A COMPARATIVE STUDY OF CONVENTIONAL GREENS WASHERS AND A PROTOTYPE SYSTEM RECYCLING WASH WATER WITH A MATHEMATICAL MODEL OF GRIT CONCENTRATION IN WASH WATER

by

Jan Kazimierz Brzozowski

Thesis submitted to the Graduate Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

in

AGRICULTURAL ENGINEERING

APPROVED:

Dr. M. E. Wright, Chairman

Dr. R. C. Hoehn

Dr. E. R. Collins

June 1977

Blacksburg, Virginia

ACKNOWLEDGEMENTS

The author would like to express his deep appreciation to the following people for their contributions towards the completion of this thesis.

1. Dr. Malcolm E. Wright, for serving as chairman of the author's graduate committee, for a help in preparing this manuscript, and his priceless patience.
2. Dr. Robert C. Hoehn, for serving on the author's committee, and for providing the photographs used in this thesis.
3. Dr. Eidridge R. Collins, for serving on the author's graduate committee.
4. , for his efforts in analyzing part of the data collected in this project.
5. , my wife, for her help, and for typing this manuscript.

In addition, the author would like to thank the Environmental Protection Agency for financial support of this project.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

Table Page

LIST OF FIGURES

Figure | Page

Figure Page

Figure		Page

INTRODUCTION

General Information.

Fresh water is one of the most deficient resources in the world. Industry is not only the largest consumer, but also the largest polluter of fresh water. An explosive population growth rate and a higher standard of living has also increased water consumption. Water resources are limited and now there is real need to conserve water and prevent its pollution. Systems using recirculation techniques represent a means of conservation.

Food processing plants are among the largest consumers of fresh water. In these plants, water is used for washing, cooling, blanching and as a transportation media. The amount of water used for processing leafy greens varies between 25 to 40 liters per kilogram (l/kg) of finished product (National Canners' Association, 1971).

This report is part of the project undertaken by the Agricultural and Civil Engineering Departments of Virginia Polytechnic Institute to reduce fresh water consumption and pollution from leafy-vegetable washing. In earlier stages of the project, a prototype system with water recirculation was constructed and tested by Robinson (1976) that included some earlier modifications by Frey (1973). In the present work, comparisons were made between the prototype and conventional models in terms of product and water quality and amount of pollutants in the effluent water. A mathematical model of the system was developed to predict water quality as a function of product and washing system parameters. Water and product quality and biological measurements were made by James R. Coleman (1976), a graduate student in the Environmental Science and Engineering Program of the Civil Engineering Department, VPI&SU. Some of his findings associated with the development of the mathematical model of the system will be reported here. Also, some of Coleman's findings were the basis for comparison of data obtained from the mathematical model of the washing process to the measured values during the trials of the prototype system.

Typical Processing Plant Layout.

Frey's description of a typical plant layout for processing leafy-greens is cited below (Figure 1). The components and their functions are as follows:

Field Trailer: The field trailer follows the cutter and collects product for transport to the processing plant.

Rotary Sand Tumbler: This machine is located exterior to the plant. The product is fed into it from the field trailer by means of a conveyor. The purpose of the tumbler is to remove grit, twigs, and undersize leaves from the prime product prior to going through the wet wash operation; and to even out the flow of product to the picking lines. The effectiveness of the tumbler is a function of the surface moisture of the product at processing time. The wetter the product, the less effective the tumbler functions, placing a greater demand on the other components of the washing operation. A vibrating conveyor can be used as an alternative to the sand tumbler as the dry wash and transporting mechanism.

Picking Lines: The product is picked over by hand to remove larger debris and discolored or badly damaged leaves.

Immersion Washer: The immersion washer removes sand and floating trash from the product.

Rotary Spray Washer: The rotary spray washer serves as a final rinse before the product is blanched. In addition, it tends to even out the flow of product to the blancher.

Blancher: The blancher semi-cooks the product by exposing it to 190-200^{o}F water or steam for a period of two to six minutes. The purpose of this process is to cleanse the product, inactivate enzymes which otherwise might produce off-flavors, expel intercellular gases, improve color and flavor, and bring about shrinkage of the product for easier

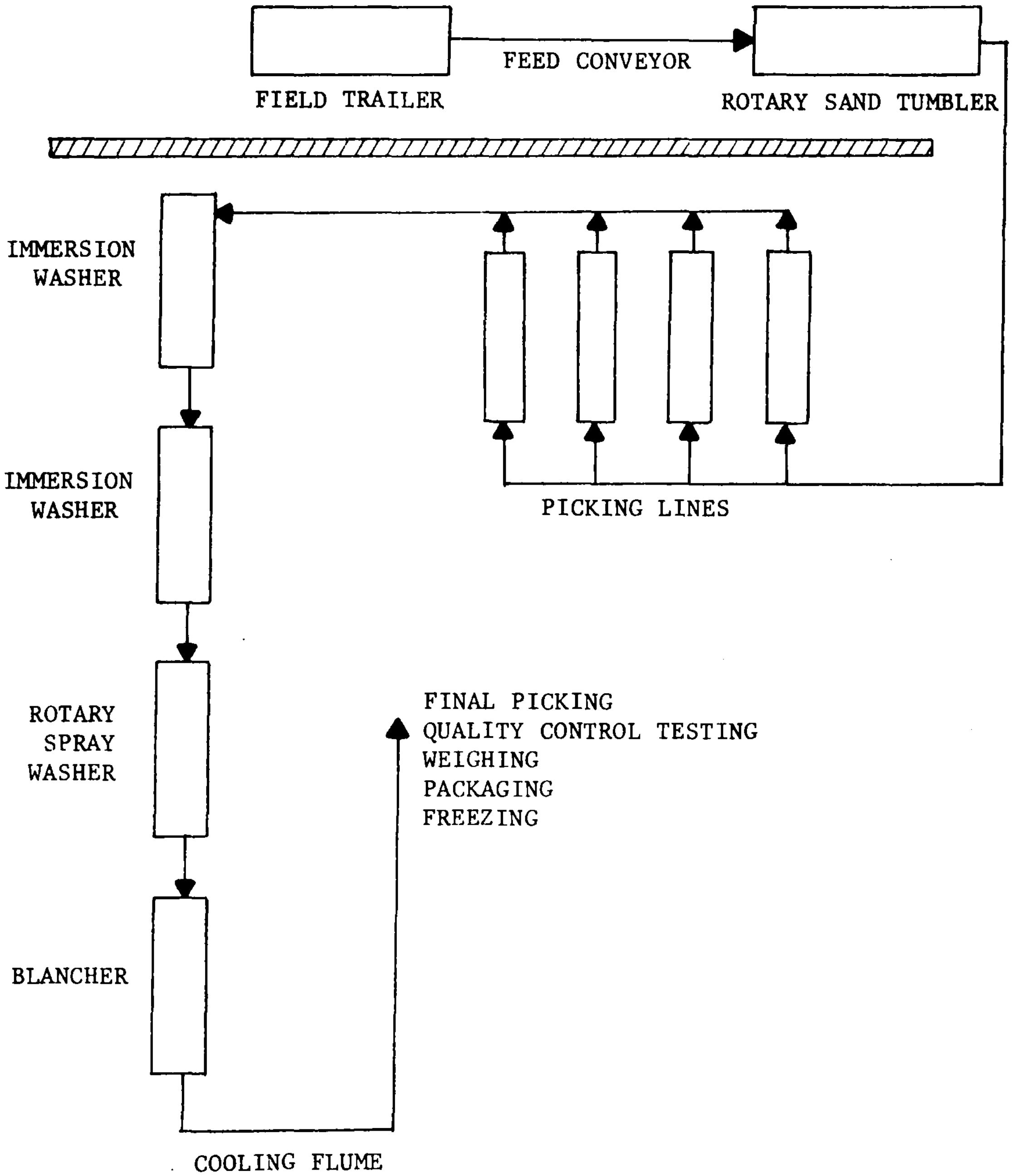


Figure 1: Typical greens processing plant layout. After Frey (1973).

handling and packaging.

Cooling Flume: It is necessary after blanching to reduce the temperature of the product to a minimum of 70°F as rapidly as possible to reduce the loss of nutrients and prevent heat degradation.

Operation of a Conventional Immersion Washer.

A conventional immersion washer is a device for separating trash and grit from processed product. Grit consists of particles of soil. Trash mainly consists of insects, or their parts, and small particles of processed material. The primary physical difference between trash and grit is that grit settles and trash floats on the surface or in a few upper centimeters of water.

A conventional immersion washer consists of a tank filled with water and has a system of rotating drums (Figure 2). Product falling into the washer is moved toward the first drum by streams of water from jets at the input end of the washer. The drums immerse the product, agitate it, and move to the exit conveyor. Effectiveness of the washing process depends on a product distribution across the washer, initial grit content, and flow rates of washing water.

Experimental Prototype Leafy-Vegetable Washing System.

The prototype system consisted of two immersion washers in line and two settling tanks. A diagram of one immersion washer is shown in Figure 3, an overall view of the system is shown in Figure 4 and a schematic of the system in Figure 5.

Recirculated water was used in the washing process except for final rinsing of the product on the exit elevator from the second washer. Water used for washing was continuously recirculated between

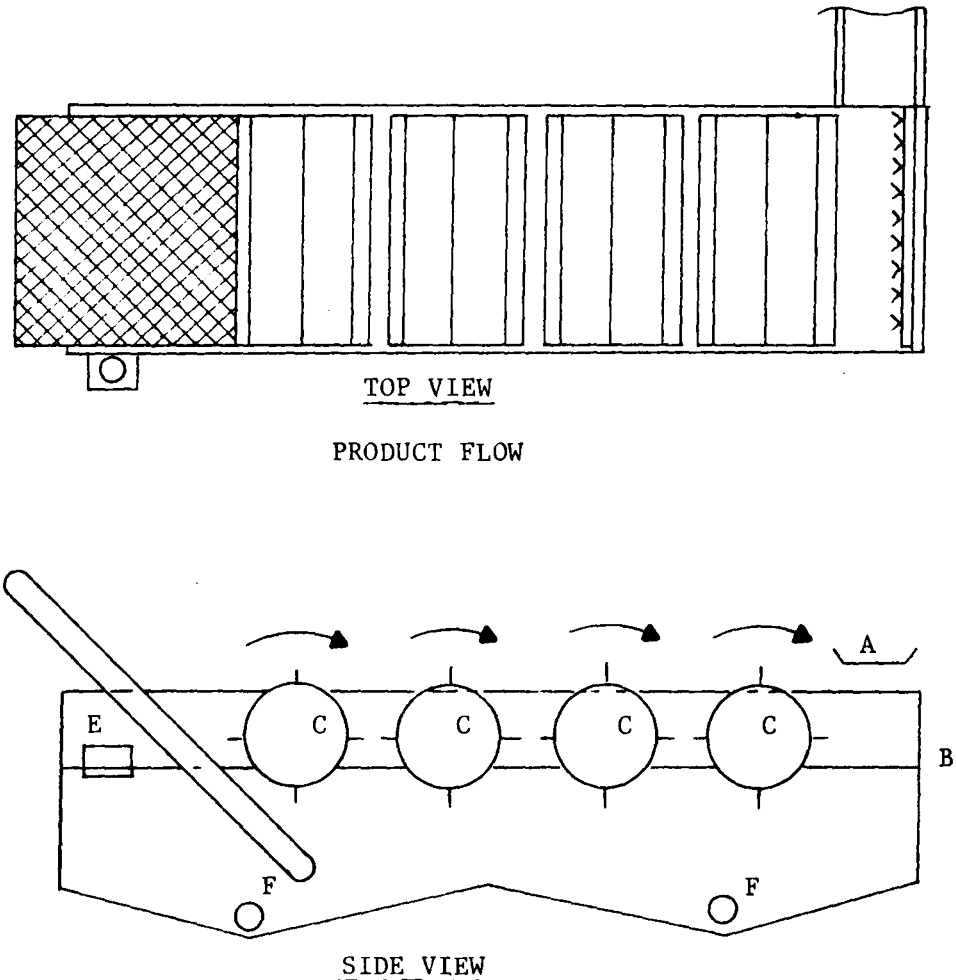


Figure 2: Conventional immersion washer. (After Frey, 1973).

A. Product feed conveyor
B. Water jets
C. Agitation drums
D. Exit conveyor
E. Overflow drain
F. Ports for draining tank

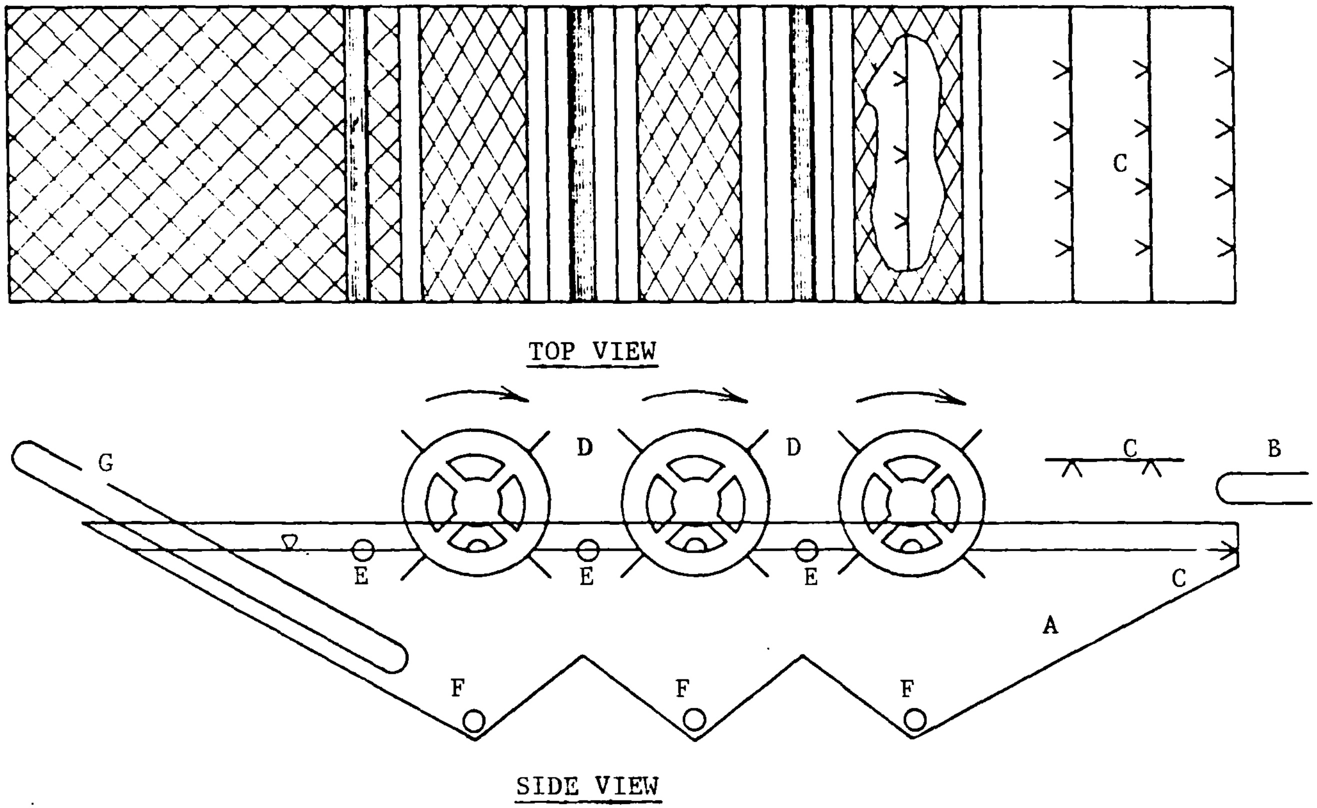


Figure 3: Prototype of test immersion washer (After Robinson,1975)

A. Washer tank
B. Input conveyor
C. Nozzle banks
D. Paddle wheels with side drains and interior nozzles
E. Skimmers
F. Ports for draining tank
G. Exit conveyor

Figure 4: Overhead view of washing system adjacent to Exmore Plant. Rotary sand tumbler and conveyor into plant are at right and foreground (After Robinson,1976).

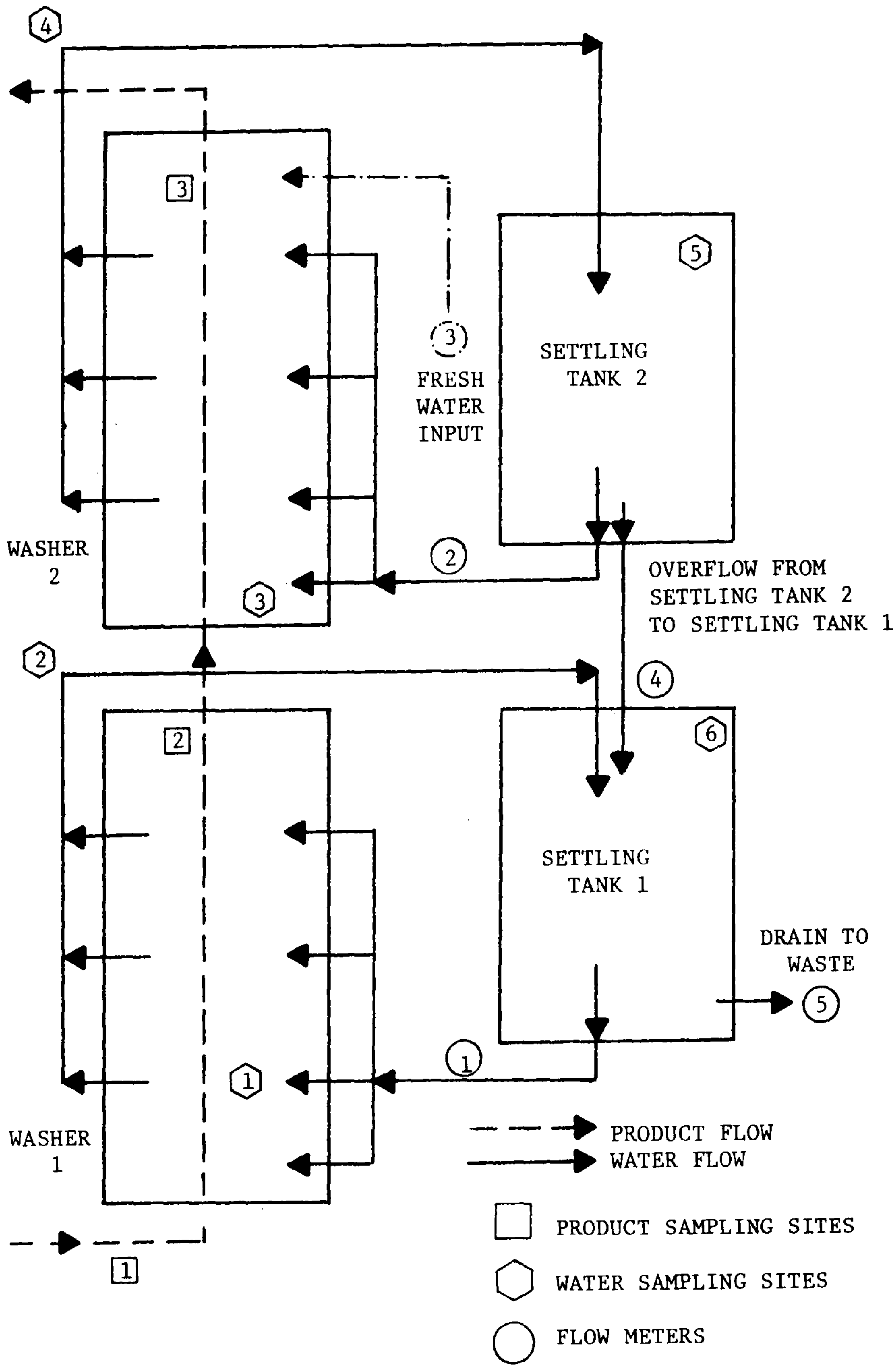


Figure 5: Diagram of washing system showing water and product flow patterns,sampling sites, and water flow meter locations.

washers and settling tanks, and means for separation of trash and grit from the water was provided. Fresh water used for the final product rinse also provided make-up for losses of water carried out with the product. An excess of water flowed from the second settling tank to the first. Overflow from the first settling tank was wasted.

The prototype system was installed at Exmore Foods, Incorporated, Exmore, Virginia, in the fall of 1975, and tested by Robinson (1975) and Geering (1975). The system performed well, saving an estimated 75 percent of water in comparison with the conventional system. However, direct comparative data with conventional washers was not taken. It was also found in these tests that water and product quality varied considerably. For these reasons it was decided that further testing to compare the prototype system with the conventional system should be undertaken. There was also evidence that small changes could increase the performance of the prototype system. The primary change made was that fresh water was used as a final rinse of the product leaving second washer instead of being introduced into the second settling tank.

Objectives.

The objectives of this study were:

1. To compare the performance of the conventional and prototype systems in terms of water usage, and water and product quality.
2. To develop a mathematical model of the prototype system to predict washing effectiveness and grit concentration in the recirculating water

in each unit as a function of initial grit content, grit removal efficiency of the washers, fresh water input, recirculation flow rates, and time.

LITERATURE REVIEW

Justification for Recycling Food Processing Water.

Recirculation of wash water in food processing was considered in a recent United Nations Report (1969) and was recommended contingent on the following factors:

a) cost of fresh water, including transport and purification;
b) compensating cost for polluting environmental waters by discharged waste water;
c) amount of valuable product carried away with waste water, and the percentage of reduction of this loss using recirculation;
d) national standards for a particular kind of pollution concentration.

The Federal Water Pollution Control Act Amendments (Public Law 92 - 500) required industries to comply with certain effluent standards. This notice was published in the Federal Register (1976) and established the final effluent limitations and guidelines for fruit and vegetable industries. After 1977, processors will have to implement the "best practicable control technology currently available" (BPCTCA), and after 1983 they will have to adjust their standards to "best available control technology economically achievable" (BACTEA). These standards are presented in Table 1.

Previous Work on Recirculation and Saving Wash Water in Leafy-Vegetable Washers.

Frey (1973) constructed and tested a modified conventional leafy-vegetable washer designed to increase removal of insects and trash from the product (Figure 6). He rearranged - compared to the conventional washer shown in Figure 2 - overflow drain locations, introduced a skimmer and used an expanded metal covering on the agitation drums. He also replaced the first agitation drum by a mechanical shaker. Cross-flow sprayers were installed inside the drums to improve agitation and remove leaves attached to the drums. Covering the drums with expanded metal allowed the trash floating with the product to rise to the surface inside the drums. The spoke-like construction of one end of each drum opened adjacent to side drains in the washer tank and helped to remove trash from the water. The skimmer was located between the exit conveyor and the last drum to remove trash floating on the water surface and prevent recontamination of the washed product . Conventional washers do not have skimmers and are equipped with one final drain behind the exit conveyor. Frey replaced the first agitation drum normally used on conventional washers with a mechanical shaker to increase agitation of the product during its initial contact with the water.

Frey compared trash removal efficiency of the conventional and modified washers. His data showed a removal efficiency of whole insects from product of 50 percent and 82.5 percent for the conventional and the modified washers, respectively. Frey also analyzed the waste from the modified washer and presented average values as follows:

pH = 7.2

alkalinity = 57.4 mg/l

chemical oxygen demand (COD) = 52.4 mg/l

biological oxygen demand (BOD_5) = 38.5 mg/l

total solids = 138.8 mg/l

suspended solids = 42.7 mg/l

Table 1. Effluent Limitations for Leafy-Greens Operations, 1977 and 1983 Standards (After Coleman, 1976)

Standard		Waste Component, lb/ton		
		BOD_5		TSS
Maximum for Any One Day				
1977		4.74		8.38
1983*	M	2.35	M	4.15
	L	2.35	L	2.35
Maximum Average for 30-Consecutive Days				
1977		2.72		5.62
1983*	M	1.66	M	2.08
	L	1.66	L	1.66
Maximum Average on Annual Basis				
1977		1.82		3.28
1983*	M	0.69	M	1.22
	L	0.69	L	0.69

* M = a point source that processes 2,000 - 10,000 tons per year
L = a point source that processes in excess of 10,000 tons per year

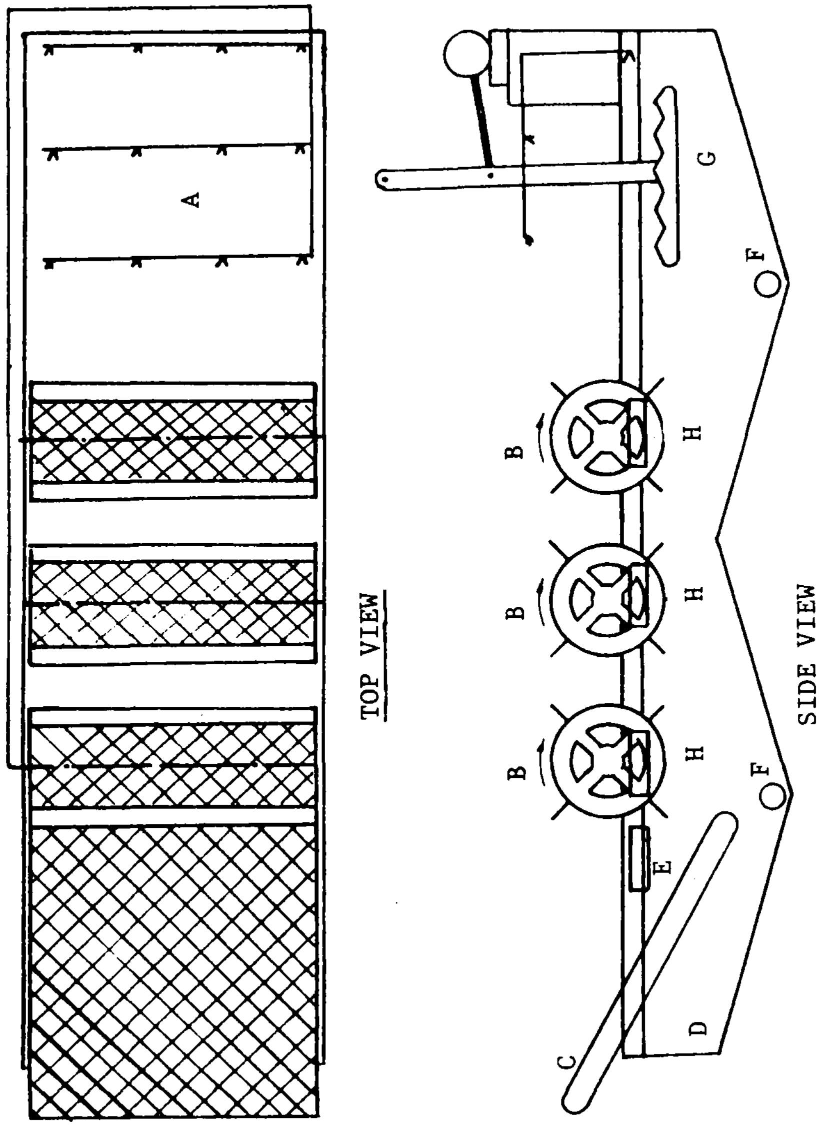


Figure 6: Prototype immersion washer (After Frey,1973)

A. Bank of nozzles
B. Paddle wheels
C. Exit conveyor
D. Washer tank
E. Skimmer
F. Ports for draining tank
G. Shaker w/motor
H. Side drains

Spinach was the material used for all tests of the conventional and modified washers. It is the principal crop processed in leafy-vegetable plants and is the most difficult to wash due to the savoy leaf surface.

Frey also presented data obtained from the managerial staff of the Dulany Foods Company during spinach processing with the conventional washers. These data are shown in Table 2. In addition, it was determined that the plant processed an average of 1850 kilograms of product per hour per washer line, and the average amount of waste water from all operations was 36.72 liters of water per kilogram of processed product.

Frey stated that the shaker on his modified washer had the following disadvantages:

a) damaged leaves;
b) tended to move part of the product backward;
c) a dead area existed on the shaker where the product would not move;
d) the product was trapped in the hardware cloth of which the shaker was constructed and in the expanded metal covering of the agitation drums.

Magette (1974) studied means of grit and trash removal in order to use wash water in a recirculation process in leafy-vegetable immersion washers. He studied the effectiveness of trash removal from water streams falling onto inclined and vibrating screens with different size openings manufactured from different materials; inclined at different angles from the horizontal; and vibrating with different frequencies. He found that a stationary, perforated metal screen with 3.2 mm diameter openings, gave the best separation of trash from the water. He also found that larger inclination angles increased trash removal ef-

Table 2. Data Collected by Dulany Foods, Incorporated, During a Study of the Combined Waste Water Flow From Spinach Processing Operations (After Frey, 1973).

Date	Time AM	Water Temp °F	pH	Dissolved Oxygen mg/1	BOD mg/1	Total Solids mg/1	Suspended Solids mg/1
4/19	8:50	76	7.7	5.20	91	750	221
4/21	9:00	74	7.6	5.72	81	692	13
4/24	9:15	72	7.6	6.00	88	648	84
4/25	11:25	68	7.7	6.75	57	528	27
4/26	11:35	65	7.8	5.05	117	662	59
5/8	11:25	66	7.9	5.80	56	738	17
Mean:		70	7.7	5.75	81	669	70

fectiveness.

Magette also considered both grit chambers and settling tanks for grit removal from water. Using a theoretical approach, he designed grit chambers and settling tanks for flow rates of 190 to 760 liters per minute (l/min) that would remove all soil particles with diameters larger than 50 microns. He concluded that either device could be used but recommended settling tanks because of their simplicity.

The effectiveness of settling tanks or grit chambers depends on the sedimentation velocity of the particles suspended in the water. The principle of sedimentation is based on Stokes Law (American Water Works Association, 1971) which states that a round particle in an immobile fluid and under gravitational forces reaches a terminal velocity equal to:

$$v = \frac{g(P_p - P)d^2}{18u} \quad (1)$$

where: v = particle terminal velocity

P_p = particle density

P = fluid density

d = particle diameter

u = absolute viscosity of fluid

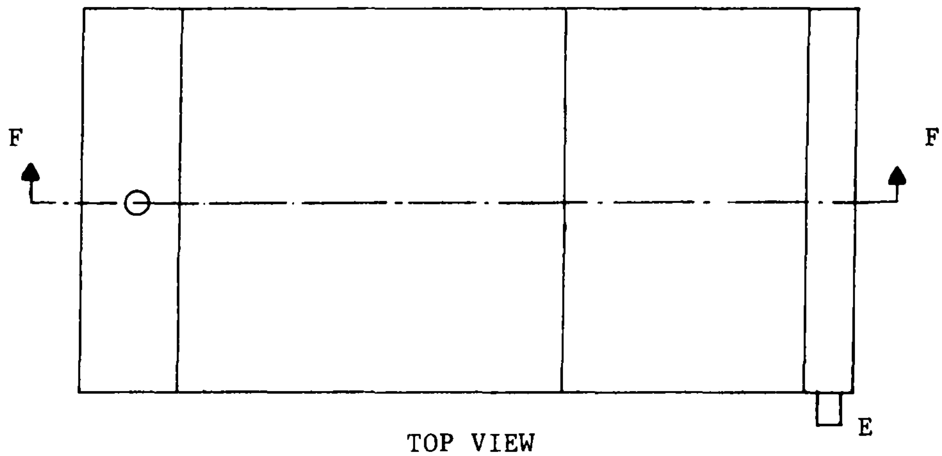
g = gravitational constant

In settling tanks, however, water is in constant movement and particle velocity is a resultant of the sedimentation and flow velocities. In this case the chamber or settling tank has to be sufficiently long so that the particles can reach the bottom before being removed with the overflow water.

Concentrations of the waste water stream from both conventional and modified washers were low, and Frey, Wright, and Hoehn (1974) indicated the possibility of recirculating wash water after a minimum treatment of filtering and settling. Based on this assumption, Robinson (1976) constructed a recirculation washing system using modified washers. An overhead view and a schematic diagram of the system are shown in Figures 4 and 5, respectively. The schematic diagrams of the modified washer and settling tank are shown in Figures 3 and 7, respectively.

Robinson analyzed Frey's results and incorporated some changes to improve performance of the washers. In the first modification of these washers, skimmers were used but were later removed because product tended to accumulate against them during washing. To prevent product from accumulating on the agitating drums, Robinson inserted banks of spray nozzles inside drums directed in the direction of product flow. He did not include shakers in his washers and used only three drums per washer instead four as in the conventional washers. The first drum was replaced by two banks of nozzles at the input end of each washer to submerge the product and direct it toward the first drum.

Robinson used settling tanks, (Figure 7), for grit removal from the recirculating water. They were rectangular with inclined bottoms. These settling tanks had a larger volume but shorter length than those designed by Magette. They were designed to remove all particles of grit with diameters larger than 56 microns. Robinson also used filters, built in the configuration of moving conveyors, from which trash was



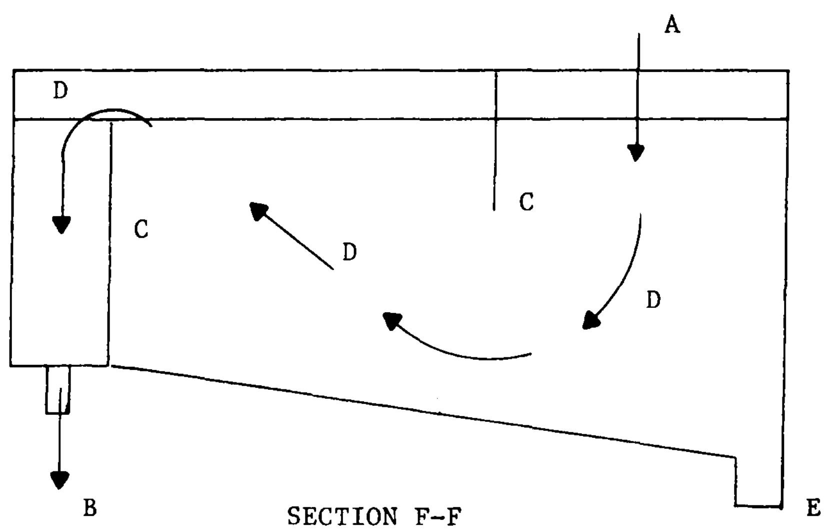


Figure 7: Settling tank

A. Water input
B. Water outlet to pump
C. Baffles
D. Direction of flow
E. Port for draining tank

removed by an air stream after separation from the water. The filters were located above the settling tanks.

The system was tested at the Exmore Foods Plant, Exmore,Virginia, in Fall, 1975, by washing collards and spinach. In the first four trials, collards were washed, and in the fifth, spinach. The average processing time of the trials was 7 hours (one normal work-day shift). Flow rates for recirculation between the washers and settling tanks varied between 340 and 540 l/min depending on the trial. Average flow rates used were about 360 l/min for collards, and about 480 for spinach. Fresh water was introduced into the second settling tank at a rate of approximately 25 l/min for collards, except during trial 4 when the rate was approximately 65 l/min. For spinach washing, the fresh water input was about 70 l/min.

Product flow rates varied from a minimum of 700 kilograms per hour (kg/hr) for spinach to a maximum 2100 kg/hr for collards. The average product flow rate increased with operating time, but significant variation in rates was observed.

Generally, the system operated well, saving 75 percent of the water used for washing, compared to the conventional washers. Significant amounts of water were carried with product from the first to the second washer, and from the second washer out of the system. These values varied considerably depending on different varieties and different cuttings within varieties. The amount of water carried from first washer was relatively constant (approximately 1.2 liters per kilogram of product). The amount of water in liters per kilogram of product carried from second washer was 0.27 during the first two trials, 0.87 for trials 3 and 4, and 1.33 during trial 5 when spinach was processed.

Grit from the bottom of the prototype system was removed only after trial 5 when spinach was washed. During the collard-washing trials, the amount of grit collected in the system was too small to be measured. The majority (64 percent) of the grit removed from the product settled in the first settling tank; 21 percent settled in the second settling tank, and almost all the rest in the first washer (14 percent). As expected, larger particles tended to settle in the washers and smaller ones in the settling tanks. These data also showed that the majority of the cleaning occurred in the first washer.

The amount of trash collected from each filter belt was about 1.25 g per kilogram of product for collard washing, and 1.4, for spinach. The trash consisted primarily of leaf fragments.

Geering (1975) studied the water and product quality aspects of the prototype system. These included measurements of total suspended solids (TSS), volatile suspended solids (VSS), five-day biological oxygen demand (BOD_5), and chemical oxygen demand (COD) for water in each unit of the prototype system and for the waste stream. She also determined bacteria counts in the water and on the product and insect counts in product and trash. Geering compared data obtained from the prototype system with similar data obtained by Bough (1973) for dunker and reel washers. These data are presented in Table 3. The analyses of samples of water taken from different locations of the prototype system showed higher concentrations of TSS in the first subsystem (washer 1 and settling tank 1), and generally higher concentrations in water leaving the washers than in that leaving the settling tanks.

Table 3. Total Waste Loads of Organic Matter and Suspended Solids Produced per Ton of Greens Processed in Recirculating Washer System (After Geering,1975, and Bough,1973). Average Values.

	BOD_5 (kg/ton)		COD (kg/ton)		TSS (kg/ton)		VSS (kg/ton)	
	spinach	collards	spinach	collards	spinach	collards	spinach	collards
After Bough	1.70	1.26	6.19	4.69	2.81	0.90	-	-
After Geering	0.17	0.20	0.90	0.86	2.44	0.36	0.25	0.22

Product samples for insect counts were taken in three locations: before washing, after washing in first washer, and after washing in second washer. The number of insects found in the product, however, was so low that comparisons between different trials were not possible. But, the number of insects in the washed product leaving the second washer was always lower than that on product entering the system.

Bacteria in the recirculating water have favorable conditions for growth, so there is concern about bacterial contamination of the final product. Data collected by Geering showed that the product, in general, had higher bacteria concentration, after washing than before. Bacterial concentration in the water increased with time but levels could be controlled by the addition of chlorine to the wash water. During each trial, foam collected on the water surface, especially in the settling tanks. This foam was formed from soluble organic materials. Geering suggested that the foam was responsible for reduction in the bacterial populations. This foam was probably also useful in the washing process by reducing surface tension of the water, having the effect similar to soap.

Coleman (1976) was responsible for analyses water and product quality in conjunction with the present study. He measured total suspended solids (TSS), volatile suspended solids, and chemical oxygen demand (COD) in the water. He also provided measurements of the grit concentrations in the fresh and washed product samples, and performed tests to determine bacterial contamination of the product before and after washing, and insect counts on the product before and after washing.

Table 4. Comparison of Waste Components for Conventional and Prototype Leafy-Vegetable Washing Systems. Average Values (After Coleman, 1976).

	TSS (mg/kg of product)		VSS (mg/kg of product)		COD (mg/kg of product)	
	spinach	turnip greens	spinach	turnip greens	spinach	turnip greens
Conventional	16.75	3.47	2.06	0.58	5.77	5.46
Prototype	5.08	1.67	0.79	0.25	2.29	1.01

Table 5. Comparison of the Number of Whole Insects and Fragments in 100 Gram Samples of Product from the Prototype and the Conventional Leafy-Vegetable Washing Systems. Average Values.

	Product Unwashed		Product Washed	
	insects	insect fragments	insects	insect fragments
Conventional	10	3	4	2
Prototype	4	3	1	1

In these tests, fresh water was introduced by a bank of nozzles suspended over the exit conveyor of the second washer, instead putting it into the second settling tank as in Robinson's system. It is believed that this final rinsing of washed product increased washing effectiveness.

Essentially, Coleman's tests confirmed observations by Geering about suspended grit distribution in the system, with the conclusion that most of the cleaning process took place in first washer. A summary of Coleman's findings include:

1. The total waste load generated by the conventional system was greater and more diluted than that generated by the prototype. Average values are shown in Table 4.
2. Greater removal of grit was achieved by the prototype system compared to conventional.
3. The product leaving the prototype system was always less contaminated by bacteria than before washing. This is not always true for the conventional system.
4. Most of the cleaning took place in the washer 1 - settling tank 1 subsystem. About 75 percent of the total waste components was found in this subsystem.
5. Insect density on the product was low but comparisons between the conventional and prototype systems were made. These results indicated a higher removal efficiency for the prototype system (Table 5).
6. Another measure of insect removal was a comparison between insect counts in the fresh product and in the trash collected on the exit end of the filter belts. Individual samples of fresh product (100 g each) never contained more than 12 insects and 7 insect fragments, but those from trash samples of the same size averaged 124 insects and 81 insect fragments.
7. The average water usage was 3.67 l per kg of product for the prototype system and 15.93 l per kg of product for the conventional system.
8. The prototype system was superior to the conventional, saving 77 percent of water used for washing; and producing a cleaner product, ready for blanching.

MATERIALS AND METHODS

Typically, the comparison between the prototype and the conventional systems was performed during full day's shift and half night's shift. The time interval during which all these measurement were performed is later called a trial.

General Design of the Washing System.

There were two separate processing lines (East and West) for processing leafy-greens in the Exmore Foods plant, with different packaging units at the end of each. Figure 8 is a schematic diagram of both lines and the prototype washing system.

The prototype washing system was connected to the west processing line and was used during the day shift for trials 1, 4, 5 and 6. During these trials product was washed in the prototype system and later, at night, in conventional west line. During trial 3 and the night shifts of trials 5 and 6, product from the picking belts was directed to the west conventional line, by-passing the prototype system. This was accomplished by reversing the direction of input conveyor movement, as shown on the diagram. The east line was used during the night shift for trials 1 and 2.

There was little difference in the construction of the conventional washers in the two lines. The arrangement of the east line is shown in Figure 9 and that of the west line in Figure 10. Each washer consisted of a tank and four paddle wheels designed to move the product through the washers. The principal difference in the two conventional lines was the water input. On the west line, water used to cool the

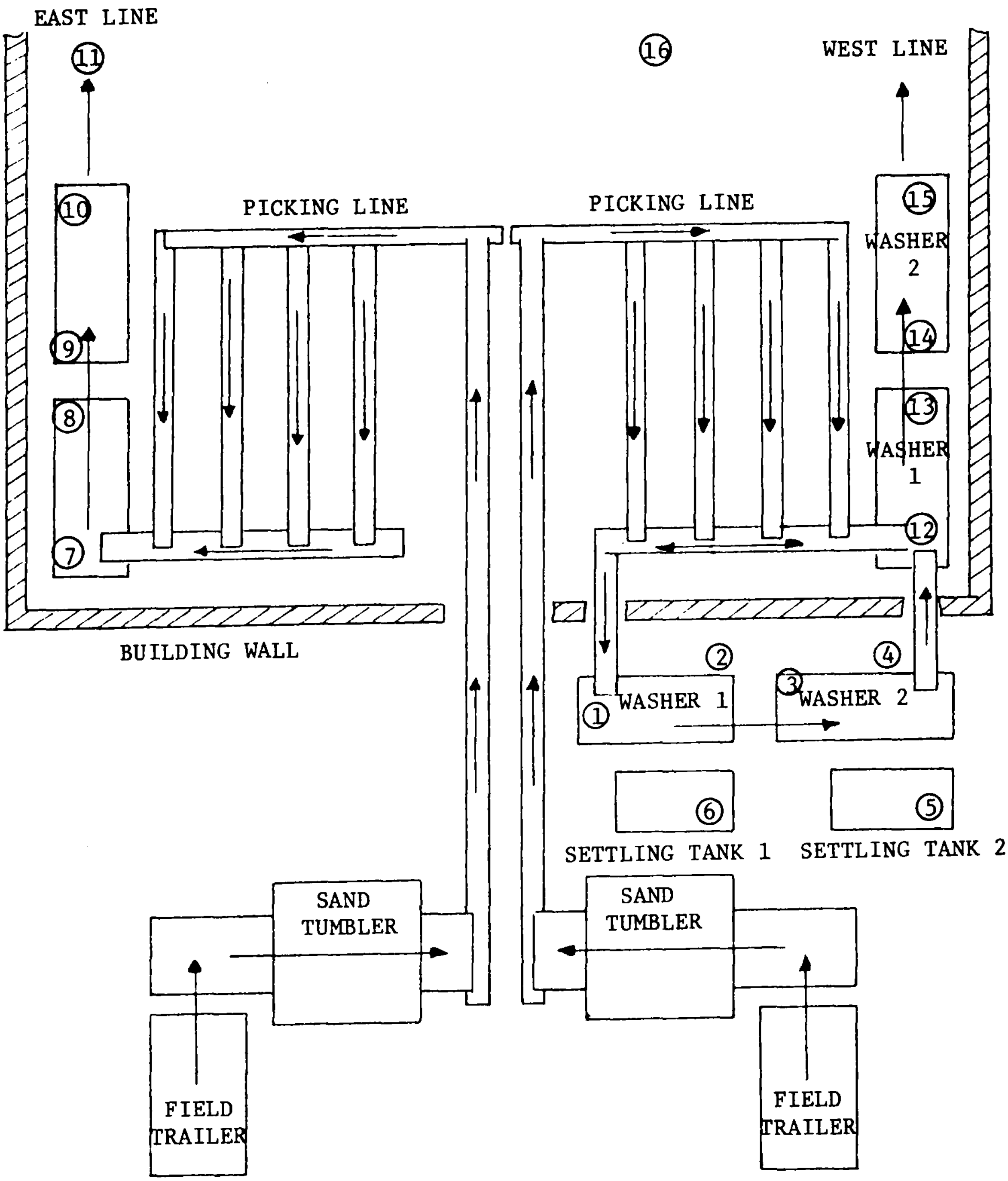


Figure 8: Schematic diagram of conventional lines at Exmore Foods, Exmore,Va. with prototype installed adjacent to plant.

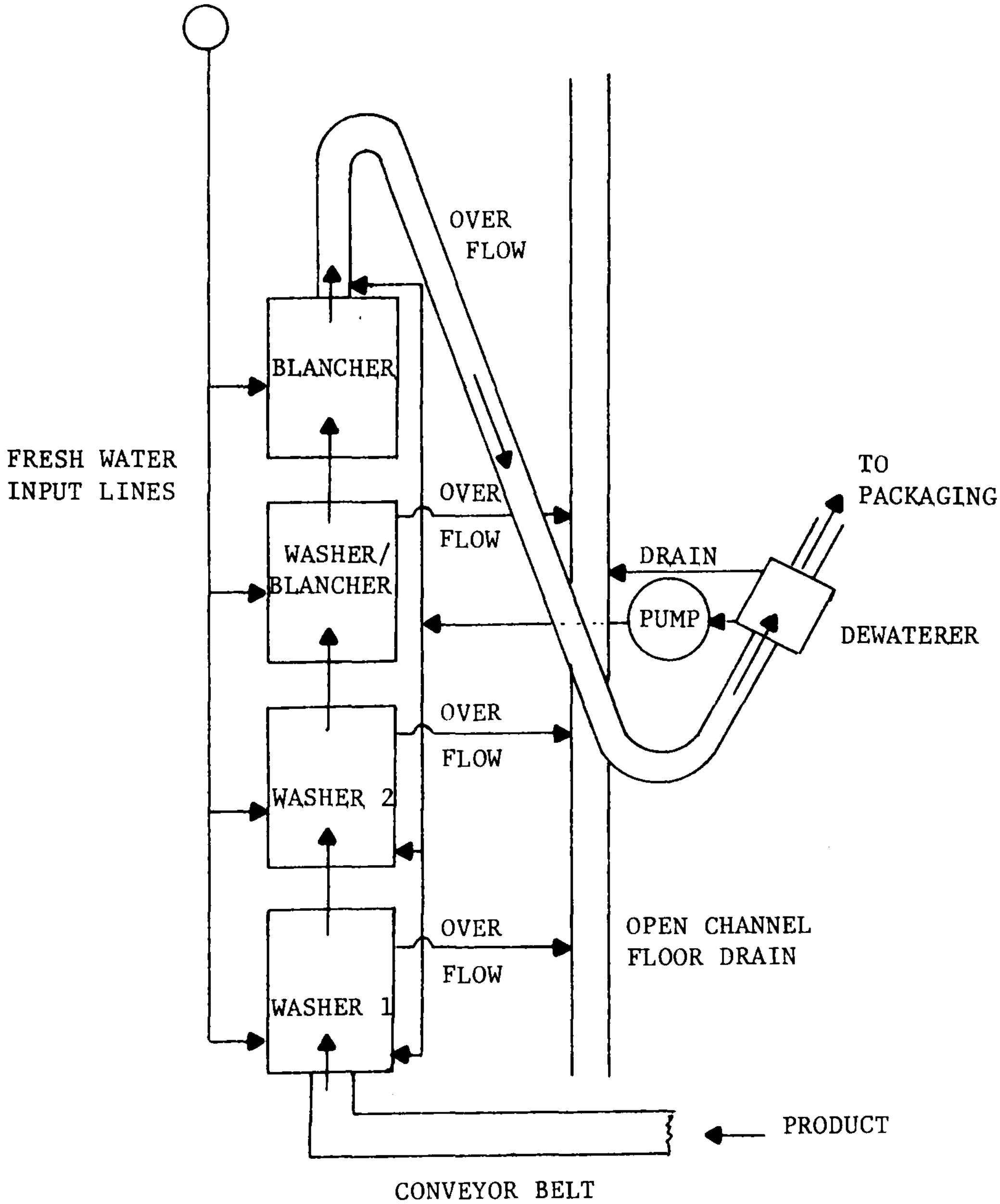


Figure 9: Flow diagram of east processing line, conventional system (After Coleman,1976).

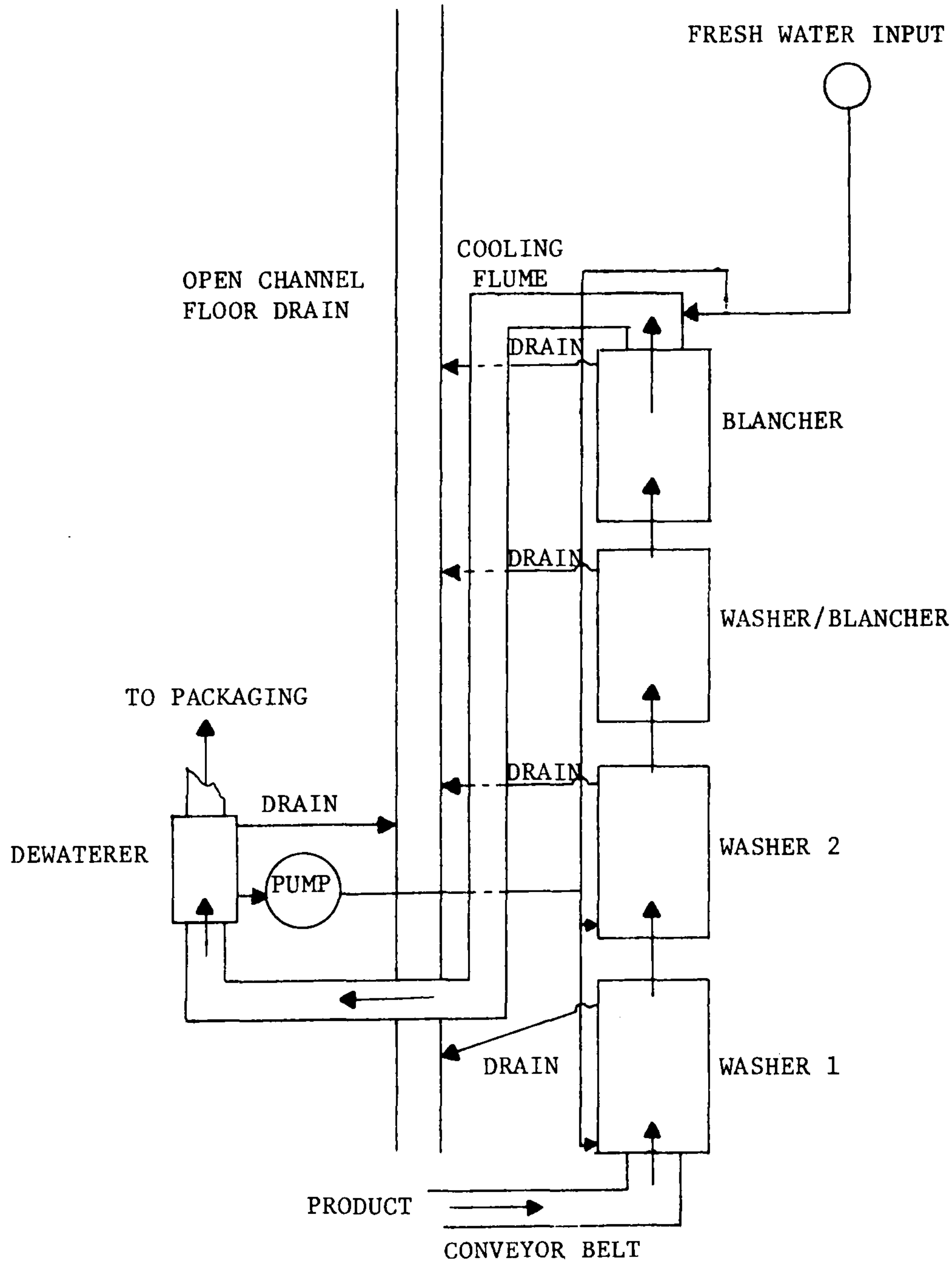


Figure 10: Flow diagram of west processing line, conventional system (After Coleman,1976).

product as it came from the blanchers was reused as wash water and introduced to the tanks through a perforated pipe at the head end of each washer. The east line was only partially fed by cooling water because most of the water used to cool product after blanching was wasted. These washers were also fed by fresh water introduced into the bottom of each.

