COMPLETION REPORT
SETTLING BASINS FOR IRRIGATION RETURN FLOW AND FRESH PACK EFFLUENT

by

C. E. Brockway

Department of Civil Engineering
University of Idaho

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ABSTRACT

Sediment yield was monitored from seven fields in southern Idaho to determine the effects of crop type, soils, topography and other parameters. Regression techniques and application of the Universal Soil Loss equation were used in attempts to develop predictive procedures for sediment yield. Measured seasonal sediment yields varied from .34 to 37.0 tons/acre depending on the crop, soil type and field slope. Average sediment and nutrient removal efficiencies for farm settling ponds for an irrigation season varied from 69 to 93 percent for sediment and from 25 to 78 percent for phosphate and nitrogen. A mathematical model was developed as a tool for settling pond design and the model results verified with measured data. Water quality parameters of effluent from four potato fresh pack operations were measured and removal efficiencies determined on four settling facilities. Removal efficiencies of 70 to 90 percent for C.O.D., 63 to 99 percent for suspended solids and 13 to 80 percent for total nitrogen were measured.

INTRODUCTION

The purpose of this study was to develop and evaluate sediment yield from cropped fields and design criteria for sedimentation basins for irrigation return flow. An additional objective was to evaluate water quality of effluent from potato fresh-pack facilities.

Irrigation return flow can contain large quantities of silt, salts, nutrients and other matter resulting from farm irrigations and subsequent runoff. Even though all constituents entrained by the flow do not remain in transport, significant amounts eventually reach a receiving stream. Upon entering the stream, these materials are deposited or remain in the flow and are deposited at a later time and place. As a result, turbidity and total suspended solids of the receiving stream are increased by the influx of sediment, and the nutrient and salt content may be increased significantly.

Because of concern for the quality of surface water runoff from agricultural lands and pending regulations for control of water quality from food processing facilities, this project was undertaken to determine the quantities of sediment and nutrients generated from gravity irrigated fields and potato shipping plants. Another concern is the feasibility of remedial action by farmers, irrigation districts or potato shippers to improve water quality of return flow and subsequently that of the receiving stream. The University of Idaho College of Engineering, the Agricultural Research Service, USDA, at the Snake River Conservation Center at Kimberly, Idaho and the Northside Canal Company of Jerome, Idaho were involved in this study.

OBJECTIVES

The objectives of this study were:

1. To determine sediment yield in tons per acre for several irrigated fields as a function of soil type and local topography,specie and age of cover crop, and the quantity and application rate of irrigation water.

2. To develop a procedure for determining the sediment input function for a settling basin constructed on a drain or farm ditch. This was to be accomplished by estimating the quantity of sediment entering the drain using data developed in objective 1.

3. To develop design criteria for determining geometric dimensions of a settling basin as a function of inflow discharge, associated sediment load, and the cleaning frequency specified for the basin.

4. To determine the characteristics of effluent water quality from potato fresh-pack installations for determination of required treatment procedures.

Supervision for the experimental work and construction of facilities was divided among the three principal parties mentioned above.

SEDIMENT YIELD FROM IRRIGATED FIELDS

Scope of Study

The objective of this segment of the project was the development of design curves or regression equations for predicting the sediment production from irrigated fields. Sediment yield was to be determined as a function of soil type and local topography, specie and age of cover crop, and the quantity and application rate of irrigation water. A literature review was conducted to find pertinent information concerning sediment production from irrigated fields; however, few applicable references were found.

General Procedures

The hydrographs of total flow onto and from selected fields and associated samples of water-sediment mixtures were obtained and sediment production or yield for each irrigation determined.

Irrigation efficiencies and the effect of water quality on the sediment yield were obtained.

Field Sites

Eleven fields in the vicinity of Jerome and Twin Falls, Idaho were monitored for the study; three in 1972, four in 1973, and four in 1974.

Of the eleven fields monitored, seven were selected for analysis. Some fields were deleted because of nontypical irrigation practices or inability to measure inflow or outflow for the total season.

Each field was surveyed and mapped. Slopes, furrow lengths, area and other parameters were calculated for each field and for each irrigation set. The survey established high and low points in the fields and thus added in the selection of positions for monitoring devices. Once these positions were chosen, three-inch Parshall flumes were installed where needed for the purpose of measuring irrigation inflows and outflows to and from the cropped lands. Details of each field are outlined by (Oliver, 1974) and (Ballard, 1975). A summary description of each field is outlined in Table 1.

Sampling and Data Collection

Measurements of inflow to the field, outflow from the field, and sediment concentration were necessary for calculating sediment yield

Table 1

Field Descriptions

Field	Year	Crop	Previous crop	Area, acres	Average slope, percent	Average length, feet	Soil type
CS	1973	Potatoes	Alfalfa	10.94	1.68	574	Sandy loam
BB	1973	Beans	Grain	5.52	1.79	449	Loam
WB	1974	Beans	Grain	19.76	1.50	859	Silt loam
SG	1974	Wheat	Beans	4.30	1.37	432	Silt clay loam
WG	1974	Barley	Beans	4.00	1.20	407	Silt loam
AB	1974	Beans	Beans	2.17	1.00	465	Silt loam
CP	1974	Potatoes	Alfalfa	7.21	2.60	902	Silt loam

and for formulating predictive equations. During the 1974 irrigation season, in addition to the above measurements, samples were collected for the determination of phosphate, nitrate, total nitrogen, turbidity, and conductivity.

The inflows and outflows were measured using several different types of flumes, current meters, headgates, or calibrated siphon tubes. Parshall and H flumes were used to measure the outflow from the field. Water-stage recorders were used on all the outflow flumes in 1974 so that continuous flow rate could be measured. Figure 1 shows a graph of flow versus time from an actual irrigation.

Samples of dry soil were taken at various points across each field for laboratory analysis to determine soil type and texture. Particle size distributions of the soils were determined using the Buoyoucos hydrometer method and soil classifications determined.

The sampler shown in Figure 2 was designed and operated to obtain a representative sample of the full vertical profile of the sediment-water mixture at the end of the Parshall flume. The hydraulic jump which occurs in the throat of the Parshall flume afforded adequate mixing of the flow and field samples were obtained at that point. The sampler was rapidly placed into the flow at the downstream end so that the vertical opening of the device was oriented directly into the flow. Approximately one liter was obtained in each sample.

Sampling Procedure and Schedule

Sediment samples and flow measurements were taken once every 30 minutes or each hour for the first few hours and then at two to four-hour intervals for the remainder of the irrigation period. This time increment was selected because data from a previous study showed the changes over a period of four hours were slight except for the first two hours of the irrigation (Oliver, 1974).

Frequency of irrigation was determined by the farmer and based on antecedent moisture condition, crop, or other criteria. The potato and bean fields were irrigated approximately every eight days throughout the season. The irrigations on the grain fields varied from seven to sixteen days, with an average of ten to eleven days. Most of the farmer cooperators were consistent in their watering schedule.

The phosphate determinations required two samples for each observation, an unfiltered and a filtered sample. The latter was filtered immediately after sampling using a millipore filter with a hand vacuum pump. Both samples were then taken to the laboratory and $HgCl_2$ added to each and then refrigerated. The $HgCl_2$ was added to keep any microorganisms in the sample from utilizing the phosphate.

