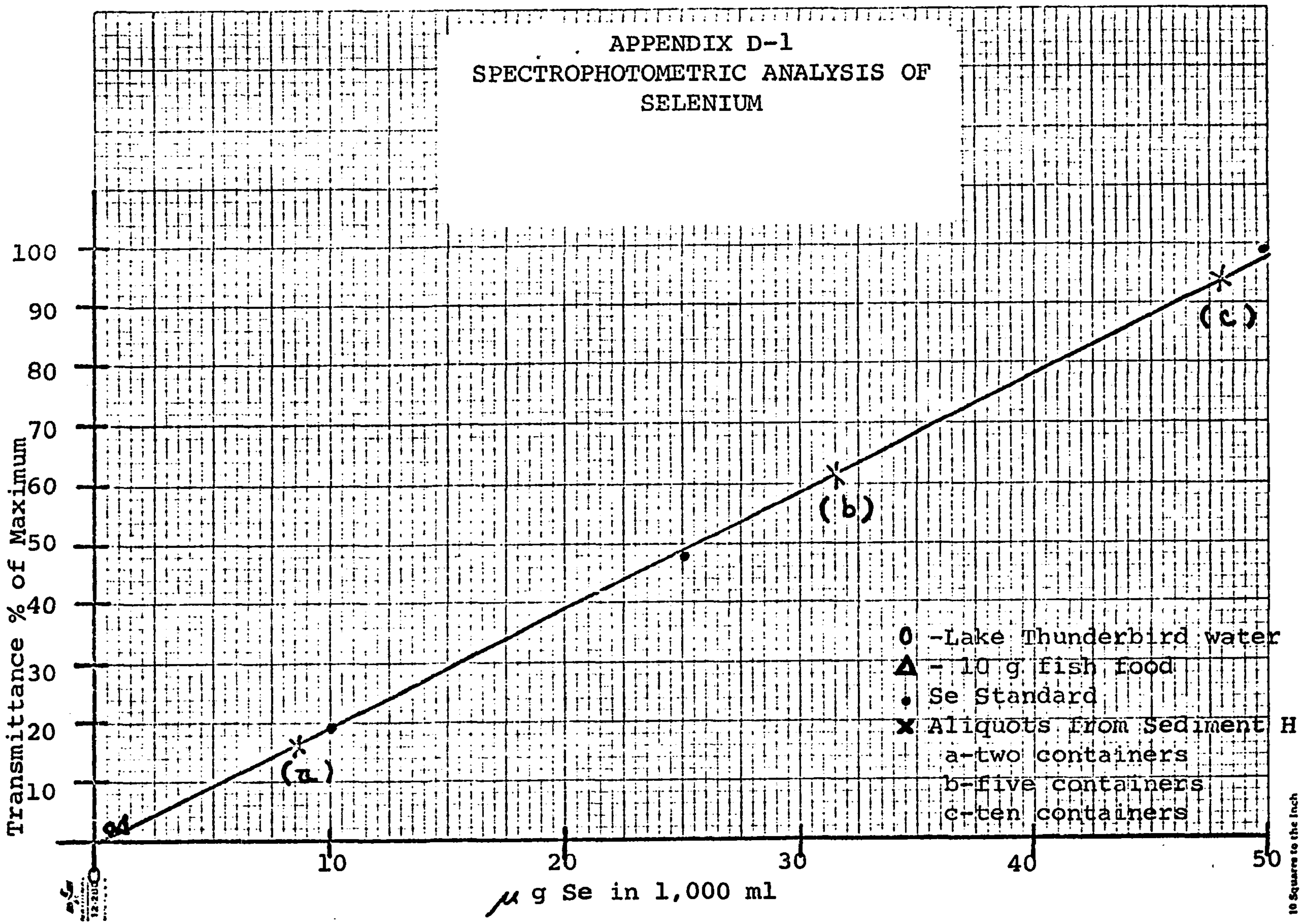
SEDIMENT COMPARTMENT
SCHEDULE OF DECAY RESIDUAL SELENIUM BACKGROUND FROM FIRST RUN *

ELAPSED TIME IN HRS.	COUNTS PER MINUTE										
	I3H	I2H	I1H	I3R	I1R	I4C	I2C	I4E	I2E	I3E	I1E
0	1,288	626	853	694	669	729	703	739	653	957	535
25	1,273	619	843	680	661	720	694	729	645	946	528
72	1,258	611	833	678	653	711	686	728	637	935	521
114	1,243	604	823	670	645	702	678	711	629	924	515
184	1,229	599	813	662	637	693	670	702	621	913	509
233	1,214	584	804	654	629	685	662	693	613	902	503
280	1,200	577	794	646	621	677	654	685	605	891	497
332	1,186	570	784	638	613	669	646	677	598	880	491
375	1,172	563	775	630	605	661	638	669	591	869	485
421	1,158	557	766	622	598	653	630	661	584	859	479
472	1,144	550	757	614	591	645	622	653	577	849	473
543	1,130	544	748	607	584	637	614	645	570	839	467
568	1,117	537	739	600	577	629	606	637	563	829	461
736	1,078	519	712	579	556	605	585	613	542	799	443
880	1,027	495	678	551	528	577	557	584	515	761	421

* Corrected for Background = 11,200 counts per 100 minutes.

APPENDIX D

APPENDIX D-1
SPECTROPHOTOMETRIC ANALYSIS OF SELENIUM



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