Description of the Prototype System.

A full scale prototype of an immersion washer system with recirculation, as designed by Robinson (1976), was tested after modifying the fresh water input. Figure 4 is an overhead view of the system and Figure 5 is a schematic diagram of flow in the system.

The system consisted of two immersion washers in line with their associated settling tanks and filters. Water from the settling tanks was pumped to the washers and used in the cleaning process. Excess water from the second settling tank flowed through a flume to the first settling tank. Excess water from the first settling tank flowed out of the system to waste. Overflow from the washer drains was collected and transported by open channels to sumps. From these sumps the water was pumped to filters to trash separation. After filtering, the water flowed into the first section of each settling tank.

To overcome losses, fresh make-up water was introduced into the second washer, instead of the second settling tank as it was in Robinson's study. This water was sprayed by a bank of nozzles over the exit conveyor as a final rinse for the product leaving the system. With this exception, the washer construction was the same as that used by Robinson.

The design cleaning capacity of the system was approximately 1800 kg of product per hour. Washers and settling tanks were constructed from stainless steel. Each washer was 4.88 meters (16 ft) long and 1.22 meters (4 ft) wide. The bottom of each was designed in the shape of three adjacent "V"'s. This shape assured that grit removed from the product was collected in the bottom of each "V" and was easy to remove at the end of the trial. The volume of each washer was approximately 2.604 cubic meters (688 gallons).

Water was introduced to the washers from pipes equipped with spray nozzles. Two such banks of nozzles were at the head end of each washer. One bank was about five centimeters (cm) above water level and the flow from it was almost perpendicular to the water surface. A second bank of nozzles was located about 40 cm above the first one and flow from it was inclined at about 30 degrees from the vertical (Figure 9). The stream of water from the first bank submerged the product, while that from the second propelled it toward the first drum. Inside of each rotating drum was a similar bank with three Flat-Fan nozzles. These banks were located on the axes of the drums and were held stationary, being inserted through hollow hubs of each drum. The system was designed to deliver 757 l/min (200 gallons per minute (gpm)) to each washer, at a pressure of 2.5×10^{-5}Pascals (35.0 pounds per square inch (psi)).

There were three agitation drums mounted on each washer frame. Each drum was cylindrical in shape constructed with an open mesh covering, and each had four fins, 0.102 meter (4 inches) wide, around the

Figure 11: Water streams from the nozzles of the prototype washer.

perimeter. The drums were driven by an electric motor and chain drive at 1.15 radians per second (rad/s) (11 revolutions per minute (rpm)). The diameter of each drum was 0.603 m (23.75 inches). Streams of water from the nozzles inside the drums were oriented to strike the drums near the water line, thus helping to remove the product from the covering and propel it toward the next drum or exit conveyor. In addition, these water sprays were helpful in removing grit and trash from the product.

The exit conveyors were made of open-mesh belting composed of plastic sections and were inclined at 30 degrees from the horizontal. Conveyor velocity was 10.06 meters per second (m/s) (33 feet per minute (fpm)).

Each agitation drum was open on one end to allow movement of water with trash toward the drains. Trash released from the submerged product could float upward through the mesh covering the drums, reach the surface of water inside the drums and flow with water to the drains. Water from the side drains was collected in a trough leading to a sump. A submersible sump pump was used to pump water with grit and trash to the filter belts located on the top of each settling tank. The pump was controlled by a liquid level switch.

The filter consisted of a 1.52 m (5 feet) long by 0.305 m (1 foot) wide conveyor inclined at an angle of 16 degrees from the horizontal. This angle prevented water from flowing off the exit end of the conveyor. The belt was made of plastic screen material and had a permeability of 183 cubic meters per square meter (600 cubic feet per square foot) under a 0.635 cm (0.25 inch) head, and was driven at 14.32

meters per minute (m/min) (47 fpm). Larger particles of trash stayed on the belt surface, and were carried to the conveyor end where they were removed by a stream of compressed air. This trash was collected in boxes at the end of the filter (Figure 4).

Water flowed through the filter to the input end of the settling tank (Figure 12). Each settling tank was 2.44 m (8 feet) long, 1.22 m (4 feet) wide, with maximum depth 1.22 m (4 feet). The bottom of the tank was inclined toward the final drain. The tank held approximately 2.718 cubic meters of water (718 gallons). The designed recirculation rate of 378.5 l/min provided an average time for sedimentation of seven minutes. Separation of small particles of trash from the grit occurred in the first part of the settling tank. The grit then started to settle out while floating trash collected on the surface. Trash and foam were held in the first part of the settling tank by a vertical baffle. Water flowed under the baffle to the second section. From the second section it flowed over another baffle into the outlet section of the tank where a centrifugal pump pumped it into the recirculation system. Excess water from this third section went out an overflow. The overflow from the second settling tank was directed to the first settling tank. Overflow from first settling tank was wasted. Pumps used for recirculation were located under the third section of each settling tank. These pumps each had a capacity 757 l/min (200 gpm) against a pressure of 2.45×10^{-5} Pascals (34 psi).

Gate valves were used to adjust flow from the settling tanks to the washers. All electrical controls for the system were arranged on one panel, making it possible for one person to control the entire

Figure 12: Conveyor filter in operation.

washing system. Robinson (1976) gives additional details on specific dimensions and items of equipment used in the washing system.

Testing Procedure - Typical Trial.

Trials were run to compare the prototype and conventional washing systems with respect to product cleanliness, and waste water amount and quality. Typically, the prototype system was tested for eight hours during the day shift of the plant, and the conventional system for approximately four hours of the night shift. During trials 2 and 3 the conventional washers were tested during the day. Spinach was processed during trials 1, 2, 3, and turnip greens during trials 4, 5, 6.

The following description outlines typical activities during preparation for the performance of a trial (After Coleman, 1976):

1. Night prior to washing.
   a) Laboratory set up on location;
   b) Water quality instruments prepared and calibrated;
   c) Prototype washers and settling tanks rinsed and filled;
2. Morning of trial before washing.
   a) Washers and instruments turned on;
   b) Recorders started on meters 4, 5;
3. Begining of trial.
   a) Start up on recorders noted;
   b) Readings taken from totalizing water meters;
4. After 15 minutes of operation.
   a) Water samples taken for analyses of total suspended solids (TSS), volatile suspended solids (VSS), chemical oxygen demand (COD), chlorine residual, and pH;
   b) Water samples collected for total bacteria plate counts;
   c) Product samples taken for moisture content, grit content, bacteria and insect counts;
5. After each hour of operating time (exclusive of work breaks and down time).
   a) Same as 4a,c;
   b) Flow meters checked with stop watch;
   c) Number of packages of processed product recorded;

6. Between sampling times.
   a) Chlorine residuals, temperature, and pH determined;
   b) Samples prepared for TSS and VSS analyses;
   c) Water samples for COD preserved;
   d) Water samples for total plate counts processed;
   e) Product samples for insect counts and bacteriological determinations frozen in sealed plastic bags;
   f) Product samples for moisture content weighed and frozen in sealed plastic bags;
   g) Product samples used for cleaning-efficiency determinations washed by hand; water filtered and samples for TSS and VSS determination prepared;

   Note: Samples for bacteria analyses were collected only at the begining, middle, and end of each trial.

7. Day following trial.
   a) Washers and settling tanks drained;
   b) Sediment collected from the bottom of each unit and weighed;
   c) Sediment samples for moisture content and size distribution preserved in waterproof containers;
   d) Bacteriological samples with sufficient growth counted; other samples packed for transportation back to laboratory at VPI&SU;
   e) Frozen product samples packed in coolers with ice;
   f) Samples for TSS and VSS determination, COD analysis, and equipment packed for transportation to laboratory at VPI&SU;

8. Laboratory at VPI&SU.
   a) Total plate counts, TSS, VSS, COD, insect counts, moisture contents, and soil size distribution determined;
   b) Preparation for next trial.

The above procedure was used for the prototype trials and the conventional trials with some exceptions. One exception was that samples of sediment could not be collected from the conventional washers without interfering with plant operation.

Experimental Methods.

For both conventional and prototype systems product, and water flow rates were determined as well as TSS, VSS, COD, and insect and bacteria counts. Following is a description of the tests that were conducted.

Sampling Points.

Figure 8 shows a schematic diagram of the Exmore Food Co. with sampling points numbered. Product samples were taken at points 1, 3, 4, 16 from the prototype line and 12, 14, 15, 16 or 7, 9, 10, 11 from the conventional lines. Water samples were taken at points 1 through 6 from the prototype line and 12, 13, 14, 15 or 7, 8, 9, 10 from the conventional lines. Figures 5 and 8 show schematic views of the prototype and conventional systems with sampling points. Samples were taken before and after washing units or settling tanks. This location of the sampling points allowed for determination of the effectiveness of the different units.

Water Flow Rates.

Before each trial, flow rates for recirculation were adjusted to approximately 380 l/min (100 gpm). Actual flow rates for recirculation during trials were calculated from readings of totalizing flowmeters 1 and 2 (Figure 5). These were recorded hourly and at the beginning and end of each break in processing.

Fresh water input rates were adjusted differently for each trial. Flow rates were obtained from readings taken from meter 3. To test the system for different operating conditions, the input water in trial 1 was shut off during each break in processing. In the other trials it was only reduced. The flow rate of fresh water input varied considerably because of variations in the pressure of the plant water system. For recirculation and fresh water input, it was assumed that flow rates were constant between times when readings were taken.

Charts from the water stage recorders for meters 4 and 5 were changed during lunch hours. Readings from these charts were taken at five minute time intervals when analyzing results. Because of the cyclical response of the sump pumps the water level in settling tanks varied with a frequency of about 2 cycles per minute. Upper and lower readings were taken and the average level of the water in the flumes was converted to flow rates using procedures described in Appendix A.

Product Flow Rates.

Product flow rates into the washers were approximated from measurements of packaged product weight. This was done because product coming from the fields was sorted on the picking lines (Figure 8) and part of it was discarded. The percentage of discarded product depended on product quality.

There were several methods of packaging the final product at the Exmore Foods plant, and different methods were employed for different trials. During trial 1 the product was loaded on trays and the trays,on special carts,were transported to the freezers. Loading times were monitored for each cart. Each cart contained an average of 181 kg (400 lbs) of product. From the difference in time between moving the first cart to the freezer and the beginning of the trial, processing time for a particular piece of product was found. These times were different for different trials. Processing times were corrected by subtracting these lag times from the time the cart went into the freezer. Product totals were recorded hourly and average values between each hour of processing time were assumed.

Similar methods were used to determine product flow rates in trial 3.

During trial 2, product was stored in three different freezers and packaged in 6.8 kg (15 lbs) trays, and also on 181 kg carts. In this case, the average lag time was approximated. In trials 4, 5, and 6 automatic packaging was employed. In trial 4 and the night shift of trial 6, product was packaged in retail containers holding 0.283 kg, (nominal net weight), of greens. For trial 5 and the day shift of trial 6, the net nominal weight of the packages was also 0.283 kg but the product contained 0.057 kg of diced turnip roots and 0.226 kg of turnip greens. In these cases samples of product were taken and the percentages of greens and roots were determined.

The package counter was checked hourly and at the beginning and at the end of each break in processing. For each trial, corrections were made to account for the different moisture content between fresh and processed product.

Product samples for moisture determination were taken before washing and after packaging. Samples were placed in sealed plastic bags and frozen. Before freezing, the net weight of each sample was found. At the VPI&SU laboratory, samples were removed from plastic bags and dried in an oven at 105°C for 24 hours. The samples were weighed again to determine dry weight. Moisture content, wet basis was calculated using the equation:

$$M = 100 \frac{W_w}{W_w + W_d} \qquad (2)$$

where: M = moisture content (wet basis)

W_w = weight of water

W_d = weight of dry matter

Because the dry mass of product during washing was essentially unchanged (the weight of grit and trash removed from the fresh product neglected) fresh weight of product could be calculated using the equation:

$$W_f(100 - M_f) = W_p(100 - M_p) \qquad (3)$$

where: W_f = weight of the fresh product

W_p = weight of the product after washing and blanching

M_f = moisture content of the fresh product in percent

M_p = moisture content of the final product in percent

Grit Analysis.

The morning after the end of each trial, each prototype washer and settling tank were carefully drained using a portable sump pump. Grit from the bottom of each unit was collected, weighed, and samples for moisture content were taken. These samples were placed in waterproof containers to avoid moisture loss during transportation. Samples were weighed, dried at 105°C, and the dry weight of total grit sediment was calculated. The same samples were later used to determine grit size distribution as follows:

1. 50 grams of the sample were weighed;
2. The sample was mixed in a mechanical shaker for 15 minutes with 100 ml of 50 percent Calgon solution in water;

3. The sample was washed with distilled water and placed in a soil dispersion cup;
4. The sample was dispersed for five minutes;
5. The sample was placed in a graduated cylinder, the cylinder was filled to the 1130 ml level with distilled water after a hydrometer was placed in it;
6. The hydrometer was removed and the sample mixed with a brass plunger. Then the hydrometer was gently lowered again;
7. Timing began at this moment;
8. A hydrometer reading was taken after 40 seconds, 15 minutes, 1 hour, and 2 hours;
9. Temperature readings were taken and calculations for temperature corrections made;
10. Calculations were made for the percentage of each fraction of sediment;
11. The sample was then washed with tap water through a 270 mesh sieve to obtain a pure sample of the sand;
12. The sand sample was dried for 2 hours in 105^{o}C and then vibrated in a sieve stack for 10 minutes (sieve sizes were 10, 18, 35, 60, and 140 mesh);
13. Sand from each sieve was then removed and weighed;
14. Calculations of the percentage of each size category were made.

Trash Accumulation.

Trash during the trials was collected in boxes at the end of the filter belts. At the end of each trial, the trash was weighed and samples for insect counts and moisture content were taken and placed in sealed bags, weighed and frozen. In the VPI&SU laboratory, the equivalent fresh weight of trash was determined by the same gravimetric procedure previously described for product analyses. From these data the amount of trash generated per kilogram of product was obtained.

Chlorine Residual, TSS, VSS, COD, and Total Plate Counts.

Water samples in the washers were taken from points 1 through 6 as shown in Figure 5 for the prototype system and from points 7 through 10 (Figure 13) or from points 12 through 15 (Figure 14) for the conventional system. The difference between measurements at different locations described the effectiveness of each component of the system. For example, the difference in grit concentrations in the water, obtained from TSS and VSS, between location 1 and 2 (Figure 5) represents sedimentation in settling tank 1.

Chlorine residual, TSS, VSS, COD and total plate counts were determined as described in Standard Methods for the Examination of Water and Waste Water (1971).

Grit in the Product.

Samples of product weighing 1.0 kg were taken from points 1, 2, 3 as shown in Figure 5 for prototype system and from points 7, 9, 10 (Figure 13) or 12, 14, 15 (Figure 14) for the conventional system. Each sample was washed by hand in a special cylinder containing 15 liters (4 gallons) of water. Water from these washing tests was filtered through a 0.95 cm (3/8 inch) mesh sieve to separate product from

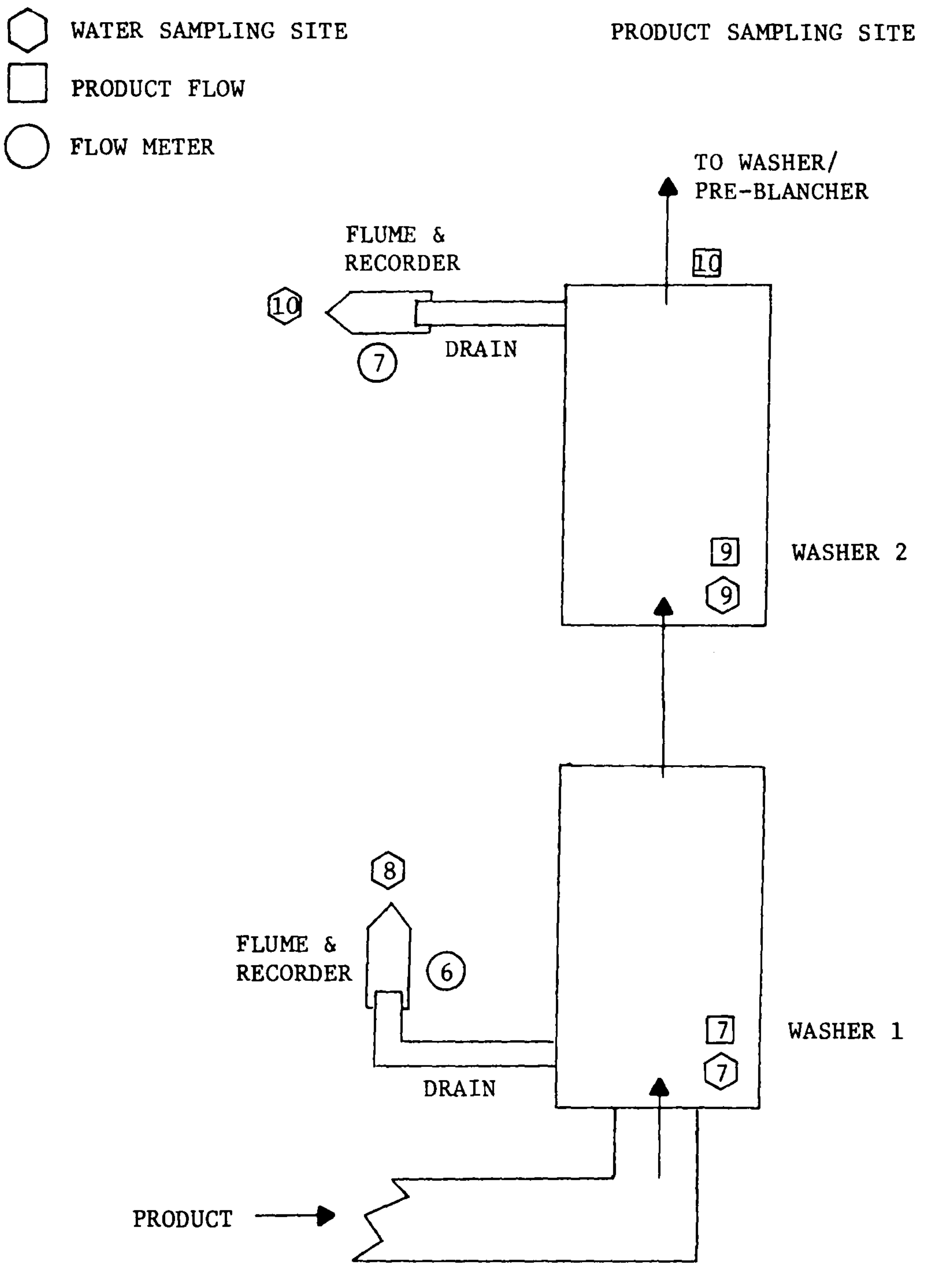


Figure 13: Diagram of conventional washing system, showing location of sampling sites and flow meters for east line.

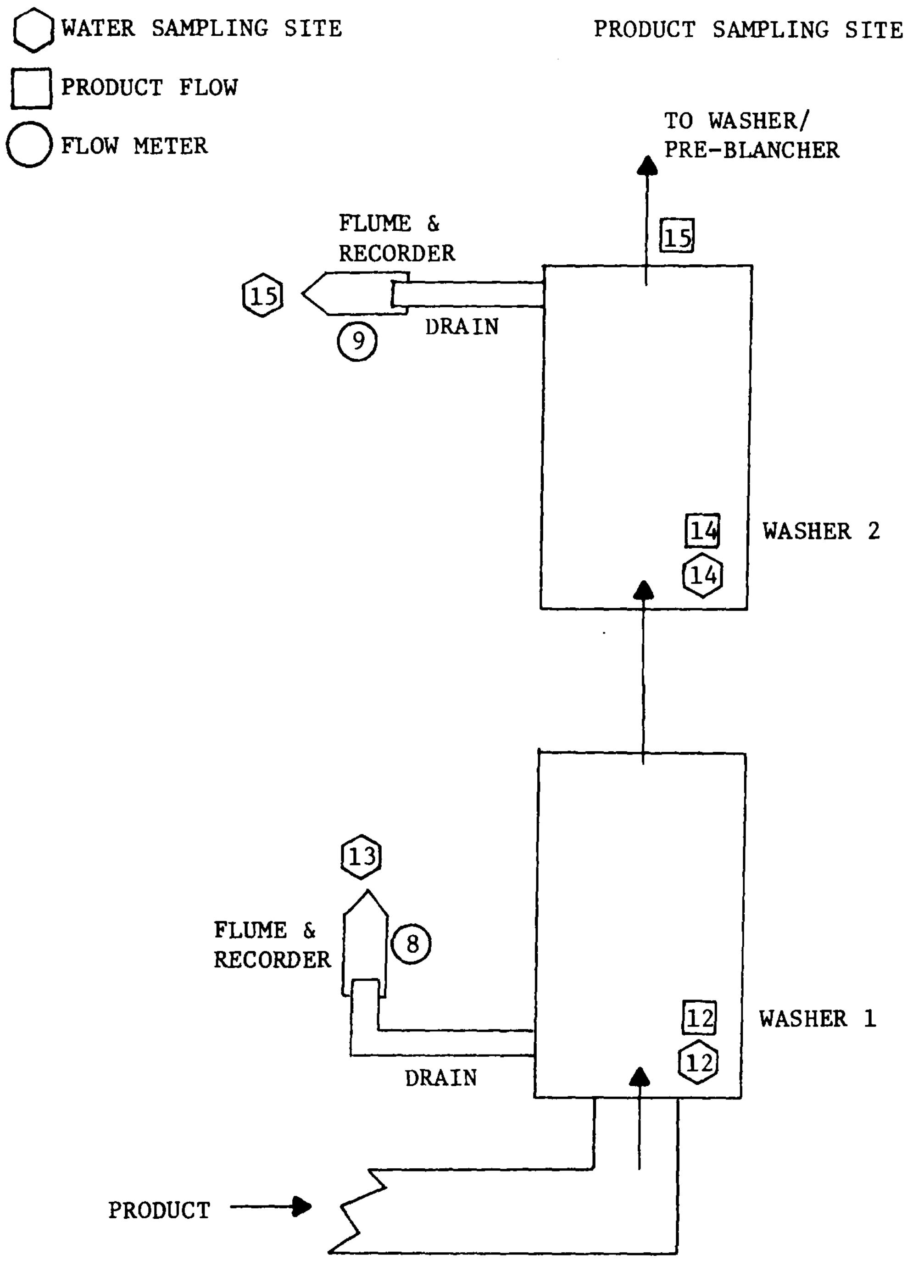


Figure 14: Diagram of conventional washing system, showing location of sampling sites and flow meters for west line.

water.

From the filtered water, a 500 ml aliquot was taken and TSS and VSS were determined. The value for VSS was subtracted from the TSS value to get the amount of inorganic solids per liter of wash water. This value was multiplied by 15 because the sample had been washed in 15 liters of water. To adjust the grit values calculated for the washed product, sample corrections were made. 1000 g samples of fresh product before washing contained more vegetables than the wet samples after washing. A simple test showed that after washing the samples contained about 29 percent and 32 percent surface water picked up from the washers for turnip greens and spinach, respectively. Grit content in the washed samples was reduced proportionately.

Insect Counts.

The insect counts on the product were determined from samples of product collected from points 1, 2, and 3 for prototype (Figure 5) and from points 7, 9, 10 (Figure 13) or 12, 14, 15 (Figure 14) for conventional lines. Samples were preserved in the same manner as the other product samples and processed in the VPI&SU laboratory using the gasoline extraction method.

For more detail on the methods used to analyze the water quality and product quality samples see Coleman (1976).

RESULTS AND DISCUSSION

Product Flow Rates.

Tables 6 and 7 show average, maximum, and minimum flow rates of product and the total amount of product processed during each trial of the prototype and conventional washers, respectively. Average product flow rates varied for different trials (from 1070 to 1454 kg/hr for the prototype trials, and from 1123 to 1620 kg/hr for the conventional lines). However, for some trials flow rates for the prototype were higher than for the conventional washers. The minimum flow rate for the prototype trials (456 kg/hr) was similar to that for the conventional line (459 kg/hr). The maximum flow rate for the prototype trials (2251 kg/hr) was significantly lower than for conventional line (3330 kg/hr). The considerable variation in product flow rates was caused by differences in product quality and in the capacity of the crews working on the inspection lines. Low quality product requires more time for inspection because a higher percentage of the raw product is discarded.

Individual package weights were measured for trials 5 and 6 as shown in Tables 8 and 9. The average weight of packaged greens varied from 191 g to 233 g. These weights vary considerably from nominal weights (283 g for pure greens and 236 g for turnip greens in a mixture with diced roots). This indicates that there was also considerable variation in the product loads on the carts and in the packages during other trials. Figure 15 shows typical variations of product flow rates as a function of operating time for the prototype and conventional washer trial. These curves were developed by assuming an average flow

Table 6. Average Product Flow Rates, and Range of Variation of Product Flow in the Prototype System.

Trial Number	Product	Date	Average Flow Rate (kg/hr)	Minimum Flow Rate (kg/hr)	Maximum Flow Rate (kg/hr)	Total Product Processed (Fresh Weight) (kg)	Processing Time (min)
1	spinach	4/22/76	1282	711	2251	8763	410
4	turnip greens	6/4/76	1454	775	1904	7999	330
5	turnip greens & roots*	6/10/76	1071	456	1611	6781	380
6	turnip greens & roots*	6/11/76	1348	1066	1783	7974	355

* Each package nominally contained 236 g of greens and 57 g of diced roots

Table 7. Average Product Flow Rates, and Range of Variation of Product Flow in the Conventional System.

Trial Number	Product	Date	Average Flow Rate (kg/hr)	Minimum Flow Rate (kg/hr)	Maximum Flow Rate (kg/hr)	Total Product Processed (Fresh Weight) (kg)	Processing Time (min)
1	spinach	4/22/76	1123	818	1534	4396	235
2	spinach	5/12/76	1548	459	2992	12132	470
3	spinach	5/21/76	1622	972	3330	5136	190
4	turnip greens	6/4/76	1381	1178	1618	5525	240
5	turnip greens & roots*	6/10/76	1483	1067	1714	5932	240
6	turnip greens	6/11/76	1141	810	2436	4658	245

* Each package nominally contained 236 g of greens and 57 g of diced roots

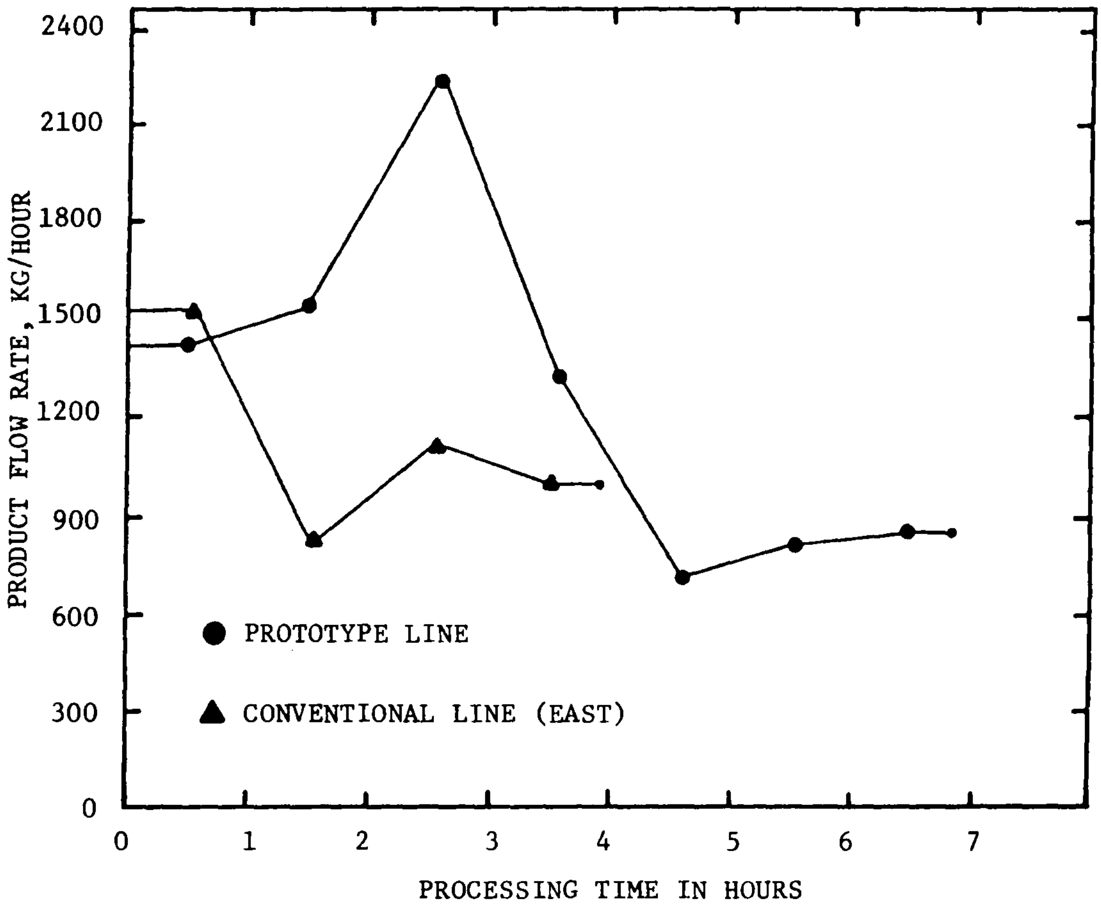


Figure 15: Variation in product flow rates, Trial 1 when processing spinach.

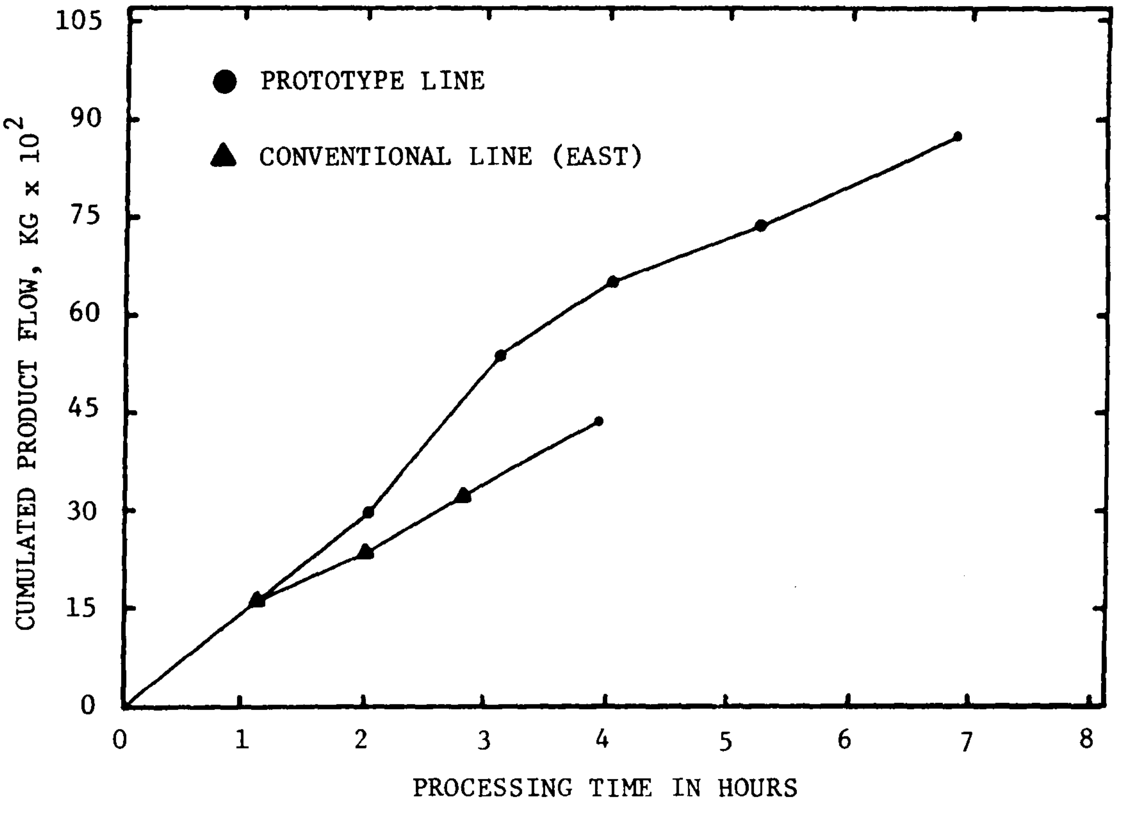


Figure 16: Cumulated product input versus time, Trial 1 when processing spinach.

rate between the times when total product output was recorded. Figure 16 shows accumulated product as a function of processing time. These data provided a basis for plots of bacteria count, total suspended solids, volatile suspended solids, and chemical oxygen demand versus accumulated product flow. Product flow data for all trials are shown in five minute intervals (Appendix A). Data for the prototype system are shown as functions of the total time from beginning to end of each trial, including breaks and downtime.

For trials 5 and 6 the product samples absorbed water from melted ice during transportation to the VPI&SU laboratory. However, fresh product weight was determined using the formula:

$$G_f = \frac{N\ G_d(100 - M_d)}{(100 - M_f)} \qquad (4)$$

where: G_f = weight of the fresh product

M_f = moisture of the fresh product

G_d = dry weight of the product in package

M_d = moisture of dry product (assumed 0)

N = number of packages processed during trial

Fresh and final weights of the product are shown in Table 10. There was significant variation in water absorption between different trials. In Tables 8 and 9, wet and dry weights of packaged components are shown for trials 5 and 6. In these two trials the prototype product flow rate was determined after removal of the diced roots from the greens. In Table 11, moisture content of the fresh and final product is shown for the prototype line. Table 12 provides similar information for

Table 8. Wet and Dry Weights of Packaged Product, Trial #5.

	Wet Weight in Grams			Dry Weight in Grams		
	Total Package	Greens	Roots	Total Package	Greens	Roots
	322.6	207.0	60.0	39.1	19.5	3.1
	430.3	195.5	61.0	36.7	17.7	2.4
	356.0	182.8	109.4	38.0	16.0	5.6
Prototype	436.0	258.0	38.5	41.3	19.2	1.9
Line	413.0	203.0	42.0	41.1	18.7	2.2
	349.5	148.0	50.0	41.7	17.3	4.9
	339.0	164.0	48.0	40.2	17.8	2.6
	328.0	175.0	52.0	42.9	20.5	2.2
Average	371.80	191.66	57.61	40.10	18.34	3.11
	311.5	209.0	62.0	40.2	17.3	2.9
Conventional	344.0	240.0	40.5	40.5	19.2	1.8
Line	355.0	207.0	48.0	44.7	20.1	3.6
	323.0	214.0	36.5	38.8	17.5	1.8
Average	333.40	217.50	46.75	41.05	18.53	2.53

Table 9. Wet and Dry Weights of Packaged Product, Trial #6.

	Wet Weight in Grams			Dry Weight in Grams		
	Total Package	Greens	Roots	Total Package	Greens	Roots
	330.0	217.0	25.0	42.1	20.4	1.2
	319.0	213.0	32.5	41.2	18.5	2.9
	327.0	199.0	58.5	37.9	14.6	2.8
Prototype	366.0	237.0	43.5	42.0	20.5	2.2
Line	364.0	227.0	51.0	41.3	19.0	2.6
	368.0	185.5	94.5	41.3	16.7	4.3
	340.0	200.0	52.0	40.6	17.8	2.8
	322.0	191.0	42.5	37.4	15.5	1.9
Average	342.00	208.69	49.94	40.50	17.88	2.59
	327.5	239.0	-	40.3	21.5	-
Conventional	332.0	231.0	-	40.5	20.7	-
Line	316.5	226.5	-	39.6	19.8	-
	324.5	238.0	-	41.1	21.2	-
Average	325.10	233.63	-	40.40	19.58	-

Table 10. Increase in Product Weight during Washing.

	Trial Number	Fresh Product Weight (kg)	Final Product Weight (kg)	Ratio of Final Product Weight/ Fresh Weight -
	1	8763	13426	1.53
Prototype	4	7999	9304	1.16
Line	5	6781	7596*	1.12
	6	7974	8916*	1.12
	1	4396	7802	1.77
	2	12132	18754	1.56
Conventional	3	5136	6713	1.31
Line	4	5525	8338	1.51
	5	5932	7064*	1.19
	6	4658	6525*	1.40

* For trials 5 and 6 wet weight of product was approximated from nominal package weight.

Table 11. Product Moisture Content, Prototype Line.

Sample Number	Moisture Content of Fresh Greens before Washing, % w.b.				Moisture Content of Packaged Greens, % w.b.			
	Trial Number				Trial Number			
	1	4	5	6	1	4	5*	6*
1	83.75	89.78	94.01	93.80	87.63	93.51	-	-
2	85.00	91.16	93.24	93.76	90.07	92.93	-	-
3	86.75	90.62	91.06	91.43	90.43	93.33	-	-
4	84.00	90.88	89.63	90.15	91.87	93.26	-	-
5	85.33	89.21	90.26	91.23	88.33	92.96	-	-
6	85.39	90.29	90.81	89.59	89.72	92.48	-	-
7	84.81		89.28	89.71	89.63		-	-
8	82.46		89.26	89.85	91.18		-	-
9	84.24				90.83			
Average	84.64	90.32	90.94	91.19	89.97	93.08	-	-

* For trials 5 and 6 only the dry weight of greens in the packages was determined.

Table 12. Product Moisture Content, Conventional Line.

Sample Number	Moisture Content of Fresh Greens before Washing, % w.b.						Moisture Content of Packaged Greens, % w.b.					
	Trial Number						Trial Number					
	1	2	3	4	5	6	1	2	3	4	5*	6*
1	82.61	90.18	91.50	90.90	91.10	90.72	89.24	91.54	93.14	93.66	-	-
2	81.40	80.80	90.90	87.56	91.23	89.27	89.54	91.44	93.38	93.37	-	-
3	81.40	78.53	89.89	89.76	89.34	89.18	91.11	90.67	92.79	93.18	-	-
4	82.82	79.83	91.03	88.55	91.67	85.57	89.91	88.92	92.63	93.04	-	-
5	83.90	88.47		90.23			90.69	92.69		92.72	-	-
6		89.09						90.25			-	-
7		90.16						92.01				
8		88.94						91.21				
9		88.73						90.74				
Average	82.43	86.08	90.83	89.40	90.83	89.72	90.10	91.05	92.98	93.19	-	-

* For trials 5 and 6 only the dry weight of greens in the package was determined.

the conventional line. The average moisture of input product was about 85 percent for spinach and about 90 percent for turnip greens. Output moisture contents were approximately 2 to 3 percent higher.

Water Flow Rates.

Water recirculation rates for both washers during each trial were set at about 380 l/min (100 gpm). This was done using a stop watch and taking readings from totalizing water meters 1 and 2, for different positions of the valves regulating recirculation. However, flow rates varied somewhat during the trials as shown in Table 13. Figure 17 shows typical water flows for prototype trial, and Figure 18 for conventional trial. These data are plotted as functions of processing time. In Appendix B, all water flow data are shown in five minute intervals of processing time for the conventional trials, and in five minute intervals of total time for the prototype trials.

Fresh water input was adjusted to different rates for different trials to find the minimum flow rate that would produce acceptable product cleanliness. Minimum, maximum, and average fresh water input for different trials are shown in Table 14 (typically between 50 and 100 l/min). Overflow from the system depended on rate of fresh water input and the amount of water removed by the product. Table 15 shows maximum, minimum, and average overflow from the prototype system for each trial.

During the washing process some water was absorbed by the product and some was carried by the product from one washer to another, and later out of the system. This explains why fresh water input, flow be-

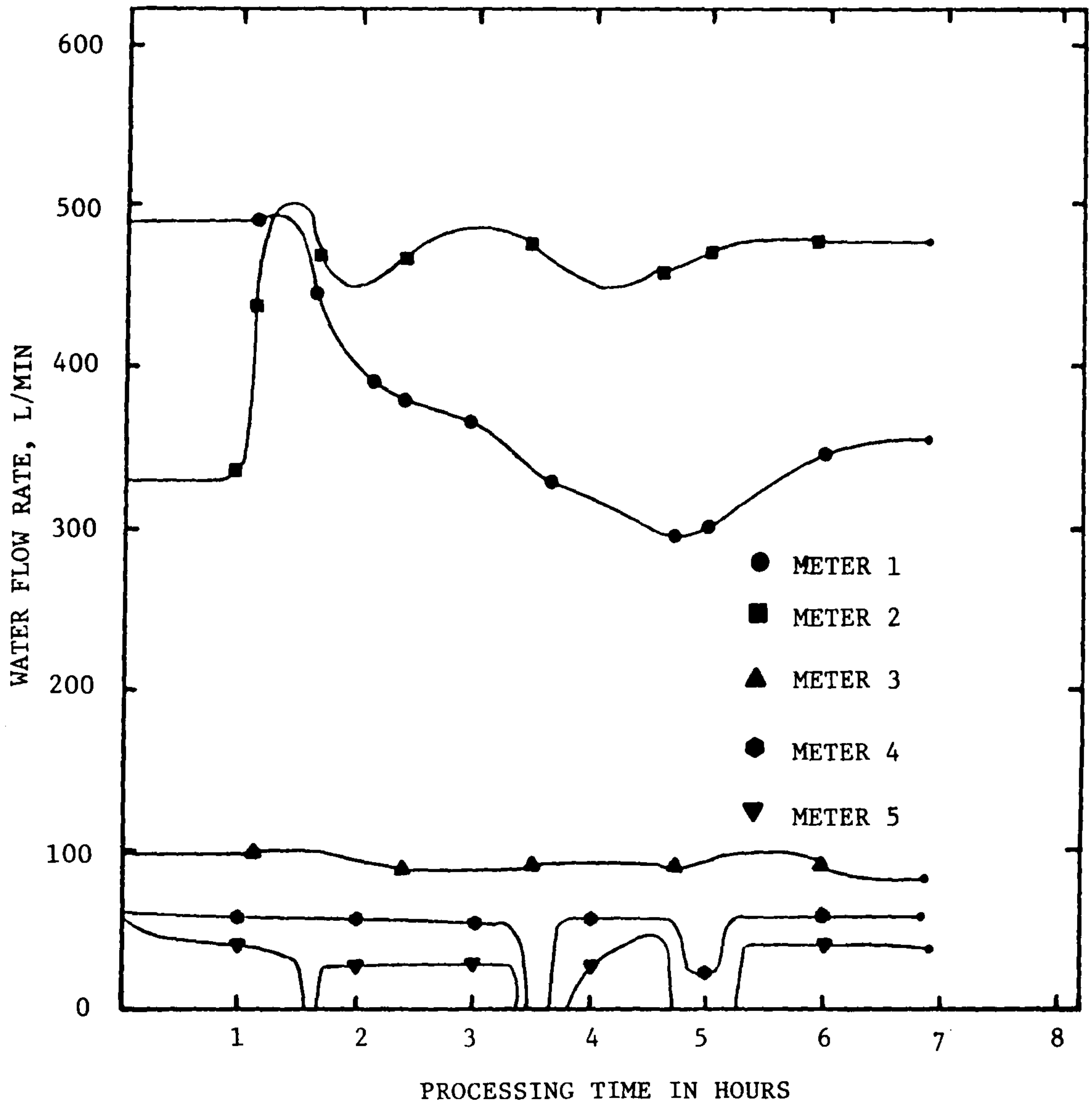


Figure 17: Water flow rates versus time, Trial 1, prototype, when processing spinach (see figure 5 for meter locations).

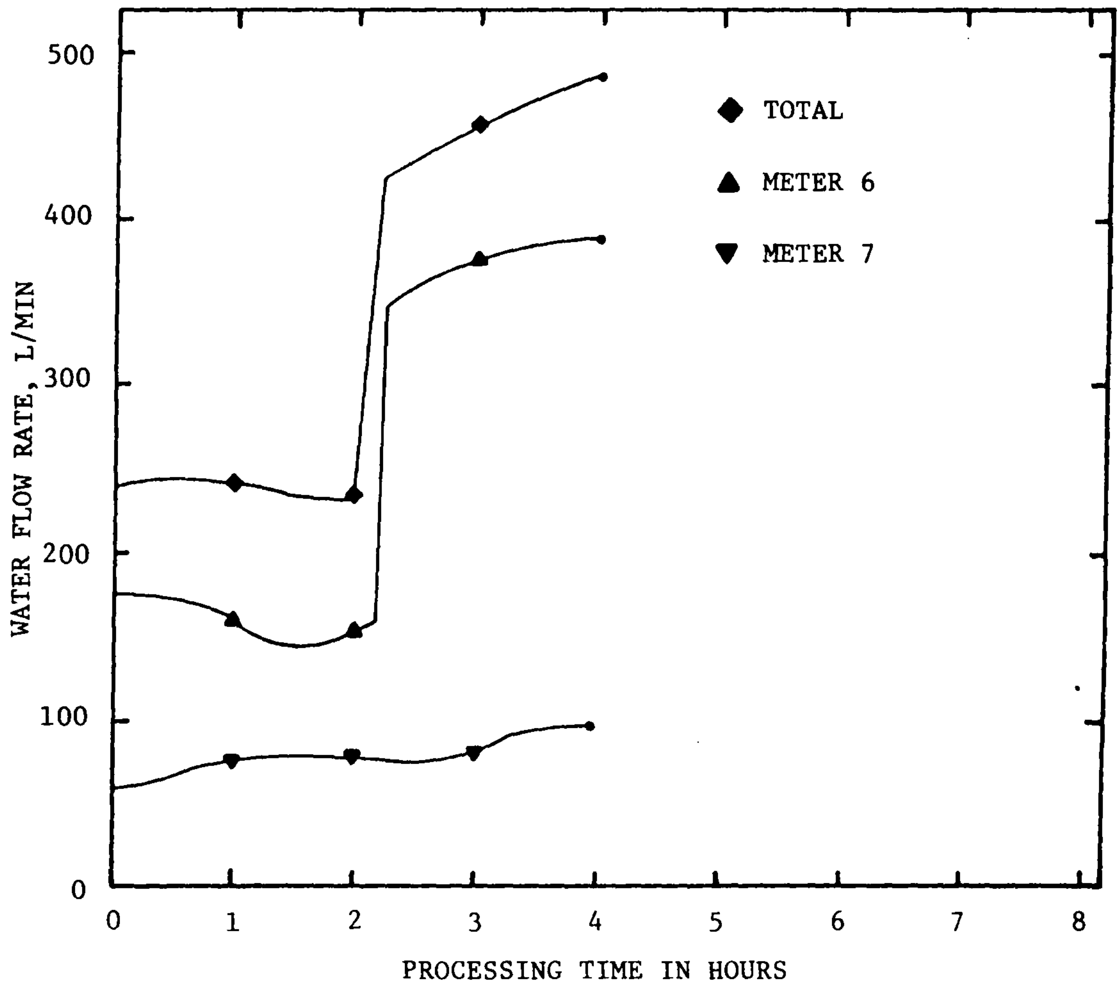


Figure 18: Water flow rates versus time, Trial 1, conventional East line, when processing spinach (see figure 13 for meter locations).

Table 13. Recirculation Water Flow Rates for the Prototype System.

Trial Number	Recirculation for Washer #1: Minimum Water Flow Rate (l/min)	Recirculation for Washer #1: Maximum Water Flow Rate (l/min)	Recirculation for Washer #1: Average Water Flow Rate (l/min)	Recirculation for Washer #2: Minimum Water Flow Rate (l/min)	Recirculation for Washer #2: Maximum Water Flow Rate (l/min)	Recirculation for Washer #2: Average Water Flow Rate (l/min)
1	217	503	377	329	538	448
4	193	463	405	261	533	451
5	102	532	361	128	601	377
6	382	508	443	326	437	398

Table 14. Fresh Water Input for the Prototype System.

Trial Number	Water Flow Rates in l/min Minimum	Maximum	Average
1	81	101	92
4	0	60	53
5	32	91	71
6	58	105	95

Table 15. Overflow Flow Rates for the Prototype System.

Trial Number	Overflow from Settling Tank #2 to Settling Tank #1 (l/min)			Overflow to Waste (l/min)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
1	0	63	53	0	57	30
4	0	70	38	0	42	4
5	0	63	48	0	69	24
6	37	75	62	3	54	38

tween settling tanks, and overflow to waste are different. The difference between the flow between tanks and the overflow from the first settling tank represents the amount of water carried with the product from the first washer. The difference between fresh water input and the overflow from the first settling tank represents the amount of water carried with the product from the second washer. The average amounts of water per kg of fresh product carried with the product from the first and second washers are shown in Table 16 (typically 1.2 and 2.5 l/kg for the first and second washers, respectively). It should be added that these data are slightly disturbed by leakage from the system. Leakage consisted of water carried with trash out of the system, leakage from the filter belts, and leakage from the sumps.

Overflows from the conventional system with their variations and average values are shown in Table 17. Average values of overflow during processing time for both lines are shown in Table 18. In Table 19, the average fresh water consumption per kg of product washed is shown for different trials. Values for prototype trials are obtained from measurements. Those for the conventional line are predicted based on the amount of water carried off with the product from the prototype system. Because the size and construction of the washers in both lines were similar, this assumption seems reasonable.

Grit Analysis.

Table 20 reflects the amount of grit collected after each trial from each unit of the prototype system. Only during the second trial was a sample of grit taken from the first washer of the conventional

Table 16. Amount of Water Carried with the Product from the First Washer and from the Total System.

Trial Number	Amount of Water Carried from First Washer l/kg	Amount of Water Carried from Total System l/kg
1	1.098	2.970
4	1.403	2.022
5	1.357	2.648
6	1.080	2.544

Table 17. Overflow Flow Rates for Conventional System.

Trial Number	Overflow from First Washer: Minimum Flow Rate (l/min)	Overflow from First Washer: Maximum Flow Rate (l/min)	Overflow from First Washer: Average Flow Rate (l/min)	Overflow from Second Washer: Minimum Flow Rate (l/min)	Overflow from Second Washer: Maximum Flow Rate (l/min)	Overflow from Second Washer: Average Flow Rate (l/min)
1	127	409	250	60	164	79
2	29	212	83	4	77	24
3	66	194	131	92	169	136
4	157	361	251	91	258	155
5	163	210	194	160	235	203
6	260	352	287	97	109	106

Table 18. Average Overflow to Waste per Unit Weight of Product during Processing Time.

Trial Number	Prototype Line (1/kg)	Conventional Line (1/kg)
1	1.38	17.55
2	-	4.15
3	-	9.85
4	0.16	17.63
5	1.35	16.04
6	1.68	20.67
Average	1.14	14.25

Table 19. Average Use of Fresh Water during Processing Time per Unit Weight of Product.

Trial Number	Prototype Line (l/kg)	Conventional Line* (l/kg)
1	4.30	20.52
2	-	7.12
3	-	12.82
4	2.18	19.65
5	4.00	18.69
6	4.22	23.21
Average	3.68	17.00

* Values predicted assuming the same amount of water per unit weight of product carried from the washers as in the corresponding prototype trial.