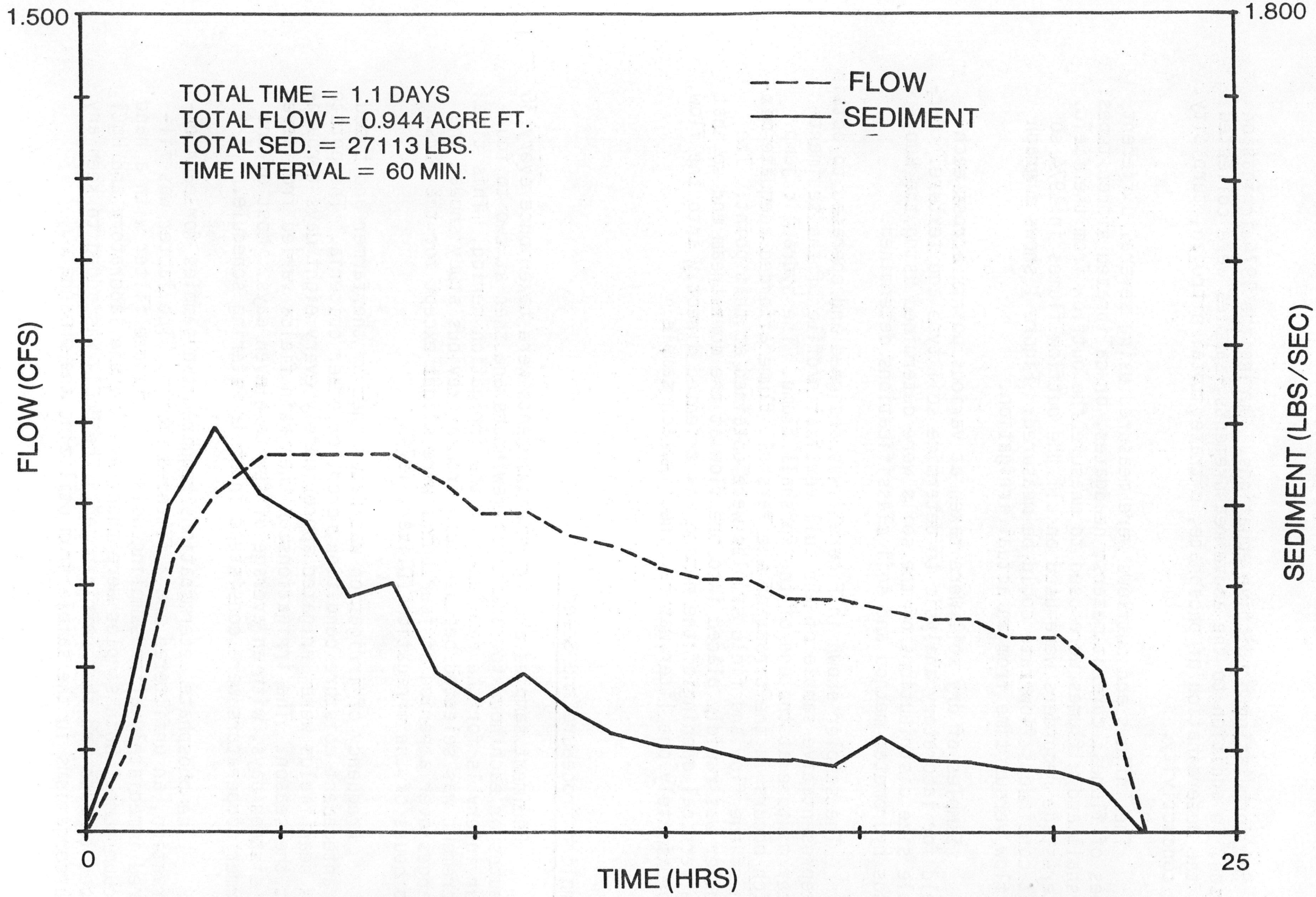

Figure 1. Time distribution of sediment yield and runoff during an irrigation

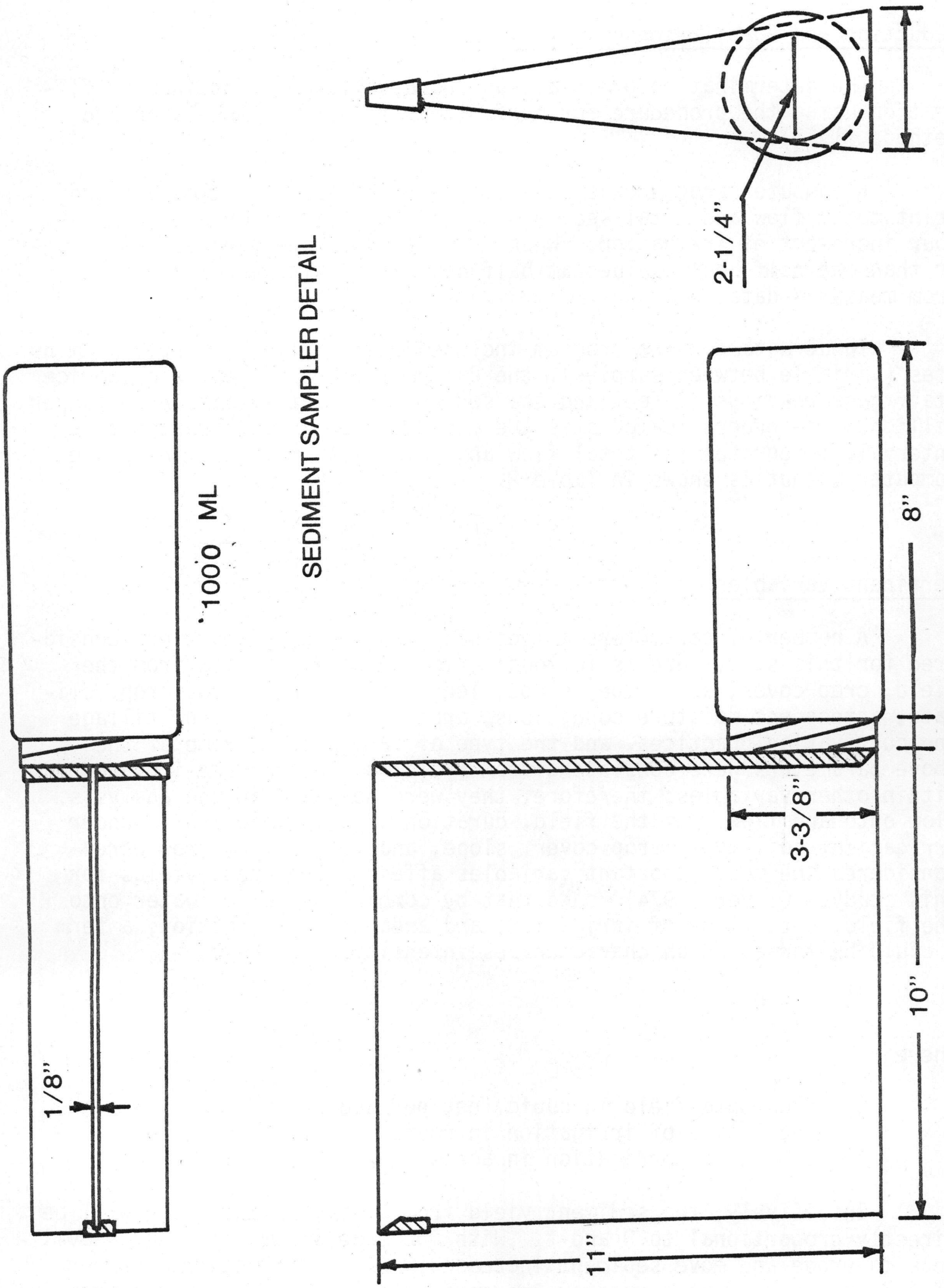

Figure 2. Sediment sampler detail

Reduction and Compilation of Data

The determination of total suspended solids was obtained by filtration using the procedure for nonfilterable residue (APHA Standard Methods, 1971).

A computer program was developed and utilized to calculate and print total flow and total sediment loss from a field for each half hour increment of irrigation. When intervals between samples were longer than one half hour, values at half hour intervals were interpolated from measured data.

Input data for the program included the sampling interval in minutes (variable between samples), the Parshall flume or measuring device staff gage readings in feet and the sediment concentrations in parts per million. The program calculates the mass sediment flow for each time interval, integrates the total flow and prints the results. A sample computer output is shown in Table 2.

Pertinent Variables

A number of parameters affect sediment yield. Parameters considered for this study were as follows: flow onto field, flow from the field, crop cover, soil type, slope, length of run, previous crop, climate, antecedent moisture conditions, area under cultivation, tillage and cultivation practices, and the type of irrigation. Some of the above parameters were consistent from field to field or are included within other variables; therefore, they were not used in the analysis. Flow onto and flow from the field, duration of irrigation, area under irrigation, soil type, crop cover, slope, and length of furrow were considered the most important variables affecting sediment yields for this study. Oliver (1974) found that by combining flow of water onto the field, total time of irrigation, and area under irrigation, a term Y could be formed which characterizes intensity or energy.

$$Y = Qt/A$$

where

Q = flow onto field in cubic feet per second
t = total time of irrigation in hours
A = area under irrigation in acres

Intuitively, the sediment yield from a given sized field will be directly proportional to Q and t. With increased flow, the energy available to erode and move sediment increases. Also the longer the water runs down a furrow, the greater the sediment yield will be for that field. This relationship must be referenced to a specific area to be significant.

Table 2

Sample Computation for Sediment Yield

Discharge Computations

Desc: HB3 720-21 0930Z Q and Sed
Time Interval = 30 min
Previous Accumulation of Acre Feet = 0

$Q = A + BH_a^N + CH_a^M$

Q = Discharge (cfs)
H_a is the gage height reading in the flume

Equation of Rating Curve:	A	B	C	RANGE	N	M
	0.	0.99	0.	0. - 1.0	1.5	0.

Time (hrs)	Flow (cfs)	Acc. Flow (acre ft.)	Sed. Conc. (ppm)	Sed. Conc. (lbs/sec.)	Acc. Sed. (lbs)
0.	0.	0.	14485.	0.	0.
0.5	0.204	0.004	14485.	0.185	166.134
1.0	0.308	0.015	15193.	0.292	595.486
1.5	0.319	0.028	13861.	0.276	1105.798
2.0	0.329	0.041	15217.	0.312	1636.072
2.5	0.339	0.055	15572.	0.351	2233.205
3.0	0.345	0.069	15492.	0.333	2849.099
3.5	0.350	0.083	14412.	0.315	3432.359
4.0	0.355	0.098	13051.	0.289	3976.132
4.5	0.361	0.113	11689.	0.263	4473.362
5.0	0.366	0.128	13330.	0.305	4984.243
5.5	0.372	0.143	14971.	0.347	5570.661
6.0	0.382	0.159	14166.	0.368	6187.841
6.5	0.393	0.175	13361.	0.328	6786.671
7.0	0.388	0.191	12518.	0.303	7354.569
7.5	0.382	0.207	11675.	0.279	7877.996
8.0	0.388	0.223	11363.	0.275	8376.253
8.5	0.393	0.239	11051.	0.271	8867.962
9.0	0.366	0.255	10350.	0.251	9337.583
9.5	0.382	0.271	9648.	0.230	9770.240
10.0	0.382	0.287	8399.	0.200	10157.805
10.5	0.382	0.302	7149.	0.171	10491.702
11.0	0.382	0.318	7076.	0.169	10797.186
11.5	0.382	0.334	7002.	0.167	11099.514
12.0	0.386	0.350	6448.	0.156	11390.343
12.5	0.393	0.366	5893.	0.145	11660.999
13.0	0.393	0.382	6023.	0.148	11924.263
13.5	0.393	0.399	6152.	0.151	12193.250
14.0	0.388	0.415	5413.	0.131	12447.092
14.5	0.382	0.431	4674	0.112	12665.389
15.0	0.382	0.447	4728.	0.113	12867.295
15.5	0.382	0.462	4781.	0.114	13071.499

An increase in sediment yield should be expected if there is an increase in slope. As the slope increases, the velocity of flow increases, thus causing more sediment to be eroded away. The effect of furrow length on sediment yield is difficult to predict. As the furrow length is increased, a larger stream is necessary to assure that the entire furrow is wetted. This increase in energy at the beginning of the furrow possibly erodes a greater amount of sediment, but whether this eroded sediment is transported to the end of the furrow and into the return flow is questionable. There is a possibility that in earlier irrigations, length has a negative effect on sediment yield whereas in subsequent irrigations the sediment eroded at the upper end of the furrow may reach the end of the furrow thus increasing the sediment yield.