Table 20. Dry Weight of Grit in Kilograms Taken from Various Units of Prototype System at End of Each Trial.

Trial Number	Product	First Washer				Second Washer				First Settling Tank	Second Settling Tank
		First Drain	Second Drain	Third Drain	Total	First Drain	Second Drain	Third Drain	Total		
1	spinach	12.281	3.070	1.535	16.886	3.080	0.770	0.000	3.850	19.047	6.853
4	turnip greens	5.950	2.975*	1.487*	10.412	0.399	0.200*	0.100*	0.699	4.690	1.268
5	turnip greens	2.533	1.266*	0.633*	4.432	0.161	0.081*	0.040*	0.282	2.356	0.579
6	turnip greens	10.242	5.121*	2.560*	17.923	0.750	0.375*	0.188*	1.312	1.098	2.350

* Value estimated relative to volume of soil in drain #1 in each case.

line. However, this sample is not representative of typical settled soil in the washers because it was shoveled out of the washer during the noon lunch break, not taken from the bottom of the washer after draining the tank. In this situation, a lower percentage of small particles can be expected. During the conventional trials, samples could not be taken without disturbing production.

For each sample collected, a particle size analysis was made. The percentage of each soil particle size fraction is shown in Tables 21 through 24 for each washer and settling tank of the prototype, and in Table 25 for the first washer of the conventional line. Table 26 shows average data of each soil fraction in the different washing units. Accumulated percentages of each particle size were counted and plotted versus particle diameter (Figure 19 as a typical example). Figure 20 shows the same data for the sample from the conventional washer. These data indicate that the majority of grit particles of larger diameter (more than 100 microns) settled in the washers and the smaller particles, which have slower sedimentation speeds, were deposited in settling tanks.

In both the settling tanks and washers, particles were found with diameters smaller than 56 microns, the diameter for which the settling tanks were designed. This can be explained in two ways:

1) small particles may sometimes settle while attached to larger ones, and
2) some small particles probably settled after the end of each trial from water contained in tanks, because, as mentioned earlier, these tanks were usually drained on the morning fol-

Table 21. Soil Size Distribution in Settling Tank #1, Prototype Line

Trial Number	Product	Percent of Particles in Each Diameter Range						
		More Than 1000 Microns	1000 - 500 Microns	500 - 250 Microns	250 - 105 Microns	105 - 50 Microns	50 - 3 Microns	Less Than 3 Microns
1	spinach	0.02	0.02	0.62	6.00	6.62	80.92	5.80
		0.00*	0.00*	0.76*	5.60*	3.72*	84.12*	5.80*
4	turnip greens	0.04	0.16	0.80	1.20	5.80	84.20	7.80
		0.00*	0.00*	1.20*	13.32*	2.72*	74.96	7.80*
5	turnip greens	0.00	0.04	1.82	15.00	9.18	69.16	4.80
		0.00*	0.00*	1.68*	13.00*	8.64*	71.88*	4.80*
6	turnip greens	0.02	0.66	2.46	20.60	9.80	59.66	6.80

* Data for trials 1, 4, 5 were taken after burning the soil sample to remove organic matter

Table 22. Soil Size Distribution in Settling Tank #2, Prototype Line.

Trial Number	Product	Percent of Particles in Each Diameter Range: More Than 1000 Microns	1000 - 500 Microns	500 - 250 Microns	250 - 105 Microns	105 - 50 Microns	50 - 3 Microns	Less Than 3 Microns
1	spinach	0.00 0.00*	0.16 0.08*	2.24 0.72*	13.70 15.32*	6.46 8.92*	71.64 69.16*	5.80 5.80*
4	turnip greens	0.00 0.00*	0.02 0.00*	0.60 0.52*	10.80 16.28*	10.20 9.28*	73.20 68.12*	5.80 5.80*
5	turnip greens	0.00 0.00*	0.48 0.12*	2.24 0.84*	18.20 18.96*	8.38 9.96*	65.90 65.32*	4.80 4.80*
6	turnip greens	0.00	0.16	1.78	17.76	28.40	45.10	6.80

* Data for trials 1, 4, 5 were taken after burning the soil sample to remove organic matter

Table 23. Soil Size Distribution in First Washer, Prototype Line.

Trial Number	Product	Percent of Particles in Each Diameter Range: More Than 1000 Microns	1000 - 500 Microns	500 - 250 Microns	250 - 105 Microns	105 - 50 Microns	50 - 3 Microns	Less Than 3 Microns
1	spinach	0.04	0.60	40.60	49.20	1.60	7.16	0.80
4	turnip greens	0.08	1.20	43.34	46.80	1.60	2.46	3.80
5	turnip greens	0.00	1.18	23.44	63.32	2.92	6.34	2.8
6	turnip greens	0.02	0.98	45.20	49.32	0.81	0.87	2.8

Table 24. Soil Size Distribution in Second Washer, Prototype Line.

Trial Number	Product	Percent of Particles in Each Diameter Range: More Than 1000 Microns	1000 - 500 Microns	500 - 250 Microns	250 - 105 Microns	105 - 50 Microns	50 - 3 Microns	Less Than 3 Microns
1	spinach	0.04	2.16	42.60	44.76	1.04	8.60	0.80
4	turnip greens	0.02	6.60	43.40	42.42	1.90	3.18	2.8
5	turnip greens	0.02	0.24	18.80	72.38	2.20	3.56	2.8
6	turnip greens	0.02	4.80	43.82	44.76	1.32	2.48	2.8

Table 25. Soil Size Distribution in First Washer, Conventional Line.

Trial Number	Product	Percent of Particles in Each Diameter Range						
		More Than 1000 Microns	1000 - 500 Microns	500 - 250 Microns	250 - 105 Microns	105 - 50 Microns	50 - 3 Microns	Less Than 3 Microns
2	spinach	0.22	3.00	30.12	49.36	2.20	13.50	1.80
		0.00*	0.44*	34.04*	56.10*	2.00*	5.60*	1.80*

* Data were taken after burning the soil sample to remove organic matter.

Table 26. Average Soil Size Distribution from All Trials.

	Unit	Percent of Particles in Each Diameter Range						
		More Than 1000 Microns	1000-500 Microns	500-250 Microns	250-105 Microns	105-50 Microns	50-3 Microns	Less Than 3 Microns
Prototype Line	first washer	0.04	0.99	38.15	52.16	1.73	4.25	2.55
	second washer	0.07	3.45	37.16	51.08	1.62	4.33	2.30
	first settling tank	0.01	0.13	1.33	10.67	6.64	74.99	6.23
	second settling tank	0.00	0.15	1.28	15.86	11.66	65.39	5.66
Conventional Line	first washer	0.01	1.72	32.08	52.73	2.1	9.56	1.8

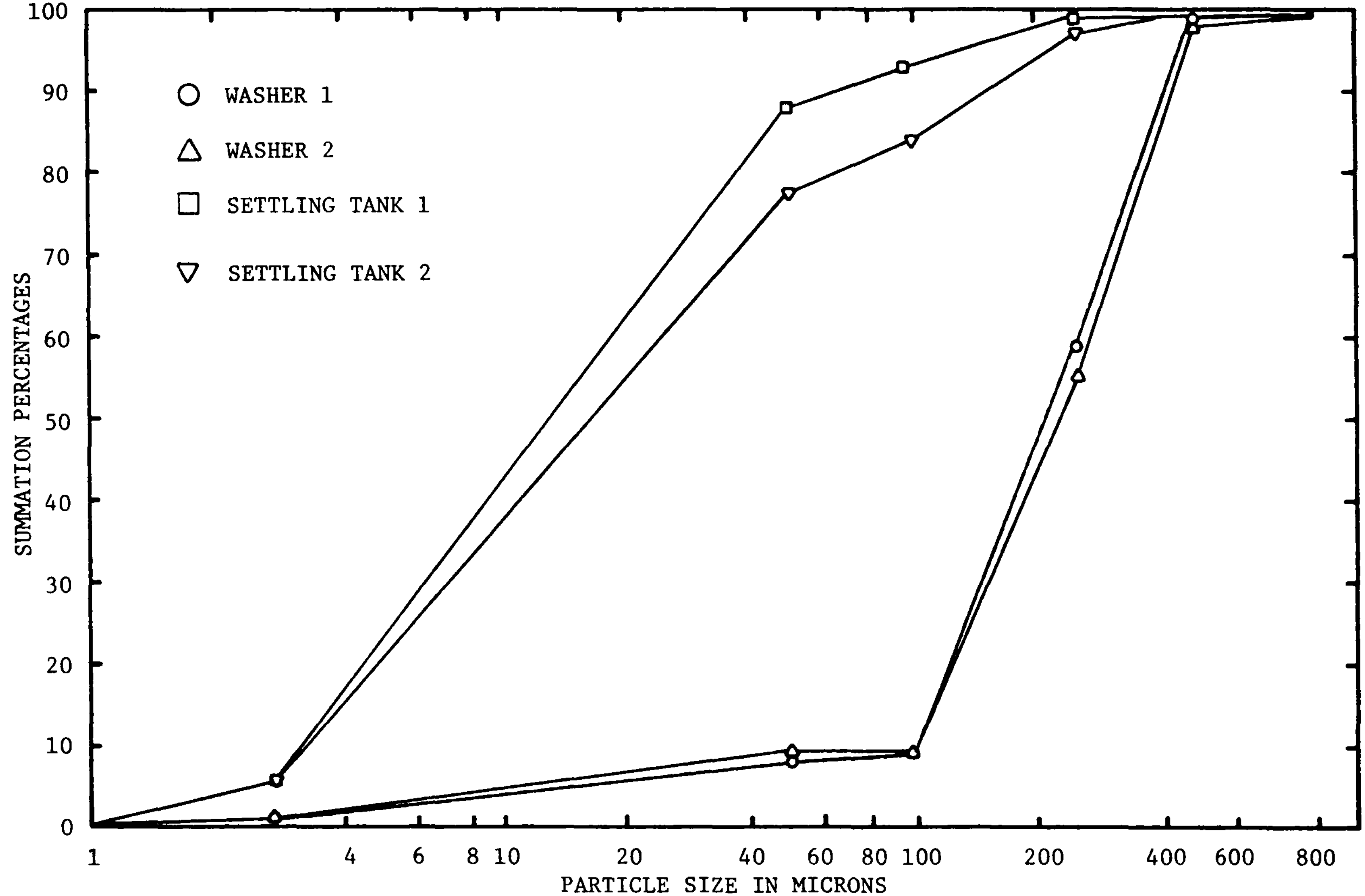


Figure 19: Summation versus particle size for grit accumulated in prototype system, Trial 1, when processing spinach.

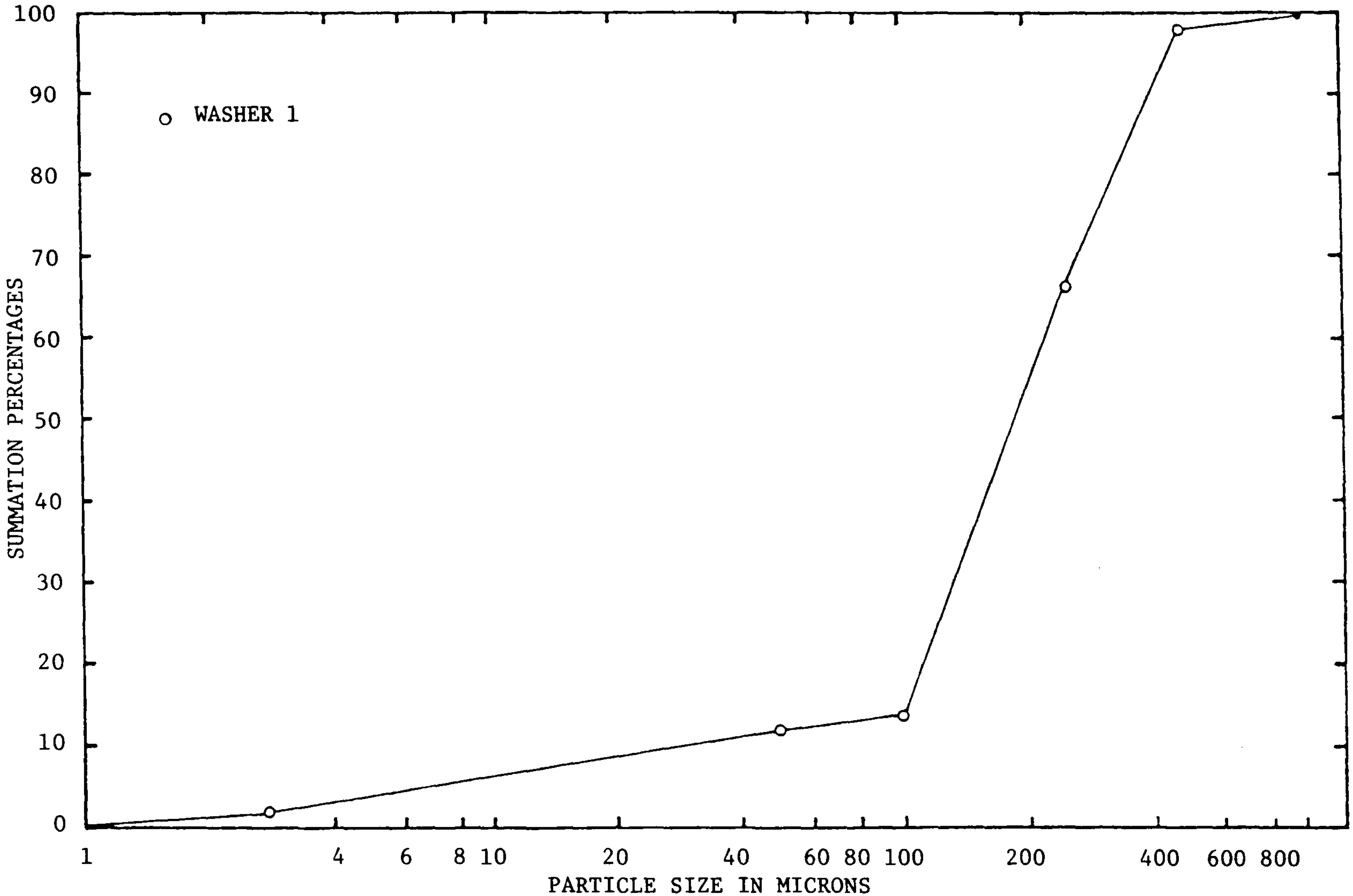


Figure 20: Summation percentages versus particle size for grit (dry weight) accumulated in first conventional washer, Trial 2, when processing spinach

lowing the trials.

Because samples of grit from the settling tanks contained significant amounts of organic matter, measurements were repeated after burning the samples in an oven. Unfortunately, sample number 6 was so small that the tests after burning could not be performed.

Particles in settling tanks had more opportunity to settle than those in the washers. The settling tanks, because of their larger volume, had lower flow velocities and longer retention time. In addition, flow in the washers was continuously disturbed by the movement of the agitation drums and streams of water from the spray nozzles. However, there was also turbulence in settling tanks caused by intermittent streams of water from the sump pumps falling through filter belts. Substitution of a gravitational system to feed the filter belts should increase not only removal efficiency of the filters but also that of the settling tanks.

Trash Accumulation.

The weight of trash collected from each filter during each trial is given in Table 27 along with moisture contents, equivalent weights of fresh product, and accumulated trash (fresh weight) per kg of washed product. Data for all trials show that more trash was collected from the second washer subsystem than from the first. Spinach produced 2.82 and 3.42 g of the trash per kg of product in washers 1 and 2, respectively. Turnip greens produced an average of 0.89 and 1.49 g of trash per kg of product in washers 1 and 2, respectively. It is possible that spinach leaves are easier to break than turnip greens and that part of

Table 27. Trash Data for Prototype Line.

Trial Number	Product	First Settling Tank				Second Settling Tank			
		Total Wet Weight (kg)	Moisture (% w.b.)**	Fresh Weight (kg)	Trash Removal* (g/kg)	Total Wet Weight (kg)	Moisture (% w.b.)**	Fresh Weight (kg)	Trash Removal* (g/kg)
1	spinach	29.937	87.315	24.723	2.82	43.091	89.325	29.948	3.42
4	turnip greens	5.103	90.650	4.930	0.61	13.608	91.750	11.599	1.45
5	turnip greens	3.400	88.470	4.329	0.64	10.886	92.430	9.099	1.34
6	turnip greens	10.886	90.830	11.333	1.42	18.597	93.650	13.407	1.68

* Fresh weight of trash per unit weight of product
** Wet basis

the trash was generated in the washers because of intensive agitation.

The trash (plant debris) contained sand. Overflow from the conventional system contained trash and a certain amount of leaves, but these went immediately into the floor drains and were thus removed from the plant. This overflow was later filtered on vibrating, inclined screens. After screening, however, it still contained some small trash particles increasing the total waste loads in the plant effluent from the conventional washers.

Grit on the Product.

Tables 28 through 31 show the variations in grit per unit weight of the fresh product at different times and at different sampling points for both the prototype and conventional systems (see Figures 5, 13, 14 for site locations). While the amount of grit in the incoming product varied considerably during the day, grit concentration in the product leaving the second washer was always relatively constant.

These data show that spinach harbors more grit than turnip greens. The maximum concentration of grit per kg of unwashed product for spinach was 22.275 g, while for turnip greens there was only 2.070g.

When spinach was processed in the prototype system, an average of 79 percent of the grit was removed, compared to an average removal of 70 percent in the conventional system. For turnip greens, 65 percent of the grit was removed in the prototype system and 56 percent in the conventional system. The greater percent of grit removal in the prototype washers was probably due to the presence of a final rinse for product leaving the second washer and the usage of three side drains, whereas in

Table 28: Milligrams of Grit per Kilogram of Product for Trial 1, Washing of Spinach Greens (After Coleman, 1976).

	HOURS OF OPERATION						
Site	.25	1.5	2	3	4	5	7
1	-	4770	-	3510	-	2925	5775
3	-	2475	-	1710	-	1665	2280
4	-	1125	-	930	-	675	645
7	10350	-	9195	-	4740	-	-
9	4050	-	4215	-	2355	-	-
10	1845	-	2595	-	2085	-	-

Table 29. Milligrams of Grit per Kilogram of Product for Trial 4, Washing of Turnip Greens (After Coleman, 1976).

	HOURS OF OPERATION			
Site	.25	2	4	5
1	2070	1560	1530	690
3	1080	855	1035	675
4	675	765	660	480
12	855	1185	750	-
14	615	750	285	-
15	375	630	270	-

Table 30. Milligrams of Grit per Kilogram of Product for Trial 5, Washing of Turnip Greens (After Coleman, 1976).

	HOURS OF OPERATION			
Site	.25	2	4	6.5
1	1005	945	1230	615
3	300	352	1410	451
4	195	300	345	242
12	615	1395	1005	-
14	300	720	570	-
15	345	510	465	-

Table 31. Milligrams of Grit per Kilogram of Product for Trial 6, Washing of Turnip Greens (After Coleman, 1976).

Site	HOURS OF OPERATION			
	.25	2	4	6.5
1	1080	1740	915	840
3	345	840	660	840
4	150	330	375	480
12	1125	750	1935	-
14	675	630	945	-
15	435	435	510	-

the conventional washers, there was only one drain below the discharge belt and no final rinse. In addition, water streams from the nozzle banks used in prototype system provided additional agitation. It was also observed that water had a different color near the exit conveyor of the second prototype washer. This was probably caused by greater dilution of the wash water, where fresh water was added. This was significant in that the water carried off with the product probably contained lower concentrations of waste than water in the second washer.

Bacteria Counts (After Coleman, 1976).

The concentration of bacteria on the product as a function of processing time is shown in Figures 21 and 22 for the prototype, and in Figures 23 and 24 for the conventional system. The data show that for the prototype line, the product leaving the system was always less contaminated than the unwashed product. This was not always true for the conventional system.

Insect Data (After Coleman, 1976).

The insect density on the product during this study was low. However, data show that product leaving the washers was less contaminated than that entering.

Product processed in the conventional washers had an average of 10 whole insects and 3 fragments per 100 g sample of input product and only 4 whole insects and 2 fragments per 100 g sample of output product (corrected to fresh weight). Product processed in the prototype line contained an average of 4 insects and 4 insect fragments per 100 g sam-

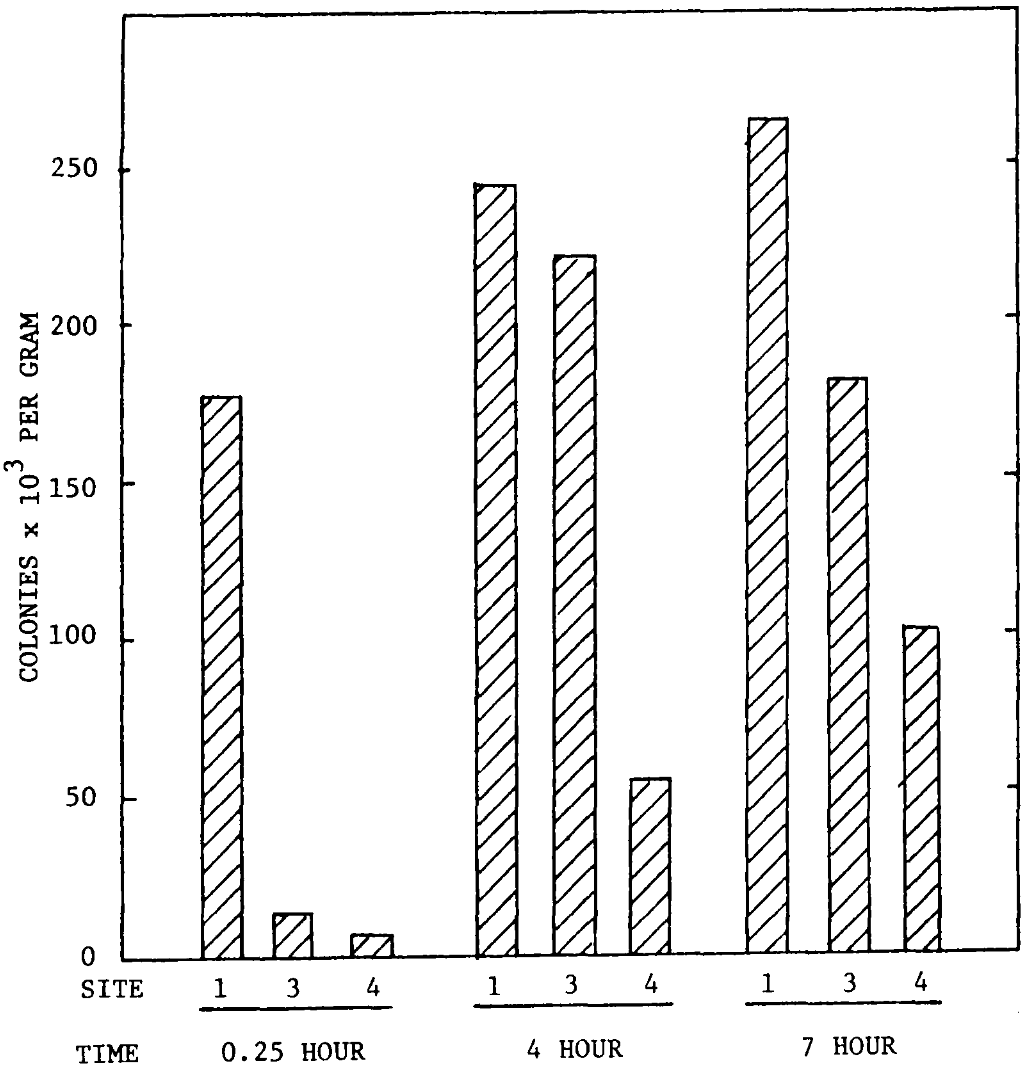


Figure 21: Total bacterial plate counts per gram of spinach at three sampling points, Trial 1, prototype system. Before washing (Site 1),exiting the first washer (Site 3), exiting the second washer (Site 4). (After Coleman,1976).

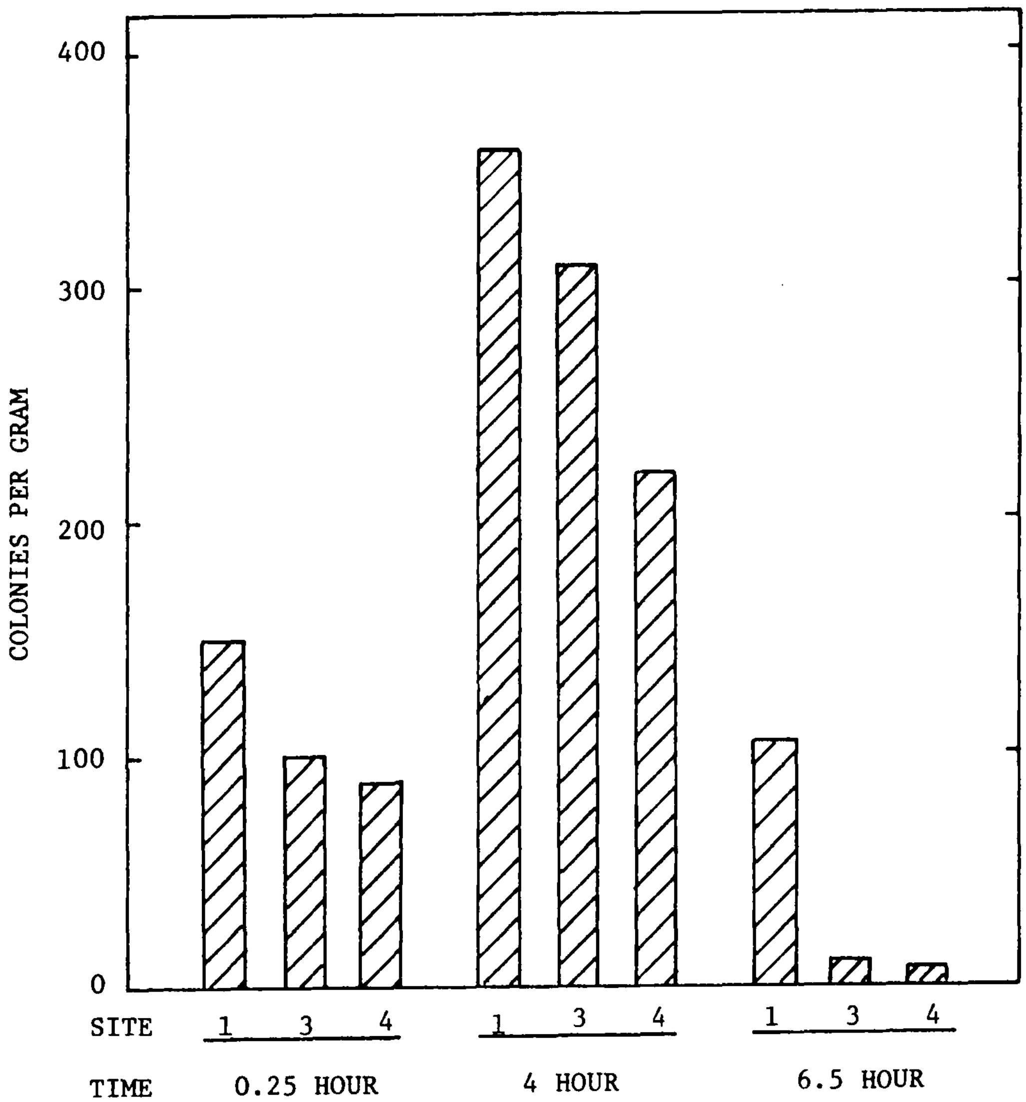


Figure 22: Total bacterial plate counts per gram of turnip greens at three sampling points, Trial 6, prototype system. Before washing (Site 1), exiting the first washer (Site 3), exiting the second washer (Site 4). (After Coleman,1976).

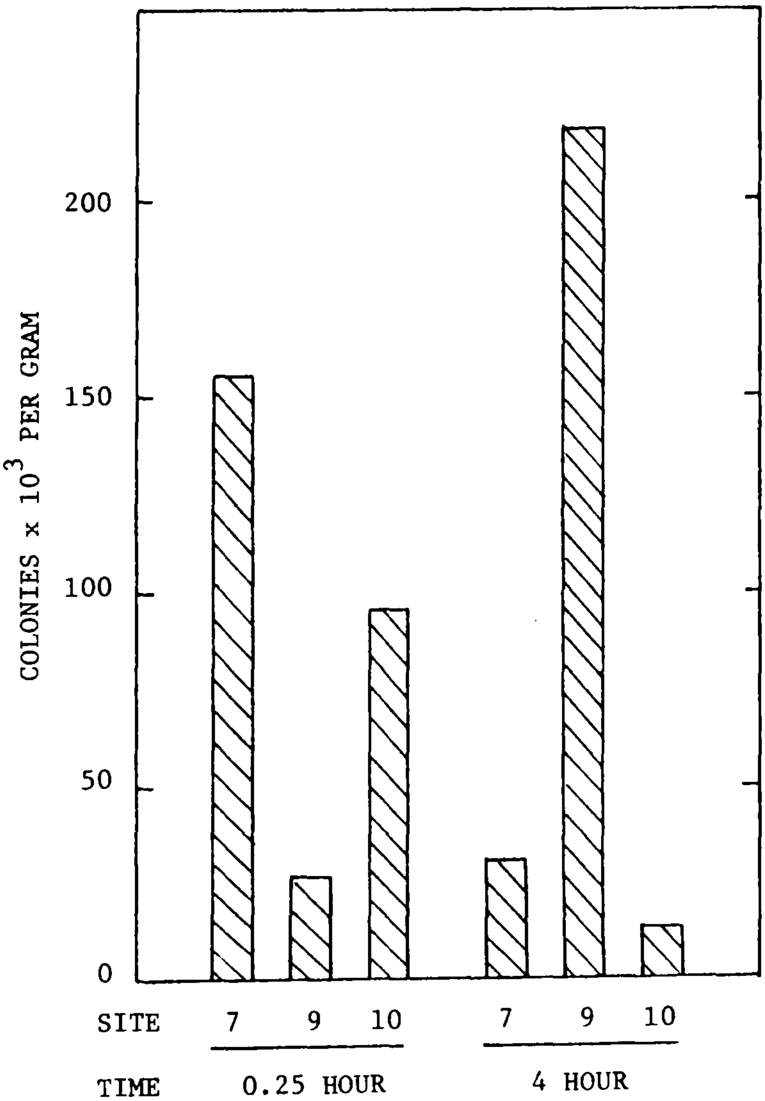


Figure 23: Total bacterial plate counts per gram of spinach at three sampling points, Trial 1. conventional system. Before washing (Site 7), exiting the first washer (Site 9), exiting the second washer (Site 10). (After Coleman,1976).

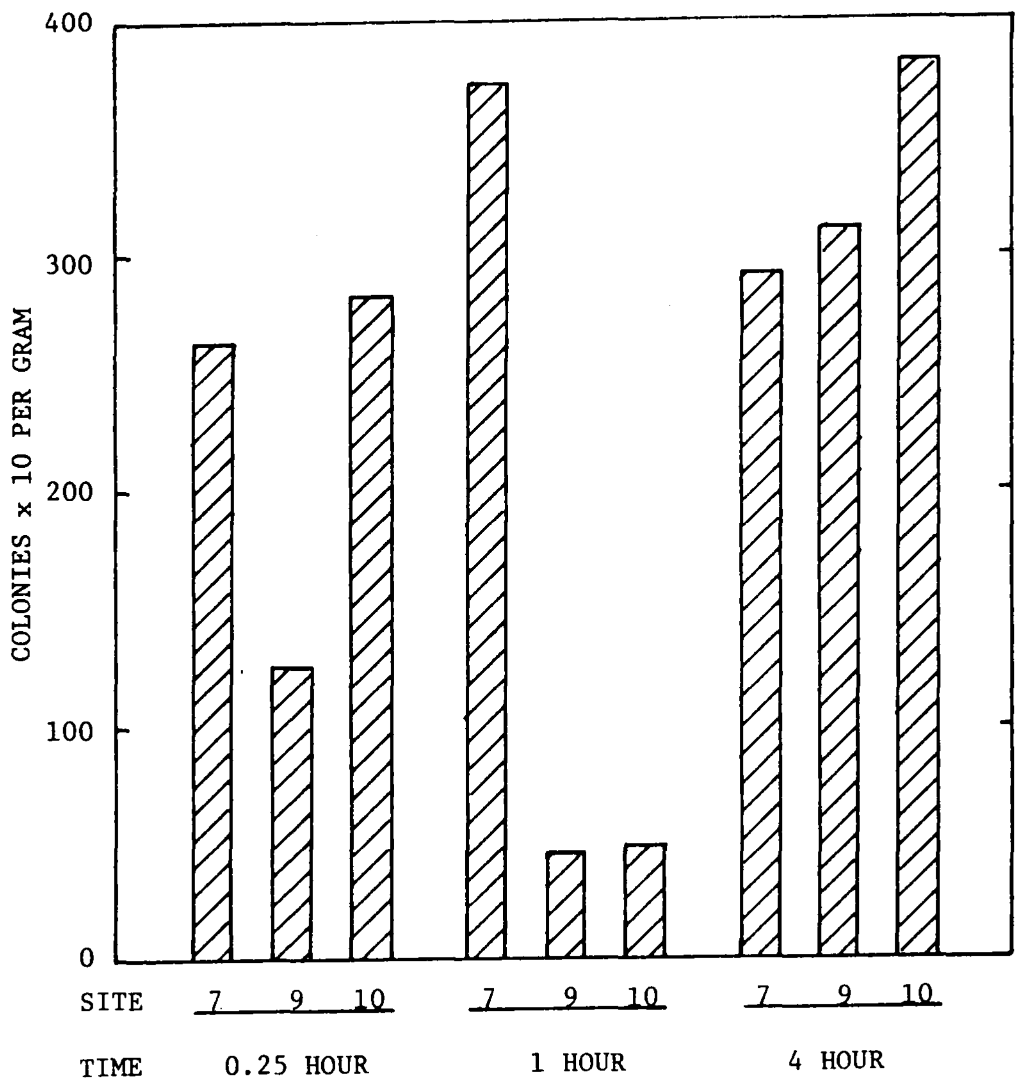


Figure 24: Total bacterial plate counts per gram of turnip greens of three sampling points, Trial 6, conventional system. Before washing (Site 7), exiting the first washer (Site 9), exiting the second washer (Site 10). (After Cpleman,1976).

ple of input product, and only 1 insect and 1 insect fragment per 100 g sample of product leaving the washers.

Waste Loads (TSS, VSS, COD).

Figure 25 shows variations in the total suspended solids for trial 6 of the prototype system; Figure 26 shows variations in volatile suspended solids for this trial; and Figure 27 shows variations in COD for this typical trial.

These figures are a condensation of Coleman's (1976) findings and some of the following explanations was contributed by him. Not all of the data collected by Coleman are shown. His complete data are presented in Appendix A of his work.

The figures show two families of plots. The difference between these two families represents the difference in water quality between the first and second washer - settling tank subsystems (sites 1, 2, 6, and sites 3, 4, 5, respectively). It can be seen that concentrations of all waste components are higher for the first subsystem, and that the rate of increase in concentration is also higher. There are two explanations for this phenomenon:

1) about 75 percent of the grit removal took place in the first washer, and
2) water in the second subsystem was diluted by fresh water input.

The first of these statements is also supported by Table 20 (presented earlier) showing the grit distribution on the bottom of each unit of the prototype system at the end of each trial. In addition, a mass accounting of the waste components in the total subsystem during all trials showed that an average of 75 percent of the waste components were contained in the first subsystem. Figures 25 and 26 for trial 6 show what seems to be typical variations in wash water quality when product was washed in the prototype system. The rapid increase of waste concentrations reaching a maximum before the lunch break, the later rapid decrease of concentration during the break, and the slow tendency to increase during the afternoon hours, appeared to be a typical pattern. The data for trial 4 deviate from this pattern, but this deviation can be explained by very low fresh water input (see Table 14).

Figures 25 through 27 show the difference in wash water quality in the input and output ends of the first washer (compare sites 1 and 2), when turnip greens were processed. Plots for sites 3 and 4 show differences in wash water quality for the second washer. The graphs show greater accumulation of TSS, VSS, and COD in the first washer indicating once again that a majority of washing process was done in the first washer.

Plots for sites 6 and 1 show the effectiveness of reducing TSS, VSS, and COD in first settling tank and plots for sites 5 and 3 provide the same information for second settling tank. It is clear from these graphs that the settling tanks reduced the concentrations of all waste components to some degree before the water was reused or discharged with the overflow.

The differences in fresh water quality were caused not only because of different flow rates of the wash water in the system, but also by different cuttings of the same product. It is also visible that spin-

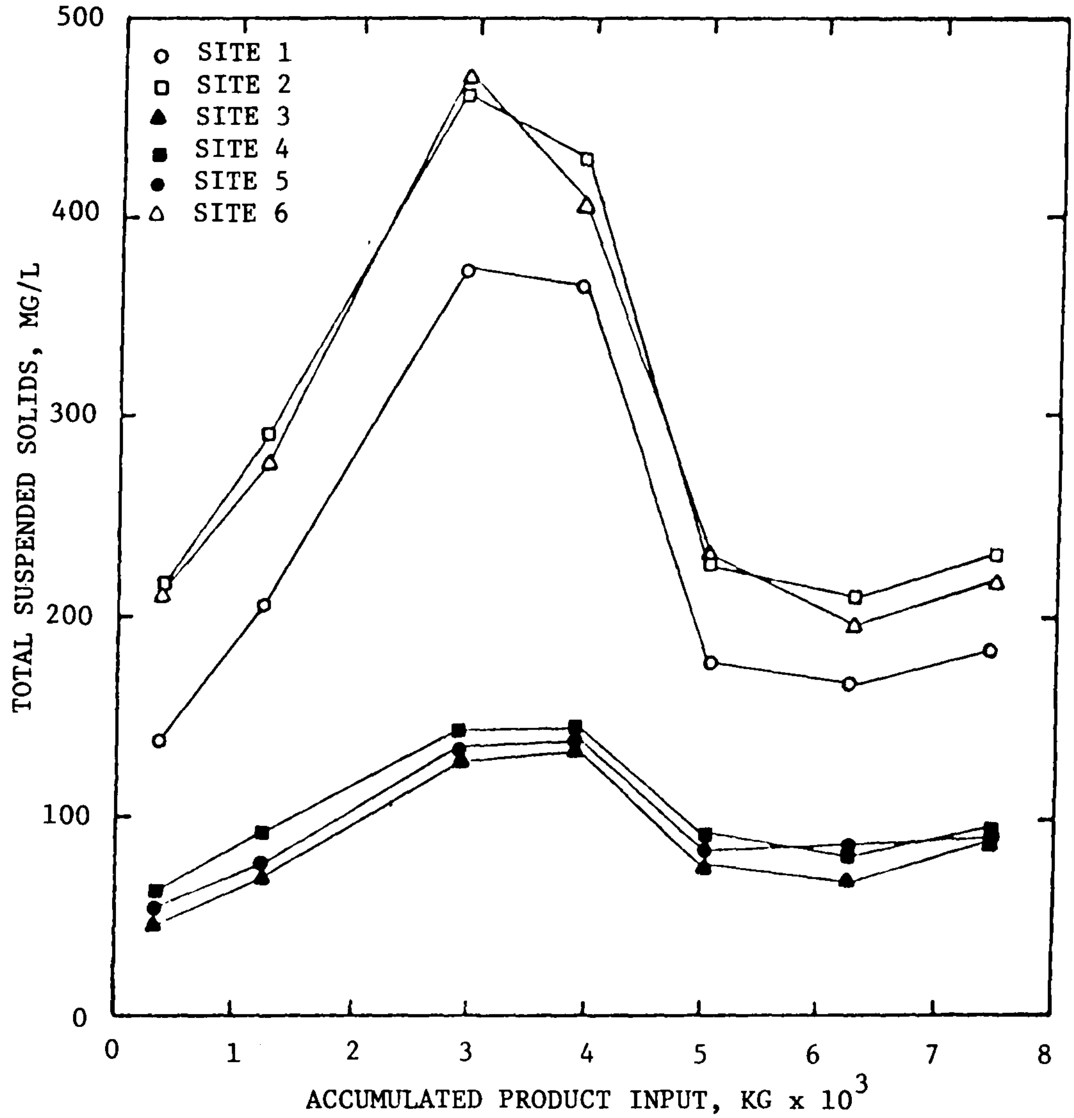


Figure 25: Variations in total suspended solids concentrations at six sampling sites, Trial 6, turnip greens processed with prototype system (After Coleman,1976).

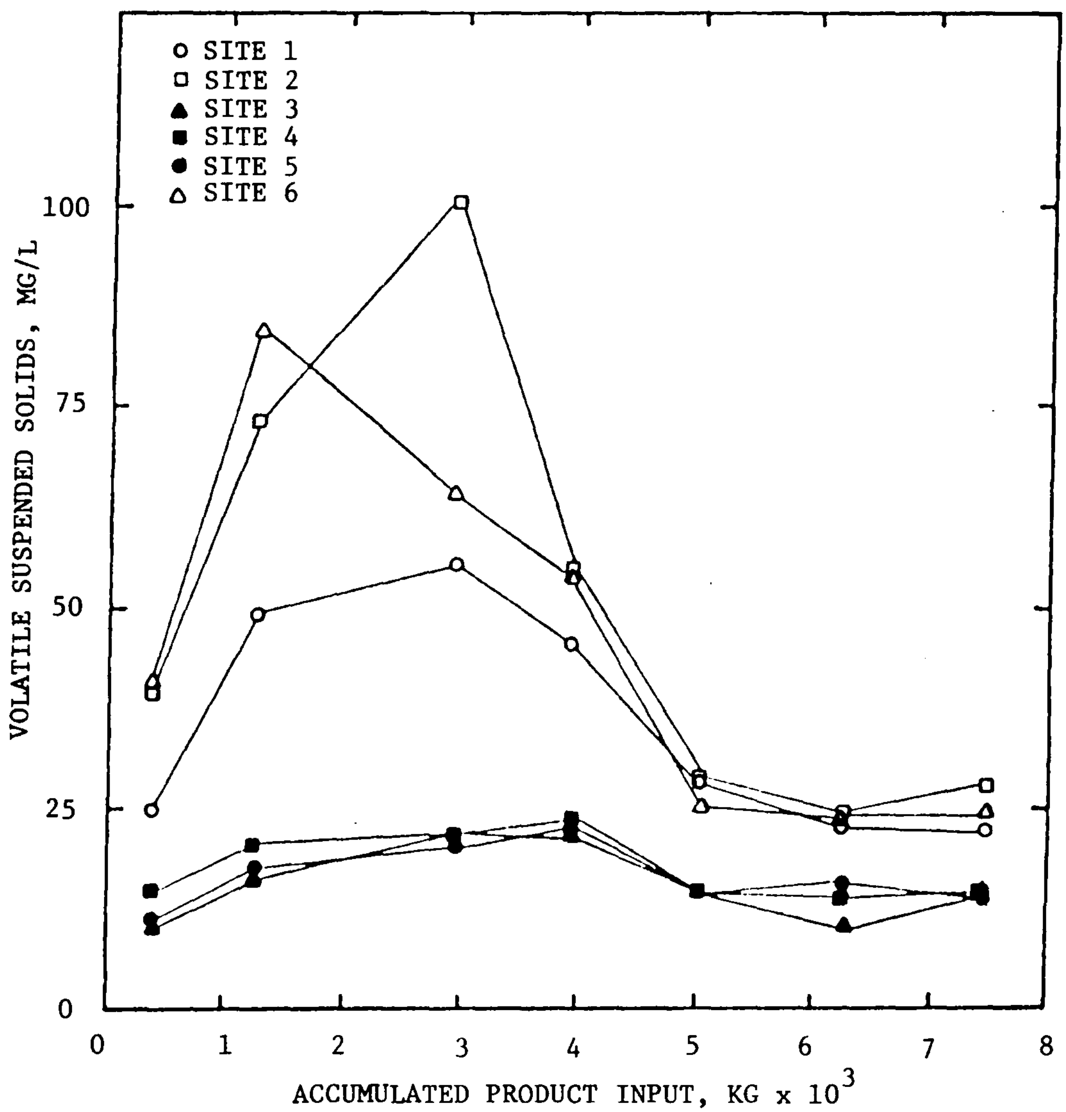


Figure 26: Variations in volatile suspended solids concentrations at six sampling sites, Trial 6, turnip greens processed with prototype system (After Coleman,1976).

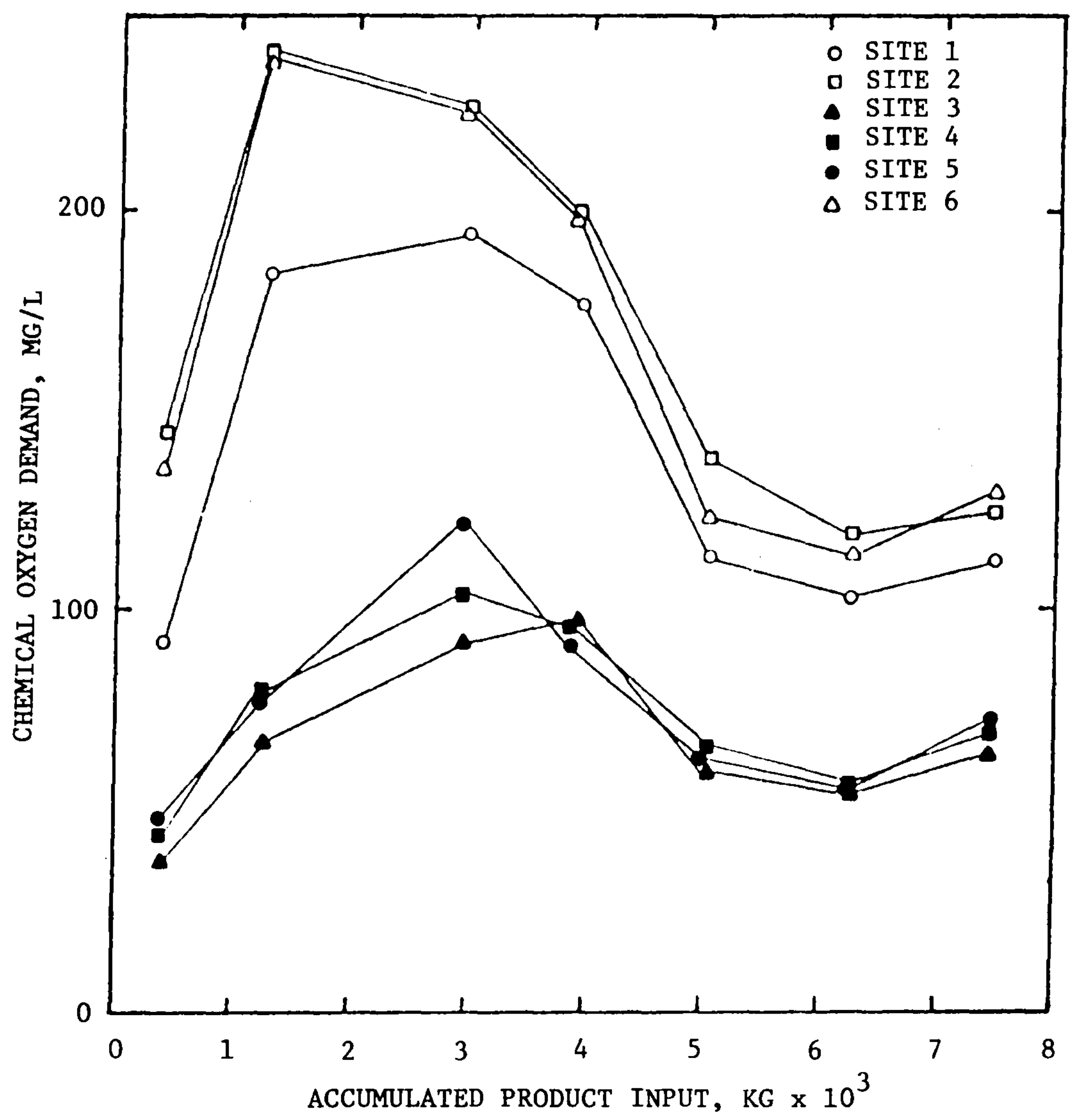


Figure 27: Variations in chemical oxygen demand concentrations at six sampling sites, Trial 6, turnip greens processed with prototype system (After Coleman,1976).

ach produced much greater concentrations of TSS than the turnip greens.

The difference in TSS between spinach and turnip greens, and between different cuttings of the same crop can be explained by variations in the growing conditions of the plants (different soil, rainfall, winds, and plantings). Generally, the higher TSS concentrations generated by the spinach can be explained by the difference in the shape and surface of spinach and turnip green leaves. Convoluted spinach leaves can harbor more dirt, and they grow closer to ground, enabling them to be more subjected to contanimation by soil.

The variable concentrations of COD and VSS with different cuttings may be explained by different ages of the plants. It is possible that because younger vegetables have thinner cuticles, they are more easily broken or bruised during washing. Leaching of organic matter from the greater surface area of broken leaves would be greater and, as a result, the concentration of VSS and COD could be higher. Additionally, the variation of concentrations of all waste components were dependent on different fresh water input rates (Tables 17, 18, 19).

Generally, TSS concentrations were higher in the input end of the washer than in the output end; the reverse was true for COD and VSS. However, these differences were very small.

Overflow rates in the conventional system were less variable than those in the prototype. However, variations in concentrations of TSS, VSS, and COD were higher for the conventional trials. A characteristic pattern of rapid increase in waste concentrations, and later rapid decrease, followed by stabilization was also observed in the conventional trials. This pattern in the conventional trials is hard to explain sim-

ply by the dilution of the fresh water, because in most of these trials, measurements were made only in the first half of the night shift.
In trial 6, however, the concentration of waste components increased continuously during trial, but probably the trial was too short to observe the later stages of decrease and stabilization.

This typical pattern can be explained under the condition that at the beginning of the trial the concentration of grit on the product was higher than later or that the removal efficiency of washers filled with fresh water was higher than later in the trials after the water become contaminated. Another possible, but not very likely explanation, is that the water viscosity decreased during the washing process, increasing the grit sedimentation velocity.

Input flow rates to the second conventional washer in each trial were about one-third of those to the first. This explains the tendency toward uniformity between waste concentrations in the effluents of the first and second washers.

Figures 28 through 30 show typical concentrations of TSS and COD in the water during trial 1 when spinach greens were processed with the conventional system. The differences in TSS for different trials were very significant (those for trial 2 were 13 times greater than those for trial 3), and can only be explained by the different concentrations of grit on the incoming product. As before, differences in waste-component concentrations for spinach and turnip greens are easy to observe.

Total Waste Loads.