Summary of Irrigations

The number of irrigations for each field depended upon the crop, weather, and antecedent moisture conditions. Each of the bean fields (AB, WB, and BB) was irrigated six times not including a pre-irrigation was not measured or used in the analysis because it is usually performed early in the season and is not always necessary. Sampling was not started until the early part of June when all the fields had been selected.

The CP field was irrigated twelve times over the season. The CS and SG fields were irrigated six times, the WG field four times.

In 1973, logistics prevented the sampling of every irrigation. This was due to several factors: communication between the farmer and technician, distance between the study fields and research station, and the inability to sample two fields at the same time. Therefore, it was necessary to study ponds and fields in 1974 that were closer together and nearer to the research station. It was also necessary to know when the irrigations were to take place. During the summer of 1974, only two and one-half irrigations were not sampled, whereas eight and one-half were missed in 1973.

Analysis

Two methods of analysis were utilized in this study for sediment yield prediction, a modification of the Universal Soil Loss Equation and step-wise multiple regression.

The Universal Soil Loss Equation was developed for heavy rainfall areas. In an attempt to correlate sediment yield from areas under furrow irrigation and the yield given by the Universal Soil Loss Equation, the Y value discussed earlier was investigated to see if there was a relationship between Y and R, the rainfall factor. Using the data available from this study, no good correlation could be found. It was concluded that the Universal Soil Loss Equation is not suitable for sediment yield prediction for fields under furrow irrigation. Oliver (1974) also found this to be true.

The basic regression program used was step-wise multiple regression with the following characteristic equation:

$$Y = a_o + a_1X_1 + a_2X_2 + a_3X_3 + \ldots + a_nX_n$$

where

Y = dependent variable
A_i = constant
X_j = independent variables

By using step-wise regression the effect of each variable in the predictive equation could be determined.

Independent variables, including the mean discharge onto the field, time of set, area irrigated, slope, length of furrow, soil type, and crop type, were considered for this analysis.

Crop type was deleted because there were not enough observations for each individual crop to be analyzed. However, by observing the total sediment yield from all fields, the potato fields were consistently higher than the other crops studied. The bean and grain fields had approximately the same range of values. Further observations are needed in order to evaluate the effect of crop type. For the same reason, soil type could not be used as a parameter. The CS field was the only sandy loam soil. All others were either silt loam or loamy soils. Regression was run on the loam soils first, and the CS field data was added later. It was found that no significant differences existed. Therefore, no attempt was made in the analysis to differentiate between soil types.

The data were tabulated according to irrigation and field and are shown in Table 3. The data were too sporadic for regression to be applied to the total sediment yield for the season; therefore, an attempt was made to derive a predictive equation for each irrigation. There were five to six observations available for each irrigation. Predictive equations utilizing At/A(Y), length, and slope as the independent variables were found for each irrigation. The results of this analysis are tabulated in Tables 4 and 5.

Inspection of the coefficients show no consistent trends in either their magnitude or sign. The coefficients of determination do show that a high correlation does exist between the sediment yield and the independent variables. Irrigations two and six show the highest correlation and lowest standard error of the estimate, but the coefficients are not consistent. Therefore, the predictive equations are not sufficiently accurate or reliable to be used at this particular time.

Table 3

Field Summary Sediment Yield

Field	Time, hours	Inflow, cfs	Pounds sediment	Area, acres	Sediment yield, pounds/acre
CS1[a]	53	1.248	36622	5.472	6692.62
	53	1.248	24215	5.472	4425.26
CS2	51	1.248	18345	5.472	3352.52
	51	1.248	12130	5.472	2216.74
CS3	51	1.248	11000[b]	5.472	2010.23[b]
	51	1.248	6500[b]	5.472	1187.87[b]
CS4	51	1.248	8259	5.472	1509.32
	53	1.248	3675	5.472	671.60
CS5	42	1.248	5100	5.472	932.02
	41	1.248	2047	5.472	374.09
CS6	41	1.248	2717	5.472	496.53
	53	1.248	546	5.472	99.78
TOTALS			131156	10.944	11984.28
BB1	13	1.500	379	2.76	137.32
	14	1.500	332	2.76	120.29
BB2	13	1.500	581[b]	2.76	210.51[b]
	14	1.500	533[b]	2.76	193.12[b]
BB3	11	1.500	2117	2.76	767.03
	16	1.500	5582	2.76	2022.46
BB4	14	1.500	1850[b]	2.76	670.29[b]
	13	1.500	1427[b]	2.76	517.03[b]
BB5	13	1.500	2148	2.76	778.26
	14	1.500	1973	2.76	714.86
BB6	13	1.500	2195	2.76	795.29
	14	1.500	2526	2.76	929.35
TOTALS			21682	5.52	3927.89

Table 3
(Continued)

Field	Time, hours	Inflow, cfs	Pounds sediment	Area, acres	Sediment yield, pounds/acre
WB1	13	1.2	639	9.881	64.67
	14	1.2	3523	9.881	356.54
WB2	13	1.2	593[b]	9.881	60.01[b]
	14	1.2	3815[b]	9.881	386.09[b]
WB3	26	1.2	1777[b]	9.881	179.84[b]
	25	1.2	11430[b]	9.881	1156.77[b]
WB4	25	1.2	2056	9.881	208.08
	26	1.2	2412	9.881	244.11
WB5	25	1.2	383	9.881	38.76
	26	1.2	12891	9.881	1304.63
WB6	25	1.2	314[b]	9.881	31.78[b]
	26	1.2	2023	9.881	204.74[b]
TOTALS			45902	19.762	2322.74
SG1	24	0.367	384	2.15	178.60
	42	0.378	1740	2.15	809.30
SG2	21	0.472	1534	2.15	713.49
	24	0.350	358	2.15	166.51
SG3	26	0.415	1870	2.15	869.77
	24	0.570	1581	2.15	735.35
SG4	25	0.916	2223	4.30	516.98
SG5	24	0.796	1082	4.30	251.63
SG6	25	1.075	477	4.30	110.93
TOTALS			11249	4.30	2616.05
WG1	23	0.554	909[b]	2.45	371.02[b]
	24	0.480	144[b]	2.45	58.78[b]
WG2	23	0.554	1301	2.45	531.02
	24	0.480	206	2.45	84.08
WG3	10	0.383	262	2.45	106.94
	11	0.228	44	2.45	17.96
WG4	14	0.405	127	2.45	51.84
	25	0.464	332	2.45	135.51
TOTALS			3325	4.90	678.57

Table 3

(Continued)

Field	Time, hours	Inflow, cfs	Pounds sediment	Area acres	Sediment yield, pounds/acre
ABPR[c]	29	0.150	932	2.17	429.49
AB1	13	0.338	809	2.17	372.81
AB2	11	0.146	552	2.17	254.38
AB3	16	0.231	1393	2.17	641.94
AB4	19	0.220	1458	2.17	671.89
AB5	20	0.259	1048	2.17	482.95
AB6	12	0.350	870	2.17	400.92
TOTALS			7062	2.17	3254.38
CP1	22	1.423	24817	3.61	6874.52
	24	1.55	83394[b]	3.61	23100.83[b]
CP2	25	1.664	28520	3.61	7900.28
	27	1.450	16826	3.61	4660.94
CP3	26	2.65	117878	7.21	16326.59
CP4	26	1.0	22508	3.47	6486.46
	21	1.0	28703	3.48	8247.99
CP5	25	2.07	65363	6.95	9404.75
CP6	29	2.09	24465	6.95	3520.14
CP7	25	2.207	36989	6.95	5322.16
CP8	26	1.958	18775	6.95	2701.44
CP9	24	2.012	27113	6.95	3901.15
CP10	25	1.929	16949[b]	6.95	2438.71[b]
CP11	25	1.882	6785	6.95	976.26
CP12	24	1.847	6847	6.95	985.18
TOTALS			525932		74000

[a] Denotes irrigation number.

[b] Estimated values based on measurement of partial irrigation.

[c] Denotes pre-irrigation.

Table 4

Regression Equations for Sediment Yield by Irrigations

N	C_1	C_2	C_3	C_4	ST	R^2
$S.Y. = C_1Y + C_2S + C_3L + C_4$						
1	+ 820.12	- 5574.32	+ 809.49	+ 313.90	455.33	0.990
2	+ 114.85	+ 316.85	+ 985.18	- 4718.30	72.66	1.000
3	- 129.13	+ 2462.16	+ 2841.57	- 14494.77	638.76	0.998
4	- 271.17	+ 6447.38	- 403.14	- 4466.16	1045.92	0.939
5	- 376.02	+ 6683.93	+ 162.58	- 8002.09	2385.43	0.826
6	- 190.58	+ 1936.28	+ 307.35	- 2616.60	74.65	1.000

Key:	
S.Y.	Sediment yield in pounds/acre
N	Irrigation number
Y	Qt/A where Q is in cfs, time t in hours, and area A in acres
S	Percent slope
L	Length of furrow in hundreds of feet
ST	Standard error of the estimate
R^2	Coefficient of determination

Table 5

Table of Residuals for Regression Equations

Irrigation	Field	Sediment yield, pound/acre		Residuals
		Observed	Estimated	
1	SG	494	865	-371
	AB	373	168	205
	BB	140	-12	162
	WB	211	251	-40
	CS	5561	5507	54
2	CP	6289	6279	10
	SG	440	477	-37
	WG	308	250	58
	AB	254	265	-11
	CS	2786	2806	-20
3	CP	16349	16303	46
	SG	802	414	388
	WG	62	-152	214
	AB	642	961	-319
	BB	1395	1723	-328
4	CP	7103	6855	248
	SG	517	1180	-663
	WG	94	556	462
	AB	672	-417	1089
	WB	431	901	-470
	CS	1091	833	258
5	CP	9405	8041	1364
	SG	252	188	64
	AB	483	-1460	1943
	WB	672	2255	-1583
	BB	747	2545	-1798
	CS	653	644	9
6	CP	3520	3528	-8
	SG	111	173	-63
	AB	401	379	22
	BB	862	832	30
	CS	376	358	18

Regression was also attempted using logarithmic transforms but with poor results. Oliver (1974) also found the data to be insufficient to produce a reliable predictive equation. He also analyzed sediment yield on an hourly basis with little success. The hourly run showed a poorer correlation than the analysis utilizing irrigation number as an input variable; therefore, the hourly analysis was not used in this study.

Sediment yield for a portion of irrigations not sampled were estimated either by using a regression equation or by interpolating between yields for two known irrigations so that a sediment yield for the entire season could be derived for each field. Utilizing the total yields for each field over the entire season, step-wise multiple regression yielded the following equation:

$$S.Y = -31.07 - 0.096Y + 24.37S + 0.0046L$$

where

$S.Y$ = annual sediment yield in tons/acre
Y = Qt/A; Q in cfs, t in hours, A in acres
S = slope in percent
L = length in feet

The coefficient of determination was 0.799, and the standard error of estimate was 8.431 tons/acre.

The range of sediment yield for three different crops is as follows:

1. Beans: 1.16 to 1.97 tons/acre
2. Grain: 0.34 to 1.31 tons/acre
3. Potatoes: 5.99 to 37.0 tons/acre

These values may be considered to approximate the ranges of amounts of sediment from a field with a specified crop on sandy loam to silt loam soils in southern Idaho.

Summary and Conclusions

The objective for this phase of the study was to determine sediment yield to ponds as a function of crop type, soil type, and topography for determination of the sediment input function for settling pond design. Sediment data from 1973 and 1974 were obtained from two potato fields, two grain fields, and three bean fields. The available data were not sufficient to allow evaluation of the applicability of the Universal Soil Loss Equation to fields under furrow irrigation. Step-wise multiple regression appears to have the most potential for analyzing data for sediment yield prediction; however, results using limited data in this study are inconclusive. Using irrigation number as an input variable and Qt/A, slope, and length of furrow as independent variables, predictive equations for six irrigations attempted. Two of the six equations closely approximated the observed sediment yields. The predicted sediment yields from the second irrigation ranged from 0.2 to 19% lower and from 0.7 to 8.4% higher than the measured values. The predicted sediment yield from the sixth irrigation ranged from 0.2% to 57% higher and 3.5% to 5.5% lower. The fifth irrigation showed the largest range of values, 236% higher to 402% lower than the observed values. The coefficients (Table 4) were not consistent from irrigation to irrigation and therefore no conclusions as to the effect of each variable on the sediment yield could be drawn. The equations derived from the currently available data are not adequate to be used as predictive equations for sediment yield from fields under furrow irrigation.

The large number of variables involved, data collection problems, field selection, and inconsistent irrigation practices prevented development of more adequate predictive equations. Thirteen variables were considered to have an effect on sediment yield and because of the limited number of observations available, only five variables could be considered.

Crop type and associated cultivation practices are closely related to one another and do affect sediment yield. For example, a bean field may be cultivated after each of the first four irrigations, whereas a potato field is usually cultivated once after the first irrigation and a grain field is very seldom cultivated after the field has been irrigated. Furthermore, bean and grain fields usually have a slick, compacted corrugate, whereas a furrow in a potato field is loosely packed. Differences in sediment yield measured in the wheel and non-wheel row were observed. When a field is tilled, planted, or cultivated with the use of a tractor, two or three of every five furrows are compacted by the wheels of the tractor. The farmer is usually careful to always run the tractor wheels in these rows, especially with beans and potatoes. The sediment yield measured from the non-wheel row was always higher than that measured in the wheel row. With additional observations, crop type can be utilized as an input variable for sediment yield.

Variables such as fertility and antecedent moisture conditions were not examined. Additional studies are needed in order to see what effect, if any, these variables have on sediment production.

Soil type was not used in the analysis because there were not enough observations taken to evaluate the sandy loam soil separately from the loam and silt loam soils. Several more observations are necessary in order to evaluate the effect of different soil types on sediment yield. Inconsistencies in irrigation practice by farmers also compounds the problem.

Additional field data are needed before any predictive equations which are applicable to a wide range of field conditions can be developed. This study indicates that there is a good possibility of developing reasonable equations if sufficient interest and funds are available.

SETTLING PONDS

Scope of Study

The objective of this section was to develop engineering design criteria for settling ponds. Removal efficiencies for suspended sediment and bed load were evaluated as a function of pond geometry, inflow discharge, and sediment loading. In addition to the above, measurements on the effectiveness of ponds to remove various nutrients was studied.

Description of Ponds

Eight ponds collecting runoff from fields evaluated were studied, four in 1973 and four in 1974. The ponds were either built by the farmer or constructed by project personnel. Seven ponds were used for analysis as shown in Table 6.

Table 6

Pond Dimensions

Pond	Length, feet	Width inflow, feet	Width outflow, feet	Average depth, ft
SCP	47.90	9.60	9.60	6.30
BBP	93.00	57.00	45.00	2.50
HGP	217.00	15.00	22.00	2.40
SGP	40.80	9.60	9.60	5.50
WGP	51.00	9.00	22.00	3.63
ABP	31.50	9.20	9.20	4.60
CPP	56.00	10.00	10.50	3.25

All ponds were rectangular in shape, except for the WGP pond, which was triangular with the inflow at the apex and decreasing depth toward the outlet. Plastic liners were placed on the outflow section of each pond studied in 1974 so that samples could be taken without sediment being contributed from the waste ditch or overflow section.

Data Collection

The data collection and laboratory work were similar to procedures used for sediment yield determinations. The inflow and outflow of each pond was monitored for sediment concentration and four were monitored for phosphate, nitrogen, nitrate, conductivity, and turbidity. Samples for nutrient determination were not taken until the pond had filled. The pond was then sampled at eight-hour intervals until the end of the irrigation period. The flow measurement was read at the inlet to the pond. During the summer of 1973 flumes were placed at each end of the pond to determine if a substantial amount of water was lost to evaporation and/or seepage. In all cases the difference, if any, between the inflow and outflow was negligible.

Sampling began as soon as the return flow from the field entered the pond. Four-hour sampling increments were used, except that two one-hour samples were taken after the water started flowing into the pond and after the flow started leaving the pond.

"Ideal" Settling Basins

Basic theories used in evaluating sediment removal in ponds are outlined by Camp (1936). Particles heavier than water are settled out or removed by gravitational action. A discrete particle will retain it's individual characteristics and when placed in a column of water will accelerate in velocity until the drag forces and the gravitational forces are in equilibrium. At this point the average velocity of the particle will become constant.

Newton proposed the first law for "drag" and when equated to the weight of a sphere in a fluid, Stokes' law was obtained as follows:

$$V_s = g(\rho_s - \rho)\ d^2/18\mu$$

or approximately

$$V_s = g(s_s - 1)\ d^2/18\nu$$

where

V_s = the settling velocity
g = acceleration due to gravity
$\rho_s \rho$ = mass densities of the particle and of the fluid, respectively

s_s = specific gravity of the particle
μ = dynamic viscosity
ν = kinematic viscosity
d = particle diameter

The above equation is applicable only for Reynolds numbers less than 1.

A rational theory of clarifications for "ideal" settling tanks can be developed if certain simplifying assumptions are made. These were proposed by Camp as follows:

1. At all points in the basin the direction of the flow is horizontal and the velocities are equal.

2. The concentration of suspended particles of each size is the same at all points in the vertical plane perpendicular to the direction of flow at the basin inlet.