Tables 32 and 33 show the waste loads generated during the trials

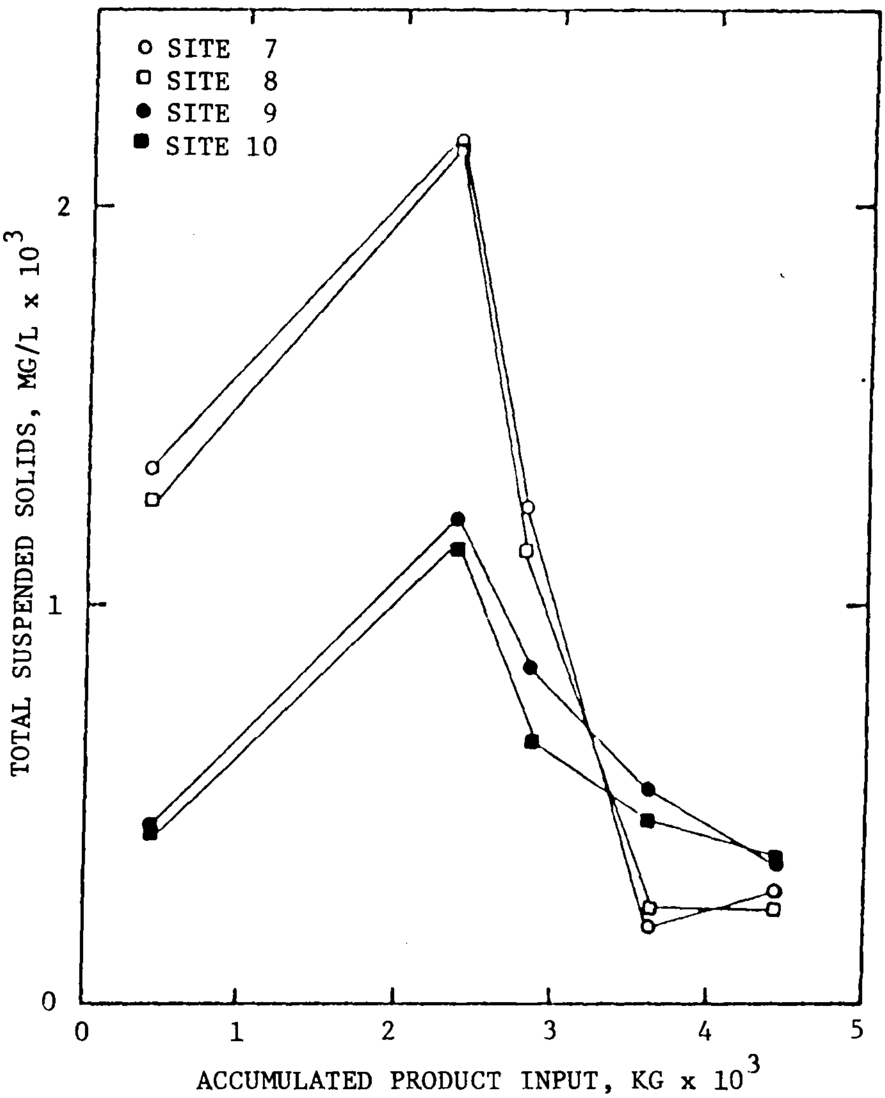


Figure 28: Variations in total suspended solids at four sampling sites, Trial 1, spinach processed with conventional washer, Sites 7 and 8 represent first washer, Sites 9 and 10 second washer (After Coleman,1976).

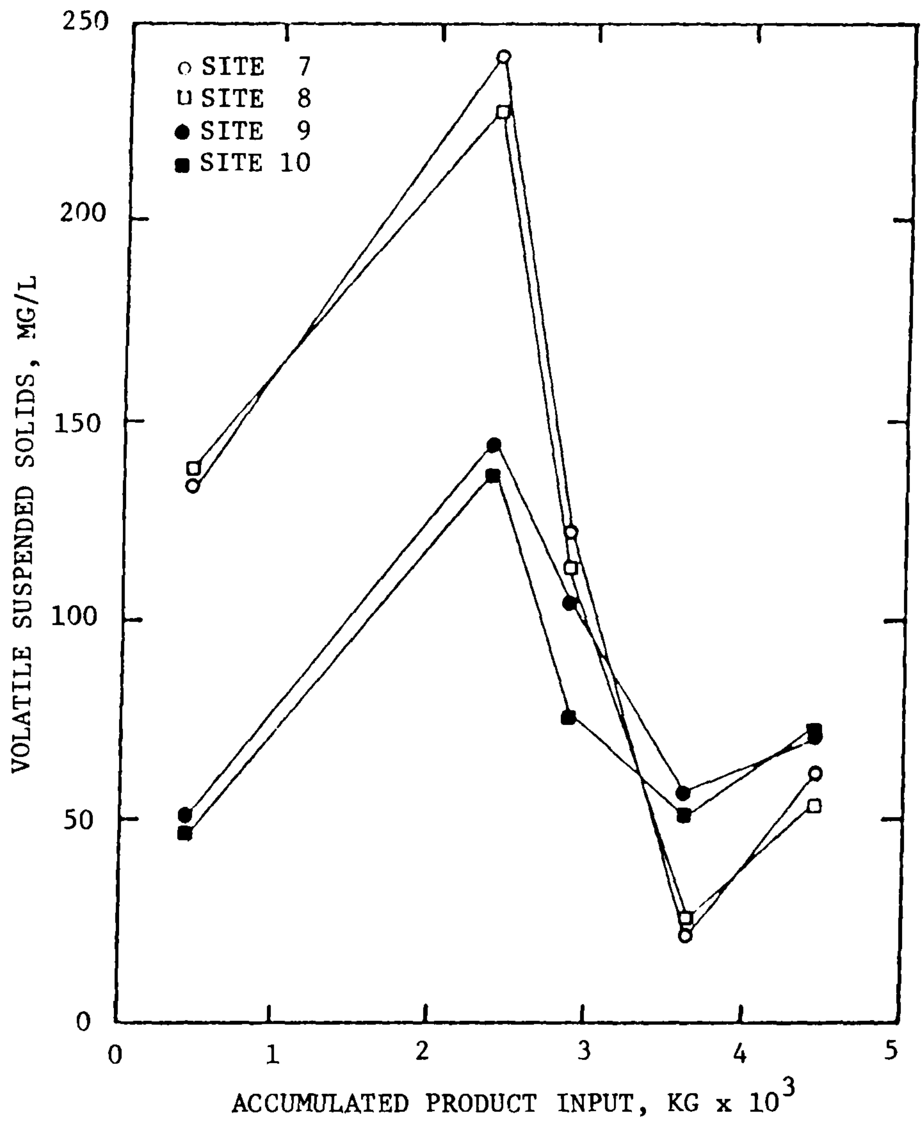


Figure 29: Variation in volatile suspended solids at four sampling sites, Trial 1, spinach processed with conventional system (After Coleman,1976).

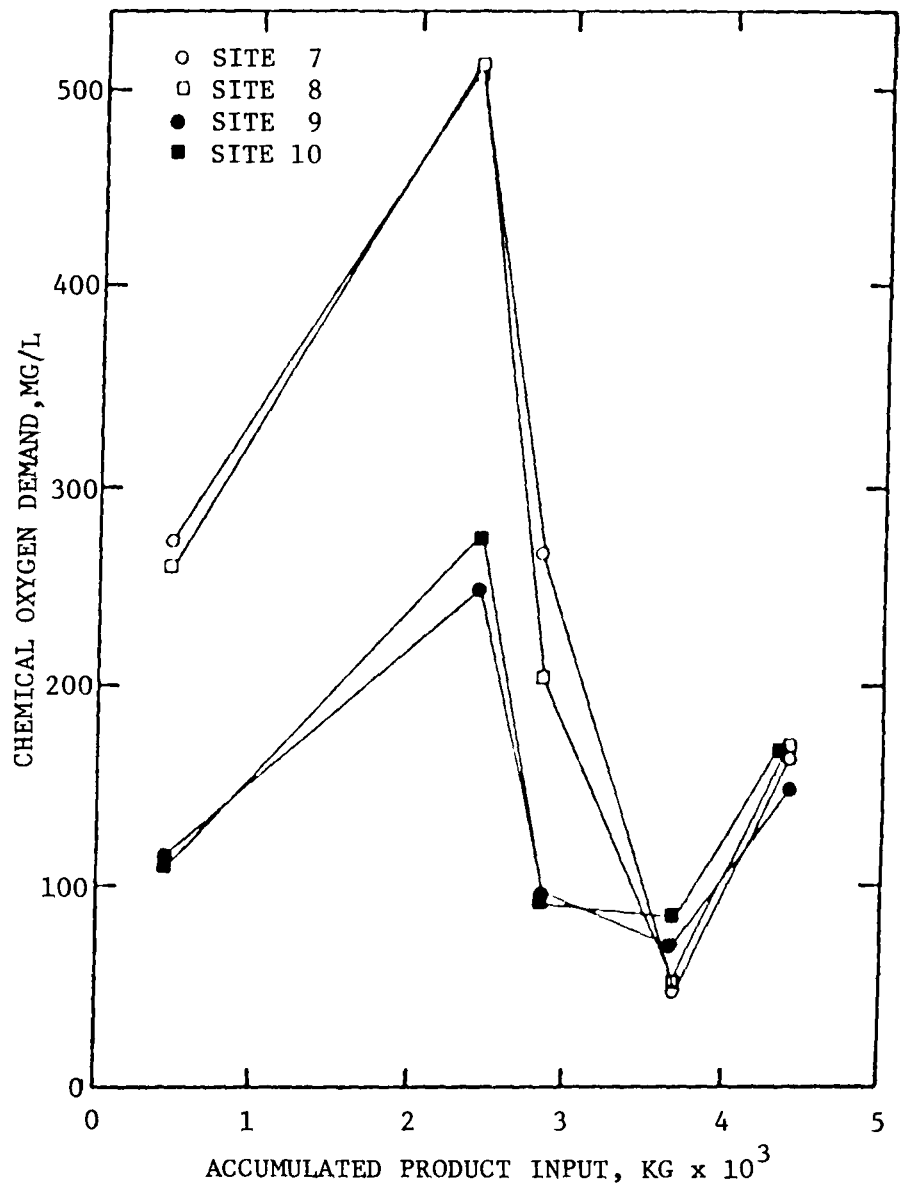


Figure 30: Variation in chemical oxygen demand at four sampling sites, Trial 1, spinach processed with the conventional system (After Coleman,1976).

Table 32. Waste Loads Generated During the Processing of Spinach and Turnip Greens and Their Distribution Within the Experimental Washing System (After Coleman,1976).

Leafy Greens	Tons Processed	Waste* Source	Waste Load, lb/ton and per cent of total TSS	VSS	COD
Spinach (Trial 1)	9.54	A	1.29 (25.4%)	0.21 (26.6%)	0.73 (32.4%)
		B	1.94 (38.2%)	0.30 (38.0%)	0.78 (34.7%)
		C	1.85 (36.4%)	0.28 (35.4%)	0.74 (32.9%)
		TOTAL	5.08 (100%)	0.79 (100%)	2.25 (100%)
Turnip (Trial 4)	8.82	A	0.85 (38.1%)	0.13 (44.8%)	0.39 (35.2%)
		B	0.11 (4.9%)	0.02 (6.9%)	0.04 (3.6%)
		C	1.27 (57.0%)	0.14 (48.3%)	0.68 (61.2%)
		TOTAL	2.23 (100%)	0.29 (100%)	1.11 (100%)
Turnip (Trial 5)	7.31	A	0.38 (32.5%)	0.08 (38.1%)	0.26 (27.7%)
		B	0.40 (34.2%)	0.06 (28.6%)	0.30 (31.9%)
		C	0.39 (33.3%)	0.07 (33.3%)	0.38 (40.4%)
		TOTAL	1.17 (100%)	0.21 (100%)	0.94 (100%)
Turnip (Trial 6)	8.22	A	0.11 (6.9%)	0.02 (8.3%)	0.08 (8.2%)
		B	1.05 (65.6%)	0.16 (66.7%)	0.63 (64.3%)
		C	0.44 (27.5%)	0.06 (25.0%)	0.27 (27.5%)
		TOTAL	1.60 (100%)	0.24 (100%)	0.98 (100%)

* A - Carried out on product
B - Discharged from settling Tank #1
C - Remaining in system at end of processing

Table 33. Waste Loads Generated during the Processing of Spinach and Turnip Greens and Their Distibution Within the Conventional Washing System (After Coleman, 1976).

Leafy Greens	Tons Processed	Waste* Source	Waste Load, lb/ton and percent of total		
			TSS	VSS	COD
Spinach (Trial 1)	4.85	A	1.92 (7.1%)	0.23 (7.4%)	0.42 (4.8%)
		B	24.19 (90.0%)	2.73 (87.8%)	7.86 (90.8%)
		C	0.77 (2.9%)	0.15 (4.8%)	0.38 (4.4%)
		TOTAL	26.88 (100%)	3.11 (100%)	8.66 (100%)
Spinach (Trial 2)	13.37	A	4.64 (31.9%)	0.43 (28.3%)	0.70 (32.0%)
		B	9.04 (62.2%)	1.02 (67.1%)	1.31 (59.8%)
		C	0.85 (5.9%)	0.07 (4.6%)	0.18 (8.2%)
		TOTAL	14.53 (100%)	1.52 (100%)	2.19 (100%)
Spinach (Trial 3)	5.66	A	0.87 (9.9%)	0.16 (10.3%)	0.60 (9.3%)
		B	7.10 (80.4%)	1.24 (79.4%)	5.17 (79.9%)
		C	0.86 (9.7%)	0.16 (10.3%)	0.70 (10.8%)
		TOTAL	8.83 (100%)	1.56 (100%)	6.47 (100%)
Turnip	6.09	A	0.38 (7.5%)	0.07 (10.3%)	0.72 (11.1%)
		B	4.52 (89.2%)	0.58 (85.3%)	5.47 (84.2%)
		C	0.17 (3.3%)	0.03 (4.4%)	0.31 (4.7%)
		TOTAL	5.07 (100%)	0.68 (100%)	6.50 (100%)

*A - Carried out on product
B - Discharged from washers #1 and #2
C - Remaining in system at end of processing

Table 33. (continued)

Leafy Greens	Tons Processed	Waste* Source	Waste Load, lb/ton and percent of total		
			TSS	VSS	COD
Turnip (Trial 5)	6.54	A	0.13 (4.7%)	0.04 (6.3%)	0.53 (8.8%)
		B	2.48 (90.6%)	0.57 (89.1%)	5.13 (85.2%)
		C	0.13 (4.7%)	0.03 (4.6%)	0.36 (6.0%)
		TOTAL	2.74 (100%)	0.64 (100%)	6.02 (100%)
Turnip (Trial 6)	4.91	A	0.15 (5.7%)	0.02 (4.8%)	0.30 (7.8%)
		B	2.28 (87.4%)	0.38 (90.4%)	3.23 (83.7%)
		C	0.18 (6.9%)	0.02 (4.8%)	0.33 (8.5%)
		TOTAL	2.61 (100%)	0.42 (100%)	3.86 (100%)

*A - Carried out on product
B - Discharged from washers #1 and #2
C - Remaining in system at end of processing

and their sources. In trial 4 less than 6 percent of the total waste components were removed from the subsystem with overflow, while the average is 45 percent of the total waste for the other trials.

Grit Suspended in the Water.

Data for the grit suspended in the water of the units of the prototype system are presented in Table 34 as a function of processing time. These data were obtained from the water quality data by subtracting the concentration of volatile suspended solids from concentration of total suspended solids for each observation. These data were of special importance because they formed a basis to evaluate the mathematical model of the prototype system that will be discused in the next chapter.

Table 34. Experimental Data of Grit Concentrations in the Water of Units of the Prototype System.

Trial Number	Time from Start (min)	First Washer (mg/l)	First Settling Tank (mg/l)	Second Washer (mg/l)	Second Settling Tank (mg/l)
1	0	0	0	0	0
	15	278	217	69	61
	60	1001	569	83	84
	140	1425	945	327	310
	200	1416	1031	471	440
	320	441	733	127	384
	415	942	653	297	267
	475	559	597	272	222
	525	1092	788	339	263
4	0	0	0	0	0
	15	288	97	98	57
	65	483	326	196	124
	125	467	354	170	192
	250	415	386	220	180
	335	540	526	244	241
	425	568	418	288	287
5	0	0	0	0	0
	15	82	61	19	23
	65	182	148	73	67
	145	174	136	-	-
	205	453	346	130	120
	350	288	232	99	134
	430	157	132	56	89
	525	130	110	59	56
6	0	0	0	0	0
	15	177	113	48	36
	95	217	155	70	51
	190	359	320	118	106
	310	375	319	118	112
	370	195	151	76	64
	460	188	143	66	61
	515	204	160	77	75

THE MATHEMATICAL MODEL

Introduction.

Knowledge of all phenomena occurring in a technical device and the ability to predict all operating parameters are very valuable. Such knowledge makes possible the development and modification of models that can be tested for effectiveness without building and testing many prototypes. This modeling saves time and money and also helps to determine optimum design.

In the case of recirculating immersion washers for leafy-vegetables one must be able to choose water flow rates and capacity of settling tanks to optimize quality of the final product and obtain the highest production capacity for a given quantity of input product. At the same time, it is important to limit fresh water consumption and minimize waste of valuable product components, while keeping waste effluent as low as possible.

This work was an attempt to build a general model of a leafy-vegetable washing system using a theoretical approach in conjunction with experimental work. Because a mathematical description of all phenomena acting on the system was not possible, simplifying assumptions were made in some cases.

The prototype washing system was described by a set of differential equations which were not amenable to analytical solutions but could be solved by numerical methods with the aid of a digital computer. Numerical analyses are not error free but do allow solution of problems otherwise unsolvable and usually give approximations sufficiently accurate for implementation.

Assumptions.

1. The rate of change of grit concentration in the water in any unit of the prototype system was calculated on the basis of mass balance. The rate of change of grit concentration in the water at any time in any unit during a given trial was equal to the rate of grit input from all input sources, minus the rate of grit output from all outputs from the unit, divided by volume of the unit. Grit settled at the bottom of the unit was considered as removed.

2. Volume changes in the washer units due to changing water levels were considered negligible.

3. Incoming product to the first washer was uniformly "dirty".

4. Output product contained the amount of grit per unit weight as indicated by the hand washing tests (see Materials and Methods).

5. A simple coefficient of sedimentation was sufficient to describe the grit settling in a unit from an input flow, although it is known that sedimentation is a function of grit concentration in the water of each unit, flow rate of wash water, and grit size distribution.

6. Grit particles were assumed either to settle out in their "first pass" through a unit, or to stay in suspension for the total trial. This was also an approximation because flow rates through the washers and settling tanks varied and, therefore, so did retention time.

7. Grit particles in the overflow from the second settling tank were considered too small to settle in the first settling tank.

8. Water removed with the product from the first washer had the same grit concentration as water in the washer.

9. Because of the final rinse on the exit elevator, water removed with the product from the second washer had a lower concentration of grit than that in the second washer.

10. All leakage, such as water carried out of the system with trash, water spilled from the filter belts, and other minor leaks, was negligible.

11. Absorption of water by the product during the washing process was negligible.

12. Washing effectiveness (the percent grit removal in each washer) was constant during the whole trial regardless of the grit concentration in the water and the effect of foam in the water.

13. The flow rate of product between measurements was constant.

14. The amount of water carried out of the system per kg of product from each washer was constant during a trial.

15. All water flow rates were constant during any five-minute interval.

Model Derivation.

A schematic diagram of the prototype circulation is shown in Figure 31. According to assumption 1 above, the concentration of grit in each unit, at time t_2 starting from time t_1 (for a given initial grit concentration at t_1) was equal to the integral of all input flows of grit, minus all output flows divided by volume of the unit. On this basis and the other assumptions, the following equations were written:

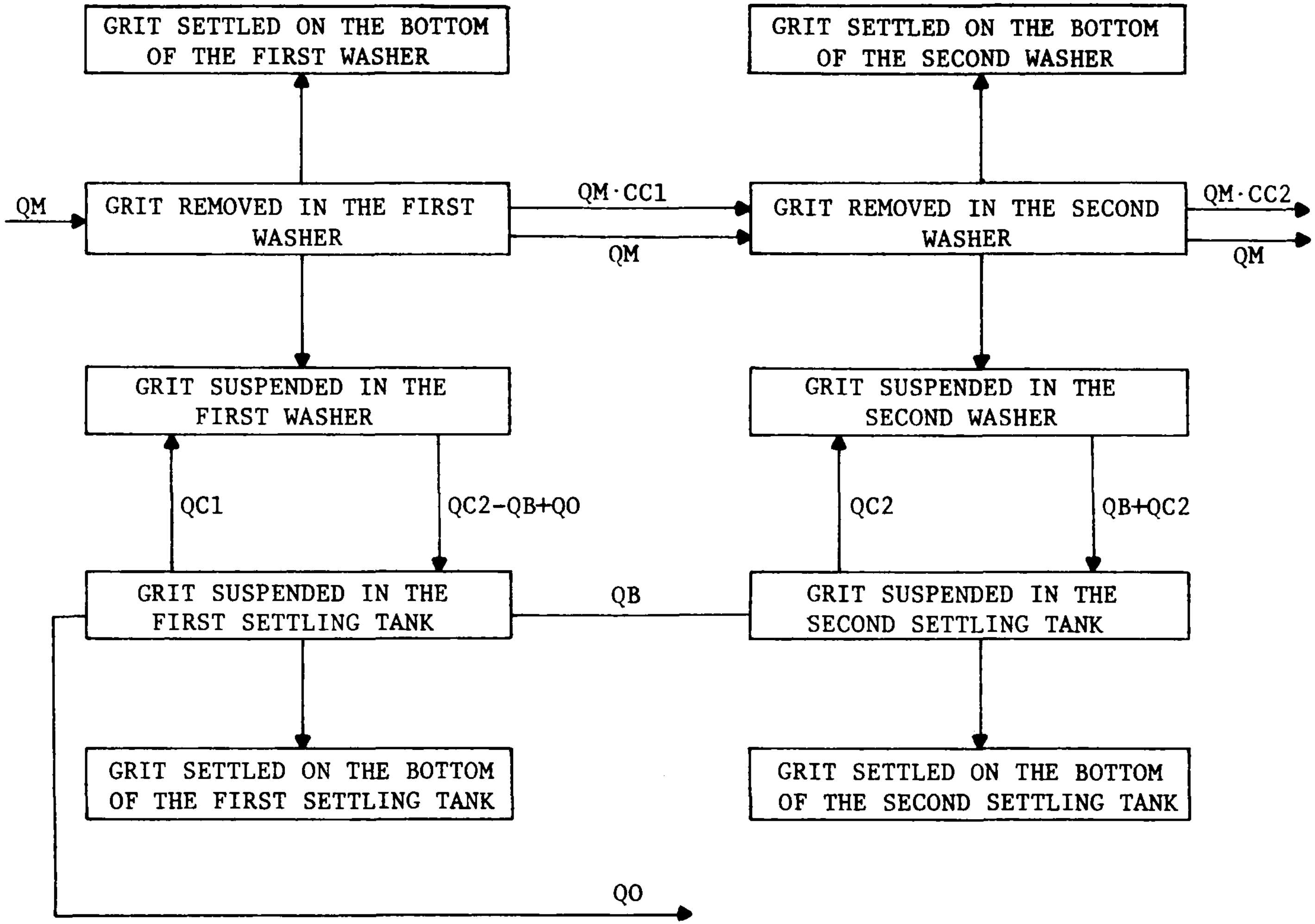


Figure 31: Schematic diagram of grit distribution.

$$Y(1) = \frac{1}{V1}\left\{\int_{t_1}^{t_2} Z\cdot C1\cdot QM\cdot dt + \int_{t_1}^{t_2} QC1\cdot Y(2)\cdot dt - \int_{t_1}^{t_2} (QC1 + QO - QB)\cdot Y(1)\cdot dt\right.$$

$$\left. - \int_{t_1}^{t_2} Z\cdot C1\cdot QM\cdot K1\cdot dt - \int_{t_1}^{t_2} QM\cdot CC1\cdot Y(1)\cdot dt\right\} \qquad (5)$$

$$Y(2) = \frac{1}{V2}\left\{\int_{t_1}^{t_2} (QC1 + QO - QB)\cdot dt + \int_{t_1}^{t_2} QB\cdot Y(4)\cdot dt - \int_{t_1}^{t_2} (QC1 + QO)\cdot Y(2)\cdot dt\right.$$

$$\left. - \int_{t_1}^{t_2} K2\cdot (QC1 + QO - QB)\cdot Y(1)\cdot dt\right\} \qquad (6)$$

$$Y(3) = \frac{1}{V3}\left\{\int_{t_1}^{t_2} Z\cdot C2\cdot QM\cdot dt + \int_{t_1}^{t_2} Q\cdot C2\cdot Y(4)\cdot dt - \int_{t_1}^{t_2} (QC2 + QB)\cdot Y(3)\cdot dt\right.$$

$$\left. - \int_{t_1}^{t_2} Z\cdot C2\cdot K3\cdot QM\cdot dt + \int_{t_1}^{t_2} QM\cdot CC1\cdot Y(1)\cdot dt - \int_{t_1}^{t_2} QM\cdot CC2\cdot Y(2)\cdot WW\cdot dt\right\} \qquad (7)$$

$$Y(4) = \frac{1}{V4}\left\{\int_{t_1}^{t_2} (QC2 + QB)\cdot Y(3)\cdot dt - \int_{t_1}^{t_2} (QC2 + QB)\cdot K4\cdot Y(3)\cdot dt\right.$$

$$\left. - \int_{t_1}^{t_2} QB\cdot Y(4)\cdot dt - \int_{t_1}^{t_2} QC2\cdot Y(4)\cdot dt\right\} \qquad (8)$$

where: Y(1) = concentration of grit suspended in the water in the first washer (mg/l);

Y(2) = concentration of grit suspended in the water in the first settling tank (mg/l);

Y(3) = concentration of grit suspended in the water in the second washer (mg/l);

Y(4) = concentration of grit suspended in the water in the second settling tank (mg/l);

K1 = sedimentation coefficient for the first washer (1); (decimal percent of grit removed from the product in first washer that settled in the bottom of the washer);

K2 = sedimentation coefficient for the first settling tank (1); (decimal percent of grit introduced to the settling tank with overflow from first washer that settled in the bottom of the settling tank);

K3 = sedimentation coefficient for the second washer (1); (decimal percent of grit removed from the product in second washer that settled in the bottom of the washer);

K4 = sedimentation coefficient for the second settling tank (1); (decimal percent of grit introduced to the settling tank with overflow from the second washer that settled in the bottom of the settling tank);

CC1 = the amount of water carried with the product from the first washer to the second washer (l/kg);

CC2 = the amount of water carried with the product from the second washer out of the system (l/kg);

C1 = grit removal efficiency for the first washer (1); (decimal percent of initial grit content on the product removed in the washer);

C2 = grit removal efficiency for the second washer (1); (decimal percent of initial grit content on the product removed in the washer);

Z = initial grit content on the product (mg/kg);

QO = rate of overflow to waste from the first settling tank (1/min);

QB = rate of overflow from the second to the first settling tank (1/min);

QC1 = rate of recirculation for the first washer - settling tank subsystem (1/min);

QC2 = rate of recirculation for the second washer - settling tank subsystem (1/min);

QM = product flow rate (kg/min);

V1 = volume of the first washer (1);

V2 = volume of the first settling tank (1);

V3 = volume of the second washer (1);

V4 = volume of the second settling tank (1);

WW = dilution factor (1); (decimal proportion of grit concentration in the water carried out with product to the grit concentration in the water in second washer).

The concentration of grit in the water leaving the first washer (Y(1), equation (5)), was equal to the sum of the incoming grit from all sources minus the sum of grit leaving the washer by all outputs, divided by its volume. The terms on the right hand side of equation (5) are explained as follows:

The input expressions are:

a) $\int_{t_1}^{t_2} Z \cdot C1 \cdot QM \cdot dt$ - represents the amount of grit removed from the product in the first washer;

b) $\int_{t_1}^{t_2} QC1 \cdot Y(2) \cdot dt$ - represents the amount of grit introduced to the washer with the recirculation flow;

The output expressions are:

a) $-\int_{t_1}^{t_2} (QC1 + QO - QB) \cdot Y(1) \cdot dt$ - represents the amount of grit removed from the first washer with the overflow to first settling tank;

b) $-\int_{t_1}^{t_2} Z \cdot C1 \cdot QM \cdot K1 \cdot dt$ - represents the amount of grit settled in the first washer;

c) $-\int_{t_1}^{t_2} QM \cdot CC1 \cdot Y(1) \cdot dt$ - represents the amount of grit removed from the first washer, suspended in the water carried from the first washer by the leaving product.

The terms in equation (6) describing the concentration Y(2) in the water of the first settling tank are as follows:

The input expressions are:

a) $\int_{t_1}^{t_2} (QC1 + QO - QB) \cdot Y(1) \cdot dt$ - represents the amount of grit introduced from the first washer into the first settling tank;

b) $\int_{t_1}^{t_2} QB \cdot Y(4) \cdot dt$ - represents the amount of grit introduced from the second settling tank into the first settling tank with the overflow from the second settling tank.

The output expressions are:

a) $-\int_{t_1}^{t_2} (QC1 + QO)\cdot Y(2)\cdot dt$ - represents the amount of grit removed from the first settling tank with overflow to waste and with the recirculation flow;

b) $-\int_{t_1}^{t_2} K2\cdot(QC1 + QO - QB)\cdot Y(1)\cdot dt$ - represents the amount of grit settled in the first settling tank from the overflow from the first washer.

The terms in equation (7) describing the concentration Y(3) in the water of the second washer are as follows:

The input expressions are:

a) $\int_{t_1}^{t_2} Z\cdot C2\cdot QM\cdot dt$ - represents the amount of grit removed from the product in the second washer;

b) $\int_{t_1}^{t_2} QC2\cdot Y(4)\cdot dt$ - represents the amount of grit introduced to the second washer with the recirculation flow;

c) $\int_{t_1}^{t_2} QM\cdot CC1\cdot Y(1)\cdot dt$ - represents the amount of grit introduced to the second washer with water carried from the first washer by the leaving product.

The output expressions are:

a) $-\int_{t_1}^{t_2} (QC2 + QB)\cdot Y(3)\cdot dt$ - represents the amount of grit removed from the second washer with the overflow;

b) $-\int_{t_1}^{t_2} Z \cdot C2 \cdot K3 \cdot QM \cdot dt$ - represents the amount of grit settled in the second washer;

c) $-\int_{t_1}^{t_2} QM \cdot CC2 \cdot Y(2) \cdot WW \cdot dt$ - represents the amount of grit carried with the water by the product leaving the second washer.

The terms in equation (8) describing the concentration Y(4) in the water of the second settling tank are as follows:

The input expression is:

a) $\int_{t_1}^{t_2} (QC2 + QB) \cdot Y(3) \cdot dt$ - represents the amount of grit introduced from the second washer into the second settling tank.

The output expressions are:

a) $-\int_{t_1}^{t_2} (QC2 + QB) \cdot K4 \cdot Y(3) \cdot dt$ - represents the amount of grit settled in the second settling tank;

b) $-\int_{t_1}^{t_2} QB \cdot Y(4) \cdot dt$ - represents the amount of grit leaving the second settling tank with the overflow to the first settling tank;

c) $-\int_{t_1}^{t_2} QC2 \cdot Y(4) \cdot dt$ - represents the amount of grit leaving the second settling tank with the recirculation flow.

Taking the derivatives of both sides of each of the above equations and simplifying, yields the following:

$$\frac{dY(1)}{dt} = \frac{1}{V1}\left\{ QC1 \cdot Y(2) - (QC1,+ QO - QB) \cdot Y(1) + Z \cdot C1 \cdot QM \cdot (1 - K1) - QM \cdot CC1 \cdot Y(1) \right\} \quad (9)$$

$$\frac{dY(2)}{dt} = \frac{1}{V2}\left\{ (QC1 + QO - QB) \cdot Y(1) + QB \cdot Y(4) - Y(2) \cdot (QC1 + QO) - K2 \cdot Y(1) \cdot (QC1 + QO - QB) \right\} \quad (10)$$

$$\frac{dY(3)}{dt} = \frac{1}{V3}\left\{ Y(4) \cdot QC2 - Y(3) \cdot (QC2 + QB) + (1 - K3) \cdot Z \cdot C2 \cdot QM + QM \cdot CC1 \cdot Y(1) - QM \cdot CC2 \cdot Y(3) \cdot WW \right\} \quad (11)$$

$$\frac{dY(4)}{dt} = \frac{1}{V4}\left\{ (QC2 + QB)\left[Y(3) - Y(4) - K4 \cdot Y(3) \right] \right\} \quad (12)$$

The previous equations were solved using Runge-Kutta methods for different values of the dilution factor WW and, consequently, different values of Z, C1, C2.

The input data (flow rates of product and water) were set up in arrays, with five-minute intervals. The equations were solved simultaneously several times for each trial. After each solution for 5 minutes, values of concentrations at the end of the time interval were taken as initial conditions for the next equation. Values of Z (initial grit content on the product) were calculated as the sum of grit collected from bottom of the units of the system, plus the amount of grit suspended in the overflow leaving the first settling tank, plus the amount of grit suspended in the water on the product leaving the second washer, and grit residuals on the product leaving the washers as determined from the hand washing tests. The amount of water per unit of product leaving the second washer was assumed to be constant; but grit concentration in this water, because of final rinsing, was equal $WW \cdot Y(3)$. Therefore the initial grit content on the product, using this approach to calculate Z, became a function of the dilution factor. Because values C1 and C2 are calculated as percentages of the initial grit content Z, they are also functions of the dilution factor. Calculation of all constants is explained in the following section.

Constant Determination.

Product leaving the second washer had surface water on it which contained suspended grit. There was also residual grit on the leaf surfaces that was not removed during washing. The amount of the residual grit was determined from the hand washing tests (see Materials and Methods). The weight of grit initially on the product was obtained by the following expression:

$$Z = W3 + A + B \qquad (13)$$

where: Z = initial grit content on the product surface (mg/kg)

W3 = grit residual on the product after washing (mg/kg)

A = the amount of grit removed from the product in the first washer (mg/kg)

B = the amount of grit removed from the product in the second washer (mg/kg)

The quantities A and B were determined by the following equations:

$$A = G1 + G2 + SQO \cdot Y(2)_{av} - SQB \cdot Y(4)_{av} + CC1 \cdot SQM \cdot Y(1)_{av} \qquad (14)$$

$$B = G3 + G4 + SQB \cdot Y(4)_{av} - CC1 \cdot SQM \cdot Y(1)_{av} + CC2 \cdot SQM \cdot WW \cdot Y(3)_{av} \qquad (15)$$

$$C1 = A/Z \quad (16)$$

$$C2 = B/Z \quad (17)$$

where: G1 = the total amount of grit (dry weight) collected from the first washer after a trial (kg)

G2 = the total amount of grit (dry weight) collected from the first settling tank after a trial (kg)

G3 = the total amount of grit (dry weight) collected from the second washer after a trial (kg)

G4 = the total amount of grit (dry weight) collected from the second settling tank after a trial (kg)

SQO = the total overflow to waste from the first settling tank during a trial (l)

SQB = the total flow from the second to the first settling tank during a trial (l)

SQM = the total amount of product processed during a trial (kg)

$Y(1)_{av}$ = the average measured concentration of grit in the water leaving the first washer during a trial (mg/kg)

$Y(2)_{av}$ = the average measured concentration of grit in the water leaving the first settling tank during a trial (mg/kg)

$Y(3)_{av}$ = the average measured concentration of grit in the water leaving the second washer during a trial (mg/kg)

$Y(4)_{av}$ = the average measured concentration of grit in the water leaving the second settling tank during a trial (mg/kg)

Sedimentation coefficients for washers were calculated as follows:

$$K1 = \frac{G1 - V1 \cdot Y_f(1)}{SQM \cdot Z \cdot C1} = \frac{G1 - V1 \cdot Y_f(1)}{SQM \cdot A} \qquad (18)$$

$$K3 = \frac{G3 - V3 \cdot Y_f(3)}{SQM \cdot Z \cdot C2} = \frac{G3 - V3 \cdot Y_f(3)}{SQM \cdot B} \qquad (19)$$

where: $Y_f(1)$ = the measured grit concentration in the water in the first washer after a trial (mg/1)

$Y_f(3)$ = the measured grit concentration in the water in the second washer after a trial (mg/1)

Sedimentation coefficients for the settling tanks were harder to define than those for the washers because it was assumed that sedimentation takes place during the "first pass" through a unit. As a consequence of this, there was no sedimentation during breaks or down time. In this case, a simple average value was not sufficient. The sedimentation coefficients for settling tanks had the form:

$$K2 = (G2 - V2\ Y_f(2))/GRIT8 \left[(SQC1 + SQO - SQB)/(AQC1 + AQO - AQB)\right] \qquad (20)$$

$$K4 = (G4 - V4\ Y_f(4))/GRIT7 \left[(SQB + SQC2)/(AQC2 + AQB)\right] \qquad (21)$$

where: $Y_f(2)$ = grit concentration in the water in the first settling tank at the end of a trial (mg/1)

$Y_f(4)$ = grit concentration in the water in the second settling tank at the end of a trial (mg/1)

GRIT7 = total amount of grit introduced to the second settling tank by overflow from the second washer (mg)

GRIT8 = total amount of grit introduced to the first settling tank by overflow from the first washer (mg)

(SQC1 + SQO - SQB) = total overflow introduced to the first settling tank from the first washer (1)

(AQC1 + AQO - AQB) = total overflow introduced into the first settling tank from the first washer during processing (1)

(SQC2 + SQB) = total overflow introduced into the second settling tank from the second washer (1)

(AQC2 + AQB) = total overflow introduced to the second settling tank from the second washer during processing (1)

$$GRIT7 = \int_0^t YM(1) \cdot (QC1 + QO - QB) \cdot dt \qquad (22)$$

$$GRIT8 = \int_0^t YM(3) \cdot (QC1 + QB) \cdot dt \qquad (23)$$

where: t = time period of the trial (min)

YM(1) = measured value of grit concentration in the first washer (mg/1)

YM(3) = measured value of grit concentration in the second washer (mg/1)

Model Results and Discussion.

To determine the most correct dilution factor, the model program was run with several different values of the dilution factor. For each run, correlation coefficients between observed and calculated values of grit concentrations in all units were found. Data for grit concentration in the water at a given time, as predicted from the model, were regressed against the measured values taken at like times.

Tables 35 through 38 show values of initial grit content, amount of grit removed per kg of product in the first and in the second washers, and removal coefficients for both washers, as a function of the dilution factor.

Table 39 shows values of the correlation coefficients for different values of the dilution factor. The average correlation coefficient was 0.83 for all four trials (range - 0.766 to 0.932) and should be considered as very high in such a complicated model with some quantities approximated.

The data show a best fit for the dilution factor of 1, i.e. zero dilution. However, observations did not appear to agree with this conclusion because the product should have been cleaner after being rinsed with fresh water on the exit conveyor. This disagreement may be explained by:

1) less grit entering the second washer in the water carried by the product than assumed because of system leakage, or absorption of water by the product;
2) other influences, not adequately described by the model, had

TABLE 35. SIMULATION COEFFICIENTS AS FUNCTIONS OF DILUTION FOR PROTOTYPE LINE-TRIAL # 1

DILUTION FACTOR	INITIAL GRIT CONTENT	AMOUNT OF GRIT REMOVED IN WASHER 1	AMOUNT OF GRIT REMOVED IN WASHER 2	REMOVAL COEFFICIENT FOR WASHER 1 C1	REMOVAL COEFFICIENT FOR WASHER 2 C2
-	(MG/KG)	(MG/KG)	(MG/KG)	-	-
0.0	7166.25	5454.	869.	0.761	0.121
0.10	7239.94	5454.	943.	0.753	0.130
0.20	7313.63	5454.	1017.	0.746	0.139
0.30	7387.32	5454.	1090.	0.738	0.148
0.40	7461.02	5454.	1164.	0.731	0.156
0.50	7534.71	5454.	1238.	0.724	0.164
0.60	7608.40	5454.	1311.	0.717	0.172
0.70	7682.10	5454.	1385.	0.710	0.180
0.80	7755.79	5454.	1459.	0.703	0.188
0.90	7829.48	5454.	1532.	0.697	0.196
1.00	7903.18	5454.	1606.	0.690	0.203

TABLE 36. SIMULATION COEFFICIENTS AS FUNCTIONS OF DILUTION FOR PROTOTYPE LINE-TRIAL # 4

DILUTION FACTOR	INITIAL GRIT CONTENT	AMOUNT OF GRIT REMOVED IN WASHER 1	AMOUNT OF GRIT REMOVED IN WASHER 2	REMOVAL COEFFICIENT FOR WASHER 1 C1	REMOVAL COEFFICIENT FOR WASHER 2 C2
-	(MG/KG)	(MG/KG)	(MG/KG)	-	-
0.0	2869.00	2326.	-102.	0.811	-.035
0.10	2909.98	2326.	-61.	0.799	-.021
0.20	2950.96	2326.	-20.	0.788	-.007
0.30	2991.94	2326.	21.	0.777	0.007
0.40	3032.92	2326.	62.	0.767	0.021
0.50	3073.90	2326.	103.	0.757	0.034
0.60	3114.87	2326.	144.	0.747	0.046
0.70	3155.85	2326.	185.	0.737	0.059
0.80	3196.83	2326.	226.	0.727	0.071
0.90	3237.81	2326.	267.	0.718	0.083
1.00	3278.79	2326.	308.	0.709	0.094

TABLE 37. SIMULATION COEFFICIENTS AS FUNCTIONS OF DILUTION FOR PROTOTYPE LINE-TRIAL # 5

DILUTION FACTOR	INITIAL GRIT CONTENT	AMOUNT OF GRIT REMOVED IN WASHER 1	AMOUNT OF GRIT REMOVED IN WASHER 2	REMOVAL COEFFICIENT FOR WASHER 1 C1	REMOVAL COEFFICIENT FOR WASHER 2 C2
-	(MG/KG)	(MG/KG)	(MG/KG)	-	-
0.0	1791.75	1379.	94.	0.770	0.052
0.10	1808.24	1379.	110.	0.763	0.061
0.20	1824.74	1379.	127.	0.756	0.069
0.30	1841.23	1379.	143.	0.749	0.078
0.40	1857.72	1379.	160.	0.742	0.086
0.50	1874.22	1379.	176.	0.736	0.094
0.60	1890.71	1379.	193.	0.729	0.102
0.70	1907.20	1379.	209.	0.723	0.110
0.80	1923.70	1379.	226.	0.717	0.117
0.90	1940.19	1379.	242.	0.711	0.125
1.00	1956.68	1379.	259.	0.705	0.132

TABLE 38. SIMULATION COEFFICIENTS AS FUNCTIONS OF DILUTION FOR PROTOTYPE LINE-TRIAL # 6

DILUTION FACTOR	INITIAL GRIT CONTENT	AMOUNT OF GRIT REMOVED IN WASHER 1	AMOUNT OF GRIT REMOVED IN WASHER 2	REMOVAL COEFFICIENT FOR WASHER 1 C1	REMOVAL COEFFICIENT FOR WASHER 2 C2
-	(MG/KG)	(MG/KG)	(MG/KG)	-	-
0.0	3716.75	2904.	479.	0.781	0.129
0.10	3737.57	2904.	500.	0.777	0.134
0.20	3758.40	2904.	521.	0.773	0.139
0.30	3779.22	2904.	542.	0.768	0.143
0.40	3800.05	2904.	563.	0.764	0.148
0.50	3820.87	2904.	584.	0.760	0.153
0.60	3841.70	2904.	604.	0.756	0.157
0.70	3862.52	2904.	625.	0.752	0.162
0.80	3883.35	2904.	646.	0.748	0.166
0.90	3904.17	2904.	667.	0.744	0.171
1.00	3924.99	2904.	688.	0.740	0.175

Table 39. Correlation Coefficients of the Modeled Concentrations of Grit vs. Dilution Factor, Prototype Line.

Trial Number	Dilution Factor					
	0.0	0.3	0.5	0.8	0.9	1.0
1	0.826	0.833	0.836	0.838	0.839	0.840
4	0.932	0.932	0.932	0.932	0.932	0.932
5	0.731	0.744	0.751	0.760	0.762	0.765
6	0.781	0.783	0.783	0.783	0.783	0.783

more effect than dilution. Perhaps the variation of sedimentation coefficients caused by different grit concentrations in the water and by changes in flow rates of water through the units, is more influencial than the dilution factor.

Table 40 shows correlation coefficients for a dilution factor of 1.0 and for each unit of the prototype system, separately. These data show higher correlation coefficients (except for trial 6) for the settling tanks than for the washers. The lower correlation coefficients for the washers can be explained by turbulence in washers.

Tables 41 through 44 show values of removal efficiency, sedimentation coefficients and other coefficients used for simulation, for each trial. It is not easy to compare the removal efficiency for washers between the one trial when spinach was processed, and the three when turnip greens were processed. However, it seems that the higher grit removal efficiency of the second washer for spinach (0.203), and the average (0.134) for turnip greens, can be explained by the convoluted surface of the spinach leaves. Probably, spinach needs longer exposure to washing to remove dirt from its leaves than do turnip greens. This may also explain the higher removal efficiency in first washer for turnip greens (average 0.713) than for spinach (0.690).

Figures 33, 35, 37, 39, 41, 43, 45, and 47 show the predicted grit concentration for different units and Figures 32, 34, 36, 38, 40, 42, 44, and 46 show the measured data for grit concentration for the different units as functions of processing time and accumulated product input. Plots made on basis of measured data are more smooth because the points were joined by straight lines. Plots obtained from the mod-

Table 40. Correlation Coefficients for an Each Unit for a Dilution Factor Equal 1.0, Prototype Line.

Unit	Trial 1	Trial 4	Trial 5	Trial 6
First Washer	0.628	0.873	0.652	0.628
First Settling Tank	0.894	0.957	0.702	0.625
Second Washer	0.683	0.913	0.745	0.800
Second Settling Tank	0.942	0.957	0.834	0.768

TABLE 41. CALCULATED COEFFICIENTS FOR THE SYSTEM SIMULATION OF THE PROTOTYPE LINE-TRIAL # 1

REMOVAL EFFICIENCY FOR WASHER #1=	0.690
REMOVAL EFFICIENCY FOR WASHER #2=	0.203
SEDIMENTATION COEFFICIENT FOR WASHER #1=	0.294
SEDIMENTATION COEFFICIENT FOR SETTLING TANK #1=	0.129
SEDIMENTATION COEFFICIENT FOR WASHER #2=	0.211
SEDIMENTATION COEFFICIENT FOR SETTLING TANK #2=	0.120
GRIT PER UNIT OF INCOMING PRODUCT=	7903.176(MG/KG)
TOTAL GRIT SETTLED IN SYSTEM(PREDICTED)=	53.540(KG)
TOTAL GRIT REMOVED WITH OVERFLOW=	8.329(KG)
TOTAL GRIT REMOVED FROM PRODUCT IN WASHER #1=	47.795(KG)
TOTAL GRIT REMOVED FROM PRODUCT IN WASHER #2=	14.075(KG)
AMOUNT OF GRIT ON PRODUCT AFTER WASHING IN WASHER # 2=	843.250(MG/KG)
AMOUNT OF WATER CARRIED FROM WASHER #1 PER KILOGRAM OF PRODUCT=	1.098(L/KG)
AMOUNT OF WATER CARRIED FROM SYSTEM PER KILOGRAM OF PRODUCT=	2.970(L/KG)

TABLE 42. CALCULATED COEFFICIENTS FOR THE SYSTEM SIMULATION OF THE PROTOTYPE LINE-TRIAL # 4

REMOVAL EFFICIENCY FOR WASHER #1=	0.709
REMOVAL EFFICIENCY FOR WASHER #2=	0.094
SEDIMENTATION COEFFICIENT FOR WASHER #1=	0.480
SEDIMENTATION COEFFICIENT FOR SETTLING TANK #1=	0.058
SEDIMENTATION COEFFICIENT FOR WASHER #2=	0.0
SEDIMENTATION COEFFICIENT FOR SETTLING TANK #2=	0.015
GRIT PER UNIT OF INCOMING PRODUCT=	3278.792(MG/KG)
TOTAL GRIT SETTLED IN SYSTEM(PREDICTED)=	20.414(KG)
TOTAL GRIT REMOVED WITH OVERFLOW=	0.655(KG)
TOTAL GRIT REMOVED FROM PRODUCT IN WASHER #1=	18.604(KG)
TOTAL GRIT REMOVED FROM PRODUCT IN WASHER #2=	2.465(KG)
AMOUNT OF GRIT ON PRODUCT AFTER WASHING IN WASHER # 2=	645.000(MG/KG)
AMOUNT OF WATER CARRIED FROM WASHER #1 PER KILOGRAM OF PRODUCT=	1.403(L/KG)
AMOUNT OF WATER CARRIED FROM SYSTEM PER KILOGRAM OF PRODUCT=	2.022(L/KG)

TABLE 43. CALCULATED COEFFICIENTS FOR THE SYSTEM SIMULATION OF THE PROTOTYPE LINE-TRIAL # 5

REMOVAL EFFICIENCY FOR WASHER #1=	0.705
REMOVAL EFFICIENCY FOR WASHER #2=	0.132
SEDIMENTATION COEFFICIENT FOR WASHER #1=	0.437
SEDIMENTATION COEFFICIENT FOR SETTLING TANK #1=	0.066
SEDIMENTATION COEFFICIENT FOR WASHER #2=	0.073
SEDIMENTATION COEFFICIENT FOR SETTLING TANK #2=	0.037
GRIT PER UNIT OF INCOMING PRODUCT=	1956.682(MG/KG)
TOTAL GRIT SETTLED IN SYSTEM(PREDICTED)=	8.423(KG)
TOTAL GRIT REMOVED WITH OVERFLOW=	2.684(KG)
TOTAL GRIT REMOVED FROM PRODUCT IN WASHER #1=	9.353(KG)
TOTAL GRIT REMOVED FROM PRODUCT IN WASHER #2=	1.755(KG)
AMOUNT OF GRIT ON PRODUCT AFTER WASHING IN WASHER # 2=	318.750(MG/KG)
AMOUNT OF WATER CARRIED FROM WASHER #1 PER KILOGRAM OF PRODUCT=	1.357(L/KG)
AMOUNT OF WATER CARRIED FROM SYSTEM PER KILOGRAM OF PRODUCT=	2.648(L/KG)

TABLE 44. CALCULATED COEFFICIENTS FOR THE SYSTEM SIMULATION OF THE PROTOTYPE LINE-TRIAL # 6

REMOVAL EFFICIENCY FOR WASHER #1=	0.740
REMOVAL EFFICIENCY FOR WASHER #2=	0.175
SEDIMENTATION COEFFICIENT FOR WASHER #1=	0.751
SEDIMENTATION COEFFICIENT FOR SETTLING TANK #1=	0.017
SEDIMENTATION COEFFICIENT FOR WASHER #2=	0.202
SEDIMENTATION COEFFICIENT FOR SETTLING TANK #2=	0.155
GRIT PER UNIT OF INCOMING PRODUCT=	3924.994(MG/KG)
TOTAL GRIT SETTLED IN SYSTEM(PREDICTED)=	23.843(KG)
TOTAL GRIT REMOVED WITH OVERFLOW=	4.795(KG)
TOTAL GRIT REMOVED FROM PRODUCT IN WASHER #1=	23.154(KG)
TOTAL GRIT REMOVED FROM PRODUCT IN WASHER #2=	5.484(KG)
AMOUNT OF GRIT ON PRODUCT AFTER WASHING IN WASHER # 2=	333.750(MG/KG)
AMOUNT OF WATER CARRIED FROM WASHER #1 PER KILOGRAM OF PRODUCT=	1.080(L/KG)
AMOUNT OF WATER CARRIED FROM SYSTEM PER KILOGRAM OF PRODUCT=	2.544(L/KG)

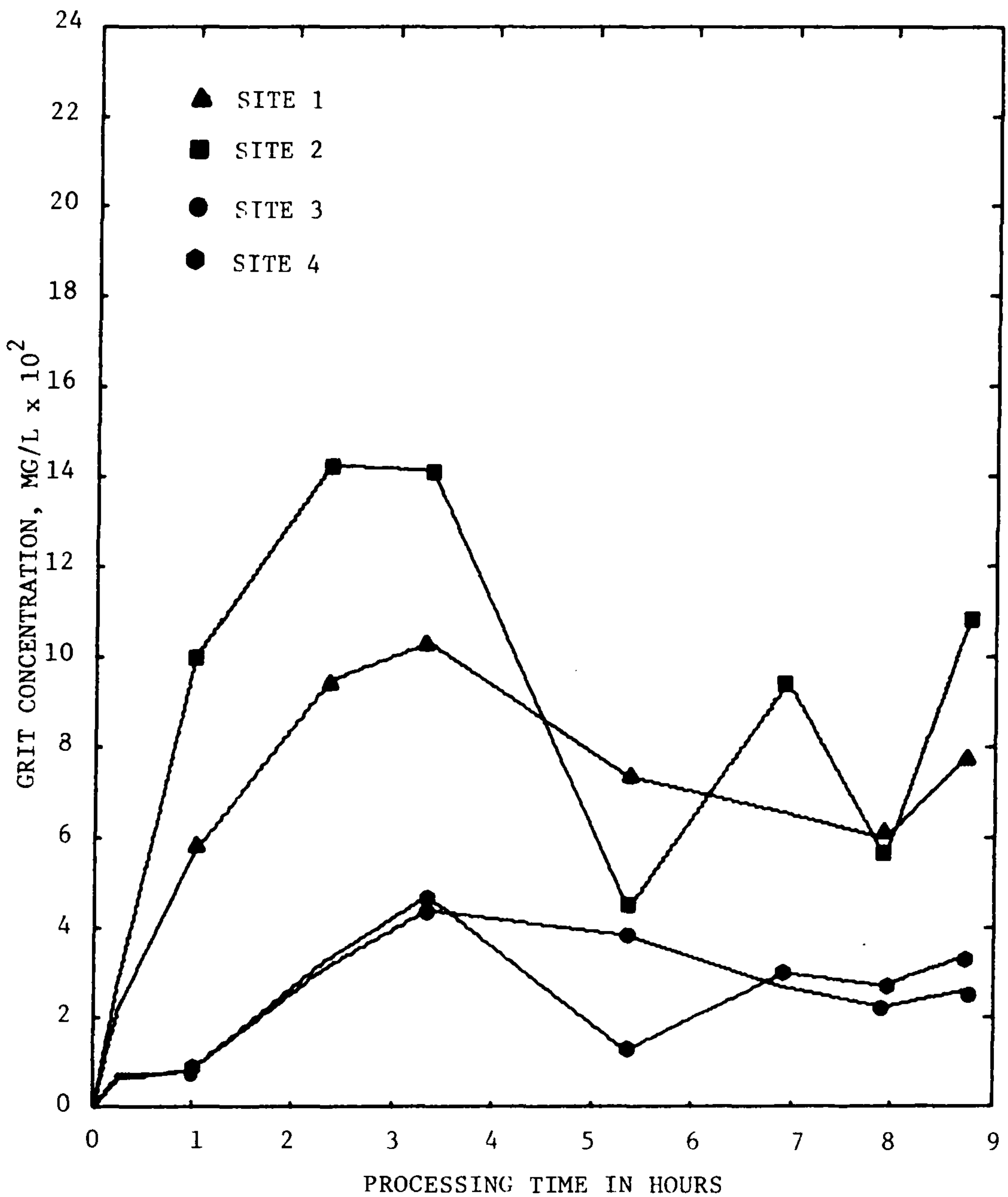


Figure 32: Variations in measured concentrations of grit suspended in wash water at four sampling sites, Trial 1, spinach processed with prototype system.