3. All suspended particles maintain their shape, size, and individuality during settling and settle without interference. Hence, each particle is assumed to settle at constant velocity.

4. A particle is removed from the flow system when it strikes the bottom.

With the above assumptions, the path followed by a particle will have a velocity and a direction equal to the vector sum of the flow velocity V and the settling velocity of the particle V_s. The particle will settle in a straight line and all other particles of the same size, shape, and weight will move along parallel paths. All particles with settling velocities greater than the overflow rate, or the velocity at which a particle must travel from the surface at the inlet to the bottom across the length of the basin will be removed. The velocity is denoted as V_o and is shown in Figure 3. Particles with settling velocities less than V_o will be removed in the ratio of the settling velocity to V_o, the overflow rate.

$$r = \frac{V_s}{V_o} = \frac{A_s V_s}{Q}$$

where r is the removal ratio of those particles settling at velocity V_s, less than the overflow rate V_o. A_s is the surface area of the tank corresponding to length L, and Q is the rate of discharge.

To calculate the total removal in a basin, a particle size-velocity curve can be constructed using settling velocity V_s as abscissa and initial concentration X of particles with velocities of V_o or less as the ordinate, where X is expressed as a ratio of the initial concentration to the total concentration. A typical curve is shown in Figure

4. The notation X_o denotes the value of X, corresponding to the overflow rate V_o. As stated earlier, all particles with settling velocity greater than the overflow rate V_o will be removed. The removal of these particles in terms of the total suspension will be $1 - X_o$. For particles having settling velocities less than V_o the following equation is given for their removal in terms of the total suspension:

$$r \, dX = \frac{1}{V_o} V_s \, dX$$

where dX is that ratio of the total suspension with $V_s < V_o$. The total removal of all particles is therefore

$$R = 1 - X_o + \frac{1}{V_o} \; {}_{o}^{X_o} \; V_s \, dX$$

Analysis

In developing engineering design criteria for settling ponds, it is necessary to determine specific factors affecting removal efficiencies. Camp (1936) found by analyzing an "ideal" settling tank that removal is independent of the depth for a given discharge and of the detention time. He also showed that for particles which have a settling velocity V_s less than overflow rate V_o the removal is directly proportional to the surface area of the tank for a given discharge or inversely proportional to the tank overflow rate.

Two approaches were taken for analyzing the data collected from ponds. First utilizing efficiency as a dependent variable and sediment size, overflow rate, length to width ratio, and detention time as independent variables, regression analysis was attempted to determine what effect each variable had on efficiency. Second, the collected data were used to determine whether a mathematical model developed by Oliver (1974) could be useful as a tool for developing design criteria for farm settling ponds. The total sediment inflow and outflow for each irrigation are shown in Table 7.

Regression

For regression analysis, the total removal efficiencies for each irrigation, average overflow rates, length to width ratios, detention times, and sediment size for each irrigation were tabulated and are shown in Table 8. The sediment size used was the 50% size of the field soil. Simple linear regression was performed on each variable, utilizing efficiency as the dependent variable.

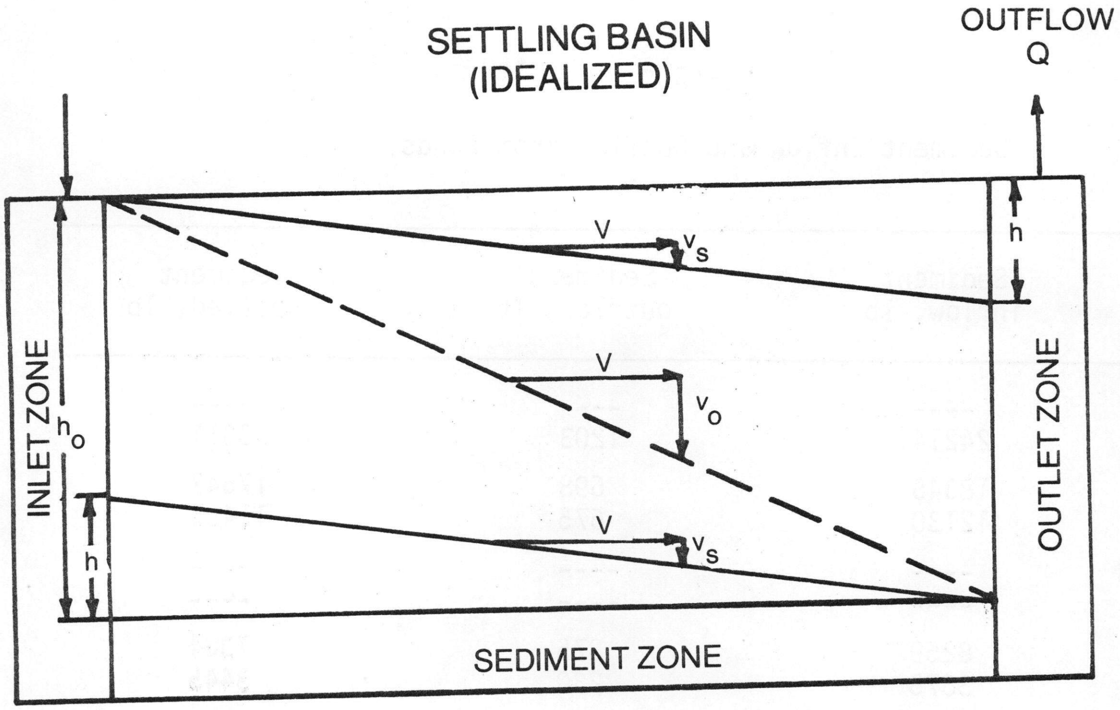

Figure 3. Settling basin schematic

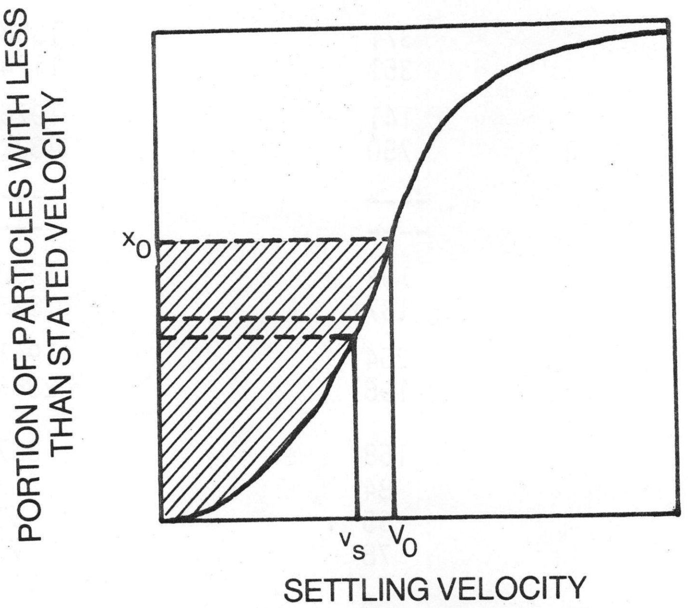

Figure 4. Particle size-velocity curve

Table 7

Sediment Inflow and Outflow from Ponds

Pond	Sediment inflow, lb	Sediment outflow, lb	Sediment settled, lb
CSP1[a]	----	----	----
	24214	1203	23011
CSP2	18345	698	17647
	12130	675	11455
CSP3	----	----	----
	----	----	----
CSP4	8259	875	7384
	3675	230	3445
CSP5	5100	557	4543
	2047	95	1952
CSP6	2717	186	2531
	4117	546	3571
BBP[b]	1083	364	719
	1113	136	977
BBP1	379	88	291
	332	83	249
BBP2	1679	371	1308
	1525	351	1174
BBP3	2117	141	1976
	5582	750	4832
BBP4	----	----	----
	----	----	----
BBP5	2148	194	1950
	1973	137	1836
BBP6	2195	254	1941
	2565	196	2369
HGP3	555	168	387
	366	84	282
	115	65	50
	151	78	73
HGP4	193	56	137
	147	39	108
HGP5	27	3	24
	33	12	21

Table 7

(Continued)

Pond	Sediment inflow, lb	Sediment outflow, lb	Sediment settled, lb
CPP1	4921	804	4117
	24817	4488	20329
CPP2	28520	4804	23716
	16826	3234	13592
SGP1	2124	235	1889
SGP2	1892	238	1654
SGP3	3451	328	3123
SGP4	2223	264	1959
SGP5	1082	155	927
SGP6	477	71	406
WGP1	----	----	----
	----	----	----
WGP2	1301	108	1193
	206	43	163
WGP3	262	21	241
	44	0	44
WGP4	127	1	126
	332	22	310
ABP Pre	932	177	755
ABP1	809	22	787
ABP2	552	17	535
ABP3	1393	145	1248
ABP4	1458	172	1286
ABP5	1048	158	890
ABP6	870	103	767

[a] Denotes irrigation.

[b] Observed irrigation for Bulcher Grain.

Table 8

Variables Used in Regression Analysis

Pond	Average overflow rate, ft/sec X 10^{-4}	Average detention time, hr	Length to width ratio	Sediment size (50%) microns	Efficiency, percent
CSP1[a]	----[b]	----	----	200	----
	4.729	3.529	5:1	200	95.0
CSP2	4.410	3.461	5:1	200	96.2
	4.579	3.109	5:1	200	94.4
CSP3	----	----	5:1	200	----
	----	----	5:1	200	----
CSP4	6.222	1.956	5:1	200	89.4
	2.882	4.089	5:1	200	93.7
CSP5	5.881	1.956	5:1	200	89.1
	3.025	3.727	5:1	200	95.4
CSP6	6.222	1.787	5:1	200	93.1
	6.966	1.565	5:1	200	86.7
				Average	92.6
BBP[c]	1.063	6.53	1.82:1	36	66.4
	0.782	8.86	1.82:1	36	87.8
BBP1	0.270	25.67	1.82:1	36	76.8
	0.527	13.14	1.82:1	36	75.0
BBP2	0.860	8.04	1.82:1	36	77.9
	0.911	7.58	1.82:1	36	77.0
BBP3	0.586	11.76	1.82:1	36	93.3
	0.658	10.42	1.82:1	36	86.6
BBP4	----	----	1.82:1	36	----
	----	----	1.82:1	36	----
BBP5	0.649	10.43	1.82:1	36	90.8
	0.702	9.62	1.82:1	36	93.1
BBP6	1.048	6.43	1.82:1	36	88.4
	0.902	7.44	1.82:1	36	92.4
				Average	83.8
HGP3	1.385	4.81	11.73:1	22	69.7
	1.285	4.18	11.73:1	22	77.1
	1.793	3.71	11.73:1	22	43.5
	2.260	2.94	11.73:1	22	48.3
HGP4	1.400	4.76	11.73:1	22	71.0
	1.330	5.00	11.73:1	22	73.5

Table 8

(Continued)

Pond	Average overflow rate, ft/sec $\times 10^{-4}$	Average detention time, hr	Length to width ratio	Sediment size (50%) microns	Efficiency, percent
HGP5	0.386	17.24	11.73:1	22	88.9
	0.483	13.77	11.73:1	22	63.6
				Average	66.9
CPP1	1.603	5.99	5.46:1	20	83.7
	3.066	2.89	5.46:1	20	81.9
	----	----	5.46:1	20	----
CPP2	3.336	0.46	5.46:1	20	83.1
	1.514	0.27	5.46:1	20	80.8
				Average	82.4
SGP1	1.748	8.69	4.25:1	17.5	88.9
SGP2	3.369	4.46	4.25:1	17.5	87.4
SGP3	5.445	2.73	4.25:1	17.5	90.5
SGP4	6.453	2.26	4.25:1	17.5	88.1
SGP5	5.259	2.75	4.25:1	17.5	85.7
SGP6	2.740	10.53	4.25:1	17.5	85.1
				Average	87.6
WGP1	----	----	3.21:1	18.0	----
	----	----	3.21:1	18.0	----
WGP2	3.110	2.99	3.21:1	18.0	91.7
	1.590	5.82	3.21:1	18.0	79.1
WGP3	2.060	4.49	3.21:1	18.0	92.0
	0.987	9.38	3.21:1	18.0	100.0
WGP4	1.340	6.90	3.21:1	18.0	99.2
	2.470	3.75	3.21:1	18.0	93.4
				Average	92.6
ABP Pre	1.104	11.51	3.42:1	18.0	81.0
ABP1	1.829	6.89	3.42:1	18.0	97.3
ABP2	1.449	8.62	3.42:1	18.0	96.9
ABP3	2.830	4.36	3.42:1	18.0	89.6
ABP4	3.934	3.08	3.42:1	18.0	88.2
ABP5	3.658	3.27	3.42:1	18.0	84.9
ABP6	2.553	4.64	3.42:1	18.0	88.2
				Average	89.4

[a] Denotes irrigation

[b] Irrigations not observed.

[c] Observed irrigation for Bulcher Grain.

The regression analysis, utilizing the data from all ponds, gave no meaningful results as to the effect of each variable on efficiency. However, regression analysis on data collected from each pond separately showed that in five of the seven ponds studied, the efficiency was inversely proportional to the overflow rate.

Intuitively lower efficiencies should be expected in both a long narrow pond and a short wide pond. In a long narrow pond the flow velocity would be high compared to a wider pond thus keeping the particles in suspension. Short circuiting could occur in a short wide pond, and much of the volume would be unused.

Mathematical Model

The mathematical model simulates the processes stated in the "ideal" settling basin concept discussed earlier. The model was designed so that the pond could be broken up into length increments and each increment analyzed for sediment deposition.

Inflow to the pond, sediment concentration and size gradations and time increments are used for model input. Flow, sediment concentration and gradation can be changed for each time increment through the pond. For this study the sediment size and gradation were assumed constant, but the sediment concentration and inflow to the pond was variable.

Three ponds were used in the analysis to compare model results with measured data. Measured removal efficiencies and model results are shown in Tables 9 and 10.

The three ponds used for this analysis were chosen because the data collected from them were more complete and filling times were short. These ponds gave good results and show reasonable agreement between the observed values and those given by the model.

The values given in Tables 9 and 10 were for a one-length increment pond, and the subroutine for dividing the pond into discrete increments was not used.

The actual efficiencies of the SGP pond are shown to be higher than those given by the model. Under actual conditions, various currents and interference from the velocity fields of closely spaced particles cause efficiencies to be less than what would be expected under ideal conditions. Also, the model assumes a tank or basin to be full of water when the irrigation begins, but in reality the SGP pond did not fill until four to eighteen hours after the inflow had begun. The same is true of the CSP and CPP ponds, though to a lesser extent. The CPP and CSP ponds took from one to four hours to fill, depending on the inflow. The model is being revised to allow for

Table 9

Observed Sediment Removal From Settling Ponds

Pond	Irrigation	Cumulative flow, acre feet	Cumulative sediment		Efficiency
			Inflow, tons	Outflow, tons	
SGP	1	0.351	1.0620	0.1175	88.9
SGP	2	0.478	0.9460	0.1190	87.4
SGP	3	0.729	1.7255	0.1640	90.5
SGP	4	0.531	1.1115	0.1320	88.1
SGP	5	0.449	0.5410	0.0775	85.7
SGP	6	0.289	0.2385	0.0355	85.1
TOTALS		2.827	5.6245	0.6455	88.5
CPP	1	0.422	14.869	2.646	82.2
CPP	2	0.578	22.673	4.019	82.3
TOTALS		1.000	37.542	6.665	82.3
CSP	1[a]	0.899	12.1075	0.6015	95.0
CSP	2	1.641	15.2375	0.6865	95.5
TOTALS		2.540	27.3450	1.2880	95.3

[a] Includes only one set of a total of two.

Table 10

Calculated Sediment Removal From Mathematical Model

Pond	Irrigation	Cumulative flow, acre feet	Cumulative sediment		Efficiency
			Inflow, tons	Outflow, tons	
SGP	1	0.364	1.095	0.215	80.4
SGP	2	0.451	0.945	0.249	73.7
SGP	3	0.727	1.726	0.446	74.2
SGP	4	0.537	1.112	0.378	66.0
SGP	5	0.437	0.538	0.159	70.5
SGP	6	0.306	0.245	0.060	75.5
TOTALS		2.822	5.661	1.507	73.4
CPP	1	0.422	14.876	2.745	81.6
CPP	2	0.578	22.711	3.936	82.7
TOTALS		1.000	37.587	6.681	82.2
CSP	1[a]	0.899	12.123	0.550	95.5
CSP	2	1.641	15.260	0.595	96.1
TOTALS		2.540	27.383	1.145	95.8

[a] Includes only one set of a total of two.

filling time. The total time for which the return flow entered the pond was used because the total volume of sediment settled must be determined for a cleaning schedule to be estimated. The results from these two ponds show the actual and estimated efficiencies to be very close.

The analysis did show the model to be useful as a tool for determining design criteria, but the engineer must use judgment when applying it. The ponds used in the analysis had length to width ratios (L:W) of four to one and five to one; therefore, other ponds with different L:W ratios may not give equivalent results. Also these ponds had uniform geometry and well defined inlets and outlets, whereas most ponds constructed by farmers are somewhat less ideal. The surface area of ponds which have continuous flow throughout the season should be increased above that shown by the model. The model computes a maximum expected efficiency, and actual operating efficiencies will be lower.

Considerations besides those listed above should be studied for on-farm settling ponds. These include location, surface area, depth, cleaning schedule, and shape.

The pond should be placed where it will be out of the way of the farm machinery and so it will take up very little of the field area. Preferably the pond should be located in an area not farmable and away from residences, unless properly fenced.

The surface area should be determined by the amount of flow entering the pond and the sediment size. It is recommended that the length to width ratio (L:W) be greater than three to one because of the possibility of short circuiting developing in ponds with a smaller L:W ratio.

The depth and cleaning schedule can be determined after the amount of sediment that will enter the pond each season is known. The volume can be adjusted to the capacity necessary to accomodate the incoming sediment for a specified time. Annual cleaning will normally be desirable for farm or single field settling ponds. Bi-annual cleaning frequencies usually require pond sizes larger than can be accomodated. If the depth is restricted due to geology or construction problems and a larger volume is required, the surface area should be adjusted to make up the discrepancy.