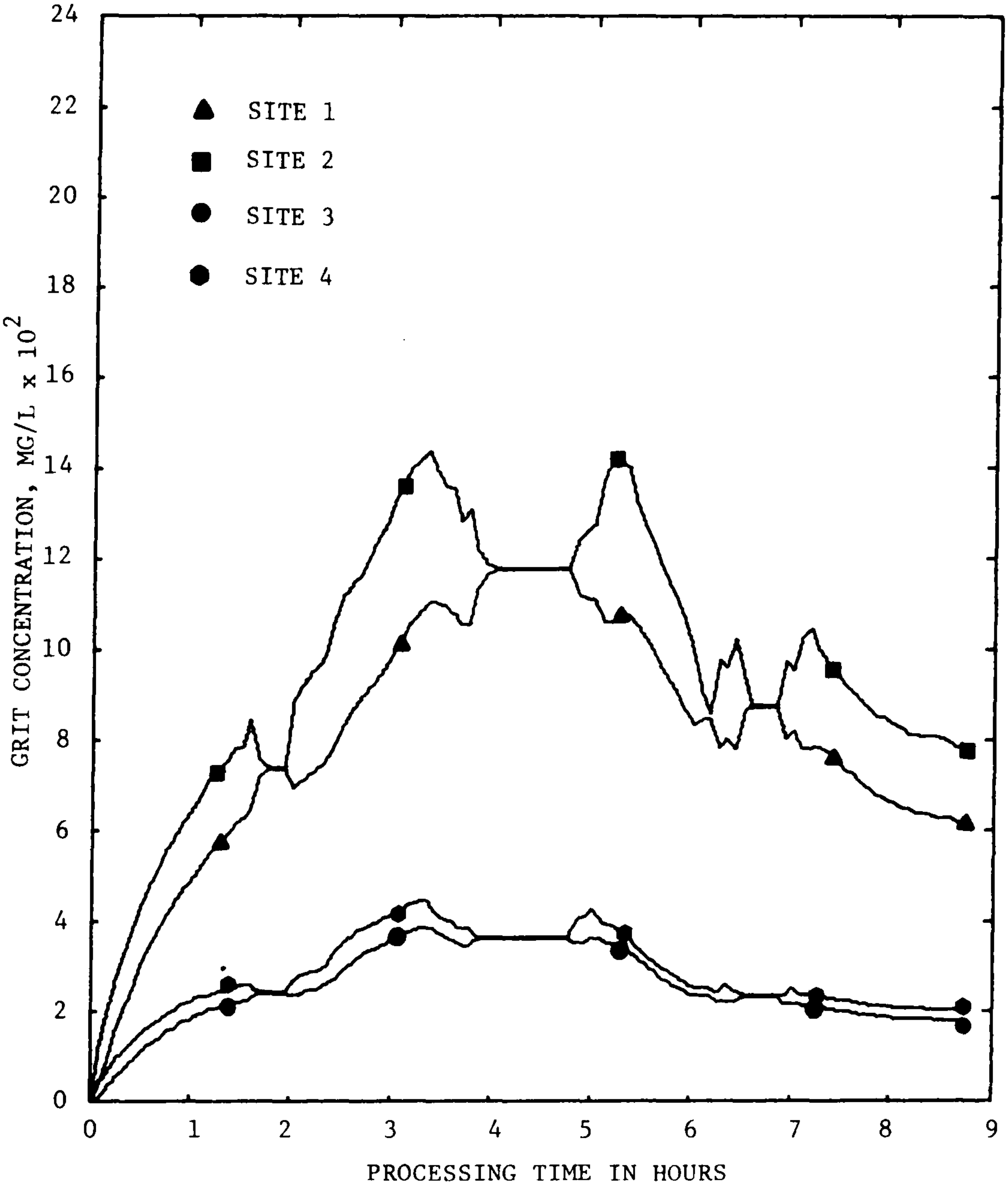


Figure 33: Variations in predicted concentrations of grit suspended in wash water at four sampling sites, Trial 1, spinach processed with prototype system.

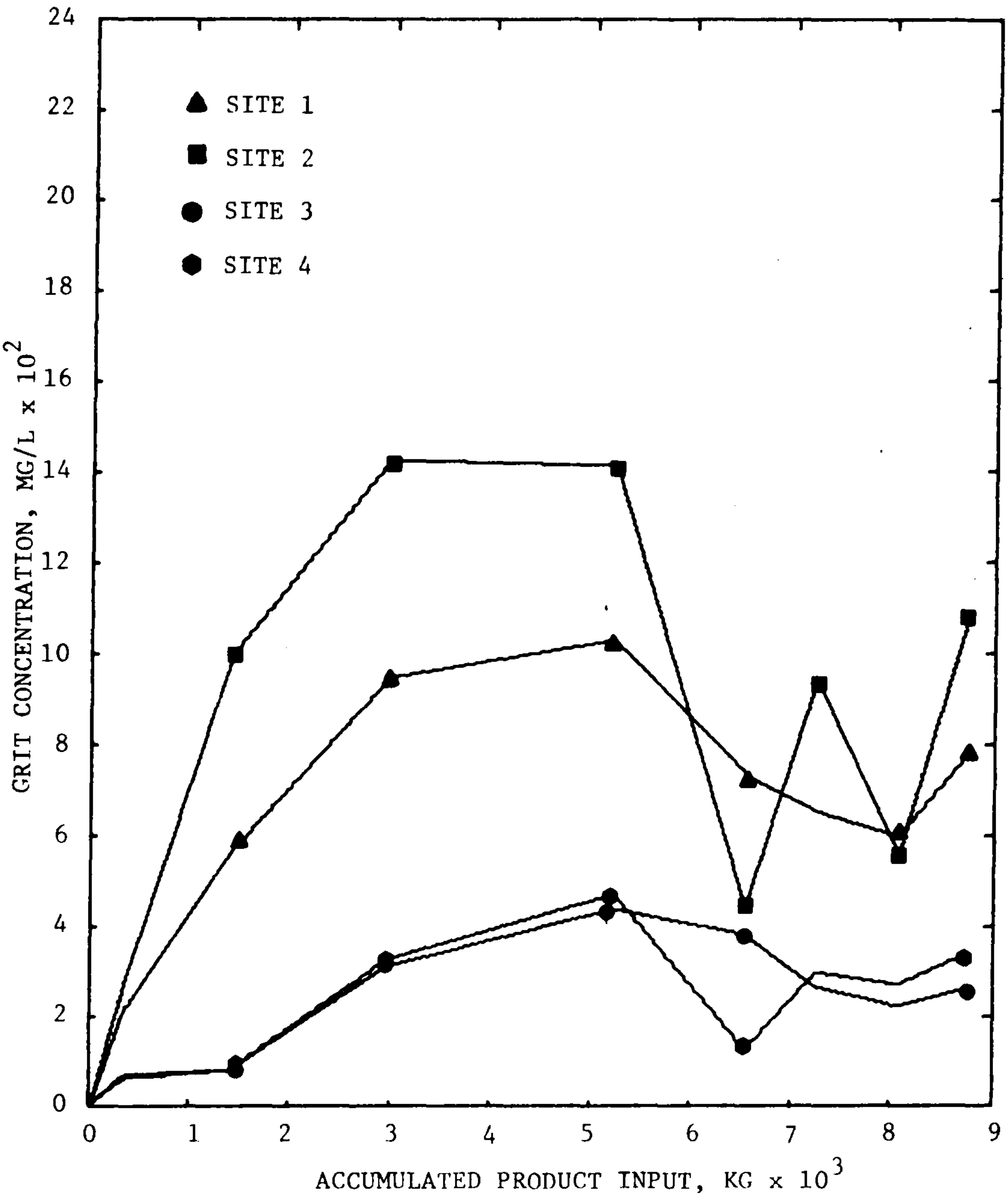


Figure 34: Variations in measured concentrations of grit suspended in wash water at four sampling sites, Trial 1, spinach processed with prototype system.

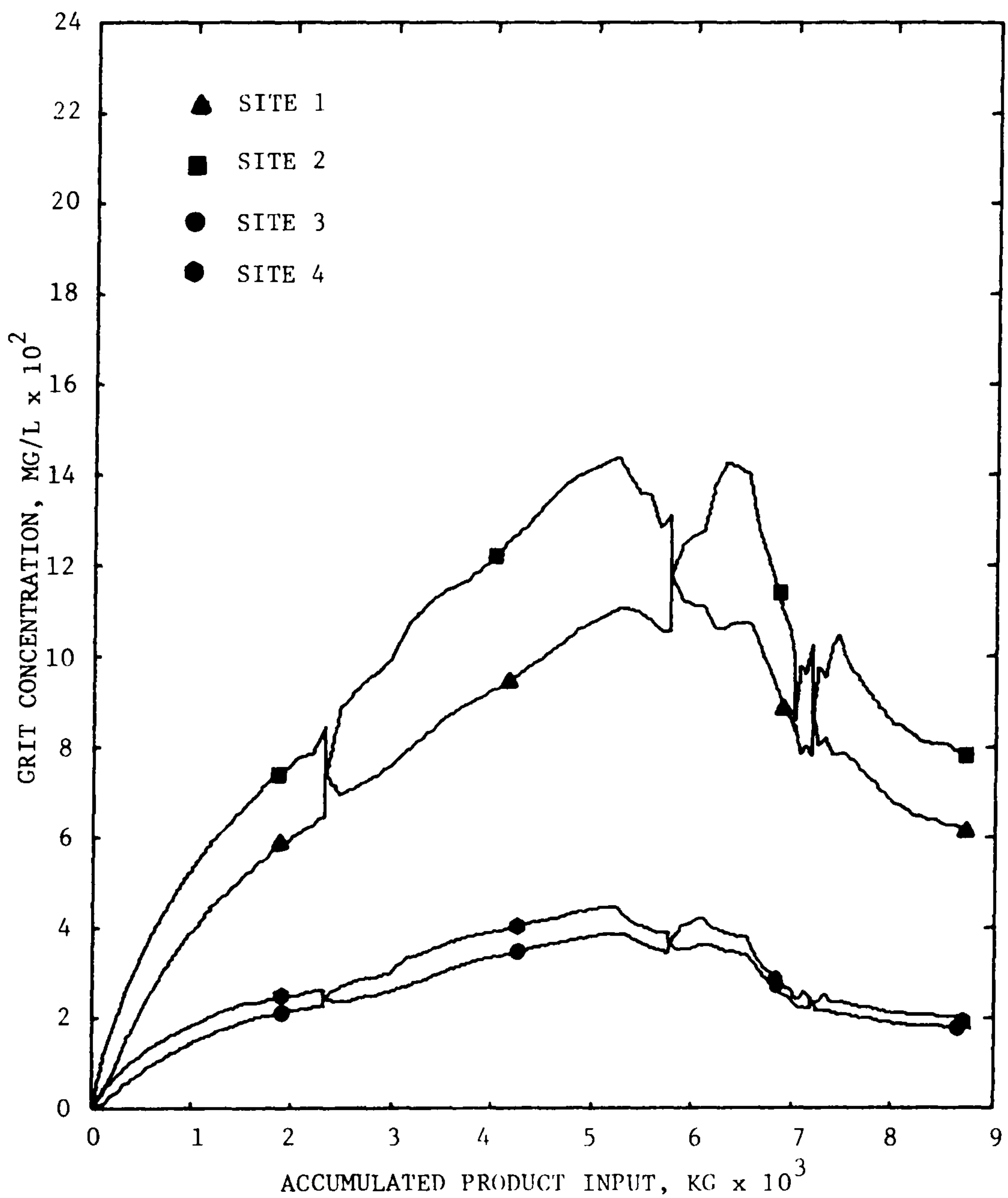


Figure 35: Variations in predicted concentrations of grit suspended in wash water at four sampling sites, Trial 1, spinach processed with prototype system.

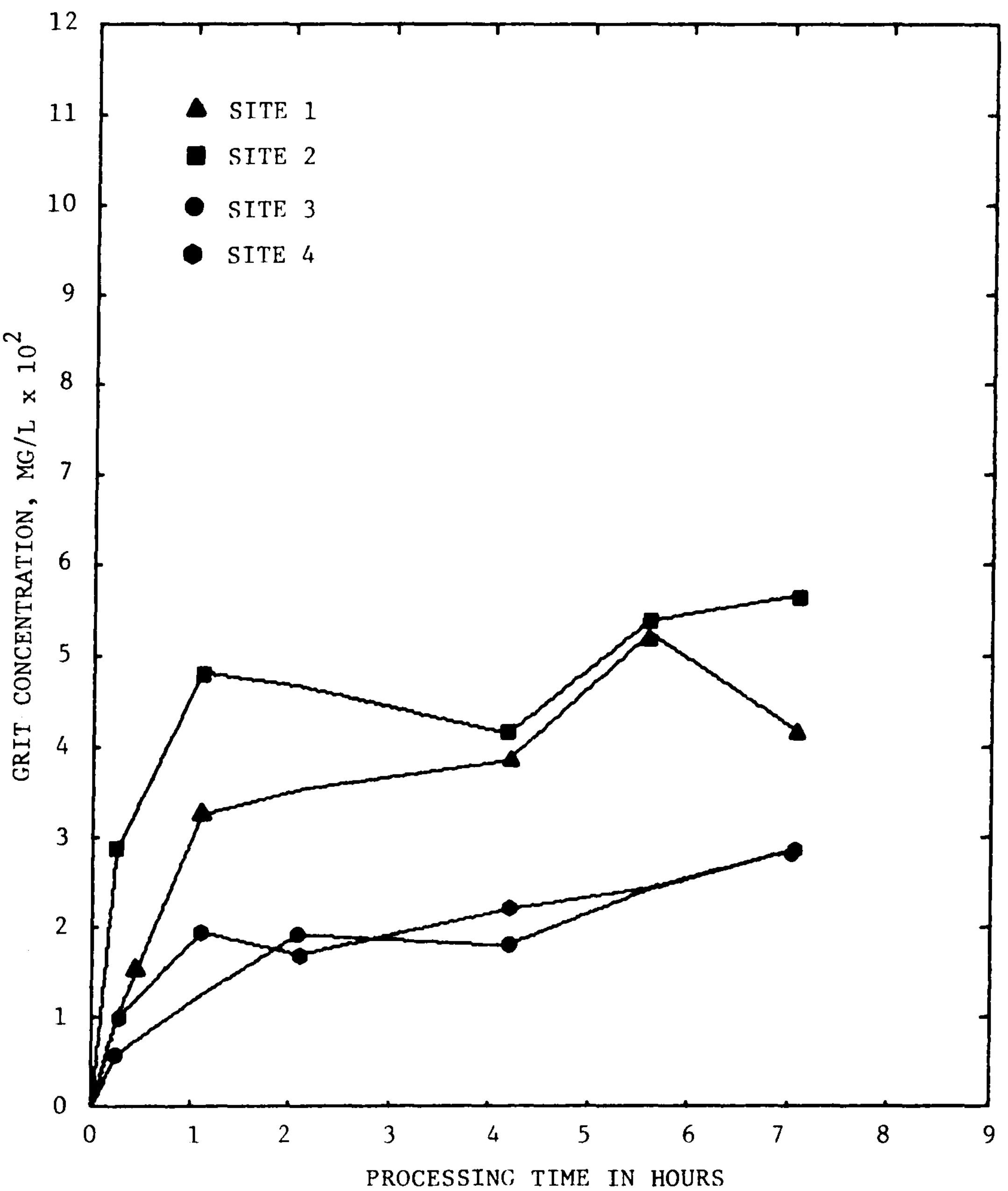


Figure 36: Variations in measured concentrations of grit suspended in wash water at four sampling sites, Trial 4, turnip greens processed with prototype system.

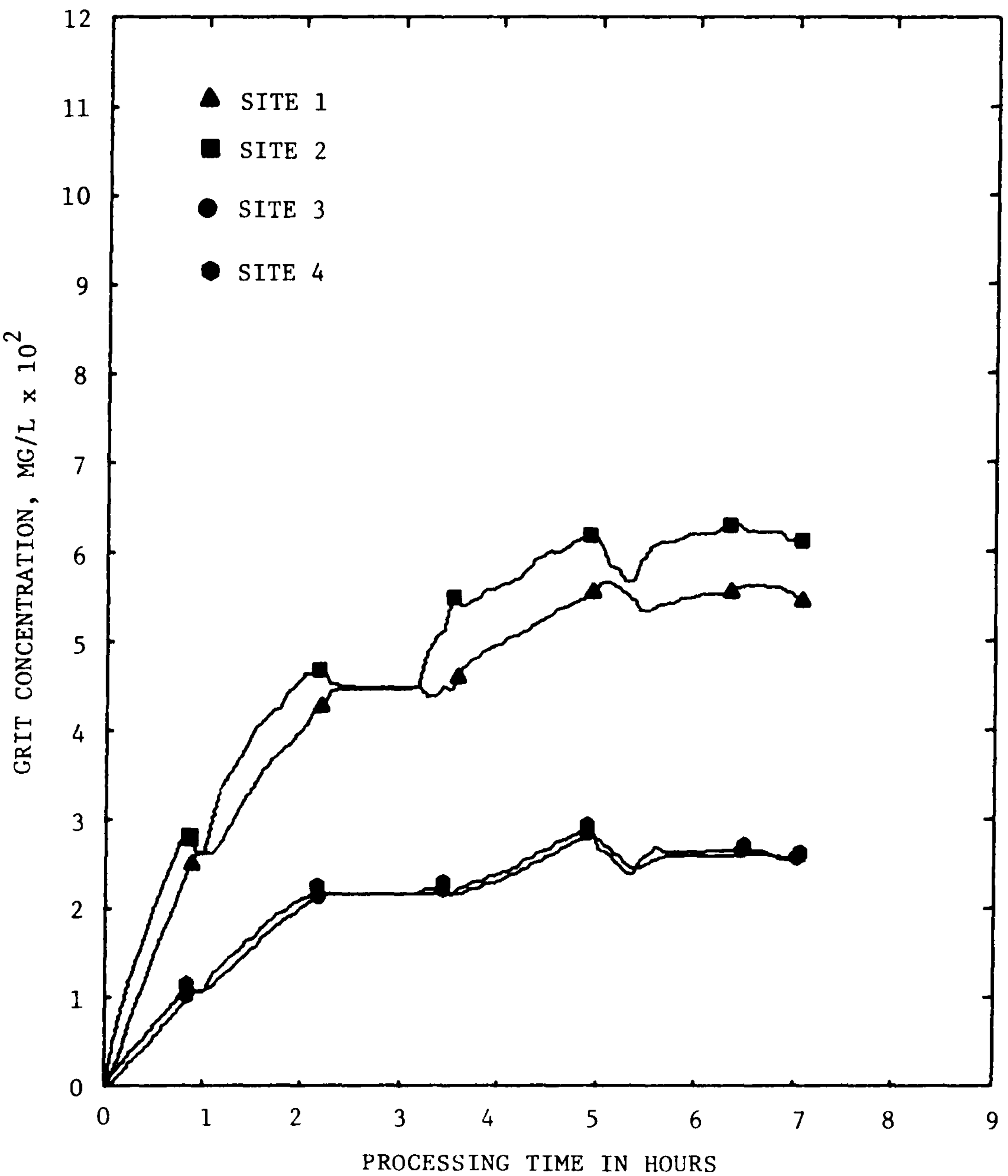


Figure 37: Variations in predicted concentrations of grit suspended in wash water at four sampling sites, Trial 4, turnip greens processed with prototype system.

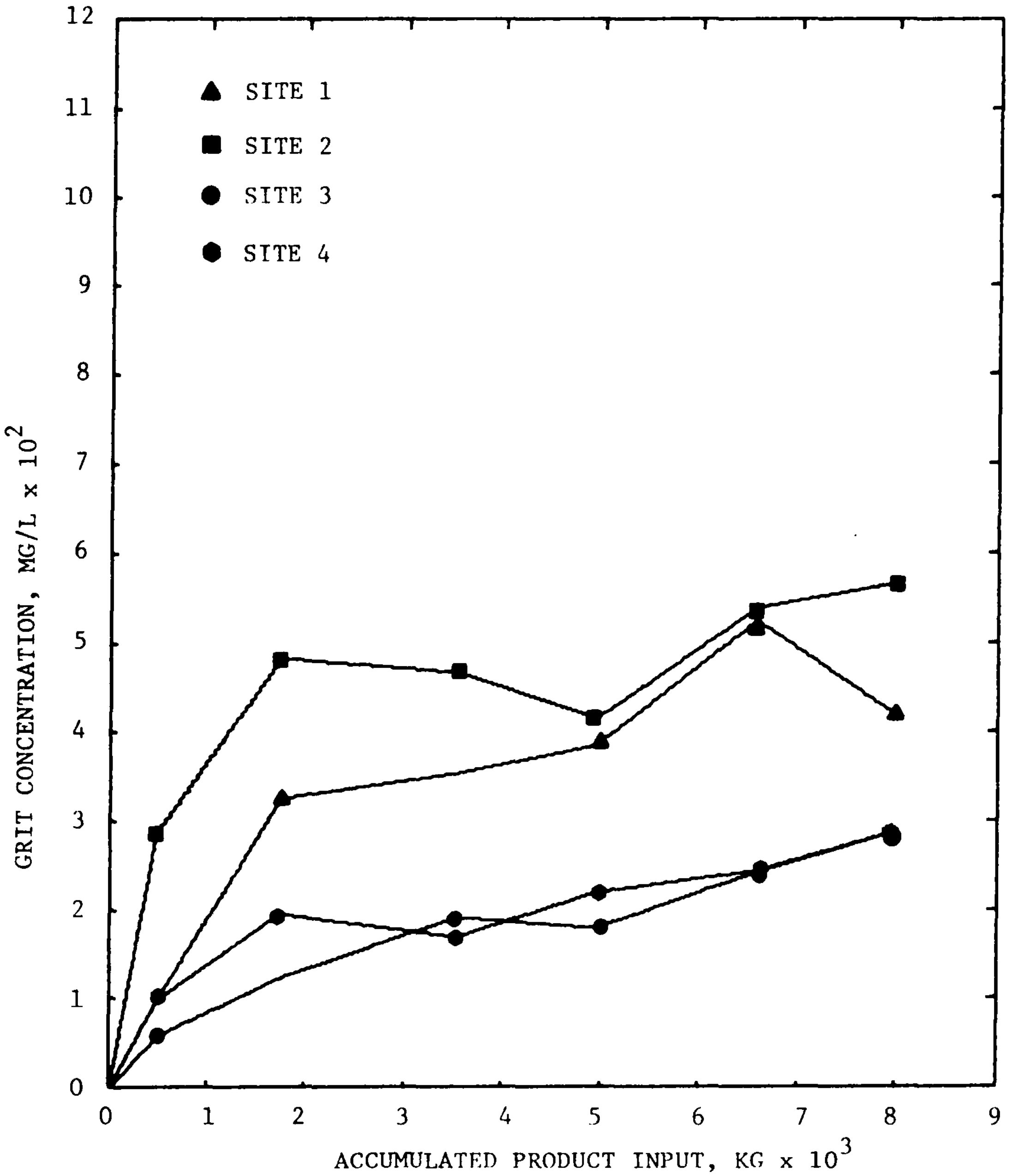


Figure 38: Variations in measured concentrations of grit suspended in wash water at four sampling sites, Trial 4, turnip greens processed with prototype system.

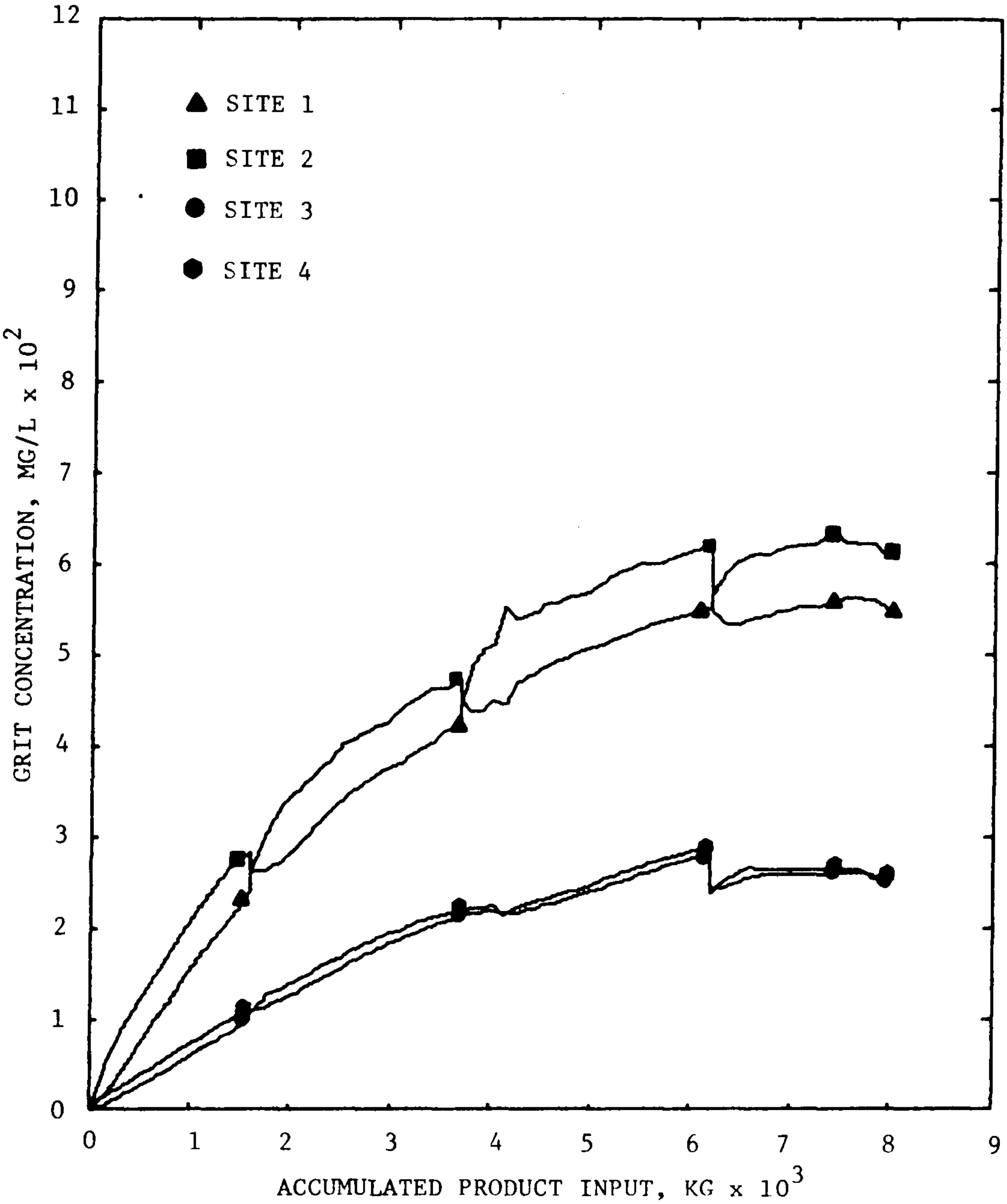


Figure 39: Variation in predicted concentrations of grit suspended in wash water at four sampling sites, Trial 4, turnip greens processed with prototype system.

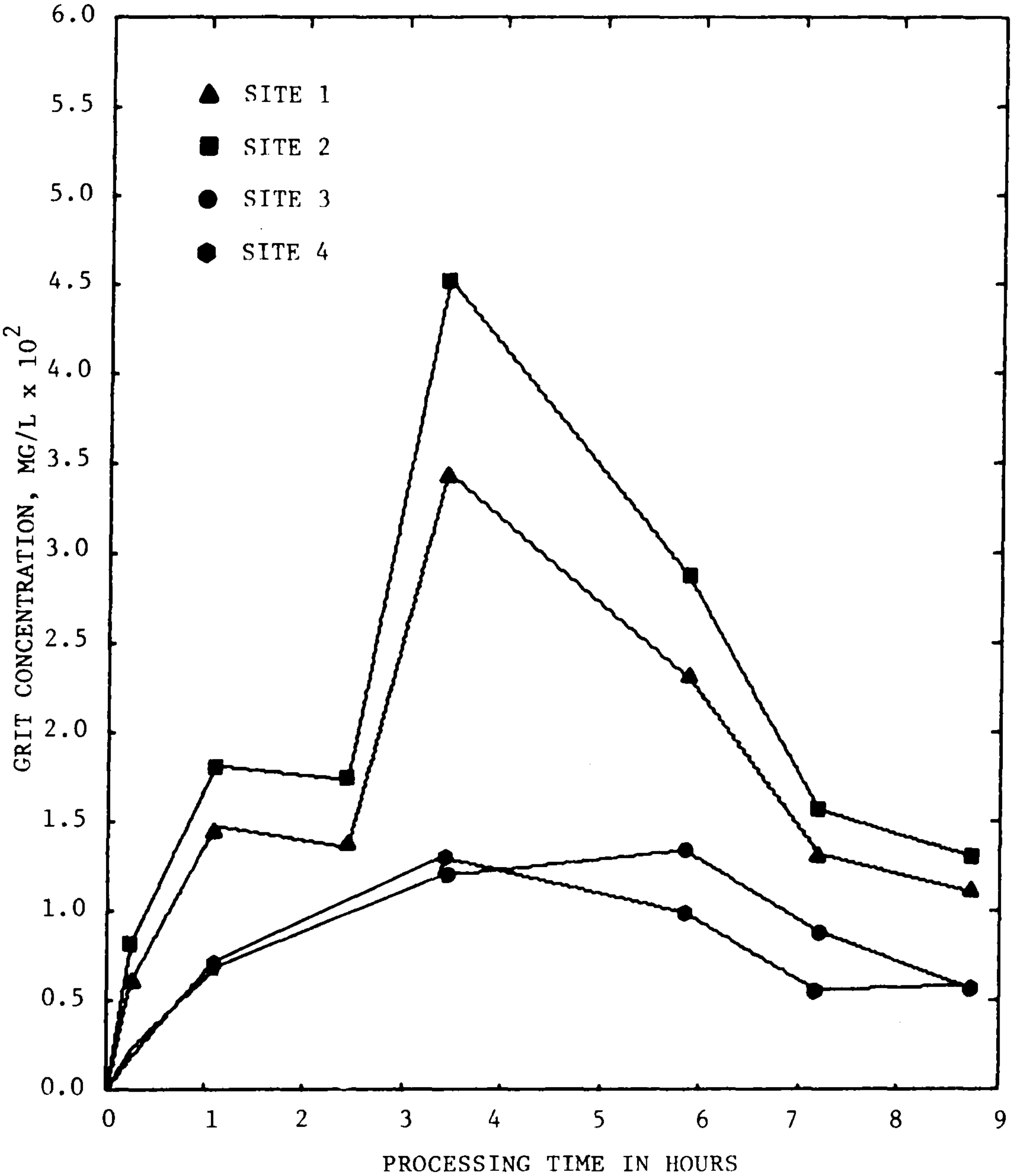


Figure 40: Variations in measured concentrations of grit suspended in wash water at four sampling sites, Trial 5, turnip greens processed with prototype system.

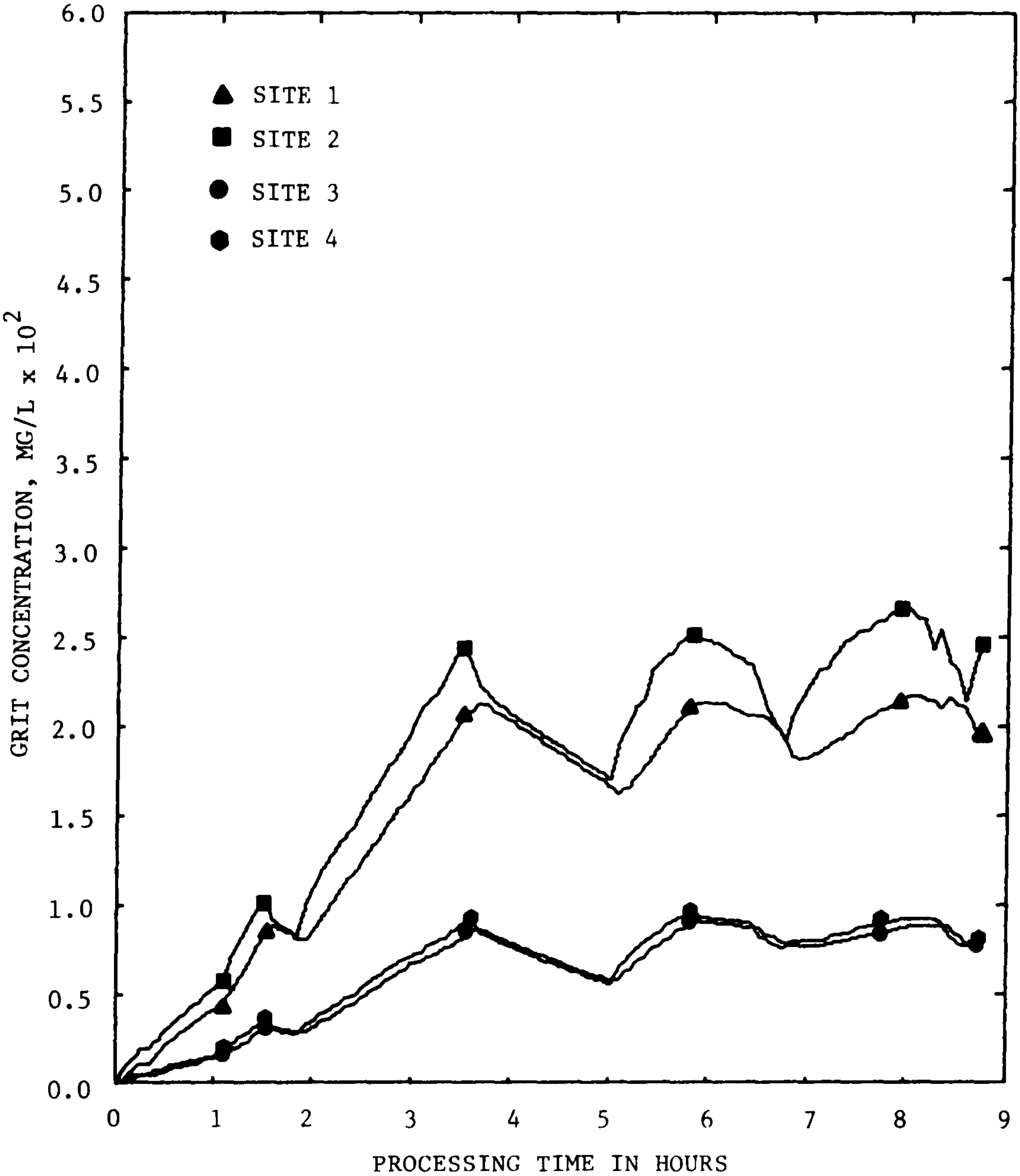


Figure 41: Variations in predicted concentrations of grit suspended in wash water at four sampling sites, Trial 5, turnip greens processed with prototype system.

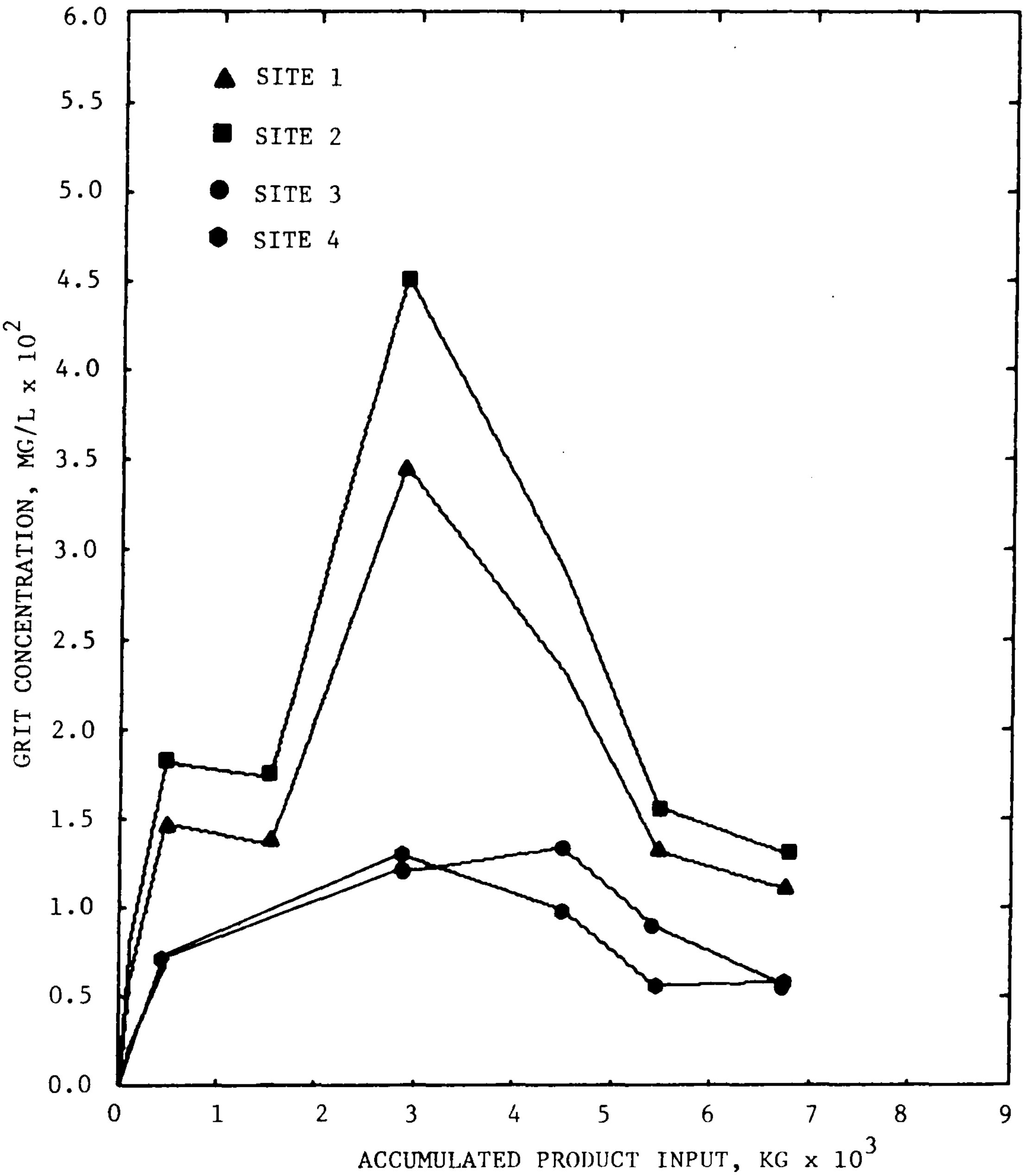


Figure 42: Variations in measured concentrations of grit suspended in wash water at four sampling sites, Trial 5, turnip greens processed with prototype system.

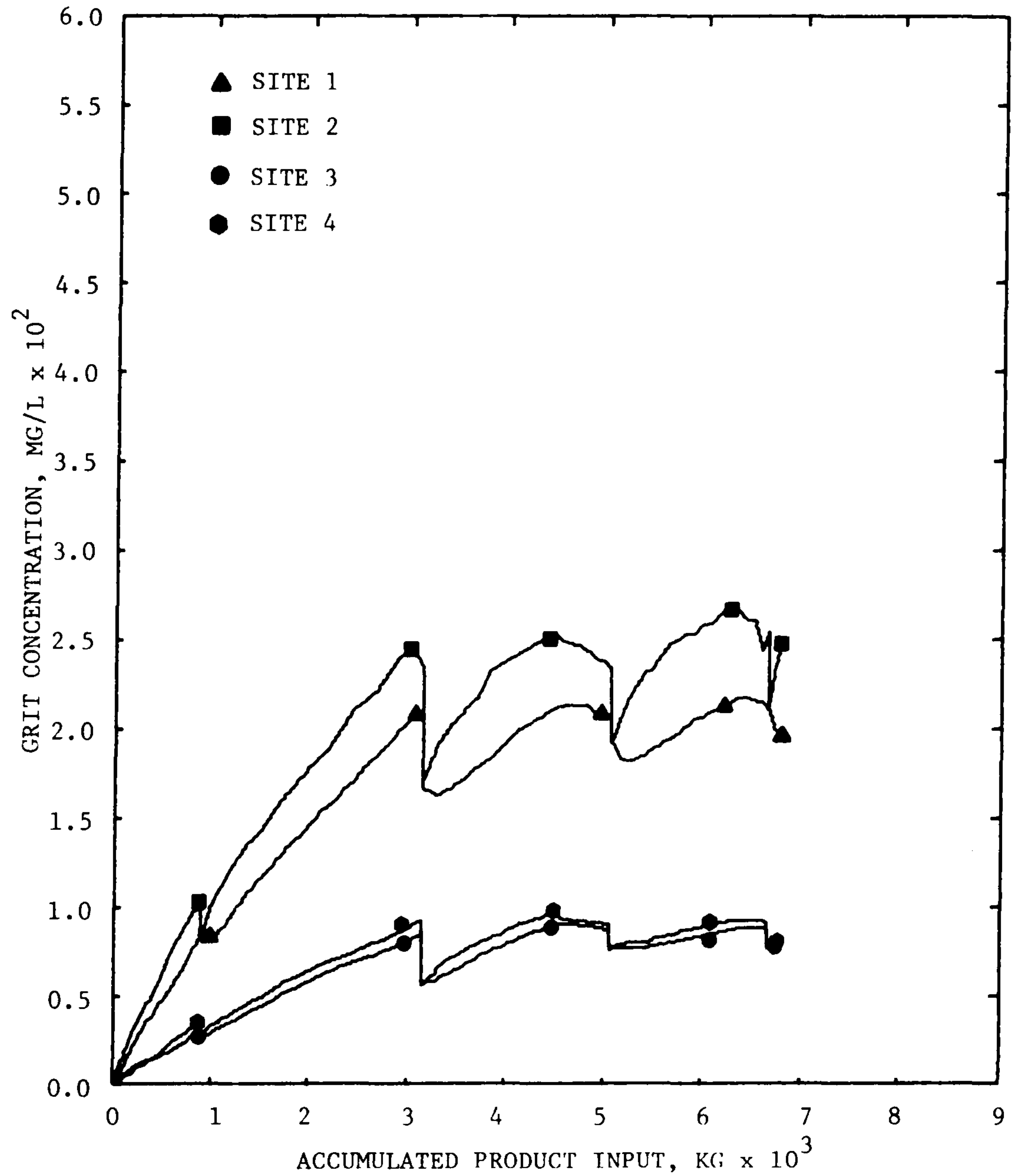


Figure 43: Variation in predicted concentrations of grit suspended in wash water at four sampling sites, Trial 5, turnip greens processed with prototype system.

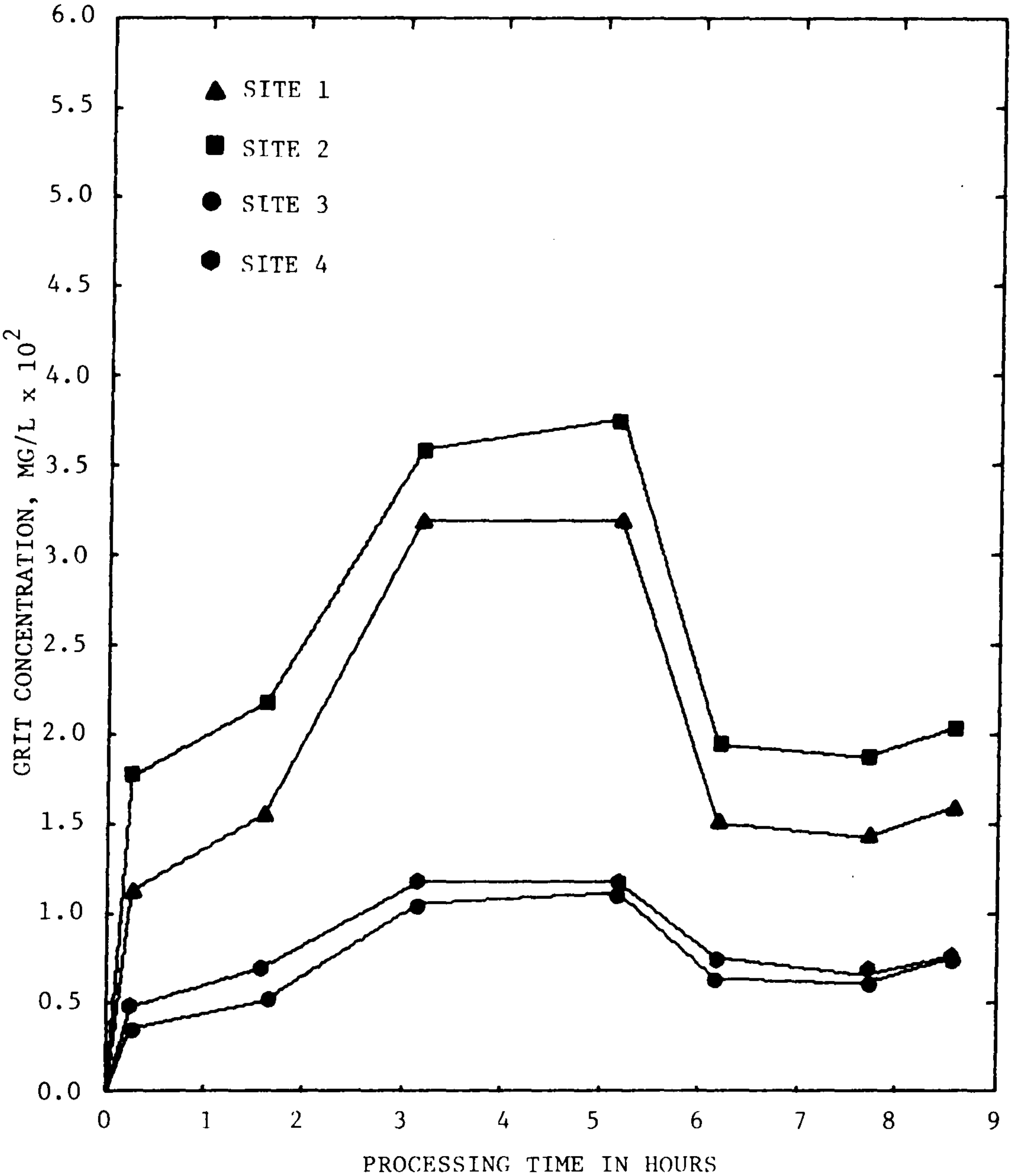


Figure 44: Variations in measured concentrations of grit suspended in wash water at four sampling sites, Trial 6, turnip greens processed with prototype system.

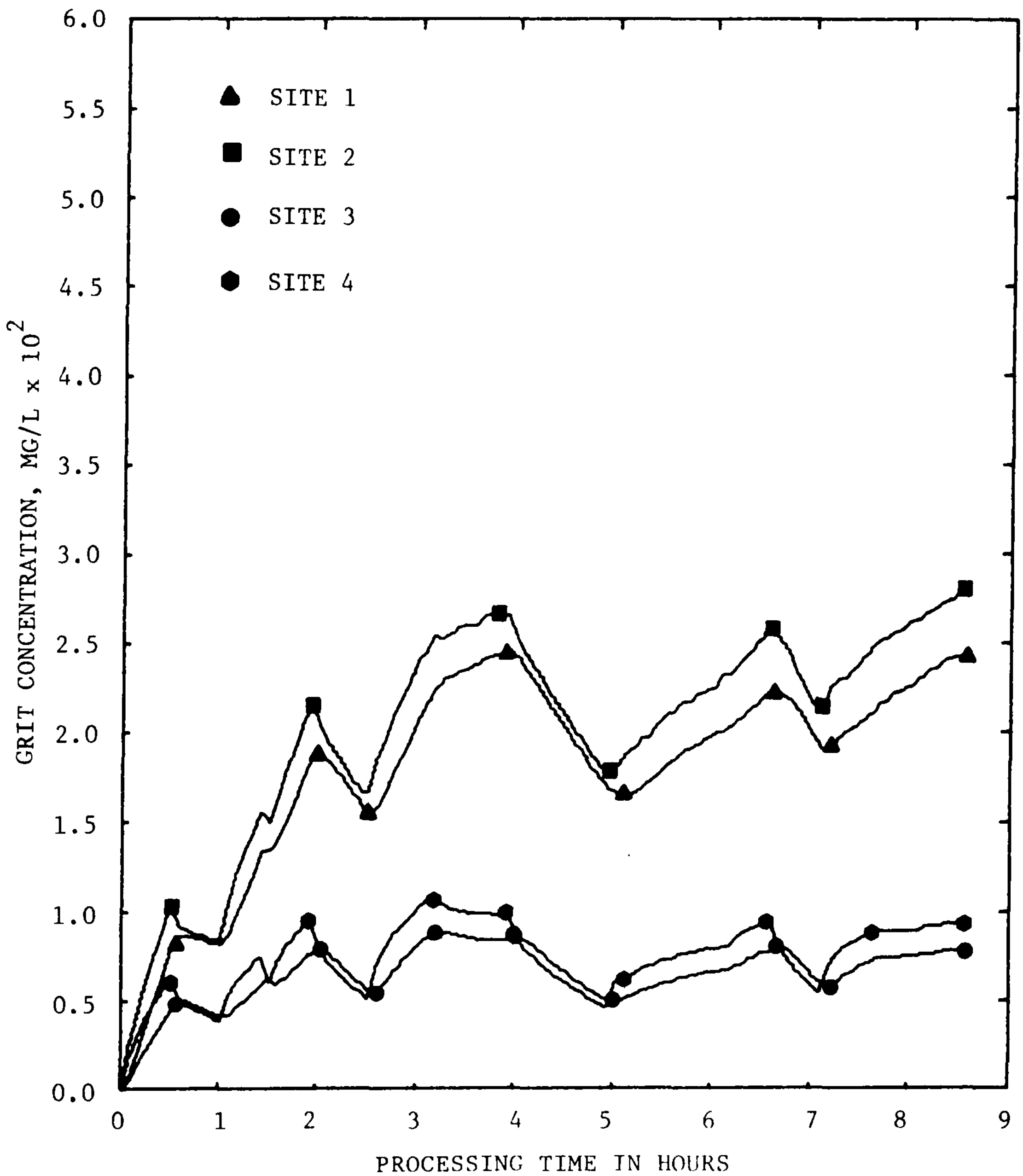


Figure 45: Variations in predicted concentrations of grit suspended in wash water at four sampling sites, Trial 6, turnip greens processed with prototype system.

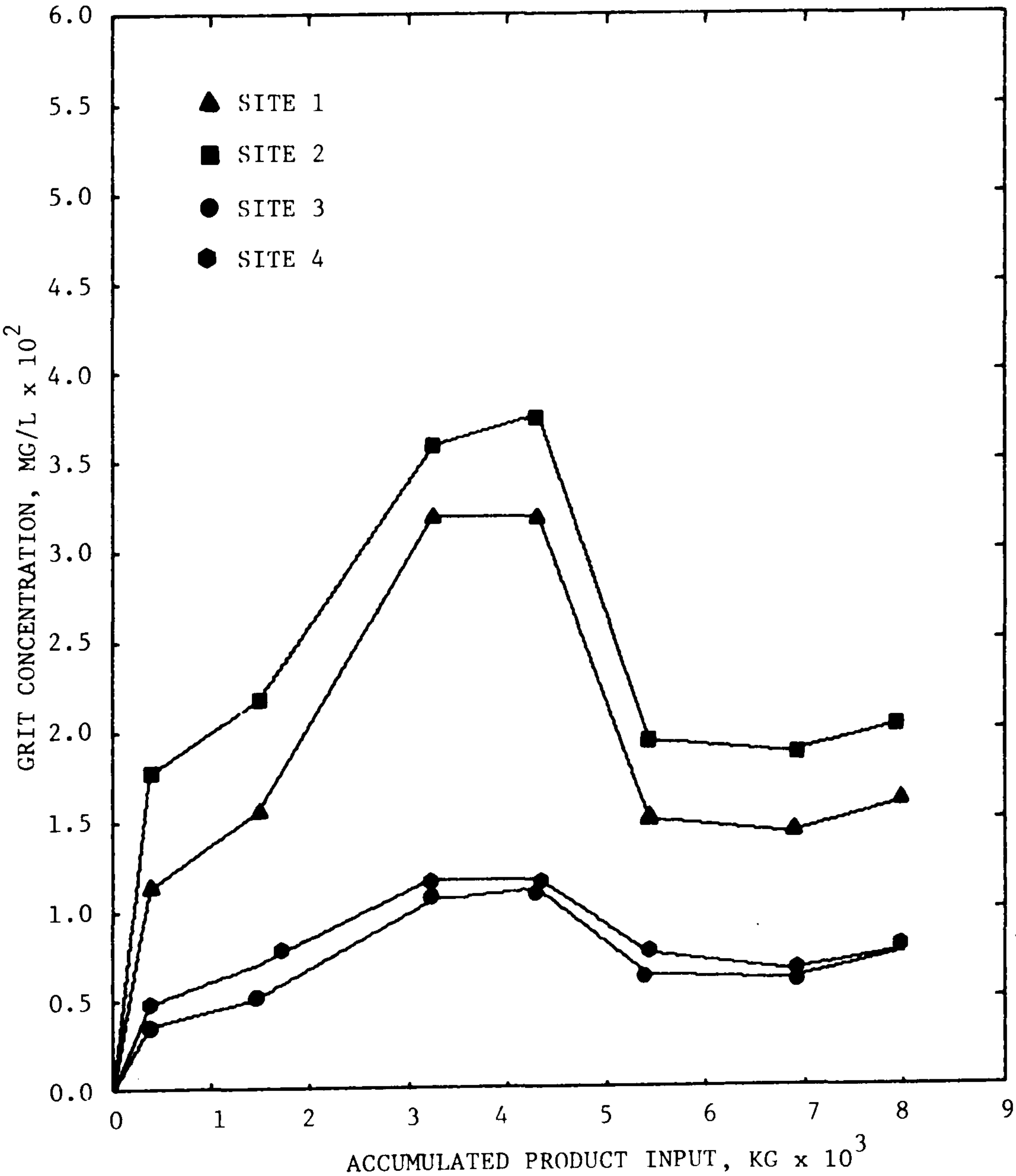


Figure 46: Variations in measured concentrations of grit suspended in wash water at four sampling sites, Trial 6, turnip greens processed with prototype system.

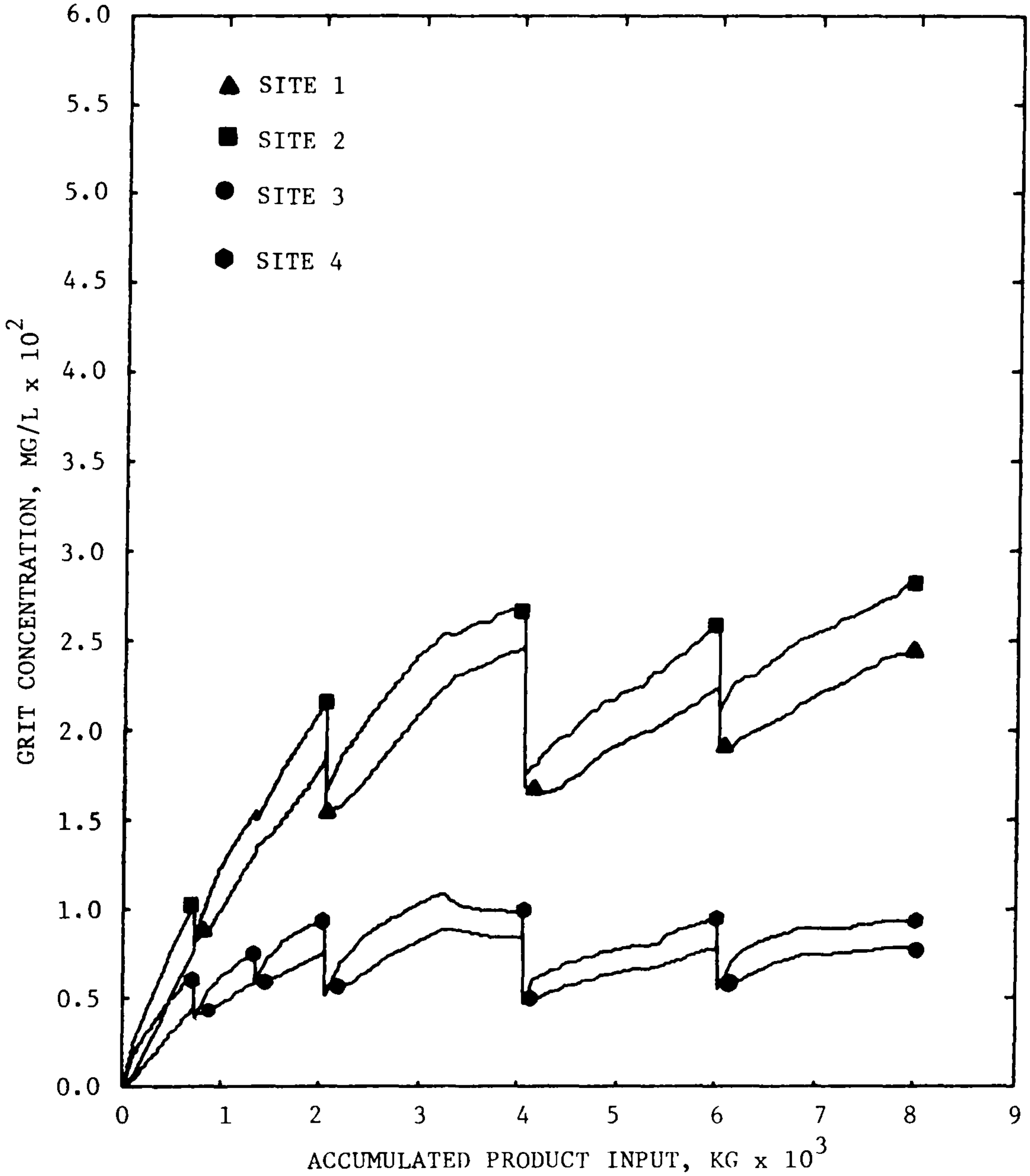


Figure 47: Variations in predicted concentrations of grit suspended in wash water at four sampling sites, Trial 6, turnip greens processed with prototype system.

eled data give continuous information about concentrations in the different units. However, the principal tendencies of increasing or decreasing concentrations are similar in both families of plots.

When comparing trials 5 and 6, it seems that the removal efficiency depends on both grit size distribution on the product and initial grit content. During trial 6 the product contained 3925 mg of grit per kg compared to only 1957 mg per kg of product in trial 5. During trial 6 the percentage of particles larger than 250 microns in diameter was about 40 for the first washer and about 45 for the second washer. In trial 5, these values were only 25 and 20, respectively. Higher initial grit contents and larger particle size, probably lead to higher removal efficiency. The grit size distribution for trials 5 and 6 apparently explains the higher sedimentation coefficients for both washers in trial 6.

Sedimentation coefficients for trial 4 were similar to those for trial 5. Initial grit content on the product was much greater for trial 4, but grit size distribution was similar. In this case, higher sedimentation coefficients were expected for trial 4. However, during trial 4, the average recirculation flow rates for first and second washers were 405 l/min and 451 l/min, respectively, compared to 361 l/min and 377 l/min for trial 5. Lower recirculation rates should increase sedimentation coefficients because it increases particle detention time in the washer. Similarity in sedimentation coefficients in trials 4 and 5 can be explained by the fact that for trial 5 the lower initial grit content on the product was balanced by a lower recirculation flow rate.

Generally, sedimentation coefficients for the different trials varied greatly. They are assumed to depend on initial grit content, grit size distribution, and water flow rates in the system. One spinach trial and three turnip green trials do not represent enough information to determine reliable sedimentation coefficients. A better understanding of the sedimentation process is needed to extend the mathematical model.

To obtain a better prediction of the washing process within the system, it is necessary to examine certain assumptions and consider their influence. It seems reasonable to:

1) consider sedimentation coefficients as a function of water flow rate through each unit, grit concentration in the water of each unit, and perhaps even viscosity (if measurements confirm changes of viscosity during the washing process);
2) consider the removal effectiveness for washers as functions of initial grit content on the product surface, grit size distribution, and variety of vegetable;
3) measure and incorporate into the model the variation of water volume in all units during a trial.

PROPOSED CHANGES

Following this study, some conclusions were drawn about the prototype system construction and improving methods of testing it.

Because the amount of grit removed, as predicted by the hand washing tests, was different from that obtained from measurements of grit collected in the bottom of each unit and removed with the overflow, a different technique for grit determination on the product should be developed. Hand washing of product samples should be replaced by procedures in which burning of samples of the unwashed and washed product (after moisture content and dry weight determination) is used to find the weight of ash. Weights of the ash from samples with greater grit amounts on the product should be higher. As a basis for comparison with the burning procedure, small samples of carefully washed product could be taken. Samples for burning could be taken in 15-minute, rather than 2-hour, intervals, because they could be more easily analyzed in the laboratory.

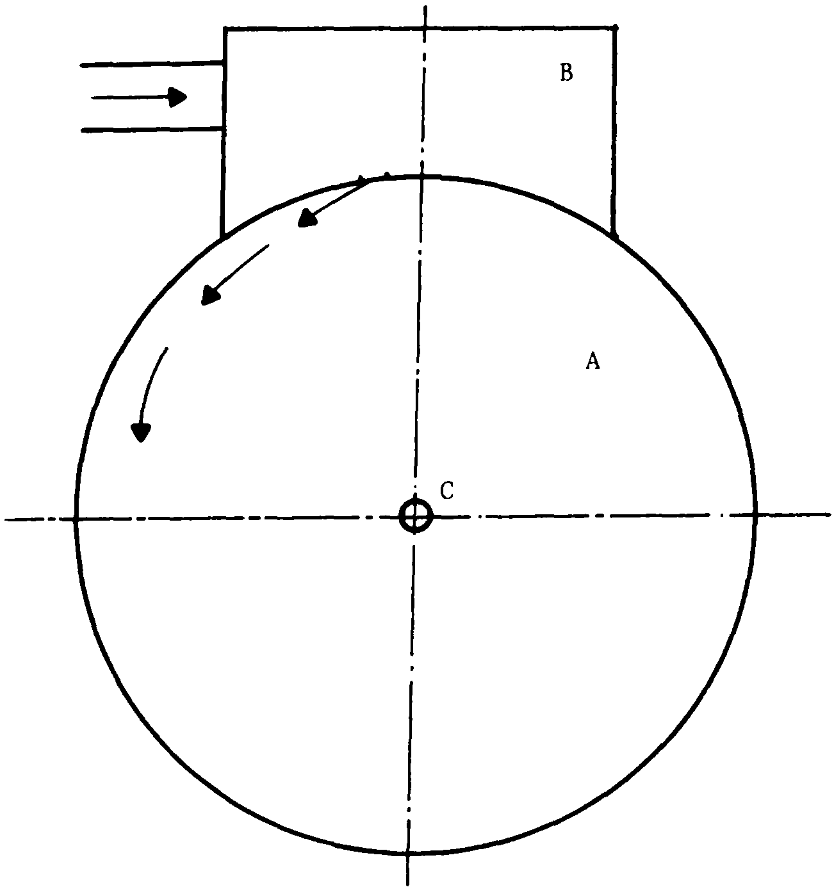
Further improvement would be continuous measurement of the incoming fresh product by a special weighing elevator. This should allow more accurate monitoring of product flow and its variation.

The amount of water in the units varied during trials depending on fresh water input and recirculation rates. Changes in the volume of water in each unit could be recorded by water level recorders.

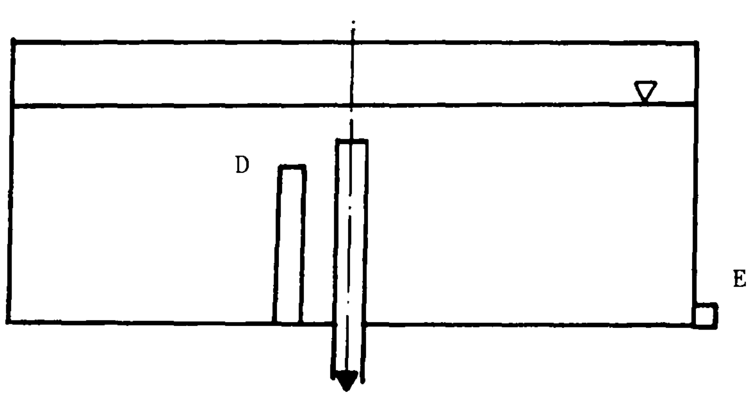
From the calculations used to build the mathematical model,and from the model itself, it seems reasonable that the fresh water input should be divided in such a way that product on the exit conveyors of both washers could be rinsed. This would prevent unnecessary contamination in the second washer by water carried from the first washer with the product. This would also decrease the grit concentration in the second washer and probably decrease bacteria counts on the product.

Additionally, it seems reasonable that the recirculation in the second washer - settling tank subsystem could be reduced. Increased detention time for grit settling in the system would help remove particles smaller than 56 microns. It is also probable that this arrangement would allow further reduction in fresh water input to the system.

Another change that would increse sedimentation in the settling tanks would be the use of round settling tanks (Figure 48), and elimination of the sump pumps. Overflow from the washers after filtering, could be easily introduced by gravity to settling tanks if they were situated below washer level. This arrangement would eliminate the sump boxes and sump pumps and assure a constant flow from the washers instead of the present cyclic flow. A finer mesh filter belt could also be used, increasing separation of trash from the water. The round sedimentation basin would increase water - particle separation by making use of the principle of centrifugal force.



TOP VIEW



SIDE VIEW

Figure 48: Proposed settling tank construction.

A. Settling tank
B. Inlet collector
C. Water output
D. Settling tank inlet
E. Draining port

CONCLUSIONS

1. The prototype system, operating at the same capacity as the conventional, performed well, removing more grit and insects from the product than the conventional system. Final rinsing of the product on the prototype exit conveyor decreased bacteria counts on the product compared to the conventional system.

2. The water consumption for the prototype washing process was about 20 percent that of the conventional system. A significant amount of water was carried by the product from the first washer (1.24 l per kg of product) to the second washer, and from the second washer out of the system (2.55 l per kg of product). The flow rate of fresh make-up water to the system should at least provide enough water to overcome losses carried out of the system with the product. The recirculation flow rate in the second washer - settling tank subsystem could be less than in the first subsystem to increase sedimentation of grit in that subsystem.

3. The waste load varied with different cuttings of the same product, and with different products. Spinach produced more TSS than turnip greens because of its convoluted leaves surface. It also produced higher rates of COD and VSS than did turnip greens.

4. The majority of grit removal (about 70 percent) took place in the first washer - settling tank subsystem of the prototype, where, as a result, grit concentration in the water was also higher. The mathematical model succeeded in producing reasonable predictions of grit in the water of the units as a function of the total amount of product

processed, but more tests of the system shout be made so that the model can be refined.

BIBLIOGRAPHY

1. Bough, W. A. 1973. Composition and waste load of unit effluents from a commercial leafy greens canning operation. Journal of Milk and Food Technology, Vol. 36, No. 11, pp. 544-553.

2. Coleman, J. R. 1976. A comparative study of conventional greens washers and a prototype system recycling wash water. Unpublished Master's Thesis, Virginia Polytechnic Institute and State University. Blacksburg, Va.

3. Final Effluent Guidelines and Standards for Phase II of the Canned and Preserved Fruits and Vegetables Processing Industry Point Source Category. 1976. Federal Register, Chapter I, Subchapter N, Part 407, April.

4. Frey, B. C. 1973. Modification of a leafy vegetable immersion washer. Unpublished Master's Thesis, Virginia Polytechnic Institute and State University. Blacksburg, Va.

5. Frey, B. C., Wright, M. E. and Hoehn, R. C. 1974. Modification of a leafy vegetable immersion washer. Transactions of the A.S.A.E., Vol. 17, No. 6, pp. 1057, 1058, 1059 and 1063, St. Joseph, Mich.

6. American Water Works Association, Inc. 1971. Water Quality and Treatment, McGraw-Hill Book Co., Inc., New York, N. Y., pp. 139-141.

7. Geering, P. B. 1976. Changes in quality of leafy vegetables and wash water in a system employing wash-water recycle. Unpublished Master's Thesis, Virginia Polytechnic Institute and State University. Blacksburg, Va.

8. Magette, W. L. 1974. Design of a grit and trash removal process to permit recycling of vegetable wash water. Unpublished Senior Report for Agricultural Engineering Department, Virginia Polytechnic Institute and State University. Blacksburg, Va.

9. National Canners Association. 1971. Liquid wastes from canning and freezing fruits and vegetables. Water Pollution Control Research Series, 12060 EDK-08/71. U.S. Goverment Printing Office, Washington, D.C.

10. Robinson, W. 1976. A study of recirculation as a means of reducing fresh water consumption in a leafy vegetable immersion washer. Unpublished Master's Thesis, Virginia Polytechnic Institute and State University. Blacksburg, Va.

11. Standard Methods for the Examination of Water and Wastewater. 1971. Edited by AWWA, APHA, and WPCF, 13th Edition.

12. Townsend, C. T., Somers, I. I., Lamb, F. C. and Olsen, N. A. 1956. A laboratory manual for the canning industry, 2nd Edition, National Canners Association Research Laboratories. Washington, D. C.

13. United Nations Industrial Development Organization. 1969. Water saving techniques in food processing plants. Food Industries Studies, Publication No. 3. New York, N.Y.

APPENDIX A

PRODUCT FLOW DATA

TABLE A-1. PRODUCT FLOW DATA FOR THE PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
0.	23.700	0.0
5.	23.700	118.500
10.	23.700	237.000
15.	23.700	355.500
20.	23.700	474.000
25.	23.700	592.499
30.	23.700	710.999
35.	23.700	829.499
40.	23.700	947.999
45.	23.700	1066.498
50.	23.700	1184.998
55.	23.700	1303.498
60.	23.700	1421.998
65.	25.670	1550.347
70.	25.670	1678.697
75.	25.670	1807.047
80.	25.670	1935.397
85.	25.670	2063.747
90.	25.670	2192.097
95.	25.670	2320.447
100.	0.0	2320.447
105.	0.0	2320.447
110.	0.0	2320.447
115.	0.0	2320.447
120.	25.670	2448.796
125.	25.670	2577.146
130.	25.670	2705.496
135.	25.670	2833.846
140.	25.670	2962.196
145.	37.520	3149.796
150.	37.520	3337.396
155.	37.520	3524.995
160.	37.520	3712.595

TABLE A-1. CONTINUATION
PRODUCT FLOW DATA FOR THE
PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
165.	37.520	3900.195
170.	37.520	4087.795
175.	37.520	4275.395
180.	37.520	4462.988
185.	37.520	4650.590
190.	37.520	4838.188
195.	37.520	5025.781
200.	37.520	5213.383
205.	21.720	5321.977
210.	21.720	5430.574
215.	21.720	5539.176
220.	21.720	5647.770
225.	21.720	5756.367
230.	0.0	5756.367
235.	0.0	5756.367
240.	0.0	5756.367
245.	0.0	5756.367
250.	0.0	5756.367
255.	0.0	5756.367
260.	0.0	5756.367
265.	0.0	5756.367
270.	0.0	5756.367
275.	0.0	5756.367
280.	0.0	5756.367
285.	0.0	5756.367
290.	21.720	5864.969
295.	21.720	5973.563
300.	21.720	6082.160
305.	21.720	6190.762
310.	21.720	6299.355
315.	21.720	6407.953
320.	21.720	6516.555
325.	11.850	6575.805
330.	11.850	6635.055

TABLE A-1. CONTINUATION
PRODUCT FLOW DATA FOR THE
PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
335.	11.850	6694.305
340.	11.850	6753.555
345.	11.850	6812.805
350.	11.850	6872.055
355.	11.850	6931.305
360.	11.850	6990.555
365.	0.0	6990.555
370.	0.0	6990.555
375.	11.850	7049.805
380.	11.850	7109.055
385.	11.850	7168.305
390.	0.0	7168.305
395.	0.0	7168.305
400.	0.0	7168.305
405.	0.0	7168.305
410.	0.0	7168.305
415.	11.850	7227.555
420.	13.750	7296.305
425.	13.750	7365.055
430.	13.750	7433.805
435.	13.750	7502.555
440.	13.750	7571.305
445.	13.750	7640.055
450.	13.750	7708.805
455.	13.750	7777.555
460.	13.750	7846.305
465.	13.750	7915.055
470.	13.750	7983.805
475.	13.750	8052.555
480.	14.220	8123.648
485.	14.220	8194.750
490.	14.220	8265.848
495.	14.220	8336.941

TABLE A-1. CONTINUATION
PRODUCT FLOW DATA FOR THE
PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
500.	14.220	8408.043
505.	14.220	8479.141
510.	14.220	8550.234
515.	14.220	8621.336
520.	14.220	8692.434
525.	14.220	8763.527

TABLE A-2. PRODUCT FLOW DATA FOR THE PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
0.	31.730	0.0
5.	31.730	158.650
10.	31.730	317.300
15.	31.730	475.950
20.	31.730	634.600
25.	31.730	793.250
30.	31.730	951.899
35.	31.730	1110.549
40.	31.730	1269.199
45.	31.730	1427.849
50.	31.730	1586.499
55.	0.0	1586.499
60.	0.0	1586.499
65.	31.730	1745.149
70.	31.730	1903.799
75.	29.660	2052.099
80.	29.660	2200.398
85.	29.660	2348.698
90.	29.660	2496.998
95.	29.660	2645.298
100.	29.660	2793.598
105.	29.660	2941.897
110.	29.660	3090.197
115.	29.660	3238.497
120.	29.660	3386.797
125.	29.660	3535.097
130.	29.660	3683.396
135.	0.0	3683.396
140.	0.0	3683.396
145.	0.0	3683.396
150.	0.0	3683.396
155.	0.0	3683.396
160.	0.0	3683.396

TABLE A-2. CONTINUATION
PRODUCT FLOW DATA FOR THE
PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
165.	0.0	3683.396
170.	0.0	3683.396
175.	0.0	3683.396
180.	0.0	3683.396
185.	0.0	3683.396
190.	0.0	3683.396
195.	21.280	3789.796
200.	21.280	3896.196
205.	21.280	4002.596
210.	21.280	4108.992
215.	21.280	4215.395
220.	21.280	4321.793
225.	21.280	4428.188
230.	21.280	4534.590
235.	21.280	4640.984
240.	21.280	4747.387
245.	21.280	4853.781
250.	21.280	4960.184
255.	27.070	5095.527
260.	27.070	5230.879
265.	27.070	5366.227
270.	27.070	5501.570
275.	27.070	5636.922
280.	27.070	5772.270
285.	27.070	5907.613
290.	27.070	6042.965
295.	27.070	6178.313
300.	0.0	6178.313
305.	0.0	6178.313
310.	0.0	6178.313
315.	0.0	6178.313
320.	0.0	6178.313
325.	27.070	6313.656
330.	27.070	6449.008

TABLE A-2. CONTINUATION
PRODUCT FLOW DATA FOR THE
PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
335.	27.070	6584.352
340.	17.120	6669.949
345.	17.120	6755.551
350.	17.120	6841.145
355.	17.120	6926.742
360.	17.120	7012.344
365.	17.120	7097.938
370.	17.120	7183.535
375.	17.120	7269.137
380.	17.120	7354.730
385.	17.120	7440.328
390.	17.120	7525.930
395.	17.120	7611.523
400.	12.930	7676.176
405.	12.930	7740.820
410.	12.930	7805.473
415.	12.930	7870.117
420.	12.930	7934.770
425.	12.930	7999.418

TABLE A-3. PRODUCT FLOW DATA FOR THE PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
0.	7.600	0.0
5.	7.600	38.000
10.	7.600	76.000
15.	7.600	114.000
20.	0.0	114.000
25.	7.600	152.000
30.	7.600	190.000
35.	7.600	228.000
40.	7.600	266.000
45.	7.600	304.000
50.	7.600	342.000
55.	7.600	380.000
60.	7.600	418.000
65.	7.600	456.000
70.	17.700	544.500
75.	17.700	633.000
80.	17.700	721.499
85.	17.700	809.999
90.	17.700	898.499
95.	0.0	898.499
100.	0.0	898.499
105.	0.0	998.499
110.	0.0	898.499
115.	17.700	986.999
120.	17.700	1075.498
125.	17.700	1163.998
130.	17.700	1252.498
135.	17.700	1340.998
140.	17.700	1429.497
145.	17.700	1517.997
150.	22.620	1631.097
155.	22.620	1744.197
160.	22.620	1857.297

TABLE A-3. CONTINUATION
PRODUCT FLOW DATA FOR THE
PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
165.	22.620	1970.396
170.	22.620	2083.496
175.	22.620	2196.596
180.	22.620	2309.696
185.	22.620	2422.796
190.	22.620	2535.896
195.	22.620	2648.996
200.	22.620	2762.095
205.	22.620	2875.195
210.	26.850	3009.445
215.	26.850	3143.695
220.	0.0	3143.695
225.	0.0	3143.695
230.	0.0	3143.695
235.	0.0	3143.695
240.	0.0	3143.695
245.	0.0	3143.695
250.	0.0	3143.695
255.	0.0	3143.695
260.	0.0	3143.695
265.	0.0	3143.695
270.	0.0	3143.695
275.	0.0	3143.695
280.	0.0	3143.695
285.	0.0	3143.695
290.	0.0	3143.695
295.	0.0	3143.695
300.	0.0	3143.695
305.	26.850	3277.945
310.	26.850	3412.195
315.	26.850	3546.445
320.	26.850	3680.695
325.	26.850	3814.945
330.	26.850	3949.195

TABLE A-3. CONTINUATION
PRODUCT FLOW DATA FOR THE
PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
335.	26.850	4083.445
340.	26.850	4217.691
345.	26.850	4351.941
350.	26.850	4486.191
355.	16.100	4566.691
360.	16.100	4647.191
365.	16.100	4727.691
370.	16.100	4808.191
375.	16.100	4888.691
380.	16.100	4969.191
385.	16.100	5049.691
390.	0.0	5049.691
395.	0.0	5049.691
400.	0.0	5049.691
405.	0.0	5049.691
410.	16.100	5130.191
415.	16.100	5210.691
420.	16.100	5291.191
425.	16.100	5371.691
430.	16.100	5452.191
435.	17.570	5540.043
440.	17.570	5627.891
445.	17.570	5715.734
450.	17.570	5803.586
455.	17.570	5891.434
460.	17.570	5979.277
465.	17.570	6067.129
470.	17.570	6154.977
475.	17.570	6242.820
480.	17.570	6330.672
485.	17.570	6418.520
490.	17.570	6506.363
495.	13.750	6575.113

TABLE A-3. CONTINUATION
PRODUCT FLOW DATA FOR THE
PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
500.	13.750	6643.863
505.	0.0	6643.863
510.	0.0	6643.863
515.	0.0	6643.863
520.	13.750	6712.613
525.	13.750	6781.363

TABLE A-4. PRODUCT FLOW DATA FOR THE PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
0.	24.220	0.0
5.	24.220	121.100
10.	24.220	242.200
15.	24.220	363.300
20.	24.220	484.400
25.	24.220	605.500
30.	24.220	726.599
35.	0.0	726.599
40.	0.0	726.599
45.	0.0	726.599
50.	0.0	726.599
55.	0.0	726.599
60.	0.0	726.599
65.	24.220	847.699
70.	24.220	968.799
75.	24.220	1089.899
80.	24.220	1210.999
85.	24.220	1332.099
90.	0.0	1332.099
95.	24.220	1453.198
100.	29.710	1601.748
105.	29.710	1750.298
110.	29.710	1898.848
115.	29.710	2047.398
120.	0.0	2047.398
125.	0.0	2047.398
130.	0.0	2047.398
135.	0.0	2047.398
140.	0.0	2047.398
145.	0.0	2047.398
150.	0.0	2047.398
155.	29.710	2195.948
160.	29.710	2344.497

TABLE A-4. CONTINUATION
PRODUCT FLOW DATA FOR THE
PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
165.	29.710	2493.047
170.	29.710	2641.597
175.	29.710	2790.147
180.	29.710	2938.697
185.	29.710	3087.246
190.	29.710	3235.796
195.	17.770	3324.646
200.	17.770	3413.496
205.	17.770	3502.346
210.	17.770	3591.196
215.	17.770	3680.045
220.	17.770	3768.895
225.	17.770	3857.745
230.	17.770	3946.595
235.	17.770	4035.445
240.	0.0	4035.445
245.	0.0	4035.445
250.	0.0	4035.445
255.	0.0	4035.445
260.	0.0	4035.445
265.	0.0	4035.445
270.	0.0	4035.445
275.	0.0	4035.445
280.	0.0	4035.445
285.	0.0	4035.445
290.	0.0	4035.445
295.	0.0	4035.445
300.	17.770	4124.293
305.	17.770	4213.141
310.	17.770	4301.984
315.	18.380	4393.887
320.	18.380	4485.781
325.	18.380	4577.684
330.	18.380	4669.578

TABLE A-4. CONTINUATION
PRODUCT FLOW DATA FOR THE
PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
335.	18.380	4761.477
340.	18.380	4853.379
345.	18.380	4945.273
350.	18.380	5037.176
355.	18.380	5129.070
360.	18.330	5220.973
365.	18.380	5312.867
370.	18.380	5404.770
375.	23.880	5524.168
380.	23.880	5643.563
385.	23.880	5762.965
390.	23.880	5882.359
395.	23.880	6001.762
400.	0.0	6001.762
405.	0.0	6001.762
410.	0.0	6001.762
415.	0.0	6001.762
420.	0.0	6001.762
425.	0.0	6001.762
430.	23.880	6121.156
435.	23.880	6240.559
440.	23.880	6359.953
445.	23.880	6479.352
450.	23.880	6598.754
455.	23.880	6718.148
460.	23.880	6837.551
465.	20.670	6940.895
470.	20.670	7044.242
475.	20.670	7147.594
480.	20.670	7250.938
485.	20.670	7354.285
490.	20.670	7457.637
495.	20.670	7560.980

TABLE A-4. CONTINUATION
PRODUCT FLOW DATA FOR THE
PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
500.	20.670	7664.328
505.	20.670	7767.680
510.	20.670	7871.023
515.	20.670	7974.375

TABLE A-5. PRODUCT FLOW DATA FOR THE CONVENTIONAL LINE-TRIAL #1

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
0.	25.567	0.0
5.	25.567	127.835
10.	25.567	255.670
15.	25.567	383.505
20.	25.567	511.339
25.	25.567	639.174
30.	25.567	767.009
35.	25.567	894.844
40.	25.567	1022.678
45.	25.567	1150.513
50.	25.567	1278.348
55.	25.567	1406.182
60.	25.567	1534.017
65.	13.633	1602.182
70.	13.633	1670.347
75.	13.633	1738.511
80.	13.633	1806.676
85.	13.633	1874.841
90.	13.633	1943.006
95.	13.633	2011.171
100.	13.633	2079.335
105.	13.633	2147.500
110.	13.633	2215.665
115.	13.633	2283.830
120.	13.633	2351.995
125.	18.750	2445.745
130.	18.750	2539.495
135.	18.750	2633.245
140.	18.750	2726.995
145.	18.750	2820.745

TABLE A-5. CONTINUATION
PRODUCT FLOW DATA FOR THE
CONVENTIONAL LINE-TRIAL #1

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
150.	18.750	2914.495
155.	18.750	3008.245
160.	18.750	3101.995
165.	18.750	3195.745
170.	18.750	3289.495
175.	18.750	3383.245
180.	18.750	3476.995
185.	16.727	3560.629
190.	16.727	3644.264
195.	16.727	3727.899
200.	16.727	3811.534
205.	16.727	3895.168
210.	16.727	3978.803
215.	16.727	4062.438
220.	16.727	4146.070
225.	16.727	4229.703
230.	16.727	4313.336
235.	16.727	4396.969

TABLE A-6. PRODUCT FLOW DATA FOR THE CONVENTIONAL LINE-TRIAL #2

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
0.	21.800	0.0
5.	21.800	109.000
10.	21.800	218.000
15.	21.800	327.000
20.	21.800	436.000
25.	21.800	544.999
30.	21.800	653.999
35.	21.800	762.999
40.	21.800	871.999
45.	21.800	980.998
50.	21.800	1089.998
55.	21.800	1198.998
60.	21.800	1307.998
65.	30.100	1458.497
70.	30.100	1608.997
75.	30.100	1759.497
80.	30.100	1909.997
85.	30.100	2060.496
90.	30.100	2210.996
95.	30.100	2361.496
100.	30.100	2511.996
105.	30.100	2662.495
110.	30.100	2812.995
115.	30.100	2963.495
120.	30.100	3113.995
125.	23.466	3231.324
130.	23.466	3348.654
135.	23.466	3465.984
140.	23.466	3583.314
145.	23.466	3700.644

TABLE A-6. CONTINUATION
PRODUCT FLOW DATA FOR THE
CONVENTIONAL LINE-TRIAL #2

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
150.	23.466	3817.974
155.	23.466	3935.303
160.	23.466	4052.633
165.	23.466	4169.961
170.	23.466	4287.289
175.	23.466	4404.617
180.	23.466	4521.945
185.	24.716	4645.523
190.	24.716	4769.102
195.	24.716	4892.680
200.	24.716	5016.258
205.	24.716	5139.836
210.	24.716	5263.414
215.	24.716	5386.992
220.	24.716	5510.570
225.	24.716	5634.148
230.	24.716	5757.727
235.	24.716	5881.305
240.	24.716	6004.883
245.	19.433	6102.047
250.	19.433	6199.211
255.	19.433	6296.375
260.	19.433	6393.539
265.	19.433	6490.703
270.	19.433	6587.867
275.	19.433	6685.031
280.	19.433	6782.195
285.	19.433	6879.359
290.	19.433	6976.523
295.	19.433	7073.688

TABLE A-6. CONTINUATION
PRODUCT FLOW DATA FOR THE
CONVENTIONAL LINE-TRIAL #2

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
300.	19.433	7170.852
305.	33.483	7338.266
310.	33.483	7505.680
315.	33.483	7673.094
320.	33.483	7840.508
325.	33.483	8007.922
330.	33.483	8175.336
335.	33.483	8342.750
340.	33.483	8510.164
345.	33.483	8677.578
350.	33.483	8844.992
355.	33.483	9012.406
360.	33.483	9179.820
365.	7.650	9218.066
370.	7.650	9256.313
375.	7.650	9294.559
380.	7.650	9332.805
385.	7.650	9371.051
390.	7.650	9409.297
395.	7.650	9447.543
400.	7.650	9485.789
405.	7.650	9524.035
410.	7.650	9562.281
415.	7.650	9600.527
420.	7.650	9638.773
425.	49.860	9888.070
430.	49.860	10137.367
435.	49.860	10386.664
440.	49.860	10635.961
445.	49.860	10885.258
450.	49.860	11134.555
455.	49.860	11383.852
460.	49.860	11633.148
465.	49.860	11882.445
470.	49.860	12131.742

TABLE A-7. PRODUCT FLOW DATA FOR THE CONVENTIONAL LINE-TRIAL #3

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
0.	37.017	0.0
5.	37.017	185.085
10.	37.017	370.170
15.	37.017	555.255
20.	37.017	740.340
25.	37.017	925.425
30.	37.017	1110.510
35.	37.017	1295.595
40.	37.017	1480.680
45.	37.017	1665.765
50.	37.017	1850.850
55.	37.017	2035.935
60.	37.017	2221.020
65.	16.200	2302.019
70.	16.200	2383.019
75.	16.200	2464.019
80.	16.200	2545.019
85.	16.200	2626.018
90.	16.200	2707.018
95.	16.200	2788.018
100.	16.200	2869.018
105.	16.200	2950.017
110.	16.200	3031.017
115.	16.200	3112.017
120.	16.200	3193.017
125.	23.133	3308.681
130.	23.133	3424.346
135.	23.133	3540.011
140.	23.133	3655.676
145.	23.133	3771.341

TABLE A-7. CONTINUATION
PRODUCT FLOW DATA FOR THE
CONVENTIONAL LINE-TRIAL #3

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
150.	23.133	3887.005
155.	23.133	4002.670
160.	23.133	4118.332
165.	23.133	4233.996
170.	23.133	4349.660
175.	23.133	4465.324
180.	23.133	4580.988
185.	55.500	4858.488
190.	55.500	5135.988

TABLE A-8. PRODUCT FLOW DATA FOR THE CONVENTIONAL LINE-TRIAL #4

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
0.	26.100	0.0
5.	26.100	130.500
10.	26.100	261.000
15.	26.100	391.500
20.	26.100	521.999
25.	26.100	652.499
30.	26.100	782.999
35.	26.100	913.499
40.	26.100	1043.998
45.	26.100	1174.498
50.	26.100	1304.998
55.	26.100	1435.498
60.	26.100	1565.997
65.	26.967	1700.832
70.	26.967	1835.667
75.	26.967	1970.502
80.	26.967	2105.337
85.	26.967	2240.172
90.	26.967	2375.007
95.	26.967	2509.842
100.	26.967	2644.677
105.	26.967	2779.512
110.	26.967	2914.347
115.	26.967	3049.182
120.	26.967	3184.017
125.	19.383	3280.932
130.	19.383	3377.846
135.	19.383	3474.761
140.	19.383	3571.676
145.	19.383	3668.591

TABLE A-8. CONTINUATION
PRODUCT FLOW DATA FOR THE
CONVENTIONAL LINE-TRIAL #4

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
150.	19.383	3765.506
155.	19.383	3862.420
160.	19.383	3959.335
165.	19.383	4056.250
170.	19.383	4153.164
175.	19.383	4250.078
180.	19.383	4346.992
185.	19.633	4445.156
190.	19.633	4543.320
195.	19.633	4641.484
200.	19.633	4739.648
205.	19.633	4837.813
210.	19.633	4935.977
215.	19.633	5034.141
220.	19.633	5132.305
225.	19.633	5230.469
230.	19.633	5328.633
235.	19.633	5426.797
240.	19.633	5524.961

TABLE A-9. PRODUCT FLOW DATA FOR THE CONVENTIONAL LINE-TRIAL #5

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
0.	17.783	0.0
5.	17.783	88.915
10.	17.783	177.830
15.	17.783	266.745
20.	17.783	355.659
25.	17.783	444.574
30.	17.783	533.489
35.	17.783	622.404
40.	17.783	711.319
45.	17.783	800.233
50.	17.783	889.148
55.	17.783	978.063
60.	17.783	1066.978
65.	28.033	1207.143
70.	28.033	1347.307
75.	28.033	1487.472
80.	28.033	1627.637
85.	28.033	1767.802
90.	28.033	1907.967
95.	28.033	2048.131
100.	28.033	2188.296
105.	28.033	2328.461
110.	28.033	2468.626
115.	28.033	2608.791
120.	28.033	2748.955
125.	28.567	2891.790
130.	28.567	3034.625
135.	28.567	3177.459
140.	28.567	3320.294
145.	28.567	3463.129

TABLE A-9. CONTINUATION
PRODUCT FLOW DATA FOR THE
CONVENTIONAL LINE-TRIAL #5

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
150.	28.567	3605.964
155.	28.567	3748.798
160.	28.567	3891.633
165.	28.567	4034.468
170.	28.567	4177.301
175.	28.567	4320.133
180.	28.567	4462.965
185.	24.500	4585.465
190.	24.500	4707.965
195.	24.500	4830.465
200.	24.500	4952.965
205.	24.500	5075.465
210.	24.500	5197.965
215.	24.500	5320.465
220.	24.500	5442.965
225.	24.500	5565.465
230.	24.500	5687.965
235.	24.500	5810.465
240.	24.500	5932.965

TABLE A-10. PRODUCT FLOW DATA FOR THE CONVENTIONAL LINE-TRIAL #6

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
0.	13.500	0.0
5.	13.500	67.500
10.	13.500	135.000
15.	13.500	202.500
20.	13.500	270.000
25.	13.500	337.500
30.	13.500	405.000
35.	13.500	472.500
40.	13.500	540.000
45.	13.500	607.500
50.	13.500	675.000
55.	13.500	742.500
60.	13.500	810.000
65.	15.850	889.250
70.	15.850	968.500
75.	15.850	1047.749
80.	15.850	1126.999
85.	15.850	1206.249
90.	15.850	1285.499
95.	15.850	1364.748
100.	15.850	1443.998
105.	15.850	1523.248
110.	15.850	1602.498
115.	15.850	1681.747
120.	15.850	1760.997
125.	21.050	1866.247
130.	21.050	1971.497
135.	21.050	2076.746
140.	21.050	2181.996
145.	21.050	2287.246

TABLE A-10. CONTINUATION
PRODUCT FLOW DATA FOR THE
CONVENTIONAL LINE-TRIAL #6

TIME FROM START (MIN)	FLOW RATE (KG/MIN)	CUMULATED FLOW (KG)
150.	21.050	2392.496
155.	21.050	2497.745
160.	21.050	2602.995
165.	21.050	2708.245
170.	21.050	2813.495
175.	21.050	2918.744
180.	21.050	3023.994
185.	23.850	3143.244
190.	23.850	3262.494
195.	23.850	3381.743
200.	23.850	3500.993
205.	23.850	3620.243
210.	23.850	3739.493
215.	23.850	3858.742
220.	23.850	3977.992
225.	23.850	4097.238
230.	23.850	4216.484
235.	23.850	4335.730
240.	23.850	4454.977
245.	40.600	4657.973

APPENDIX B

WATER FLOW DATA

Sample Calculations (After Robinson, 1976).

Water level recorders were used to monitor the flow through meters 4 through 9. The cycling action of the sump pumps is reflected by a band of ink on the recorder chart. Upper and lower extremes of this band were measured at five-minute intervals. An average depth for each time interval was determined and the flow rates were calculated in the following manner.

$$D = 2.4\ (d/12)$$

Where: D = water depth in the flume (ft)

d = average chart reading (in)

2.4 = ratio of water depth to chart reading

and:

$$Q = 1698.89\ q$$

Where: Q = water flow rate (1/min)

q = water flow rate in cfs. obtained from the formula:

$$q = 0.719897\ D^{2.14565}$$

Example:

$$D = 2.4\ (1.18/12)$$

$$D = 0.236\ \text{ft}$$

$$q = 0.719897\ (0.236)^{2.14565}$$

$$q = 0.034\ \text{cfs}$$

$$Q = 1698.89 \times 0.034$$

$$Q = 57.77\ \text{1/min}$$

TABLE B-1. FRESH WATER INPUT TO THE PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	99.000	0.0
5.	99.000	495.000
10.	99.000	990.000
15.	99.000	1485.000
20.	99.000	1980.000
25.	99.000	2475.000
30.	99.000	2970.000
35.	99.000	3465.000
40.	99.000	3960.000
45.	99.000	4455.000
50.	99.000	4950.000
55.	99.000	5445.000
60.	99.000	5940.000
65.	99.000	6435.000
70.	100.940	6939.699
75.	100.940	7444.398
80.	100.940	7949.098
85.	100.940	8453.797
90.	100.940	8958.496
95.	100.940	9463.195
100.	0.0	9463.195
105.	0.0	9463.195
110.	0.0	9463.195
115.	0.0	9463.195
120.	92.530	9925.844
125.	92.530	10388.492
130.	92.530	10851.141
135.	92.530	11313.789
140.	92.530	11776.438
145.	92.530	12239.086
150.	92.530	12701.734
155.	92.530	13164.383
160.	92.530	13627.031

TABLE B-1. CONTINUATION
FRESH WATER INPUT TO THE
PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	87.360	14063.828
170.	87.360	14500.625
175.	87.360	14937.422
180.	87.360	15374.219
185.	87.360	15811.016
190.	87.360	16247.813
195.	87.360	16684.609
200.	87.360	17121.406
205.	87.360	17558.203
210.	87.360	17995.000
215.	87.360	18431.797
220.	87.360	18868.594
225.	87.360	19305.391
230.	0.0	19305.391
235.	0.0	19305.391
240.	0.0	19305.391
245.	0.0	19305.391
250.	0.0	19305.391
255.	0.0	19305.391
260.	0.0	19305.391
265.	0.0	19305.391
270.	0.0	19305.391
275.	0.0	19305.391
280.	0.0	19305.391
285.	0.0	19305.391
290.	90.310	19756.938
295.	90.310	20208.484
300.	90.310	20660.031
305.	90.310	21111.578
310.	90.310	21563.125
315.	90.310	22014.672
320.	90.310	22466.219
325.	90.310	22917.766
330.	90.310	23369.313

TABLE B-1. CONTINUATION
FRESH WATER INPUT TO THE
PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	90.310	23820.859
340.	90.310	24272.406
345.	90.310	24723.953
350.	90.310	25175.500
355.	90.310	25627.047
360.	98.420	26119.145
365.	0.0	26119.145
370.	0.0	26119.145
375.	84.540	26541.844
380.	84.540	26964.543
385.	84.540	27387.242
390.	0.0	27387.242
395.	0.0	27387.242
400.	0.0	27387.242
405.	0.0	27387.242
410.	0.0	27387.242
415.	97.480	27874.641
420.	97.480	28362.039
425.	97.480	28849.438
430.	97.480	29336.836
435.	97.480	29824.234
440.	97.480	30311.633
445.	97.480	30799.031
450.	97.480	31286.430
455.	97.480	31773.828
460.	97.480	32261.227
465.	97.480	32748.625
470.	97.480	33236.023
475.	81.210	33642.070
480.	81.210	34048.117
485.	81.210	34454.164
490.	81.210	34860.211
495.	81.210	35266.258

TABLE B-1. CONTINUATION
FRESH WATER INPUT TO THE
PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
500.	81.210	35672.305
505.	81.210	36078.352
510.	81.210	36484.398
515.	81.210	36890.445
520.	81.210	37296.492
525.	81.210	37702.539

TABLE B-2. WATER FLOW DATA-RECIRCULATION IN WASHER #1 OF THE PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	329.040	0.0
5.	329.040	1645.199
10.	329.040	3290.398
15.	329.040	4935.594
20.	329.040	6580.789
25.	329.040	8225.984
30.	329.040	9871.180
35.	329.040	11516.375
40.	329.040	13161.570
45.	329.040	14806.766
50.	329.040	16451.961
55.	329.040	18097.156
60.	329.040	19742.352
65.	329.040	21387.547
70.	538.790	24081.492
75.	538.790	26775.438
80.	538.790	29469.383
85.	538.790	32163.328
90.	538.790	34857.273
95.	538.790	37551.219
100.	433.420	39718.316
105.	433.420	41885.414
110.	433.420	44052.512
115.	433.420	46219.609
120.	432.380	48381.508
125.	432.380	50543.406
130.	432.380	52705.305
135.	432.380	54867.203
140.	432.380	57029.102
145.	432.380	59191.000
150.	432.380	61352.898
155.	432.380	63514.797
160.	432.380	65676.688

TABLE B-2. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #1
OF THE PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	486.860	68110.938
170.	486.860	70545.188
175.	486.860	72979.438
180.	486.860	75413.688
185.	486.860	77847.933
190.	486.860	80282.183
195.	486.860	82716.438
200.	486.860	85150.688
205.	486.860	87584.938
210.	486.860	90019.188
215.	486.860	92453.438
220.	486.860	94887.683
225.	486.860	97321.938
230.	270.030	98672.063
235.	270.030	100022.188
240.	270.030	101372.313
245.	270.030	102722.438
250.	270.030	104072.563
255.	270.030	105422.688
260.	270.030	106772.813
265.	270.030	108122.938
270.	270.030	109473.063
275.	270.030	110823.188
280.	270.030	112173.313
285.	270.030	113523.438
290.	445.060	115748.688
295.	445.060	117973.938
300.	445.060	120199.188
305.	445.060	122424.438
310.	445.060	124649.683
315.	445.060	126874.938
320.	445.060	129100.188
325.	445.060	131325.438
330.	445.060	133550.688

TABLE B-2. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #1
OF THE PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	445.060	135775.938
340.	445.060	138001.188
345.	445.060	140226.438
350.	445.060	142451.688
355.	445.060	144676.938
360.	590.520	147629.500
365.	0.0	147629.500
370.	0.0	147629.500
375.	421.440	149736.688
380.	421.440	151843.875
385.	421.440	153951.063
390.	402.770	155964.875
395.	402.770	157978.688
400.	402.770	159992.500
405.	402.770	162006.313
410.	402.770	164020.125
415.	476.330	166401.750
420.	476.330	168783.375
425.	476.330	171165.000
430.	476.330	173546.625
435.	476.330	175928.250
440.	476.330	178309.875
445.	476.330	180691.500
450.	476.330	183073.125
455.	476.330	185454.750
460.	476.330	187836.375
465.	476.330	190218.000
470.	476.330	192599.625
475.	475.590	194977.563
480.	475.590	197355.500
485.	475.590	199733.438
490.	475.590	202111.375
495.	475.590	204489.313

TABLE B-2. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #1
OF THE PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
500.	475.590	206867.250
505.	475.590	209245.138
510.	475.590	211623.125
515.	475.590	214001.063
520.	475.590	216379.000
525.	475.590	218756.938

TABLE B-3. WATER FLOW DATA-RECIRCULATION IN WASHER #2 OF THE PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	489.190	0.0
5.	489.190	2445.950
10.	489.190	4891.898
15.	489.190	7337.848
20.	489.190	9783.797
25.	489.190	12229.746
30.	489.190	14675.695
35.	489.190	17121.645
40.	489.190	19567.594
45.	489.190	22013.543
50.	489.190	24459.492
55.	489.190	26905.441
60.	489.190	29351.391
65.	489.190	31797.340
70.	503.460	34314.637
75.	503.460	36831.934
80.	503.460	39349.230
85.	503.460	41866.527
90.	503.460	44383.824
95.	503.460	46901.121
100.	380.340	48802.820
105.	380.340	50704.520
110.	380.340	52606.219
115.	380.340	54507.918
120.	391.160	56463.715
125.	391.160	58419.512
130.	391.160	60375.309
135.	391.160	62331.105
140.	391.160	64286.902
145.	391.160	66242.688
150.	391.160	68198.438
155.	391.160	70154.188
160.	391.160	72109.938