The shape should be such that it is easy to build, maintain, and locate. Rectangular ponds are recommended unless the topography dictates a different pond geometry. Rectangular ponds are the easiest to build and maintain. Since most fields under furrow irrigation are straight-sided, the rectangular pond normally will require smaller field area than ponds with other shapes. The triangular WGP pond mentioned earlier did not show any appreciable increase in efficiency over any of the other ponds with the same flow and sediment characteristics, but it did take longer to construct and utilized more field area than the rectangular ponds.

Nutrient Analysis

During the summer of 1974, phosphate, nitrogen, nitrate, conductivity, and turbidity samples were taken from ponds to determine removal efficiencies for each parameter. The ranges of values and average removals over the entire season were examined. These values for total nitrogen, total phosphate, and turbidity are tabulated in Table 11. The nitrates and conductivities are not shown because their values were either too small to be significant or showed no change across the pond.

Phosphate analysis was run on both filtered and unfiltered samples. Up to 98% of the phosphate can be tied up with the sediment; therefore, if a significant amount of sediment is removed, a large portion of the phosphate will be reduced. The average efficiencies for phosphate removal across the pond ranged from 34.6% to 77.7%, whereas the sediment removal ranged from 82.2% to 91.4%. Phosphate removals are lower for the runoff from silt loam soils than from sandy soils since the phosphate is mainly tied up with the clay particles which are not effectively settled in the pond. However, a significant degree of phosphate removal can be achieved thereby keeping part of the phosphate from entering the waste stream and eventually a receiving stream.

The removals for total nitrogen ranged from 28.6% to 75.2%. It is believed that the nitrogen removed was organic. Several samples were filtered and analyzed for total nitrogen. These observations showed 89.4% to 96.5% of the total nitrogen to be non-soluble forms.

As expected, turbidity removals were highest when a high concentration of sediment entered the pond. At the lower concentrations of sediment with apparently smaller particle sizes the turbidity was reduced very little, if any.

Summary and Conclusions

Regression analysis with limited data available did not provide sufficient justification for using overflow rate, L:W ratio, and sediment size as parameters for developing engineering design criteria. A mathematical model based on the concept of "ideal" settling basins was found to be the best tool for pond design.

When using the model, engineering judgments must be used as to the size, shape, and location of each pond. Response and efficiency of a prototype pond utilizing different lengths, widths, depths, inflows, sediment concentrations, and particle size gradations can be determined using the model. Appropriate designs can therefore be selected for any combination of parameters. The designer must decide on the cleaning interval for the pond by estimating the sediment yield from the particular field and the approximate efficiency of the pond. The size of the pond can be changed depending on the cleaning interval. Also the designer

Table 11

Summary of Nutrient Removal by Ponds

Pond	Inflow range, mg/l	Outflow range, mg/l	Percentage removal, av. season
	Total phosphate		
WGP	0.120 - 2.867	0.0[a] - 1.206	34.6
SGP	0.240 - 10.802	0.0 - 2.800	39.2
ABP	0.400 - 13.200	0.0 - 1.000	49.7
CPP	0.800 - 62.676	0.0 - 12.660	77.7
	Total nitrogen		
WGP	1.92 - 13.40	0.0 - 12.75	28.6
SGP	3.87 - 159.79	0.0 - 77.47	25.1
ABP	9.80 - 92.99	0.0 - 20.90	58.4
CPP	75.15 - 597.64	0.0 - 83.22	75.2
	Turbidity		
WGP	34 - 300	0 - 100	4.3
SGP	40 - 2100	0 - 700	20.5
ABP	126 - 2000	0 - 400	35.5
CPP	2300 - 16200	0 - 4000	62.1

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[a] 0.0 Outflow was zero during initial filling.

must decide whether the pond should be located in the field or placed on unused land outside the field. The economic feasibility of having one pond for each field or using one pond to treat the return flow from several fields must be evaluated.

This study showed that with properly designed and operated on-farm settling ponds, between 67% and 93% of the total seasonal sediment load contained in irrigation return flows can be removed. Also nutrients such as phosphate and nitrogen can be reduced through the use of ponds, thereby reducing pollution effects on streams and rivers.

POTATO FRESH PACK EFFLUENT STUDIES

Objective four of this study was to determine characteristics of effluent water quality from potato fresh-pack installations for use in determining required treatment procedures. Since sediment is the primary water quality problem in these effluents, the use of settling ponds or settling tank facilities has been the most used treatment. Several operating pond facilities were selected for monitoring.

Monitoring Site

Four sites selected for monitoring of effluent water quality provided useful data:

Idaho Falls:	This facility consisted of a pump-back sump within the packing shed with make up and washing water supplied from the city system. Overflow from the sump was pumped to a 50 foot by 200 foot settling pond with an overflow outlet into the city sewer. Water quality samples were obtained at the pond inlet and outlet and volmetric use determined from water meters on the city supply.
Fort Hall:	A small outdoor concrete sump received wash and cleanup water from the shed. Overflow from the sump was pumped into a baffled silt trap prior to entering the settling pond or flowed by gravity ditch into the pond. Outflow from the pond entered the city sewer. There was considerable down-time at this facility during 1975. During the down-time period, effluent from the filled sump flowed directly into an earthen ditch and spread out in an adjacent field and thus never reached the settling pond.
Blackfoot:	Effluent from the packing facility entered a sediment sump with automatic water level control. Effluent from the sump flowed into a 40 foot by 80 foot sediment pond and thence over a check structure into the city sewer. No water measurement facilities were available and since the outflow from the sump was intermittent, no water use determinations were made. During 1975 two foot diameter sedimentation cones were installed within the facility but limited data were secured because of operational difficulties with the cones.

Rigby: Plant effluent from the sediment sump located inside the packing shed was pumped intermittently into a pond adjacent to the sheds. There was no outlet from the pond and no overflow onto the adjacent fields was observed during visits to the site. No water quantity measurements were secured at this plant.

Analysis and Results

Sampling was conducted on an intermittent basis at the Idaho Falls plant during the period 12-11-73 through 5-28-74 and at all four facilities from 5-28-74 through 4-29-75. Grab samples were obtained at inflow and outflow points when facilities were operating normally. No outflow samples were taken when sumps were being cleaned or sediment removal facilities were not operating.

The one liter samples were immediately frozen and transported to the laboratory at Kimberly, Idaho for analysis.

Each sample was analyzed for chemical oxygen demand (C.O.D.); electrical conductivity, total nitrogen (Kjeldahl), pH, total phosphate (filtered and unfiltered), potassium and total suspended solids.

Table 12 shows the temperature, C.O.D., electrical conductivity, total nitrogen and pH measured at the four sites for the 1974-75 season. The water use for the Idaho Falls plant is also shown. Table 13 shows the turbidity, total phosphate of filtered and unfiltered samples, potassium, and suspended solids in inflow and outflow at the four sites. No production data were available from the plants to relate to total output of sedimentation, nutrients or concentration levels.

In general, C.O.D. levels were higher than expected with values of pond inflow ranging from 4 to 9140 ppm. Large variations occurred from site to site with the largest values occurring at the Blackfoot site. Significant removal was achieved at all locations except at Fort Hall and at Blackfoot when facilities were not functioning. Removals of 70 to 90 percent of C.O.D. can be achieved when facilities are maintained and cleaned.

Total nitrogen removal was significant ranging from 13 to 80 percent on facilities when properly operating. The organic nitrogen component in the total nitrogen is largely due to potato pieces and spoiled potatoes. Since most of this component will settle out, the reduction in nitrogen is expected.

Suspended solids reduction varied from 62.8 to 99.6 percent. Removal was consistently 98 percent or greater at the Idaho Falls site, and all facilities achieved at least 92 percent removal when operating properly.

Table 12

POTATO FRESH PACK STUDY

Water Use and Quality Parameters

Idaho Falls

		Temperature ^{o}C		C.O.D.			Electrical Conductivity (μmho/cm)		Nitrogen			pH	
Date	Gallons/day	Inflow	Outflow	Inflow ppm	Outflow ppm	% Removal	Inflow	Outflow	Inflow ppm	Outflow ppm	% Removal	Inflow	Outflow
5/28/74		11.5	18.5	372.4	216.0	41.9	694	636	21.34	7.62	64.3	6.80	7.10
12/11/74		9.7	4.5	3.7	0.0	100.0	518	547	4.20	4.59		7.17	7.07
1/3/75	44522	3.2	2.4	484.2	130.4	73.0	643	590	16.35	6.20	62.1	6.88	7.26
1/16/75	80969			113.6	119.2		580	608	5.18	6.11		7.23	7.12
1/28/75	72316	9.0	4.0	186.2	108.8	41.5	531	535	5.81	5.05	13.1	7.05	7.20
2/11/75	76943	10.0	12.5	898.5	89.7	90.0	682	518	24.43	4.97	79.7	6.59	7.14
2/25/75	93921	7.0	4.0	92.6	125.0		559	510	7.21	5.6	22.3	6.79	6.96
3/11/75	85671	9.0	7.0	453.5	132.3	70.8	540	543	12.11	6.72	44.5	8.81	6.87
4/3/75	101852	8.5	6.5	620.6	125.0	79.8	327	559	16.94	6.72	60.3	6.76	7.01
4/15/75	96033	10.0	10.0	470.9	101.7	78.4	542	557	12.25	5.32	56.6	6.93	7.22
4/29/75	65893	9.0	8.0	790.7	191.9	75.7	631	612	25.48	8.89	65.1	6.80	7.03
							Blackfoot						
5/28/74		16.0	19.0	8501.2	841.7	90.0	2290	1050	131.21	23.12	82.3	6.05	6.88
12/11/74		10.0	10.5	506.5	467.4	7.7	674	648	25.94	16.61	36.0	6.80	6.87
1/3/75		10.0		717.3	135.9	81.0	2120	495	76.18	6.64	91.3	6.31	7.40
1/28/75		10.0	11.0	8673.2	817.7	90.5	2080	1040	120.02	82.03	31.7	5.98	6.77
2/25/75		4.0	4.5	3024.4	551.4	81.7	1370	685	76.93	32.27	58.1	6.32	6.80
3/11/75		12.0	10.0	2926.3	514.5	82.4	1280	765	83.09	19.25	76.8	6.37	7.01
4/3/75*		8.5	9.5	2770.7	7512.1		1660	1390	66.50	82.11		6.23	6.57
4/29/75*		10.0	10.5	9140.0	8658.5	5.2	1620	1810	127.61	139.37		6.33	6.12

*All sediment collection facilities were full.