TABLE B-3. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #2
OF THE PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	364.560	73932.688
170.	364.560	75755.438
175.	364.560	77578.188
180.	364.560	79400.938
185.	364.560	81223.688
190.	364.560	83046.438
195.	364.560	84869.188
200.	364.560	86691.938
205.	364.560	88514.688
210.	364.560	90337.438
215.	364.560	92160.188
220.	364.560	93982.938
225.	364.560	95805.688
230.	289.580	97253.563
235.	289.580	98701.438
240.	289.580	100149.313
245.	289.580	101597.188
250.	289.580	103045.063
255.	289.580	104492.938
260.	289.580	105940.813
265.	289.580	107388.688
270.	289.580	108836.563
275.	289.580	110284.438
280.	289.580	111732.313
285.	289.580	113180.188
290.	310.400	114732.125
295.	310.400	116284.063
300.	310.400	117836.000
305.	310.400	119387.938
310.	310.400	120939.875
315.	310.400	122491.813
320.	310.400	124043.750
325.	310.400	125595.688
330.	310.400	127147.625

TABLE B-3. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #2
OF THE PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	310.400	128699.563
340.	310.400	130251.500
345.	310.400	131803.438
350.	310.400	133355.375
355.	310.400	134907.313
360.	469.390	137254.250
365.	0.0	137254.250
370.	0.0	137254.250
375.	217.030	138339.375
380.	217.030	139424.500
385.	217.030	140509.625
390.	307.380	142046.500
395.	307.380	143583.375
400.	307.380	145120.250
405.	307.380	146657.125
410.	307.380	148194.000
415.	328.700	149837.438
420.	328.700	151480.875
425.	328.700	153124.313
430.	328.700	154767.750
435.	328.700	156411.188
440.	328.700	158054.625
445.	328.700	159698.063
450.	328.700	161341.500
455.	328.700	162984.938
460.	328.700	164628.375
465.	328.700	166271.813
470.	328.700	167915.250
475.	349.630	169663.375
480.	349.630	171411.500
485.	349.630	173159.625
490.	349.630	174907.750
495.	349.630	176655.875

TABLE B-3. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #2
OF THE PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
500.	349.630	178404.000
505.	349.630	180152.125
510.	349.630	181900.250
515.	349.630	183648.375
520.	349.630	185396.500
525.	349.630	187144.625

TABLE B-4. OVERFLOW TO WASTE FROM THE PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	62.358	0.0
5.	51.119	255.595
10.	46.738	489.285
15.	48.174	730.155
20.	48.893	974.619
25.	41.330	1181.269
30.	39.083	1376.684
35.	40.855	1580.959
40.	44.932	1805.619
45.	39.919	2005.214
50.	39.173	2201.078
55.	42.676	2414.458
60.	40.855	2618.733
65.	41.234	2824.903
70.	34.188	2995.843
75.	36.192	3176.803
80.	40.009	3376.848
85.	33.161	3542.653
90.	37.174	3728.522
95.	0.009	3728.567
100.	8.745	3772.292
105.	0.063	3772.607
110.	0.021	3772.712
115.	0.021	3772.817
120.	0.009	3772.862
125.	31.989	3932.807
130.	28.686	4076.237
135.	25.742	4204.945
140.	17.981	4294.848
145.	11.500	4352.348
150.	27.085	4487.770
155.	31.337	4644.453
160.	36.633	4827.617

TABLE B-4. CONTINUATION
OVERFLOW TO WASTE FROM THE
PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	37.440	5014.816
170.	24.348	5136.555
175.	26.029	5266.699
180.	15.467	5344.031
185.	11.456	5401.309
190.	16.549	5484.051
195.	21.098	5589.539
200.	24.161	5710.344
205.	23.435	5827.516
210.	31.018	5982.605
215.	23.001	6097.609
220.	56.797	6381.594
225.	0.0	6381.594
230.	0.0	6381.594
235.	0.0	6381.594
240.	0.0	6381.594
245.	0.0	6381.594
250.	0.0	6381.594
255.	0.0	6381.594
260.	0.0	6381.594
265.	0.0	6381.594
270.	0.0	6381.594
275.	0.0	6381.594
280.	0.0	6381.594
285.	0.0	6381.594
290.	0.0	6381.594
295.	0.0	6381.594
300.	0.0	6381.594
305.	0.0	6381.594
310.	0.0	6381.594
315.	18.368	6473.434
320.	24.373	6595.297
325.	38.912	6789.855
330.	38.808	6983.895

TABLE B-4. CONTINUATION
OVERFLOW TO WASTE FROM THE
PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	36.823	7168.008
340.	42.410	7380.055
345.	43.164	7595.871
350.	46.339	7827.563
355.	48.174	8068.430
360.	45.556	8296.207
365.	47.655	8534.480
370.	27.305	8671.004
375.	0.276	8672.383
380.	3.356	8689.160
385.	0.0	8689.160
390.	0.0	8689.160
395.	31.337	8845.844
400.	0.009	8845.887
405.	0.0	8845.887
410.	0.0	8845.887
415.	0.0	8845.887
420.	0.0	8845.887
425.	0.0	8845.887
430.	1.224	8852.004
435.	38.447	9044.238
440.	40.955	9249.012
445.	39.744	9447.730
450.	44.542	9670.438
455.	40.585	9873.359
460.	44.158	10094.148
465.	46.339	10325.840
470.	48.174	10566.707
475.	31.018	10721.797
480.	39.173	10917.660
485.	43.279	11134.055
490.	37.986	11323.984
495.	36.192	11504.941

TABLE B-4. CONTINUATION
OVERFLOW TO WASTE FROM THE
PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
500.	32.176	11665.820
505.	31.989	11825.762
510.	34.898	12000.250
515.	39.173	12196.113
520.	43.448	12413.352
525.	45.171	12639.203

TABLE B-5. OVERFLOW FROM SETTLING TANK #2 TO SETTLING TANK #1 IN THE PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	59.837	0.0
5.	63.265	316.325
10.	60.544	619.045
15.	59.666	917.375
20.	59.946	1217.104
25.	60.990	1522.054
30.	58.475	1814.429
35.	61.755	2123.204
40.	58.636	2416.384
45.	62.044	2726.604
50.	60.269	3027.949
55.	59.234	3324.119
60.	60.445	3626.344
65.	60.705	3929.868
70.	61.755	4238.641
75.	59.234	4534.809
80.	58.807	4828.840
85.	56.872	5113.199
90.	51.391	5370.152
95.	56.872	5654.512
100.	0.0	5654.512
105.	0.0	5654.512
110.	0.0	5654.512
115.	0.0	5654.512
120.	55.955	5934.285
125.	57.714	6222.852
130.	57.604	6510.871
135.	55.458	6788.160
140.	53.323	7054.773
145.	53.065	7320.098
150.	58.384	7612.016
155.	54.454	7884.285
160.	56.188	8165.223

TABLE B-5. CONTINUATION
OVERFLOW FROM SETTLING TANK #2 TO SETTLING TANK #1 IN THE PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	54.871	8439.574
170.	58.050	8729.820
175.	54.871	9004.172
180.	54.454	9276.441
185.	54.454	9548.711
190.	54.041	9818.914
195.	53.886	10088.344
200.	56.445	10370.566
205.	54.041	10640.770
210.	53.473	10908.133
215.	54.041	11178.336
220.	55.605	11456.359
225.	38.551	11649.113
230.	0.0	11649.113
235.	0.0	11649.113
240.	0.0	11649.113
245.	0.0	11649.113
250.	0.0	11649.113
255.	0.0	11649.113
260.	0.0	11649.113
265.	0.0	11649.113
270.	0.0	11649.113
275.	0.0	11649.113
280.	0.0	11649.113
285.	0.0	11649.113
290.	0.0	11649.113
295.	0.0	11649.113
300.	0.0	11649.113
305.	57.967	11938.945
310.	58.807	12232.977
315.	56.776	12516.855
320.	56.776	12800.734
325.	56.776	13084.613
330.	56.776	13368.492

TABLE B-5. CONTINUATION
OVERFLOW FROM SETTLING TANK #2 TO SETTLING TANK #1 IN THE PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	56.776	13652.371
340.	58.475	13944.742
345.	56.872	14229.102
350.	56.294	14510.570
355.	55.721	14789.172
360.	56.872	15073.531
365.	0.276	15074.910
370.	0.009	15074.953
375.	57.028	15360.090
380.	0.0	15360.090
385.	45.423	15587.203
390.	0.612	15590.262
395.	0.0	15590.262
400.	0.0	15590.262
405.	0.0	15590.262
410.	0.0	15590.262
415.	55.027	15865.395
420.	0.0	15865.395
425.	64.506	16187.922
430.	56.188	16468.859
435.	55.027	16743.992
440.	54.871	17013.344
445.	55.605	17296.367
450.	55.027	17571.500
455.	54.041	17841.703
460.	56.872	18126.063
465.	56.606	18409.090
470.	57.028	18694.227
475.	55.605	18972.250
480.	56.606	19255.277
485.	58.209	19546.320
490.	53.633	19814.434
495.	54.206	20085.512

TABLE B-5. CONTINUATION
OVERFLOW FROM SETTLING TANK #2 TO SETTLING TANK #1 IN THE PROTOTYPE LINE-TRIAL # 1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
500.	50.438	20337.699
505.	57.028	20622.836
510.	56.023	20902.949
515.	53.633	21171.113
520.	54.041	21441.316
525.	58.636	21734.496

TABLE B-6. FRESH WATER INPUT TO THE PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	55.120	0.0
5.	55.120	275.600
10.	55.120	551.200
15.	55.120	826.800
20.	55.120	1102.399
25.	55.120	1377.999
30.	55.120	1653.599
35.	55.120	1929.199
40.	55.120	2204.799
45.	55.120	2480.399
50.	55.120	2755.999
55.	0.0	2755.999
60.	0.0	2755.999
65.	52.810	3020.048
70.	52.810	3284.098
75.	52.810	3548.148
80.	52.810	3812.198
85.	52.810	4076.248
90.	52.810	4340.297
95.	52.810	4604.344
100.	52.810	4868.391
105.	52.810	5132.438
110.	52.810	5396.484
115.	52.810	5660.531
120.	52.810	5924.578
125.	67.380	6261.477
130.	67.380	6598.375
135.	22.140	6709.074
140.	22.140	6819.773
145.	22.140	6930.473
150.	22.140	7041.172
155.	22.140	7151.871
160.	22.140	7262.570

TABLE B-6. CONTINUATION
FRESH WATER INPUT TO THE
PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	22.140	7373.270
170.	22.140	7483.969
175.	22.140	7594.668
180.	22.140	7705.367
185.	22.140	7816.066
190.	22.140	7926.766
195.	0.0	7926.766
200.	56.820	8210.863
205.	56.820	8494.961
210.	56.820	8779.059
215.	56.820	9063.156
220.	56.820	9347.254
225.	56.820	9631.352
230.	56.820	9915.449
235.	56.820	10199.547
240.	56.820	10483.645
245.	56.820	10767.742
250.	56.820	11051.840
255.	56.820	11335.938
260.	56.820	11620.035
265.	56.820	11904.133
270.	56.820	12188.230
275.	56.820	12472.328
280.	56.820	12756.426
285.	56.820	13040.523
290.	56.820	13324.621
295.	56.820	13608.719
300.	34.070	13779.066
305.	34.070	13949.414
310.	34.070	14119.762
315.	34.070	14290.109
320.	34.070	14460.457
325.	48.340	14702.156
330.	48.340	14943.855

TABLE B-6. CONTINUATION
FRESH WATER INPUT TO THE
PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	48.340	15185.555
340.	48.340	15427.254
345.	48.340	15668.953
350.	48.340	15910.652
355.	48.340	16152.352
360.	48.340	16394.051
365.	48.340	16635.750
370.	48.340	16877.449
375.	48.340	17119.148
380.	48.340	17360.848
385.	48.340	17602.547
390.	59.940	17902.246
395.	59.940	18201.945
400.	59.940	18501.645
405.	59.940	18801.344
410.	59.940	19101.043
415.	59.940	19400.742
420.	24.610	19523.789
425.	24.610	19646.836

TABLE B-7. WATER FLOW DATA-RECIRCULATION IN WASHER #1 OF THE PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	432.290	0.0
5.	432.290	2161.449
10.	432.290	4322.895
15.	432.290	6484.340
20.	432.290	8645.785
25.	432.290	10807.230
30.	432.290	12968.676
35.	432.290	15130.121
40.	432.290	17291.566
45.	432.290	19453.012
50.	432.290	21614.457
55.	533.740	24283.156
60.	533.740	26951.855
65.	419.550	29049.602
70.	419.550	31147.348
75.	419.550	33245.094
80.	419.550	35342.840
85.	419.550	37440.586
90.	419.550	39538.332
95.	419.550	41636.078
100.	419.550	43733.824
105.	419.550	45831.570
110.	419.550	47929.316
115.	419.550	50027.063
120.	419.550	52124.809
125.	586.740	55058.508
130.	586.740	57992.207
135.	460.560	60295.004
140.	460.560	62597.801
145.	460.560	64900.598
150.	460.560	67203.375
155.	460.560	69506.125
160.	460.560	71808.875

TABLE B-7. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #1
OF THE PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	460.560	74111.625
170.	460.560	76414.375
175.	460.560	78717.125
180.	460.560	81019.875
185.	460.560	83322.625
190.	460.560	85625.375
195.	461.820	87934.438
200.	467.880	90273.813
205.	467.880	92613.188
210.	467.880	94952.563
215.	467.880	97291.938
220.	467.880	99631.313
225.	467.880	101970.688
230.	467.880	104310.063
235.	467.880	106649.438
240.	467.880	108988.813
245.	467.880	111328.188
250.	467.880	113667.563
255.	467.880	116006.938
260.	467.880	118346.313
265.	467.880	120685.688
270.	467.880	123025.063
275.	467.880	125364.438
280.	467.880	127703.813
285.	467.880	130043.188
290.	467.880	132382.563
295.	467.880	134721.938
300.	432.970	136886.750
305.	432.970	139051.563
310.	432.970	141216.375
315.	432.970	143381.188
320.	432.970	145546.000
325.	451.920	147805.563
330.	451.920	150065.125

TABLE B-7. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #1
OF THE PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	451.920	152324.688
340.	451.920	154584.250
345.	451.920	156843.813
350.	451.920	159103.375
355.	451.920	161362.938
360.	451.920	163622.500
365.	451.920	165882.063
370.	451.920	168141.625
375.	451.920	170401.188
380.	451.920	172660.750
385.	451.920	174920.313
390.	533.740	177589.000
395.	533.740	180257.688
400.	533.740	182926.375
405.	533.740	185595.063
410.	533.740	188263.750
415.	533.740	190932.438
420.	261.190	192238.375
425.	261.190	193544.313

TABLE B-8. WATER FLOW DATA-RECIRCULATION IN WASHER #2 OF THE PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	463.330	0.0
5.	463.330	2316.649
10.	463.330	4633.297
15.	463.330	6949.945
20.	463.330	9266.594
25.	463.330	11583.242
30.	463.330	13899.891
35.	463.330	16216.539
40.	463.330	18533.188
45.	463.330	20849.836
50.	463.330	23166.484
55.	484.530	25589.133
60.	484.530	28011.781
65.	430.280	30163.180
70.	430.280	32314.578
75.	430.280	34465.977
80.	430.280	36617.375
85.	430.280	38768.773
90.	430.280	40920.172
95.	430.280	43071.570
100.	430.280	45222.969
105.	430.280	47374.367
110.	430.280	49525.766
115.	430.280	51677.164
120.	430.280	53828.563
125.	662.450	57140.809
130.	662.450	60453.055
135.	316.080	62033.453
140.	316.080	63613.852
145.	316.080	65194.250
150.	316.080	66774.625
155.	316.080	68355.000
160.	316.080	69935.375

TABLE B-8. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #2
OF THE PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	316.080	71515.750
170.	316.080	73096.125
175.	316.080	74676.500
180.	316.080	76256.875
185.	316.080	77837.250
190.	316.080	79417.625
195.	121.130	80023.250
200.	397.090	82008.688
205.	397.090	83994.125
210.	397.090	85979.563
215.	397.090	87965.000
220.	397.090	89950.438
225.	397.090	91935.875
230.	397.090	93921.313
235.	397.090	95906.750
240.	397.090	97892.188
245.	397.090	99877.625
250.	397.090	101863.063
255.	397.090	103848.500
260.	397.090	105833.938
265.	397.090	107819.375
270.	397.090	109804.813
275.	397.090	111790.250
280.	397.090	113775.688
285.	397.090	115761.125
290.	397.090	117746.563
295.	397.090	119732.000
300.	366.430	121564.125
305.	366.430	123396.250
310.	366.430	125228.375
315.	366.430	127060.500
320.	366.430	128892.625
325.	359.320	130689.188
330.	359.320	132485.750

TABLE B-8. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #2
OF THE PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	359.320	134282.313
340.	359.320	136078.875
345.	359.320	137875.438
350.	359.320	139672.000
355.	359.320	141468.563
360.	359.320	143265.125
365.	359.320	145061.688
370.	359.320	146858.250
375.	359.320	148654.813
380.	359.320	150451.375
385.	359.320	152247.938
390.	418.920	154342.500
395.	418.920	156437.063
400.	418.920	158531.625
405.	418.920	160626.188
410.	418.920	162720.750
415.	418.920	164815.313
420.	193.050	165780.500
425.	193.050	166745.688

TABLE B-9. OVERFLOW TO WASTE FROM THE PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	42.307	0.0
5.	36.712	183.560
10.	17.137	269.245
15.	18.925	363.870
20.	15.354	440.639
25.	6.365	472.464
30.	3.519	490.059
35.	1.375	496.934
40.	0.636	500.114
45.	2.504	512.634
50.	0.0	512.634
55.	0.409	514.679
60.	0.0	514.679
65.	0.0	514.679
70.	0.063	514.994
75.	0.009	515.039
80.	0.0	515.039
85.	0.0	515.039
90.	0.0	515.039
95.	6.854	549.309
100.	10.296	600.789
105.	15.072	676.148
110.	12.184	737.068
115.	4.523	759.683
120.	3.650	777.933
125.	1.337	784.618
130.	0.409	786.663
135.	0.032	786.823
140.	0.0	786.823
145.	0.0	786.823
150.	0.0	786.823
155.	0.0	786.823
160.	0.0	786.823

TABLE B-9. CONTINUATION
OVERFLOW TO WASTE FROM THE
PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	0.063	787.138
170.	0.039	787.333
175.	0.002	787.342
180.	0.0	787.342
185.	0.0	787.342
190.	0.0	787.342
195.	0.0	787.342
200.	0.0	787.342
205.	0.0	787.342
210.	0.0	787.342
215.	0.0	787.342
220.	0.0	787.342
225.	0.0	787.342
230.	0.0	787.342
235.	0.0	787.342
240.	0.0	787.342
245.	0.0	787.342
250.	0.0	787.342
255.	0.0	787.342
260.	0.0	787.342
265.	0.0	787.342
270.	3.495	804.817
275.	5.198	830.807
280.	1.183	836.722
285.	2.667	850.057
290.	2.287	861.492
295.	2.958	876.281
300.	22.193	987.246
305.	31.542	1144.956
310.	29.077	1290.341
315.	31.969	1450.186
320.	23.166	1566.016
325.	6.538	1598.706
330.	0.063	1599.021

TABLE B-9. CONTINUATION
OVERFLOW TO WASTE FROM THE
PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	0.382	1600.931
340.	3.519	1618.526
345.	1.502	1626.035
350.	0.661	1629.340
355.	1.563	1637.155
360.	3.552	1654.915
365.	0.468	1657.255
370.	1.940	1666.955
375.	4.277	1688.340
380.	0.535	1691.014
385.	1.393	1697.979
390.	2.073	1708.344
395.	0.315	1709.919
400.	0.021	1710.024
405.	0.002	1710.034
410.	0.0	1710.034
415.	10.441	1762.239
420.	16.229	1843.384
425.	11.585	1901.308

TABLE B-10. OVERFLOW FROM SETTLING TANK #2 TO SETTLING TANK #1 IN THE PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	50.842	0.0
5.	70.201	351.005
10.	60.102	651.515
15.	52.502	914.024
20.	53.473	1181.389
25.	48.564	1424.209
30.	46.589	1657.154
35.	48.031	1897.309
40.	41.549	2105.053
45.	44.046	2325.283
50.	0.0	2325.283
55.	0.276	2326.663
60.	0.021	2326.768
65.	25.742	2455.478
70.	48.175	2696.353
75.	37.740	2885.052
80.	35.345	3061.777
85.	31.969	3221.622
90.	42.168	3432.462
95.	34.124	3603.082
100.	33.359	3769.877
105.	33.472	3937.237
110.	44.662	4160.543
115.	35.137	4336.227
120.	34.457	4508.508
125.	39.383	4705.422
130.	46.459	4937.715
135.	0.0	4937.715
140.	0.0	4937.715
145.	0.0	4937.715
150.	0.0	4937.715
155.	0.0	4937.715
160.	0.0	4937.715

TABLE B-10. CONTINUATION
OVERFLOW FROM SETTLING TANK #2 TO SETTLING TANK #1 IN THE PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	0.0	4937.715
170.	0.977	4942.598
175.	0.276	4943.977
180.	0.340	4945.676
185.	0.486	4948.105
190.	0.276	4949.484
195.	27.770	5088.332
200.	41.549	5296.074
205.	34.565	5468.898
210.	89.342	5915.605
215.	34.124	6086.223
220.	36.251	6267.477
225.	35.682	6445.883
230.	38.675	6639.254
235.	33.796	6808.230
240.	34.124	6978.848
245.	32.176	7139.727
250.	30.290	7291.176
255.	36.251	7472.430
260.	37.393	7659.395
265.	37.279	7845.789
270.	38.205	8036.813
275.	30.604	8189.832
280.	33.796	8358.609
285.	36.476	8541.188
290.	34.124	8711.805
295.	36.723	8895.418
300.	47.895	9134.891
305.	28.163	9275.703
310.	36.251	9456.957
315.	31.337	9613.641
320.	32.176	9774.520
325.	34.457	9946.801
330.	34.795	10120.773

TABLE B-10. CONTINUATION
OVERFLOW FROM SETTLING TANK #2 TO SETTLING
TANK #1 IN THE PROTOTYPE LINE-TRIAL # 4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	31.337	10277.457
340.	36.192	10458.414
345.	33.035	10623.586
350.	33.796	10792.563
355.	36.589	10975.504
360.	33.472	11142.863
365.	33.035	11308.035
370.	33.152	11473.793
375.	37.138	11659.480
380.	38.675	11852.852
385.	31.857	12012.133
390.	30.290	12163.582
395.	33.035	12328.754
400.	31.018	12483.844
405.	34.237	12655.027
410.	33.472	12822.387
415.	36.516	13004.965
420.	28.686	13148.395
425.	21.846	13257.621

TABLE B-11. FRESH WATER INPUT TO THE PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	90.850	0.0
5.	90.850	454.250
10.	90.850	908.500
15.	90.850	1362.749
20.	0.0	1362.749
25.	73.820	1731.849
30.	73.820	2100.949
35.	73.820	2470.049
40.	73.820	2839.149
45.	73.820	3208.249
50.	73.820	3577.348
55.	73.820	3946.448
60.	73.820	4315.547
65.	73.820	4684.645
70.	73.820	5053.742
75.	73.820	5422.840
80.	73.820	5791.938
85.	87.820	6231.035
90.	87.820	6670.133
95.	80.060	7070.430
100.	80.060	7470.727
105.	80.060	7871.023
110.	80.060	8271.320
115.	65.490	8598.770
120.	65.490	8926.219
125.	65.490	9253.668
130.	65.490	9581.117
135.	65.490	9908.566
140.	65.490	10236.016
145.	65.490	10563.465
150.	65.490	10890.914
155.	65.490	11218.363
160.	65.490	11545.813

TABLE B-11. CONTINUATION
FRESH WATER INPUT TO THE
PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	74.950	11920.559
170.	74.950	12295.305
175.	74.950	12670.051
180.	74.950	13044.797
185.	74.950	13419.543
190.	81.390	13826.492
195.	81.390	14233.441
200.	81.390	14640.391
205.	81.390	15047.340
210.	81.390	15454.289
215.	81.390	15861.238
220.	54.330	16132.887
225.	54.330	16404.535
230.	54.330	16676.184
235.	54.330	16947.832
240.	54.330	17219.480
245.	54.330	17491.129
250.	54.330	17762.777
255.	54.330	18034.426
260.	54.330	18306.074
265.	54.330	18577.723
270.	54.330	18849.371
275.	54.330	19121.020
280.	54.330	19392.668
285.	54.330	19664.316
290.	54.330	19935.965
295.	54.330	20207.613
300.	54.330	20479.262
305.	73.040	20844.461
310.	73.040	21209.660
315.	73.040	21574.859
320.	73.040	21940.059
325.	73.040	22305.258
330.	73.040	22670.457

TABLE B-11. CONTINUATION
FRESH WATER INPUT TO THE
PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	73.040	23035.656
340.	73.040	23400.855
345.	73.040	23766.055
350.	73.040	24131.254
355.	73.040	24496.453
360.	73.040	24861.652
365.	73.040	25226.852
370.	73.040	25592.051
375.	73.040	25957.250
380.	73.040	26322.449
385.	73.040	26687.648
390.	68.100	27028.145
395.	68.100	27368.641
400.	68.100	27709.137
405.	68.100	28049.633
410.	70.410	28401.680
415.	70.410	28753.727
420.	70.410	29105.773
425.	70.410	29457.820
430.	70.410	29809.867
435.	64.350	30131.613
440.	64.350	30453.359
445.	64.350	30775.105
450.	64.350	31096.852
455.	64.350	31418.598
460.	64.350	31740.344
465.	64.350	32062.090
470.	64.350	32383.836
475.	64.350	32705.582
480.	64.350	33027.328
485.	64.350	33349.074
490.	66.880	33683.473
495.	66.880	34017.871

TABLE B-11. CONTINUATION
FRESH WATER INPUT TO THE
PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
500.	66.880	34352.270
505.	94.600	34825.266
510.	94.600	35298.262
515.	94.600	35771.258
520.	32.170	35932.105
525.	32.170	36092.953

TABLE B-12. WATER FLOW DATA-RECIRCULATION IN WASHER #1 OF THE PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	600.620	0.0
5.	600.620	3003.099
10.	600.620	6006.195
15.	600.620	9009.293
20.	0.0	9009.293
25.	415.130	11084.941
30.	415.130	13160.590
35.	415.130	15236.238
40.	415.130	17311.887
45.	415.130	19387.535
50.	415.130	21463.184
55.	415.130	23538.832
60.	415.130	25614.480
65.	415.130	27690.129
70.	415.130	29765.777
75.	415.130	31841.426
80.	415.130	33917.074
85.	507.250	36453.324
90.	507.250	38989.574
95.	461.820	41298.672
100.	461.820	43607.770
105.	461.820	45916.867
110.	461.820	48225.965
115.	395.950	50205.711
120.	395.950	52185.457
125.	395.950	54165.203
130.	395.950	56144.949
135.	395.950	58124.695
140.	395.950	60104.441
145.	395.950	62084.188
150.	395.950	64063.934
155.	395.950	66043.625
160.	395.950	68023.313

TABLE B-12. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #1
OF THE PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	436.080	70203.688
170.	436.080	72384.063
175.	436.080	74564.438
180.	436.080	76744.813
185.	436.080	78925.188
190.	330.590	80578.125
195.	330.590	82231.063
200.	330.590	83884.000
205.	330.590	85536.938
210.	330.590	87189.875
215.	330.590	88842.813
220.	442.230	91053.938
225.	442.230	93265.063
230.	442.230	95476.188
235.	442.230	97687.313
240.	442.230	99898.438
245.	442.230	102109.563
250.	442.230	104320.688
255.	442.230	106531.813
260.	442.230	108742.938
265.	442.230	110954.063
270.	442.230	113165.188
275.	442.230	115376.313
280.	442.230	117587.438
285.	442.230	119798.563
290.	442.230	122009.688
295.	442.230	124220.813
300.	442.230	126431.938
305.	397.690	128420.375
310.	397.690	130408.813
315.	397.690	132397.250
320.	397.690	134385.688
325.	397.690	136374.125
330.	397.690	138362.563

TABLE B-12. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #1
OF THE PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	397.690	140351.000
340.	397.690	142339.438
345.	397.690	144327.875
350.	397.690	146316.313
355.	397.690	148304.750
360.	397.690	150293.188
365.	397.690	152281.625
370.	397.690	154270.063
375.	397.690	156258.500
380.	397.690	158246.938
385.	397.690	160235.375
390.	367.150	162071.063
395.	367.150	163906.750
400.	367.150	165742.438
405.	367.150	167578.125
410.	345.230	169304.250
415.	345.230	171030.375
420.	345.230	172756.500
425.	345.230	174482.625
430.	345.230	176208.750
435.	287.000	177643.750
440.	287.000	179078.750
445.	287.000	180513.750
450.	287.000	181948.750
455.	287.000	183383.750
460.	287.000	184818.750
465.	287.000	186253.750
470.	287.000	187688.750
475.	287.000	189123.750
480.	287.000	190558.750
485.	287.000	191993.750
490.	280.120	193394.313
495.	280.120	194794.875

TABLE B-12. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #1
OF THE PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
500.	280.120	196195.438
505.	388.630	198138.563
510.	388.630	200081.688
515.	388.630	202024.813
520.	128.700	202668.250
525.	128.700	203311.688

TABLE B-13. WATER FLOW DATA-RECIRCULATION IN WASHER #2 OF THE PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	532.480	0.0
5.	532.480	2662.400
10.	532.480	5324.797
15.	532.480	7987.195
20.	0.0	7987.195
25.	438.480	10179.594
30.	438.480	12371.992
35.	438.480	14564.391
40.	438.480	16756.789
45.	438.480	18949.188
50.	438.480	21141.586
55.	438.480	23333.984
60.	438.480	25526.383
65.	438.480	27718.781
70.	438.480	29911.180
75.	438.480	32103.578
80.	438.480	34295.977
85.	503.460	36813.273
90.	503.460	39330.570
95.	459.930	41630.219
100.	459.930	43929.867
105.	459.930	46229.516
110.	459.930	48529.164
115.	395.200	50505.160
120.	395.200	52481.156
125.	395.200	54457.152
130.	395.200	56433.148
135.	395.200	58409.145
140.	395.200	60385.141
145.	395.200	62361.137
150.	395.200	64337.133
155.	395.200	66313.125
160.	395.200	68289.063

TABLE B-13. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #2
OF THE PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	416.400	70371.000
170.	416.400	72452.938
175.	416.400	74534.875
180.	416.400	76616.813
185.	416.400	78698.750
190.	446.680	80932.125
195.	446.680	83165.500
200.	446.680	85398.875
205.	446.680	87632.250
210.	446.680	89865.625
215.	446.680	92099.000
220.	387.450	94036.188
225.	387.450	95973.375
230.	387.450	97910.563
235.	387.450	99847.750
240.	387.450	101784.938
245.	387.450	103722.125
250.	387.450	105659.313
255.	387.450	107596.500
260.	387.450	109533.688
265.	387.450	111470.875
270.	387.450	113408.063
275.	387.450	115345.250
280.	387.450	117282.438
285.	387.450	119219.625
290.	387.450	121156.813
295.	387.450	123094.000
300.	387.450	125031.188
305.	350.040	126781.375
310.	350.040	128531.563
315.	350.040	130281.750
320.	350.040	132031.938
325.	350.040	133782.125
330.	350.040	135532.313

TABLE B-13. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #2
OF THE PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	350.040	137282.500
340.	350.040	139032.688
345.	350.040	140782.875
350.	350.040	142533.063
355.	350.040	144283.250
360.	350.040	146033.438
365.	350.040	147783.625
370.	350.040	149533.813
375.	350.040	151284.000
380.	350.040	153034.188
385.	350.040	154784.375
390.	274.440	156156.563
395.	274.440	157528.750
400.	274.440	158900.938
405.	274.440	160273.125
410.	271.030	161628.250
415.	271.030	162983.375
420.	271.030	164338.500
425.	271.030	165693.625
430.	271.030	167048.750
435.	241.580	168256.625
440.	241.580	169464.500
445.	241.580	170672.375
450.	241.580	171880.250
455.	241.580	173088.125
460.	241.580	174296.000
465.	241.580	175503.875
470.	241.580	176711.750
475.	241.580	177919.625
480.	241.580	179127.500
485.	241.580	180335.375
490.	222.080	181445.750
495.	222.080	182556.125

TABLE B-13. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #2
OF THE PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
500.	222.080	183666.500
505.	312.920	185231.063
510.	312.920	186795.625
515.	312.920	188360.188
520.	102.250	188871.438
525.	102.250	189382.688

TABLE B-14. OVERFLOW TO WASTE FROM THE PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	0.0	0.0
5.	0.063	0.315
10.	19.095	95.790
15.	36.051	276.045
20.	0.276	277.425
25.	0.092	277.885
30.	0.039	278.079
35.	31.354	434.849
40.	35.727	613.484
45.	26.029	743.629
50.	26.895	878.104
55.	25.560	1005.903
60.	20.906	1110.433
65.	17.510	1197.983
70.	16.450	1280.233
75.	18.453	1372.498
80.	22.029	1482.642
85.	23.262	1598.952
90.	22.193	1709.917
95.	48.424	1952.037
100.	44.931	2176.692
105.	49.421	2423.796
110.	47.113	2659.361
115.	32.223	2820.476
120.	19.577	2918.361
125.	16.904	3002.881
130.	15.072	3078.240
135.	16.229	3159.385
140.	24.637	3282.570
145.	24.637	3405.755
150.	25.180	3531.655
155.	25.286	3658.085
160.	24.262	3779.395

TABLE B-14. CONTINUATION
OVERFLOW TO WASTE FROM THE
PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	22.809	3893.439
170.	19.339	3990.134
175.	19.249	4086.379
180.	10.839	4140.570
185.	13.021	4205.672
190.	11.422	4262.781
195.	12.050	4323.027
200.	0.276	4324.406
205.	0.009	4324.449
210.	5.418	4351.539
215.	63.568	4669.379
220.	27.165	4805.203
225.	27.165	4941.027
230.	27.165	5076.852
235.	27.165	5212.676
240.	27.165	5348.500
245.	27.165	5484.324
250.	27.165	5620.148
255.	27.165	5755.973
260.	27.165	5891.797
265.	27.165	6027.621
270.	27.165	6163.445
275.	27.165	6299.270
280.	27.165	6435.094
285.	27.165	6570.918
290.	27.165	6706.742
295.	27.165	6842.566
300.	27.165	6978.391
305.	28.647	7121.625
310.	30.049	7271.867
315.	27.027	7407.000
320.	28.647	7550.234
325.	12.307	7611.766
330.	22.860	7726.063

TABLE B-14. CONTINUATION
OVERFLOW TO WASTE FROM THE
PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	26.722	7859.672
340.	27.807	7998.703
345.	31.333	8155.367
350.	30.327	8307.000
355.	33.867	8476.332
360.	33.260	8642.629
365.	32.513	8805.191
370.	34.947	8979.926
375.	46.204	9210.945
380.	41.598	9418.934
385.	43.172	9634.793
390.	49.103	9880.305
395.	49.103	10125.816
400.	49.496	10373.293
405.	54.565	10646.117
410.	30.566	10798.945
415.	20.720	10902.543
420.	19.018	10997.633
425.	17.396	11084.609
430.	22.416	11196.688
435.	20.237	11297.871
440.	16.360	11379.668
445.	23.410	11496.715
450.	22.192	11607.672
455.	25.874	11737.039
460.	24.192	11857.996
465.	23.410	11975.043
470.	20.799	12079.035
475.	20.389	12180.977
480.	32.467	12343.309
485.	45.939	12573.000
490.	44.353	12794.762
495.	69.007	13139.793

TABLE B-14. CONTINUATION
OVERFLOW TO WASTE FROM THE
PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
500.	17.396	13226.770
505.	48.424	13468.887
510.	47.502	13706.395
515.	58.179	13997.289
520.	23.766	14116.117
525.	23.766	14234.945

TABLE B-15. OVERFLOW FROM SETTLING TANK #2 TO SETTLING TANK #1 IN THE PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	47.502	0.0
5.	55.867	279.335
10.	37.393	466.300
15.	47.791	705.254
20.	34.665	878.579
25.	0.0	878.579
30.	42.307	1090.114
35.	46.348	1321.854
40.	51.700	1580.354
45.	45.825	1809.479
50.	48.873	2053.843
55.	52.662	2317.153
60.	49.103	2562.668
65.	50.987	2817.603
70.	47.257	3053.888
75.	50.842	3308.098
80.	49.496	3555.577
85.	47.791	3794.532
90.	40.753	3998.297
95.	34.811	4172.352
100.	37.315	4358.926
105.	38.123	4549.539
110.	38.803	4743.551
115.	62.652	5056.809
120.	47.791	5295.762
125.	48.564	5538.578
130.	48.564	5781.395
135.	43.172	5997.254
140.	45.306	6223.781
145.	48.175	6464.652
150.	45.306	6691.180
155.	45.079	6916.574
160.	47.791	7155.527

TABLE B-15. CONTINUATION
OVERFLOW FROM SETTLING TANK #2 TO SETTLING TANK #1 IN THE PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	50.987	7410.461
170.	42.904	7624.930
175.	49.257	7871.262
180.	50.438	8123.449
185.	61.593	8431.414
190.	51.142	8687.121
195.	49.496	8934.598
200.	49.105	9180.121
205.	52.098	9440.609
210.	47.113	9676.172
215.	43.681	9894.574
220.	27.165	10030.398
225.	27.165	10166.223
230.	27.165	10302.047
235.	27.165	10437.871
240.	27.165	10573.695
245.	27.165	10709.520
250.	27.165	10845.344
255.	27.165	10981.168
260.	27.165	11116.992
265.	27.165	11252.816
270.	27.165	11388.641
275.	27.165	11524.465
280.	27.165	11660.289
285.	27.165	11796.113
290.	27.165	11931.938
295.	27.165	12067.762
300.	27.165	12203.586
305.	47.791	12442.539
310.	47.791	12681.492
315.	47.791	12920.445
320.	47.791	13159.398
325.	59.467	13456.730
330.	51.142	13712.438

TABLE B-15. CONTINUATION
OVERFLOW FROM SETTLING TANK #2 TO SETTLING TANK #1 IN THE PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	49.646	13960.664
340.	51.700	14219.160
345.	52.831	14483.313
350.	49.103	14728.824
355.	52.263	14990.137
360.	50.748	15243.875
365.	49.496	15491.352
370.	46.339	15723.043
375.	52.098	15983.531
380.	49.496	16231.008
385.	50.706	16484.535
390.	45.604	16712.555
395.	30.485	16864.977
400.	31.100	17020.473
405.	30.485	17172.895
410.	44.792	17396.652
415.	44.046	17617.078
420.	47.288	17853.516
425.	52.662	18116.824
430.	49.421	18363.926
435.	48.958	18608.715
440.	48.958	18853.504
445.	51.700	19112.000
450.	47.502	19349.508
455.	46.729	19583.152
460.	49.975	19833.023
465.	46.878	20067.410
470.	47.949	20307.152
475.	49.895	20556.625
480.	49.496	20804.102
485.	50.842	21058.309
490.	53.011	21323.363
495.	42.094	21533.832

TABLE B-15. CONTINUATION
OVERFLOW FROM SETTLING TANK #2 TO SETTLING TANK #1 IN THE PROTOTYPE LINE-TRIAL # 5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
500.	48.424	21775.949
505.	48.031	22016.102
510.	57.714	22304.668
515.	36.663	22487.980
520.	47.621	22726.082
525.	47.621	22964.184

TABLE B-16. FRESH WATER INPUT TO THE PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	58.030	0.0
5.	58.030	290.150
10.	58.030	580.300
15.	58.030	870.450
20.	58.030	1160.600
25.	58.030	1450.750
30.	58.030	1740.899
35.	75.710	2119.449
40.	75.710	2497.999
45.	75.710	2876.549
50.	75.710	3255.099
55.	75.710	3633.648
60.	75.710	4012.198
65.	95.390	4489.145
70.	95.390	4966.094
75.	95.390	5443.043
80.	95.390	5919.992
85.	95.390	6396.941
90.	102.210	6907.988
95.	104.480	7430.387
100.	104.480	7952.785
105.	104.480	8475.184
110.	104.480	8997.582
115.	104.480	9519.980
120.	87.610	9958.027
125.	87.610	10396.074
130.	87.610	10834.121
135.	87.610	11272.168
140.	87.610	11710.215
145.	87.610	12148.262
150.	87.610	12586.309
155.	88.620	13029.406
160.	88.620	13472.504

TABLE B-16. CONTINUATION
FRESH WATER INPUT TO THE
PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	88.620	13915.602
170.	88.620	14358.699
175.	88.620	14801.797
180.	88.620	15244.895
185.	88.620	15687.992
190.	88.620	16131.090
195.	88.620	16574.188
200.	88.620	17017.285
205.	88.620	17460.383
210.	88.620	17903.480
215.	88.620	18346.578
220.	88.620	18789.676
225.	88.620	19232.773
230.	88.620	19675.871
235.	88.620	20118.969
240.	107.250	20655.219
245.	107.250	21191.469
250.	107.250	21727.719
255.	107.250	22263.969
260.	107.250	22800.219
265.	107.250	23336.469
270.	107.250	23872.719
275.	107.250	24408.969
280.	107.250	24945.219
285.	107.250	25481.469
290.	107.250	26017.719
295.	107.250	26553.969
300.	105.050	27079.215
305.	105.050	27604.461
310.	105.050	28129.707
315.	105.050	28654.953
320.	105.050	29180.199
325.	105.050	29705.445
330.	105.050	30230.691

TABLE B-16. CONTINUATION
FRESH WATER INPUT TO THE
PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	105.050	30755.938
340.	105.050	31281.184
345.	105.050	31806.430
350.	105.050	32331.676
355.	105.050	32856.922
360.	105.050	33382.168
365.	105.050	33907.414
370.	105.050	34432.660
375.	105.050	34957.906
380.	105.050	35483.152
385.	105.050	36008.398
390.	105.050	36533.645
395.	105.050	37058.891
400.	53.000	37323.891
405.	53.000	37588.891
410.	53.000	37853.891
415.	53.000	38118.891
420.	53.000	38383.891
425.	53.000	38648.891
430.	98.630	39142.039
435.	98.630	39635.188
440.	98.630	40128.336
445.	98.630	40621.484
450.	98.630	41114.633
455.	98.630	41607.781
460.	98.630	42100.930
465.	98.630	42594.078
470.	98.630	43087.227
475.	98.630	43580.375
480.	98.630	44073.523
485.	98.630	44566.672
490.	98.630	45059.820
495.	98.630	45552.969

TABLE B-16. CONTINUATION
FRESH WATER INPUT TO THE
PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
500.	98.630	46046.117
505.	98.630	46539.266
510.	98.630	47032.414
515.	98.630	47525.563

TABLE B-17. WATER FLOW DATA-RECIRCULATION IN WASHER #1 OF THE PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	326.810	0.0
5.	326.810	1634.049
10.	326.810	3268.098
15.	326.810	4902.145
20.	326.810	6536.191
25.	326.810	8170.238
30.	326.810	9804.285
35.	417.660	11892.582
40.	417.660	13980.879
45.	417.660	16069.176
50.	417.660	18157.473
55.	417.660	20245.770
60.	417.660	22334.066
65.	387.630	24272.215
70.	387.630	26210.363
75.	387.630	28148.512
80.	387.630	30086.660
85.	387.630	32024.809
90.	378.540	33917.504
95.	398.230	35908.652
100.	398.230	37899.801
105.	398.230	39890.949
110.	398.230	41882.098
115.	398.230	43873.246
120.	336.360	45555.043
125.	336.360	47236.840
130.	336.360	48918.637
135.	336.360	50600.434
140.	336.360	52282.230
145.	336.360	53964.027
150.	336.360	55645.824
155.	387.000	57580.824
160.	387.000	59515.824

TABLE B-17. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #1
OF THE PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	387.000	61450.824
170.	387.000	63385.824
175.	387.000	65320.824
180.	387.000	67255.813
185.	387.000	69190.813
190.	387.000	71125.813
195.	387.000	73060.813
200.	387.000	74995.813
205.	387.000	76930.813
210.	387.000	78865.813
215.	387.000	80800.813
220.	387.000	82735.813
225.	387.000	84670.813
230.	387.000	86605.813
235.	387.000	88540.813
240.	287.370	89977.625
245.	287.370	91414.438
250.	287.370	92851.250
255.	287.370	94288.063
260.	287.370	95724.875
265.	287.370	97161.688
270.	287.370	98598.500
275.	287.370	100035.313
280.	287.370	101472.125
285.	287.370	102908.938
290.	287.370	104345.750
295.	287.370	105782.563
300.	394.820	107756.625
305.	394.820	109730.688
310.	394.820	111704.750
315.	394.820	113678.813
320.	394.820	115652.875
325.	394.820	117626.938
330.	394.820	119601.000

TABLE B-17. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #1
OF THE PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	394.820	121575.063
340.	394.820	123549.125
345.	394.820	125523.188
350.	394.820	127497.250
355.	394.820	129471.313
360.	394.820	131445.375
365.	394.820	133419.438
370.	394.820	135393.500
375.	394.820	137367.563
380.	394.820	139341.625
385.	394.820	141315.688
390.	394.820	143289.750
395.	394.820	145263.813
400.	300.310	146765.313
405.	300.310	148266.813
410.	300.310	149768.313
415.	300.310	151269.813
420.	300.310	152771.313
425.	300.310	154272.813
430.	437.430	156459.938
435.	437.430	158647.063
440.	437.430	160834.188
445.	437.430	163021.313
450.	437.430	165208.438
455.	437.430	167395.563
460.	437.430	169582.688
465.	437.430	171769.813
470.	437.430	173956.938
475.	437.430	176144.063
480.	437.430	178331.188
485.	437.430	180518.313
490.	437.430	182705.438
495.	437.430	184892.563

TABLE B-17. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #1
OF THE PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
500.	437.430	187079.688
505.	437.430	189266.813
510.	437.430	191453.938
515.	437.430	193641.063

TABLE B-18. WATER FLOW DATA-RECIRCULATION IN WASHER #2 OF THE PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	382.330	0.0
5.	382.330	1911.649
10.	382.330	3823.298
15.	382.330	5734.945
20.	382.330	7646.594
25.	382.330	9558.242
30.	382.330	11469.891
35.	494.630	13943.039
40.	494.630	16416.188
45.	494.630	18889.336
50.	494.630	21362.484
55.	494.630	23835.633
60.	494.630	26308.781
65.	481.500	28716.281
70.	481.500	31123.781
75.	481.500	33531.281
80.	481.500	35938.781
85.	481.500	38346.281
90.	476.960	40731.078
95.	508.760	43274.875
100.	508.760	45818.672
105.	508.760	48362.469
110.	508.760	50906.266
115.	508.760	53450.063
120.	430.460	55602.359
125.	430.460	57754.656
130.	430.460	59906.953
135.	430.460	62059.250
140.	430.460	64211.547
145.	430.460	66363.813
150.	430.460	68516.063
155.	474.250	70887.313
160.	474.250	73258.563

TABLE B-18. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #2
OF THE PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	474.250	75629.813
170.	474.250	78001.063
175.	474.250	80372.313
180.	474.250	82743.563
185.	474.250	85114.813
190.	474.250	87486.063
195.	474.250	89857.313
200.	474.250	92228.563
205.	474.250	94599.813
210.	474.250	96971.063
215.	474.250	99342.313
220.	474.250	101713.563
225.	474.250	104084.813
230.	474.250	106456.063
235.	474.250	108827.313
240.	476.330	111208.938
245.	476.330	113590.563
250.	476.330	115972.188
255.	476.330	118353.813
260.	476.330	120735.438
265.	476.330	123117.063
270.	476.330	125498.688
275.	476.330	127880.313
280.	476.330	130261.938
285.	476.330	132643.563
290.	476.330	135025.188
295.	476.330	137406.813
300.	439.110	139602.313
305.	439.110	141797.813
310.	439.110	143993.313
315.	439.110	146188.813
320.	439.110	148384.313
325.	439.110	150579.813
330.	439.110	152775.313

TABLE B-18. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #2
OF THE PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	439.110	154970.813
340.	439.110	157166.313
345.	439.110	159361.813
350.	439.110	161557.313
355.	439.110	163752.813
360.	439.110	165948.313
365.	439.110	168143.813
370.	439.110	170339.313
375.	439.110	172534.813
380.	439.110	174730.313
385.	439.110	176925.813
390.	439.110	179121.313
395.	439.110	181316.813
400.	292.740	182780.500
405.	292.740	184244.188
410.	292.740	185707.875
415.	292.740	187171.563
420.	292.740	188635.250
425.	292.740	190098.938
430.	409.670	192147.250
435.	409.670	194195.563
440.	409.670	196243.875
445.	409.670	198292.188
450.	409.670	200340.500
455.	409.670	202388.813
460.	409.670	204437.125
465.	409.670	206485.438
470.	409.670	208533.750
475.	409.670	210582.063
480.	409.670	212630.375
485.	409.670	214678.688
490.	409.670	216727.000
495.	409.670	218775.313

TABLE B-18. CONTINUATION
WATER FLOW DATA-RECIRCULATION IN WASHER #2
OF THE PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
500.	409.670	220823.625
505.	409.670	222871.938
510.	409.670	224920.250
515.	409.670	226968.563

TABLE B-19. OVERFLOW TO WASTE FROM THE PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	2.504	0.0
5.	2.504	12.520
10.	14.147	83.255
15.	16.751	167.010
20.	15.214	243.080
25.	7.664	281.400
30.	22.111	391.955
35.	39.383	588.870
40.	44.046	809.099
45.	41.549	1016.844
50.	41.549	1224.589
55.	41.184	1430.509
60.	44.283	1651.924
65.	31.018	1307.014
70.	28.376	1948.894
75.	26.792	2082.854
80.	25.654	2211.123
85.	40.338	2412.813
90.	53.323	2679.428
95.	53.740	2948.128
100.	32.716	3111.708
105.	31.542	3269.418
110.	35.345	3446.143
115.	32.716	3609.723
120.	48.564	3852.542
125.	64.506	4175.070
130.	66.050	4505.316
135.	67.149	4841.059
140.	66.050	5171.305
145.	64.799	5495.297
150.	63.609	5813.340
155.	37.393	6000.305
160.	39.026	6195.434

TABLE B-19. CONTINUATION
OVERFLOW TO WASTE FROM THE
PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	32.284	6356.852
170.	35.345	6533.574
175.	29.980	6683.473
180.	30.087	6833.906
185.	38.205	7024.930
190.	39.026	7220.059
195.	39.383	7416.973
200.	35.796	7595.949
205.	33.472	7763.309
210.	36.984	7948.227
215.	35.248	8124.465
220.	28.378	8266.352
225.	30.393	8418.316
230.	34.359	8590.109
235.	35.134	8765.777
240.	53.625	9033.902
245.	53.625	9302.027
250.	53.625	9570.152
255.	53.625	9838.277
260.	53.625	10106.402
265.	53.625	10374.527
270.	53.625	10642.652
275.	53.625	10910.777
280.	53.625	11178.902
285.	53.625	11447.027
290.	53.625	11715.152
295.	53.625	11983.277
300.	53.065	12248.602
305.	54.454	12520.871
310.	54.303	12792.383
315.	48.175	13033.254
320.	48.564	13276.070
325.	44.046	13496.297
330.	38.328	13687.934

TABLE B-19. CONTINUATION
OVERFLOW TO WASTE FROM THE
PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	41.313	13894.496
340.	40.956	14099.273
345.	46.729	14332.918
350.	46.204	14563.938
355.	45.973	14793.801
360.	44.046	15014.027
365.	39.150	15209.773
370.	46.348	15441.512
375.	43.681	15659.914
380.	46.348	15891.652
385.	44.417	16113.734
390.	40.466	16316.063
395.	44.931	16540.715
400.	44.931	16765.367
405.	48.958	17010.156
410.	62.044	17320.375
415.	63.265	17636.699
420.	64.962	17961.508
425.	61.926	18271.137
430.	38.803	18465.148
435.	44.931	18689.801
440.	53.065	18955.125
445.	53.065	19220.449
450.	48.175	19461.320
455.	44.931	19635.973
460.	44.792	19909.930
465.	47.113	20145.492
470.	42.667	20358.824
475.	44.417	20580.906
480.	44.046	20801.133
485.	40.956	21005.910
490.	33.913	21175.473
495.	39.150	21371.219

TABLE B-19. CONTINUATION
OVERFLOW TO WASTE FROM THE
PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
500.	34.237	21542.402
505.	38.675	21735.773
510.	37.986	21925.703
515.	43.537	22143.387

TABLE B-20. OVERFLOW FROM SETTLING TANK #2 TO SETTLING TANK #1 IN THE PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	46.729	0.0
5.	46.729	233.645
10.	48.031	473.800
15.	42.168	684.640
20.	45.825	913.764
25.	36.663	1097.079
30.	44.561	1319.884
35.	45.079	1545.279
40.	45.973	1775.144
45.	45.079	2000.539
50.	44.046	2220.768
55.	47.113	2456.333
60.	59.234	2752.503
65.	64.647	3075.738
70.	66.210	3406.788
75.	59.799	3705.783
80.	53.633	3973.948
85.	60.251	4275.199
90.	86.628	4708.336
95.	70.829	5062.480
100.	71.478	5419.867
105.	65.460	5747.164
110.	72.962	6111.973
115.	68.783	6455.887
120.	62.961	6770.691
125.	66.833	7104.855
130.	66.358	7436.645
135.	65.735	7765.316
140.	65.735	8093.988
145.	66.358	8425.777
150.	86.628	8858.914
155.	65.735	9187.586
160.	66.358	9519.375

TABLE B-20. CONTINUATION
OVERFLOW FROM SETTLING TANK #2 TO SETTLING TANK #1 IN THE PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
165.	63.568	9837.215
170.	65.888	10166.652
175.	59.946	10466.379
180.	58.912	10760.938
185.	54.871	11035.289
190.	60.990	11340.238
195.	51.798	11599.227
200.	54.041	11869.430
205.	53.473	12136.793
210.	56.153	12417.555
215.	48.564	12660.371
220.	48.958	12905.160
225.	48.031	13145.313
230.	49.646	13393.539
235.	37.858	13582.828
240.	53.625	13850.953
245.	53.625	14119.078
250.	53.625	14387.203
255.	53.625	14655.328
260.	53.625	14923.453
265.	53.625	15191.578
270.	53.625	15459.703
275.	53.625	15727.828
280.	53.625	15995.953
285.	53.625	16264.078
290.	53.625	16532.203
295.	53.625	16800.328
300.	37.858	16989.617
305.	66.210	17320.664
310.	74.796	17694.641
315.	73.125	18060.266
320.	66.210	18391.313
325.	73.125	18756.938
330.	68.426	19099.066

TABLE B-20. CONTINUATION
OVERFLOW FROM SETTLING TANK #2 TO SETTLING
TANK #1 IN THE PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
335.	64.647	19422.301
340.	63.896	19741.777
345.	62.961	20056.582
350.	67.313	20393.145
355.	64.647	20716.379
360.	62.500	21028.879
365.	73.373	21395.742
370.	69.059	21741.035
375.	65.423	22068.143
380.	67.619	22406.242
385.	71.478	22763.629
390.	70.340	23115.328
395.	72.472	23477.688
400.	66.358	23809.477
405.	66.986	24144.406
410.	66.358	24476.195
415.	67.462	24813.504
420.	69.549	25161.246
425.	75.829	25540.391
430.	73.283	25906.805
435.	63.721	26225.406
440.	65.735	26554.078
445.	73.125	26919.703
450.	70.829	27273.848
455.	74.287	27645.281
460.	69.059	27990.574
465.	71.824	28349.691
470.	66.986	28684.621
475.	68.094	29025.090
480.	71.478	29382.477
485.	63.568	29700.316
490.	57.741	29989.020
495.	62.040	30299.219

TABLE B-20. CONTINUATION
OVERFLOW FROM SETTLING TANK #2 TO SETTLING
TANK #1 IN THE PROTOTYPE LINE-TRIAL # 6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
500.	57.741	30587.922
505.	59.353	30884.684
510.	70.043	31234.898
515.	70.023	31585.012

TABLE B-21. OVERFLOW TO WASTE FROM WASHER #1 OF THE CONVENTIONAL LINE-TRIAL #1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	192.082	0.0
5.	171.236	856.180
10.	153.390	1623.130
15.	143.185	2339.055
20.	153.390	3106.005
25.	158.634	3899.175
30.	155.128	4674.813
35.	182.448	5587.051
40.	190.134	6537.719
45.	226.826	7671.848
50.	127.006	8306.875
55.	136.589	8989.816
60.	133.354	9656.586
65.	151.663	10414.893
70.	138.222	11106.008
75.	146.545	11838.730
80.	160.403	12640.742
85.	148.241	13381.945
90.	141.520	14089.543
95.	146.545	14822.266
100.	158.634	15615.434
105.	171.236	16471.613
110.	148.241	17212.816
115.	163.972	18032.676
120.	163.972	18852.535
125.	174.931	19727.188
130.	133.354	20393.957
135.	380.044	22294.176
140.	352.480	24056.574
145.	326.021	25686.675

TABLE B-21. CONTINUATION
OVERFLOW TO WASTE FROM WASHER #1 OF THE
CONVENTIONAL LINE-TRIAL #1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
150.	326.021	27316.777
155.	331.225	28972.898
160.	336.473	30655.262
165.	391.381	32612.164
170.	371.659	34470.457
175.	388.530	36413.105
180.	380.044	38313.324
185.	374.443	40185.535
190.	374.443	42057.746
195.	382.862	43972.055
200.	380.044	45872.273
205.	368.886	47716.703
210.	391.381	49673.605
215.	385.690	51602.055
220.	377.238	53488.242
225.	371.659	55346.535
230.	366.124	57177.152
235.	408.720	59220.750

TABLE B-22. OVERFLOW TO WASTE FROM WASHER #2 OF THE CONVENTIONAL LINE-TRIAL #1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	63.541	0.0
5.	65.724	328.620
10.	67.947	668.355
15.	70.210	1019.405
20.	66.831	1353.559
25.	67.947	1693.294
30.	64.627	2016.429
35.	66.831	2350.584
40.	65.724	2679.204
45.	69.074	3024.573
50.	67.947	3364.308
55.	67.947	3704.043
60.	66.831	4038.198
65.	67.947	4377.930
70.	78.442	4770.137
75.	72.513	5132.699
80.	77.236	5518.879
85.	125.445	6146.102
90.	74.855	6520.375
95.	73.679	6888.770
100.	70.210	7239.816
105.	71.356	7596.594
110.	73.679	7964.988
115.	73.679	8333.383
120.	76.041	8713.586
125.	79.658	9111.875
130.	79.658	9510.164
135.	89.746	9958.891
140.	67.947	10298.625
145.	65.724	10627.242

TABLE B-22. CONTINUATION
OVERFLOW TO WASTE FROM WASHER #2 OF THE CONVENTIONAL LINE-TRIAL #1

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
150.	63.541	10944.945
155.	61.396	11251.922
160.	60.339	11553.613
165.	65.724	11882.230
170.	79.658	12280.520
175.	67.947	12620.254
180.	67.947	12959.988
185.	92.368	13421.828
190.	125.445	14049.051
195.	114.806	14623.078
200.	114.806	15197.105
205.	114.806	15771.133
210.	67.947	16110.867
215.	117.795	16699.840
220.	163.972	17519.699
225.	60.339	17821.391
230.	65.724	18150.008
235.	66.831	18484.160

TABLE B-23. OVERFLOW TO WASTE FROM WASHER #1 OF THE CONVENTIONAL LINE-TRIAL #2

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	98.169	0.0
5.	98.169	490.845
10.	98.169	981.689
15.	98.169	1472.534
20.	98.169	1963.379
25.	98.169	2454.224
30.	98.169	2945.068
35.	98.169	3435.913
40.	98.169	3926.758
45.	98.169	4417.602
50.	98.169	4908.445
55.	98.169	5399.289
60.	99.100	5894.785
65.	99.100	6390.281
70.	99.100	6885.777
75.	99.100	7381.273
80.	99.100	7876.770
85.	99.100	8372.266
90.	99.100	8867.762
95.	99.100	9363.258
100.	99.100	9858.754
105.	79.658	10257.043
110.	77.236	10643.223
115.	70.210	10994.270
120.	79.658	11392.559
125.	67.947	11732.293
130.	99.100	12227.789
135.	64.627	12550.922
140.	89.746	12999.648
145.	59.291	13296.102

TABLE B-23. CONTINUATION
OVERFLOW TO WASTE FROM WASHER #1 OF THE
CONVENTIONAL LINE-TRIAL #2

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
150.	96.377	13777.984
155.	74.855	14152.258
160.	123.895	14771.730
165.	62.463	15084.043
170.	155.128	15859.680
175.	73.679	16228.074
180.	62.463	16540.387
185.	55.198	16816.375
190.	49.351	17063.129
195.	44.744	17286.848
200.	67.947	17626.582
205.	46.558	17859.371
210.	57.225	18145.492
215.	24.622	18268.602
220.	180.553	19171.363
225.	101.865	19680.688
230.	28.703	19824.199
235.	46.558	20056.988
240.	32.359	20218.781
245.	73.679	20587.176
250.	29.415	20734.250
255.	212.146	21794.977
260.	52.231	22056.129
265.	38.698	22249.617
270.	55.198	22525.605
275.	38.698	22719.094
280.	30.868	22873.434
285.	76.041	23253.637
290.	37.057	23438.918
295.	116.295	24020.391

TABLE B-23. CONTINUATION
OVERFLOW TO WASTE FROM WASHER #1 OF THE
CONVENTIONAL LINE-TRIAL #2

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
300.	87.163	24456.203
305.	47.479	24693.598
310.	141.520	25401.195
315.	82.120	25811.793
320.	92.368	26273.633
325.	79.658	26671.922
330.	117.795	27260.895
335.	91.052	27716.152
340.	92.368	28177.992
345.	99.100	28673.488
350.	107.515	29211.063
355.	117.795	29800.035
360.	87.163	30235.848
365.	77.236	30622.027
370.	119.304	31218.547
375.	108.952	31763.305
380.	50.301	32014.809
385.	79.658	32413.098
390.	79.658	32811.387
395.	55.198	33087.375
400.	89.746	33536.102
405.	89.746	33984.828
410.	114.806	34558.855
415.	84.622	34981.965
420.	41.232	35138.121
425.	83.366	35604.949
430.	55.198	35880.938
435.	97.734	36369.605
440.	49.351	36616.359
445.	71.356	36973.137
450.	65.724	37301.754
455.	74.855	37676.027
460.	80.884	38080.445
465.	79.658	38478.734
470.	82.120	38889.332

TABLE B-24. OVERFLOW TO WASTE FROM WASHER #2 OF THE CONVENTIONAL LINE-TRIAL #2

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	24.141	0.0
5.	24.141	120.705
10.	24.141	241.410
15.	24.141	362.115
20.	24.141	482.820
25.	24.141	603.524
30.	24.141	724.229
35.	24.141	844.934
40.	24.141	965.639
45.	24.141	1086.344
50.	24.141	1207.049
55.	24.141	1327.753
60.	24.622	1450.863
65.	24.622	1573.973
70.	24.622	1697.083
75.	24.622	1820.193
80.	24.622	1943.303
85.	12.025	2003.427
90.	12.025	2063.552
95.	9.910	2113.102
100.	8.012	2153.162
105.	9.910	2202.712
110.	9.513	2250.277
115.	8.012	2290.336
120.	11.585	2348.261
125.	19.124	2443.881
130.	4.853	2468.146
135.	10.316	2519.726
140.	12.025	2579.851
145.	11.153	2635.615

TABLE B-24. CONTINUATION
OVERFLOW TO WASTE FROM WASHER #2 OF THE
CONVENTIONAL LINE-TRIAL #2

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
150.	12.932	2700.275
155.	21.476	2807.655
160.	18.002	2897.665
165.	14.853	2971.930
170.	10.316	3023.510
175.	19.698	3122.000
180.	7.658	3160.290
185.	12.025	3220.414
190.	8.746	3264.144
195.	12.932	3328.804
200.	25.945	3458.529
205.	38.698	3652.019
210.	41.232	3858.179
215.	27.305	3994.704
220.	14.853	4068.969
225.	16.917	4153.551
230.	8.375	4195.426
235.	7.658	4233.715
240.	6.648	4266.953
245.	9.910	4316.500
250.	9.513	4364.063
255.	19.124	4459.680
260.	4.068	4480.020
265.	34.665	4653.344
270.	30.868	4807.684
275.	29.415	4954.758
280.	35.453	5132.020
285.	29.415	5279.094
290.	30.863	5433.434
295.	24.622	5556.543

TABLE B-24. CONTINUATION
OVERFLOW TO WASTE FROM WASHER #2 OF THE
CONVENTIONAL LINE-TRIAL #2

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
300.	27.999	5696.535
305.	82.120	6107.133
310.	26.621	6240.234
315.	29.415	6387.309
320.	33.118	6552.898
325.	30.868	6707.238
330.	26.621	6840.340
335.	35.453	7017.602
340.	38.698	7211.090
345.	55.198	7487.078
350.	28.703	7630.590
355.	28.703	7774.102
360.	33.887	7943.535
365.	29.415	8090.609
370.	28.703	8234.121
375.	64.627	8557.254
380.	27.999	8697.246
385.	26.621	8830.348
390.	26.621	8963.449
395.	26.621	9096.551
400.	26.621	9229.652
405.	30.137	9380.336
410.	29.415	9527.410
415.	26.621	9660.512
420.	27.305	9797.035
425.	30.137	9947.719
430.	29.415	10094.793
435.	28.703	10238.305
440.	29.415	10385.379
445.	77.236	10771.559
450.	20.874	10875.926
455.	30.137	11026.609
460.	27.999	11166.602
465.	33.887	11336.035
470.	28.703	11479.547

TABLE B-25. OVERFLOW TO WASTE FROM WASHER #1 OF THE CONVENTIONAL LINE-TRIAL #3

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	117.795	0.0
5.	117.795	588.975
10.	162.182	1399.885
15.	87.163	1835.700
20.	138.222	2526.810
25.	101.865	3036.135
30.	158.634	3829.304
35.	91.052	4284.563
40.	155.128	5060.199
45.	92.368	5522.039
50.	162.182	6332.945
55.	110.400	6884.941
60.	167.583	7722.855
65.	128.578	8365.742
70.	119.304	8962.262
75.	108.952	9507.020
80.	108.952	10051.777
85.	130.159	10702.570
90.	70.210	11053.617
95.	194.041	12023.820
100.	165.772	12852.680
105.	176.795	13736.652
110.	176.795	14620.625
115.	176.795	15504.598
120.	176.795	16388.570
125.	176.795	17272.543
130.	176.795	18156.516
135.	66.831	18490.668
140.	139.866	19189.996
145.	92.368	19651.836

TABLE B-25. CONTINUATION
OVERFLOW TO WASTE FROM WASHER #1 OF THE
CONVENTIONAL LINE-TRIAL #3

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
150.	120.824	20255.953
155.	136.589	20938.895
160.	84.622	21362.004
165.	138.222	22053.113
170.	160.403	22855.125
175.	67.947	23194.859
180.	133.354	23861.629
185.	69.074	24206.996
190.	123.895	24826.469

TABLE B-26. OVERFLOW TO WASTE FROM WASHER #2 OF THE CONVENTIONAL LINE-TRIAL #3

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	108.952	0.0
5.	108.952	544.760
10.	136.589	1227.705
15.	92.368	1689.544
20.	186.270	2620.894
25.	108.952	3165.654
30.	155.128	3941.294
35.	117.795	4530.266
40.	169.404	5377.285
45.	107.515	5914.859
50.	167.583	6752.773
55.	106.087	7283.207
60.	160.403	8085.219
65.	111.859	8644.512
70.	162.182	9455.418
75.	122.354	10067.188
80.	149.947	10816.922
85.	120.824	11421.039
90.	139.866	12120.367
95.	127.006	12755.395
100.	127.006	13390.422
105.	162.182	14201.328
110.	123.895	14820.801
115.	144.860	15545.098
120.	143.185	16261.020
125.	141.520	16968.617
130.	134.966	17643.445
135.	148.241	18384.648
140.	123.895	19004.121
145.	143.185	19720.043

TABLE B-26. CONTINUATION
OVERFLOW TO WASTE FROM WASHER #2 OF THE
CONVENTIONAL LINE-TRIAL #3

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
150.	117.795	20309.016
155.	146.545	21041.738
160.	125.445	21668.961
165.	151.663	22427.273
170.	133.354	23094.043
175.	153.390	23860.992
180.	123.895	24480.465
185.	141.520	25188.063
190.	128.578	25830.949

TABLE B-27. OVERFLOW TO WASTE FROM WASHER #1 OF THE CONVENTIONAL LINE-TRIAL #4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	242.032	0.0
5.	242.032	1210.160
10.	276.395	2592.134
15.	237.634	3780.304
20.	281.161	5186.105
25.	250.957	6440.887
30.	295.721	7919.488
35.	231.117	9075.070
40.	156.876	9859.449
45.	298.186	11350.375
50.	231.117	12505.957
55.	323.436	14123.133
60.	210.092	15173.590
65.	331.225	16829.711
70.	203.993	17849.676
75.	300.661	19352.977
80.	210.092	20403.434
85.	278.773	21797.297
90.	210.092	22847.754
95.	380.044	24747.973
100.	231.117	25903.555
105.	360.633	27706.719
110.	208.048	28746.957
115.	300.661	30250.258
120.	226.826	31384.387
125.	190.134	32335.055
130.	176.795	33219.027
135.	226.826	34353.156
140.	176.795	35237.129
145.	248.710	36480.676

TABLE B-27. CONTINUATION
OVERFLOW TO WASTE FROM WASHER #1 OF THE CONVENTIONAL LINE-TRIAL #4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
150.	199.980	37480.574
155.	237.634	38668.742
160.	216.287	39750.176
165.	288.392	41192.133
170.	218.374	42284.000
175.	323.436	43901.176
180.	235.451	45078.430
185.	276.395	46460.402
190.	206.015	47490.477
195.	293.267	48956.809
200.	216.287	50038.242
205.	298.186	51529.168
210.	210.092	52579.625
215.	276.395	53961.598
220.	212.146	55022.324
225.	283.561	56440.125
230.	233.278	57606.512
235.	264.670	58929.859
240.	242.032	60140.016

TABLE B-28. OVERFLOW TO WASTE FROM WASHER #2 OF THE CONVENTIONAL LINE-TRIAL #4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	153.390	0.0
5.	153.390	766.950
10.	153.390	1533.900
15.	153.390	2300.850
20.	153.390	3067.800
25.	128.578	3710.690
30.	144.860	4434.988
35.	149.947	5184.723
40.	156.876	5969.102
45.	149.947	6718.836
50.	146.545	7451.559
55.	146.545	8184.281
60.	143.185	8900.203
65.	149.947	9649.938
70.	136.589	10332.879
75.	144.860	11057.176
80.	139.866	11756.504
85.	192.082	12716.910
90.	165.772	13545.770
95.	167.583	14383.684
100.	153.390	15150.633
105.	167.583	15988.547
110.	91.052	16443.805
115.	257.765	17732.629
120.	123.895	18352.102
125.	190.134	19302.770
130.	153.390	20069.719
135.	169.404	20916.738
140.	128.578	21559.625
145.	169.404	22406.645

TABLE B-28. CONTINUATION
OVERFLOW TO WASTE FROM WASHER #2 OF THE
CONVENTIONAL LINE-TRIAL #4

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
150.	160.403	23208.656
155.	160.403	24010.663
160.	125.445	24637.891
165.	127.006	25272.918
170.	119.304	25869.438
175.	190.134	26820.105
180.	149.947	27569.840
185.	165.772	28398.699
190.	156.876	29183.078
195.	160.403	29985.090
200.	158.634	30778.258
205.	160.403	31580.270
210.	160.403	32382.281
215.	160.403	33184.293
220.	163.972	34004.152
225.	167.583	34842.066
230.	158.634	35635.234
235.	169.404	36482.254
240.	160.403	37284.266

TABLE B-29. OVERFLOW TO WASTE FROM WASHER #1 OF THE CONVENTIONAL LINE-TRIAL #5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	190.134	0.0
5.	190.134	950.670
10.	190.134	1901.340
15.	190.134	2852.010
20.	163.972	3671.870
25.	165.772	4500.727
30.	188.197	5441.711
35.	171.236	6297.891
40.	190.134	7248.559
45.	163.972	8068.418
50.	210.092	9118.875
55.	210.092	10169.332
60.	210.092	11219.789
65.	171.236	12075.969
70.	199.980	13075.367
75.	171.236	13932.047
80.	210.092	14982.504
85.	180.553	15885.266
90.	208.048	16925.504
95.	186.270	17856.852
100.	194.041	18827.055
105.	197.990	19817.004
110.	190.134	20767.672
115.	194.041	21737.375
120.	197.990	22727.824
125.	201.981	23737.727
130.	210.092	24788.184
135.	210.092	25838.641
140.	197.990	26828.590
145.	197.990	27818.539

TABLE B-29. CONTINUATION
OVERFLOW TO WASTE FROM WASHER #1 OF THE
CONVENTIONAL LINE-TRIAL #5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
150.	199.980	28818.438
155.	171.236	29674.617
160.	210.092	30725.074
165.	180.553	31627.836
170.	218.374	32719.703
175.	206.015	33749.777
180.	206.015	34779.852
185.	184.354	35701.621
190.	203.993	36721.586
195.	165.772	37550.445
200.	194.041	38520.648
205.	201.981	39530.551
210.	224.697	40654.035
215.	165.772	41482.895
220.	203.993	42502.859
225.	192.082	43463.266
230.	210.092	44513.723
235.	196.010	45493.770
240.	192.082	46454.176

TABLE B-30. OVERFLOW TO WASTE FROM WASHER #2 OF THE CONVENTIONAL LINE-TRIAL #5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	199.980	0.0
5.	199.980	999.900
10.	199.980	1999.800
15.	199.980	2999.700
20.	199.980	3999.600
25.	199.980	4999.496
30.	199.980	5999.395
35.	231.117	7154.977
40.	226.826	8289.105
45.	210.092	9339.563
50.	206.015	10369.637
55.	194.041	11339.840
60.	196.010	12319.887
65.	203.993	13339.852
70.	196.010	14319.898
75.	197.990	15309.848
80.	201.981	16319.750
85.	199.980	17319.648
90.	199.980	18319.547
95.	206.015	19349.621
100.	206.015	20379.695
105.	214.211	21450.750
110.	210.092	22501.207
115.	212.146	23561.934
120.	196.010	24541.980
125.	194.041	25512.184
130.	196.010	26492.230
135.	269.327	27838.863
140.	206.015	28868.938
145.	233.278	30035.324

TABLE B-30. CONTINUATION
OVERFLOW TO WASTE FROM WASHER #2 OF THE
CONVENTIONAL LINE-TRIAL #5

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
150.	199.980	31035.223
155.	199.980	32035.121
160.	210.092	33085.578
165.	194.041	34055.781
170.	210.092	35106.238
175.	203.993	36126.203
180.	212.146	37186.930
185.	197.990	38176.879
190.	214.211	39247.934
195.	199.980	40247.832
200.	192.082	41208.238
205.	184.354	42130.008
210.	160.403	42932.020
215.	208.048	43972.258
220.	167.583	44810.172
225.	190.134	45760.840
230.	167.583	46598.754
235.	197.990	47588.703
240.	235.451	48765.957

TABLE B-31. OVERFLOW TO WASTE FROM WASHER #1 OF THE CONVENTIONAL LINE-TRIAL #6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	276.395	0.0
5.	290.824	1454.120
10.	290.824	2908.240
15.	290.824	4362.359
20.	295.721	5840.961
25.	293.267	7307.293
30.	276.395	8689.266
35.	290.824	10143.383
40.	276.395	11525.355
45.	290.824	12979.473
50.	281.161	14385.273
55.	300.661	15888.574
60.	283.561	17306.375
65.	285.971	18736.227
70.	285.971	20166.078
75.	300.661	21669.379
80.	300.661	23172.680
85.	295.721	24651.281
90.	276.395	26033.254
95.	303.148	27548.992
100.	276.395	28930.965
105.	300.661	30434.266
110.	295.721	31912.867
115.	293.267	33379.199
120.	293.267	34845.531
125.	283.561	36263.332
130.	281.161	37669.133
135.	293.267	39135.465
140.	295.721	40614.066
145.	285.971	42043.918

TABLE B-31. CONTINUATION
OVERFLOW TO WASTE FROM WASHER #1 OF THE CONVENTIONAL LINE-TRIAL #6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
150.	278.773	43437.781
155.	298.186	44928.707
160.	276.395	46310.680
165.	260.056	47610.957
170.	305.646	49139.184
175.	269.327	50485.816
180.	283.561	51903.617
185.	281.161	53309.418
190.	264.670	54632.766
195.	300.661	56136.066
200.	276.395	57518.039
205.	281.161	58923.840
210.	274.028	60293.977
215.	288.392	61735.934
220.	285.971	63165.785
225.	288.392	64607.742
230.	276.395	65989.688
235.	293.267	67456.000
240.	260.056	68756.250
245.	352.480	70518.625

TABLE B-32. OVERFLOW TO WASTE FROM WASHER #2 OF THE CONVENTIONAL LINE-TRIAL #6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
0.	103.262	0.0
5.	103.262	516.310
10.	103.262	1032.620
15.	104.669	1555.964
20.	106.087	2086.399
25.	106.087	2616.834
30.	106.087	3147.269
35.	106.087	3677.704
40.	106.087	4208.137
45.	106.087	4738.570
50.	106.087	5269.004
55.	106.087	5799.438
60.	106.087	6329.871
65.	106.087	6860.305
70.	106.087	7390.738
75.	106.087	7921.172
80.	106.087	8451.605
85.	106.087	8982.039
90.	106.087	9512.473
95.	106.087	10042.906
100.	106.087	10573.340
105.	106.087	11103.773
110.	106.087	11634.207
115.	106.087	12164.641
120.	106.087	12695.074
125.	106.087	13225.508
130.	106.087	13755.941
135.	106.087	14286.375
140.	106.087	14816.809
145.	106.087	15347.242

TABLE B-32. CONTINUATION
OVERFLOW TO WASTE FROM WASHER #2 OF THE
CONVENTIONAL LINE-TRIAL #6

TIME FROM START (MIN)	FLOW RATE (L/MIN)	CUMULATED FLOW (L)
150.	106.087	15877.676
155.	106.087	16408.109
160.	108.952	16952.867
165.	103.262	17469.176
170.	107.515	18006.750
175.	106.087	18537.184
180.	107.515	19074.758
185.	107.515	19612.332
190.	106.087	20142.766
195.	106.087	20673.199
200.	106.087	21203.633
205.	106.087	21734.066
210.	106.087	22264.500
215.	106.087	22794.934
220.	106.087	23325.367
225.	106.087	23855.801
230.	106.087	24386.234
235.	106.087	24916.668
240.	106.087	25447.102
245.	97.734	25935.770

APPENDIX C

MODELED GRIT CONCENTRATION IN UNITS OF THE PROTOTYPE SYSTEM

TABLE C-1. PREDICTED GRIT CONCENTRATION IN THE UNITS OF THE PROTOTYPE LINE-TRIAL # 1

START FROM START (MIN)	1ST WASHER (MG/L)	1ST SETT -LING TANK (MG/L)	2ND WASHER (MG/L)	2ND SETT -LING TANK (MG/L)
0.	0.0	0.0	0.0	0.0
5.	121.9	38.7	43.0	11.7
10.	203.3	98.9	71.6	32.6
15.	270.0	157.9	94.9	54.1
20.	328.8	211.5	115.3	74.3
25.	385.2	259.7	133.6	92.9
30.	435.2	304.9	150.8	109.8
35.	480.8	345.0	165.6	125.3
40.	517.3	381.8	179.8	139.3
45.	557.0	413.7	191.8	152.1
50.	590.8	444.4	203.4	163.6
55.	618.0	471.8	214.1	174.1
60.	646.0	495.6	223.3	183.7
65.	678.8	520.1	235.3	193.4
70.	710.8	545.6	235.7	202.2
75.	734.5	569.9	240.8	207.4
80.	753.0	589.8	245.7	212.1
85.	776.1	608.5	250.9	216.7
90.	787.4	626.6	257.1	221.6
95.	844.9	647.3	261.3	226.0
100.	758.5	718.9	246.8	239.9
105.	743.0	733.6	243.9	242.6
110.	739.3	737.1	243.4	243.1
115.	738.4	737.9	243.3	243.2
120.	885.6	694.9	267.5	234.2
125.	917.7	704.6	277.7	238.2
130.	944.2	720.5	284.8	244.0
135.	967.1	739.3	291.7	250.0
140.	995.8	759.7	298.7	256.1
145.	1075.8	793.1	328.6	269.6
150.	1118.2	830.7	346.9	286.8
155.	1145.0	866.7	363.9	302.9
160.	1167.6	893.8	377.2	317.2

TABLE C-1. CONTINUATION
PREDICTED GRIT CONCENTRATION IN THE UNITS
OF THE PROTOTYPE LINE-TRIAL # 1

START FROM START (MIN)	1ST WASHER (MG/L)	1ST SETT -LING TANK (MG/L)	2ND WASHER (MG/L)	2ND SETT -LING TANK (MG/L)
165.	1196.4	915.2	386.0	329.2
170.	1247.5	937.3	394.6	338.5
175.	1277.7	966.7	404.8	347.3
180.	1324.6	995.4	414.4	356.0
185.	1370.5	1026.8	423.8	364.5
190.	1398.9	1057.7	432.7	372.6
195.	1417.3	1083.4	440.5	380.2
200.	1436.6	1101.5	446.0	386.6
205.	1399.2	1107.3	421.6	381.4
210.	1362.8	1097.2	407.7	370.2
215.	1353.8	1082.5	396.4	359.2
220.	1281.5	1057.8	385.0	348.9
225.	1308.6	1052.7	384.1	342.4
230.	1221.9	1135.8	370.5	355.4
235.	1192.7	1163.7	365.6	360.1
240.	1182.9	1173.1	363.8	361.8
245.	1179.5	1176.3	363.1	362.4
250.	1178.4	1177.3	362.9	362.6
255.	1178.0	1177.6	362.8	362.7
260.	1177.9	1177.7	362.7	362.7
265.	1177.8	1177.8	362.7	362.7
270.	1177.8	1177.8	362.7	362.7
275.	1177.8	1177.8	362.7	362.7
280.	1177.8	1177.8	362.7	362.7
285.	1177.8	1177.8	362.7	362.7
290.	1242.2	1126.9	397.9	349.7
295.	1263.9	1112.3	411.8	354.1
300.	1272.1	1109.1	420.9	361.3
305.	1373.4	1066.6	398.9	358.9
310.	1426.3	1063.1	389.5	350.9
315.	1416.7	1072.1	383.6	344.2
320.	1401.0	1073.6	378.3	338.5
325.	1326.6	1059.3	351.0	326.0
330.	1274.6	1029.7	332.0	309.6

TABLE C-1. CONTINUATION
PREDICTED GRIT CONCENTRATION IN THE UNITS
OF THE PROTOTYPE LINE-TRIAL # 1

START FROM START (MIN)	1ST WASHER (MG/L)	1ST SETT -LING TANK (MG/L)	2ND WASHER (MG/L)	2ND SETT -LING TANK (MG/L)
335.	1235.0	997.3	315.9	294.0
340.	1191.0	963.3	301.0	279.6
345.	1147.8	931.0	288.4	266.7
350.	1103.4	898.8	277.0	255.3
355.	1060.9	866.6	266.8	245.2
360.	990.9	834.6	252.1	232.3
365.	904.2	843.7	251.9	232.3
370.	857.7	845.5	251.9	232.3
375.	976.4	782.2	243.9	223.5
380.	961.0	802.2	256.6	222.5
385.	1024.7	779.4	247.8	221.5
390.	939.3	861.5	237.1	231.5
395.	869.4	877.7	234.9	233.6
400.	872.3	874.9	234.4	234.1
405.	873.2	874.0	234.3	234.2
410.	873.4	873.7	234.2	234.2
415.	973.2	802.0	235.1	217.5
420.	952.5	817.4	251.3	216.7
425.	1024.1	782.1	238.9	214.9
430.	1045.2	783.5	235.8	210.9
435.	1001.1	784.3	232.6	207.8
440.	970.4	772.0	229.6	204.9
445.	949.7	755.9	226.3	202.0
450.	924.0	739.7	223.3	199.2
455.	906.9	724.3	220.8	196.7
460.	889.5	708.1	217.5	194.1
465.	870.0	693.2	214.7	191.4
470.	851.1	678.4	211.9	188.9
475.	849.2	668.9	209.8	186.7
480.	837.7	661.2	208.6	185.0
485.	824.6	651.8	206.7	183.4
490.	815.0	645.6	206.2	182.3
495.	809.7	639.3	205.3	181.5

TABLE C-1. CONTINUATION
PREDICTED GRIT CONCENTRATION IN THE UNITS
OF THE PROTOTYPE LINE-TRIAL # 1

START FROM START (MIN)	1ST WASHER (MG/L)	1ST SETT-LING TANK (MG/L)	2ND WASHER (MG/L)	2ND SETT-LING TANK (MG/L)
500.	805.2	636.5	205.4	181.0
505.	808.2	630.6	203.6	180.2
510.	803.4	627.9	202.6	179.2
515.	792.3	625.2	202.2	178.5
520.	780.2	619.5	201.5	177.9
525.	773.2	610.4	199.5	176.8

TABLE C-2. PREDICTED GRIT CONCENTRATION IN THE UNITS OF THE PROTOTYPE LINE-TRIAL # 4

START FROM START (MIN)	1ST WASHER (MG/L)	1ST SETT -LING TANK (MG/L)	2ND WASHER (MG/L)	2ND SETT -LING TANK (MG/L)
0.	0.0	0.0	0.0	0.0
5.	51.8	16.8	14.6	5.1
10.	88.6	43.3	25.8	14.5
15.	118.8	71.6	36.7	24.6
20.	147.7	98.1	47.2	34.9
25.	175.5	123.8	58.0	45.4
30.	201.9	148.7	68.8	55.9
35.	227.9	172.2	79.3	66.3
40.	250.8	195.8	90.3	76.8
45.	273.4	217.2	100.6	87.3
50.	282.6	242.7	116.3	98.8
55.	265.4	259.0	108.5	106.2
60.	262.7	261.6	107.5	107.2
65.	304.0	262.0	124.3	112.1
70.	335.2	273.7	133.1	120.9
75.	351.7	292.0	142.2	129.7
80.	367.5	308.9	151.4	138.5
85.	381.9	325.0	160.7	147.5
90.	401.1	338.2	167.6	155.9
95.	409.9	353.1	176.5	164.0
100.	418.6	364.7	184.7	172.2
105.	425.4	374.0	192.2	180.2
110.	440.2	381.0	196.8	186.9
115.	451.1	392.6	204.6	193.4
120.	462.1	403.5	211.7	200.3
125.	463.3	416.2	215.2	207.2
130.	473.6	423.4	218.1	211.7
135.	455.7	440.5	215.4	214.3
140.	450.3	445.6	214.9	214.7
145.	448.6	447.2	214.8	214.8
150.	448.1	447.7	214.8	214.8
155.	447.9	447.8	214.8	214.8
160.	447.9	447.8	214.8	214.8

TABLE C-2. CONTINUATION
PREDICTED GRIT CONCENTRATION IN THE UNITS
OF THE PROTOTYPE LINE-TRIAL # 4

START FROM START (MIN)	1ST WASHER (MG/L)	1ST SETT -LING TANK (MG/L)	2ND WASHER (MG/L)	2ND SETT -LING TANK (MG/L)
165.	447.8	447.8	214.8	214.8
170.	448.3	447.6	214.5	214.7
175.	448.2	447.8	214.5	214.6
180.	448.3	447.9	214.5	214.5
185.	448.4	447.9	214.3	214.4
190.	448.4	448.0	214.3	214.4
195.	489.3	436.6	220.9	214.9
200.	504.3	440.0	221.5	216.7
205.	510.3	448.1	224.8	218.8
210.	552.3	444.2	212.8	215.5
215.	539.9	466.1	221.5	215.4
220.	542.6	474.9	225.2	218.4
225.	547.3	481.4	228.6	221.7
230.	554.7	486.3	230.9	224.6
235.	557.7	492.8	234.9	227.8
240.	562.4	497.8	238.2	231.1
245.	565.8	502.8	241.9	234.6
250.	568.5	507.5	245.9	238.2
255.	579.5	511.1	252.3	243.0
260.	588.2	516.9	257.5	248.2
265.	595.5	523.4	262.5	253.3
270.	600.2	529.1	266.8	258.0
275.	598.2	535.4	273.5	263.3
280.	605.3	538.9	277.9	268.5
285.	611.5	542.8	281.4	272.9
290.	615.3	547.8	285.9	277.1
295.	620.8	551.6	289.1	281.0
300.	611.3	562.7	266.8	277.4
305.	586.1	567.8	260.4	269.3
310.	580.5	560.6	250.6	260.8
315.	568.3	554.2	243.6	252.6
320.	566.1	547.4	236.1	244.9
325.	589.4	533.4	251.0	243.4
330.	603.8	533.2	258.7	248.4

TABLE C-2. CONTINUATION
PREDICTED GRIT CONCENTRATION IN THE UNITS
OF THE PROTOTYPE LINE-TRIAL # 4

START FROM START (MIN)	1ST WASHER (MG/L)	1ST SETT-LING TANK (MG/L)	2ND WASHER (MG/L)	2ND SETT-LING TANK (MG/L)
335.	609.6	538.6	266.1	254.8
340.	610.9	540.9	262.4	257.7
345.	612.0	543.9	262.7	258.2
350.	615.1	546.1	262.8	258.6
355.	619.2	547.6	262.2	258.6
360.	618.1	550.2	263.0	258.8
365.	620.8	552.1	263.7	259.2
370.	622.0	553.9	264.2	259.8
375.	624.4	554.0	263.4	259.8
380.	630.5	555.0	262.5	259.3
385.	628.5	559.1	264.4	259.6
390.	622.1	562.2	265.4	260.6
395.	623.2	561.7	265.2	261.1
400.	620.4	561.7	262.5	260.1
405.	621.1	560.0	259.6	258.0
410.	620.3	559.3	257.6	255.8
415.	612.6	555.6	254.5	253.3
420.	613.1	548.4	255.5	252.5
425.	610.1	546.3	258.5	252.9

TABLE C-3. PREDICTED GRIT CONCENTRATION IN THE UNITS OF THE PROTOTYPE LINE-TRIAL # 5

START FROM START (MIN)	1ST WASHER (MG/L)	1ST SETT -LING TANK (MG/L)	2ND WASHER (MG/L)	2ND SETT -LING TANK (MG/L)
0.	0.0	0.0	0.0	0.0
5.	8.1	2.7	2.4	1.0
10.	13.6	7.4	4.1	2.6
15.	18.5	11.9	5.6	4.1
20.	19.7	11.0	5.2	4.2
25.	23.9	16.3	7.5	5.3
30.	29.6	20.3	8.9	6.8
35.	33.6	24.5	10.2	8.2
40.	37.5	28.2	11.4	9.5
45.	41.5	31.8	12.6	10.7
50.	45.4	35.3	13.8	11.9
55.	49.4	38.5	14.8	13.0
60.	53.2	41.9	15.8	14.1
65.	57.1	45.2	16.8	15.0
70.	70.6	51.5	21.7	17.3
75.	81.0	59.6	25.3	20.5
80.	89.7	67.8	28.5	23.8
85.	96.3	75.4	31.3	27.1
90.	103.0	83.9	34.4	30.1
95.	92.2	88.4	31.0	31.3
100.	88.6	86.7	29.6	30.6
105.	85.4	84.1	28.4	29.6
110.	82.9	81.5	27.4	28.5
115.	100.5	80.2	32.2	29.0
120.	110.5	86.1	35.9	31.3
125.	119.2	93.0	38.9	34.0
130.	127.5	100.0	41.7	36.8
135.	134.1	107.2	44.6	39.5
140.	139.6	113.4	47.1	42.2
145.	145.6	118.7	49.4	44.7
150.	154.7	125.2	53.9	47.7
155.	162.3	132.0	57.6	51.2
160.	170.2	138.5	60.8	54.5

TABLE C-3. CONTINUATION
PREDICTED GRIT CONCENTRATION IN THE UNITS
OF THE PROTOTYPE LINE-TRIAL # 5

START FROM START (MIN)	1ST WASHER (MG/L)	1ST SETT -LING TANK (MG/L)	2ND WASHER (MG/L)	2ND SETT -LING TANK (MG/L)
165.	177.4	145.1	63.3	57.7
170.	183.4	152.2	66.7	60.7
175.	191.1	158.0	69.1	63.6
180.	200.3	164.2	71.6	66.1
185.	210.2	169.8	73.1	68.3
190.	214.9	178.0	76.4	70.3
195.	220.3	184.4	79.2	72.7
200.	229.6	190.8	81.9	75.2
205.	238.5	197.4	84.1	77.7
210.	246.0	205.3	88.9	80.7
215.	233.6	208.2	92.6	84.2
220.	222.2	212.9	85.8	86.4
225.	217.0	211.5	82.8	85.0
230.	213.3	208.7	80.5	83.0
235.	210.0	205.6	78.4	80.9
240.	206.8	202.5	76.4	78.8
245.	203.6	199.4	74.5	76.8
250.	200.5	196.3	72.6	74.8
255.	197.4	193.2	70.7	72.9
260.	194.3	190.2	68.9	71.0
265.	191.2	187.1	67.1	69.2
270.	188.2	184.2	65.4	67.4
275.	185.2	181.2	63.7	65.7
280.	182.2	178.3	62.1	64.0
285.	179.3	175.4	60.5	62.3
290.	176.4	172.5	58.9	60.7
295.	173.5	169.7	57.4	59.2
300.	170.6	166.9	55.9	57.7
305.	191.7	162.0	64.7	58.5
310.	202.0	165.6	70.0	62.3
315.	210.3	171.2	74.4	66.6
320.	216.3	177.3	78.3	70.6
325.	231.3	182.4	81.0	74.2
330.	236.2	190.6	84.8	77.5

TABLE C-3. CONTINUATION
PREDICTED GRIT CONCENTRATION IN THE UNITS
OF THE PROTOTYPE LINE-TRIAL # 5

START FROM START (MIN)	1ST WASHER (MG/L)	1ST SETT -LING TANK (MG/L)	2ND WASHER (MG/L)	2ND SETT -LING TANK (MG/L)
335.	240.4	197.2	88.2	80.9
340.	245.6	202.4	91.0	84.1
345.	249.7	206.9	93.6	86.9
350.	252.9	211.4	96.4	89.6
355.	249.4	213.0	93.6	90.4
360.	247.6	213.1	92.6	89.9
365.	246.4	212.7	92.0	89.3
370.	243.7	212.2	91.8	88.8
375.	239.7	209.7	90.7	88.2
380.	237.2	207.5	90.2	87.6
385.	234.8	205.2	89.4	86.9
390.	221.9	206.2	82.7	86.0
395.	209.2	204.4	80.3	83.6
400.	200.5	199.0	77.9	81.1
405.	191.4	192.5	75.6	78.8
410.	205.9	183.2	78.5	76.6
415.	215.4	181.5	79.8	76.5
420.	222.6	182.6	80.3	76.8
425.	230.1	184.5	80.3	77.1
430.	232.9	188.0	80.9	77.4
435.	239.4	190.3	82.6	78.1
440.	246.1	193.6	83.9	79.1
445.	249.9	196.9	84.6	80.1
450.	252.6	200.7	86.3	81.2
455.	253.8	204.1	87.5	82.4
460.	257.5	206.3	88.3	83.4
465.	259.9	209.2	89.5	84.5
470.	263.8	211.6	90.5	85.5
475.	268.2	213.9	91.3	86.5
480.	266.7	216.4	92.1	87.3
485.	261.5	217.1	92.5	88.0
490.	260.9	215.5	92.6	88.5
495.	243.9	214.6	92.0	88.7

TABLE C-3. CONTINUATION
PREDICTED GRIT CONCENTRATION IN THE UNITS
OF THE PROTOTYPE LINE-TRIAL # 5

START FROM START (MIN)	1ST WASHER (MG/L)	1ST SETT-LING TANK (MG/L)	2ND WASHER (MG/L)	2ND SETT-LING TANK (MG/L)
500.	254.4	210.8	90.9	88.3
505.	236.5	216.6	83.8	87.5
510.	230.1	213.0	78.2	83.5
515.	215.0	210.1	76.1	80.0
520.	233.8	199.8	78.4	78.5
525.	248.0	193.6	80.3	77.9

TABLE C-4. PREDICTED GRIT CONCENTRATION IN THE UNITS OF THE PROTOTYPE LINE-TRIAL # 6

START FROM START (MIN)	1ST WASHER (MG/L)	1ST SETT -LING TANK (MG/L)	2ND WASHER (MG/L)	2ND SETT -LING TANK (MG/L)
0.	0.0	0.0	0.0	0.0
5.	25.7	6.9	18.7	4.8
10.	43.9	20.1	30.6	13.2
15.	59.5	34.7	40.3	21.7
20.	75.0	49.1	48.4	29.8
25.	89.9	63.6	56.2	37.0
30.	103.6	77.4	62.6	43.7
35.	92.2	85.3	51.5	50.2
40.	89.0	86.5	47.8	49.6
45.	87.5	85.4	45.5	47.8
50.	86.1	84.1	43.5	45.8
55.	85.0	82.7	41.5	43.8
60.	84.6	81.1	39.0	41.6
65.	106.6	86.3	53.1	41.0
70.	121.7	97.4	60.1	45.2
75.	134.4	109.7	65.8	49.9
80.	146.0	121.7	71.1	54.5
85.	155.7	132.0	74.9	58.6
90.	149.2	135.0	60.5	62.6
95.	161.5	139.8	71.5	59.5
100.	178.9	149.4	80.0	62.6
105.	191.7	161.7	86.2	67.3
110.	204.6	172.7	90.2	71.6
115.	216.2	184.1	94.5	75.5
120.	204.0	188.3	79.7	80.4
125.	194.8	184.7	72.3	77.7
130.	187.4	178.9	67.3	73.4
135.	180.3	172.6	62.9	68.9
140.	173.8	166.2	59.0	64.6
145.	167.9	160.1	55.2	60.6
150.	166.1	152.9	50.2	56.1
155.	185.3	157.0	70.0	54.5
160.	197.4	166.3	79.2	59.8

TABLE C-4. CONTINUATION
PREDICTED GRIT CONCENTRATION IN THE UNITS
OF THE PROTOTYPE LINE-TRIAL # 6

START FROM START (MIN)	1ST WASHER (MG/L)	1ST SETT -LING TANK (MG/L)	2ND WASHER (MG/L)	2ND SETT -LING TANK (MG/L)
165.	209.3	176.8	86.1	65.7
170.	220.0	186.9	91.4	71.2
175.	230.4	197.5	96.8	76.0
180.	240.3	207.6	101.5	80.5
185.	246.4	216.9	106.0	84.7
190.	254.9	223.8	109.0	88.2
195.	252.5	229.2	104.3	88.9
200.	255.2	231.3	101.9	87.8
205.	258.1	233.6	100.5	86.4
210.	260.2	235.3	99.0	85.2
215.	260.6	237.9	98.9	84.3
220.	264.3	240.0	98.5	83.8
225.	266.3	242.5	98.4	83.4
230.	267.5	244.0	98.0	83.1
235.	265.1	246.5	99.2	83.3
240.	252.9	242.5	86.4	87.0
245.	244.3	235.6	79.8	84.9
250.	236.6	228.3	75.0	81.3
255.	229.1	221.1	71.0	77.3
260.	221.8	214.0	67.3	73.4
265.	214.7	207.0	63.8	69.6
270.	207.7	200.2	60.5	66.0
275.	200.9	193.6	57.4	62.6
280.	194.3	187.1	54.4	59.4
285.	187.8	180.8	51.6	56.4
290.	181.5	174.7	49.0	53.4
295.	175.3	168.7	46.4	50.7
300.	179.4	166.7	59.2	48.2
305.	186.0	164.5	62.6	50.3
310.	190.8	165.1	64.4	52.3
315.	195.6	167.9	66.7	54.2
320.	197.9	171.9	69.1	56.1
325.	203.6	174.7	70.4	57.8
330.	208.6	179.1	72.2	59.3

TABLE C-4. CONTINUATION
PREDICTED GRIT CONCENTRATION IN THE UNITS
OF THE PROTOTYPE LINE-TRIAL # 6

START FROM START (MIN)	1ST WASHER (MG/L)	1ST SETT -LING TANK (MG/L)	2ND WASHER (MG/L)	2ND SETT -LING TANK (MG/L)
335.	211.6	183.7	74.0	60.7
340.	215.1	187.5	75.5	62.2
345.	216.7	190.7	76.9	63.5
350.	220.1	192.7	77.6	64.5
355.	222.3	195.4	78.7	65.4
360.	224.7	198.1	79.8	66.4
365.	231.4	199.7	79.7	66.9
370.	232.6	202.9	80.3	67.3
375.	238.1	206.9	85.5	69.2
380.	242.6	210.8	88.5	71.8
385.	248.4	214.5	90.6	74.1
390.	254.3	219.1	92.6	76.1
395.	258.6	223.3	94.1	77.8
400.	251.1	221.8	79.9	81.5
405.	244.3	218.4	72.6	78.5
410.	233.5	213.3	67.4	74.1
415.	224.5	206.3	62.8	69.5
420.	216.3	198.5	58.5	65.0
425.	210.9	190.2	54.0	60.5
430.	224.7	190.0	69.1	56.6
435.	228.5	195.6	75.7	59.8
440.	230.8	199.6	79.8	63.6
445.	235.7	202.0	82.4	66.7
450.	240.5	205.9	85.0	69.2
455.	246.8	209.6	86.9	71.4
460.	250.6	214.7	89.2	73.3
465.	252.7	217.8	88.2	74.2
470.	255.4	221.3	88.7	74.5
475.	257.9	223.9	89.0	74.9
480.	261.5	225.8	89.0	75.0
485.	263.2	229.4	90.0	75.4
490.	266.4	233.4	91.4	76.2
495.	269.2	235.8	91.9	76.9

TABLE C-4. CONTINUATION
PREDICTED GRIT CONCENTRATION IN THE UNITS
OF THE PROTOTYPE LINE-TRIAL # 6

START FROM START (MIN)	1ST WASHER (MG/L)	1ST SETT-LING TANK (MG/L)	2ND WASHER (MG/L)	2ND SETT-LING TANK (MG/L)
500.	272.4	239.2	92.9	77.7
505.	274.3	241.7	93.6	78.4
510.	280.1	242.3	93.0	78.6
515.	281.5	244.1	92.8	78.5

The vita has been removed from the scanned document

A COMPARATIVE STUDY OF CONVENTIONAL GREENS WASHERS
AND A PROTOTYPE SYSTEM RECYCLING WASH WATER
WITH A MATHEMATICAL MODEL
OF GRIT CONCENTRATION IN WASH WATER

by

Jan K. Brzozowski

(ABSTRACT)

A prototype system with wash water recirculation was studied as a possible method of water conservation in the food processing industry. A conventional leafy-greens washer at the Exmore Foods Company, Incorporated, Exmore, Virginia, was compared with a prototype system. Spinach and turnip greens were processed with the two systems.

The quality of the product and that of the wash water from both systems was compared by measuring grit content, bacteria contamination, and insect contamination of the product;TSS, VSS, COD, and grit concentrations in the wash water.

The results indicated the better performance of prototype system which required only 23 percent of the water used by the conventional washers. The mathematical model developed to describe the grit content in the wash water of the prototype during washing succeeded in producing predicted values generally close to measured values.