Table 12 (Cont.)

POTATO FRESH PACK STUDY

Water Use and Quality Parameters

Fort Hall

Date	Temperature °C		C.O.D.			Electrical Conductivity (μmho/cm)		Nitrogen			pH	
	Inflow	Outflow	Inflow ppm	Outflow ppm	% Removal	Inflow	Outflow	Inflow ppm	Outflow ppm	% Removal	Inflow	Outflow
1/3/75	6.5		1176.9			672		35.53			6.39	
2/11/75			713.2			629		37.42			6.73	
2/11/75	4.5	0.5	772.1	291.2	62.2	830	559	35.70	12.81	64.1	6.71	6.8
2/25/75	2.5	0.0	360.3	442.7		615	840	16.52	16.38	0.8	7.05	6.9
3/11/75	9.0	5.0	377.9	348.8	7.7	665	757	21.56	38.92		6.62	6.8
4/15/75	10.5	9.0	488.4	450.6	7.7	653	738	26.25	14.91	43.2	6.79	6.9
4/29/75	9.5	6.5	393.3	472.4		700	714	29.68	14.98	49.5	6.59	7.0
						Rigby						
5/28/74	11.5		555.9			1150		66.27			6.79	
12/11/74	8.0		726.3			745		38.31			6.66	
1/3/75	7.5		286.8			445		13.08			7.36	
1/16/75	8.0		733.7			870		50.12			6.71	
1/28/75	8.0		400.0			674		21.37			6.62	
2/11/75	8.0		1166.1			890		50.61			6.50	
2/25/75	6.5		636.8			670		24.29			6.71	
3/11/75	8.0		633.7			635		28.98			6.69	
4/3/75	8.0		2243.9			808		47.95			6.51	
4/15/75	9.0		1171.9			882		148.96			6.99	
4/29/75	9.0		953.8			1000		67.06			6.40	

Table 13

POTATO FRESH PACK STUDY

Water Quality Parameters

Idaho Falls

	Turbidity (J.T.U.)		Total Phosphate-Ulfiltered			Total Phosphate-Filtered		Potassium		Suspended Solids		
Date	Inflow	Outflow	Inflow ppm	Outflow ppm	% Removal	Inflow ppm	Outflow ppm	Inflow meq/1	Outflow meq/1	Inflow mg/1	Outflow mg/1	% Removal
5/28/74	390	120	10.31	1.925	81.3	1.102	1.328	0.75	0.82	5531.7	43.8	99.2
12/11/74	580	120	1.790	0.968	45.9	0.123	0.540	0.27	0.39	1326.8	12.8	99.0
1/3/75	650	96	6.386	1.270	80.1	0.404	0.761	0.60	0.54	3549.4	22.3	99.2
1/16/75	170	170	1.223	1.011	13.6	0.576	0.613	0.46	0.48	0073.9	79.6	
1/28/75	570	110	4.107	1.025	75.0	0.326	0.486	0.42	0.41	2371.3	50.9	97.9
2/11/75	210	110	17.395	1.238	92.9	1.51	0.655	0.58	0.46	15272.8	50.6	99.3
2/25/75	470	77	2.869	1.057	63.2	0.410	0.694	0.41	0.46	2118.1	8.0	99.6
3/11/75	570	110	5.405	1.449	73.2	0.878	0.667	0.51	0.55	2298.6	21.0	99.1
4/3/75	190	110	6.281	1.298	79.3	0.721	0.323	0.75	0.61	4157.0	17.7	99.6
4/15/75	620	130	3.956	1.147	71.0	0.815	0.540	0.48	0.51	1732.4	19.4	98.9
4/29/75	330	170	11.959	2.168	86.0	0.899	0.972	1.07	0.88	7311.7	45.9	99.4
						Blackfoot						
5/28/74	0.20	430	35.59	5.311	85.1	4.832	2.627	3.97	2.54	16336.0	435.1	97.3
12/11/74	430	510	9.153	4.967	45.7	1.479	1.386	1.07	1.04	4244.6	1577.8	62.8
1/3/75	0.17	820	138.315	2.663	98.1	2.476	0.591	3.04	0.29	87503.1	1782.3	98.0
1/28/75	0.30	14	52.803	23.697	55.1	1.192	3.684	3.68	2.64	56715.1	12431.3	78.1
2/25/75	15	640	27.180	7.489	72.4	2.023	1.691	2.62	1.68	17648.5	1996.4	88.7
3/11/75	0.11	390	44.696	3.503	92.2	2.385	0.688	2.11	2.27	23768.8	676.3	97.2
4/3/75	0.07	0.26	55.870	41.676	25.4	0.930	0.582	2.07	1.83	33352.9	27546.5	17.4
4/29/75	0.01	0.01	94.224	70.366	25.3	1.963	3.624	4.27	4.36	75565.9	39200.4	48.07

Table 13 (Cont.)

POTATO FRESH PACK STUDY

Water Quality Parameters

Fort Hall

	Turbidity (J.T.U.)		Total Phosphate-Unfiltered			Total Phosphate-Filtered		Potassium		Suspended Solids		
Date	Inflow	Outflow	Inflow ppm	Outflow ppm	% Removal	Inflow ppm	Outflow ppm	Inflow meq/1	Outflow meq/1	Inflow mg/1	Outflow mg/1	% Removal
1/3/75	490		6.797			1.781		1.32		1979.0		
2/11/75	49		9.116			4.862		1.57		1040.6		
2/11/75	470	113	10.207	4.288	58.0	5.828	2.959	2.20	0.76	781.5	11.2	98.6
2/25/75	570	110	6.462	5.617	13.1	1.147	4.197	0.99	2.02	851.0	68.3	92.0
3/11/75	550	110	5.556	3.382	39.1	1.211	2.265	0.77	1.54	3796.5	12.1	99.7
4/15/75	390	130	4.952	3.231	34.8	2.869	1.525	1.74	1.73	503.6	6.1	98.8
4/29/75	470	190	9.784	3.171	67.6	2.023	1.751	1.55	1.79	4189.7	68.8	98.4
Rigby												
5/28/74	57		19.32			4.892		4.29		6291.6		
12/11/74	28		14.653			0.628		1.23		13493.7		
1/3/75	330		6.399			0.087		0.24		4288.7		
1/16/75	110		16.730			2.114		1.54		9771.5		
1/28/75	50		15.478			0.739		0.65		16351.9		
2/11/75	120		1.902			3.593		1.87		9397.2		
2/25/75	170		3.684			0.658		1.12		7090.3		
3/11/75	280		11.717			1.510		1.15		5008.3		
4/3/75	210		10.811			2.476		1.92		433.0		
4/15/75	0.31		65.836			0.936		1.52		111020.2		
4/29/75	33		21.744			1.401		2.41		15202.1		

Differences in total suspended solids and total phosphate in the effluent from different plants is probably related to the general soils in the primary area served by the processing plant. For instance, the Blackfoot plant effluent contained significantly higher concentrations of suspended solids and phosphate than did any of the other plants. Since similar inplant washing facilities are used, the concentration in the effluent should reflect the amount of soil retained on the field run potatoes or the amount of clay and silt in the soil.

Turbidity measurements were run on all samples using a Hatch turbidimeter. The validity and meaning of turbidity measurements is questionable in view of the wide variation. Determination of turbidity of a total sample with a large proportion of rapidly settling particles is difficult as readings change rapidly with time. However, since turbidity is being considered as a water quality parameter, it was measured and is presented in this report. No correlation is expected between turbidity and total suspended solids for any site.

Summary and Conclusions

Water quality monitoring of effluent from four potato processing plants in eastern Idaho was conducted for the 1974-75 season. Removal efficiencies of settling ponds or facilities for treating these effluents were measured.

With proper operation of settling ponds, C.O.D. removals of 70 to 90 percent can be achieved. However, effluent from the treatment ponds may contain from 100 to 500 ppm C.O.D. and may require additional treatment before discharge to city sewers or the effluent require land treatment.

Suspended solids reduction of 90 percent or greater can be achieved with proper operation of ponds. Reduction levels depend on soil types on which potatoes are grown with coarser textured soils resulting in higher removal percentages.

Total nitrogen removal of from 13 to 80 percent was measured and the reduction was attributed to removal of organic particles from the plant effluent.

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