Predicting Irrigation Return Flow Rates

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DESIGNING efficient sediment ponds requires data on expected sediment concentration and particle size distribution and on stream flow rate and volume. With these data, ponds may be designed to trap given particle sizes, and the quantities of trapped and passed sediment can be computed (Bondurant et al., 1975).

In the context of Public Law 92-500, the Clean Water Act amendments of 1972, return flow from man-controlled irrigation may be classified as point source pollution and, therefore, permits may be required to discharge these return flows into rivers or streams. Little is known about return flows from most irrigation districts. Water, sediment, and chemical balances of the Twin Falls Canal Company and the Northside Canal Company areas in southern Idaho yielded information on flow and sediment concentrations and volume (Brown et al., 1974). Many of the return flow streams in this area had not been previously studied, and very little was known about their flow characteristics. Many return streams are ephemeral, flowing only in response to runoff from irrigation and regulation waste. More information is needed on these streams so that efficient and economical sediment ponds may be designed and constructed.

If a pond is designed for too small a stream, the efficiency will be low and sediment removal will not be adequate. If the pond is designed for too large a stream, the efficiency will be improved but the cost will be greater than necessary.

Hydrologic techniques for predicting stream flow rates are mainly concerned with peak flows and maximum and minimum expected annual runoff. Predictive techniques utilize double-mass plots, rating curves, and extreme value techniques (Linsley et al., 1949). These techniques are for precipitation induced runoff and not for irrigation runoff. New techniques for predicting return flow rates from irrigated areas need to be developed.

PROCEDURE

Flow rate and volume were computed from discrete values taken every 6 hr from continuous stage records for flow through two sediment retention ponds.

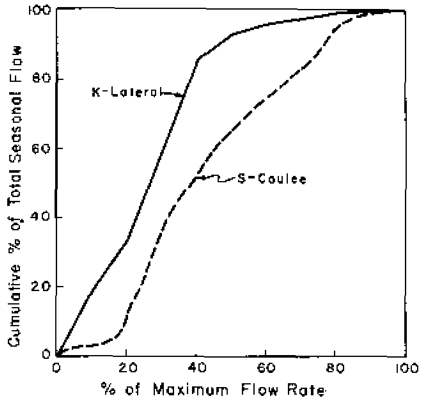

FIG. 1 Cumulative percent of total seasonal flow vs percent of maximum flow rate for K-Lateral and S-Coulee, 1975.

The flow rate at beginning and end of each 6-hr period was used to obtain an average flow rate for the 6-hr period. The flow rate range was divided into 20 flow-rate intervals and the frequency of flows in each interval was determined. The flow volume occurring in each flow-rate interval was summed and plotted as the cumulative percent of total seasonal flow vs the percent of maximum flow rate, yielding a relationship for predicting flow rates in irrigation runoff streams as shown for the K-Lateral in Fig. 1, (Table 1).

Data from other sediment study areas were then analyzed along with data from water management

TABLE 1. FLOW RATE INTERVALS, PERCENT OF MAXIMUM FLOW RATE, NUMBER OF FLOWS OCCURRING PER INTERVAL AND ACCUMULATIVE PERCENT OF TOTAL ANNUAL FLOW, K-LATERAL, 1975

Flow rate Range m^3/s	ft^3/s	% max	No. of flows*	Accumulated flow volume, percent
0.00 – 0.05	0 – 2	5	89	11.71
0.05 – 0.11	2 – 4	10	50	18.29
0.11 – 0.17	4 – 6	15	48	24.61
0.17 – 0.23	6 – 8	20	58	45.13
0.23 – 0.28	8 – 10	25	98	45.13
0.28 – 0.34	10 – 12	30	109	59.47
0.34 – 0.04	12 – 14	35	143	78.29
0.40 – 0.45	14 – 16	40	54	85.39
0.45 – 0.51	16 – 18	45	33	89.74
0.51 – 0.57	18 – 20	50	23	92.76
0.57 – 0.62	20 – 22	55	12	94.34
0.62 – 0.68	22 – 24	60	11	95.79
0.68 – 0.74	24 – 26	65	4	94.32
0.74 – 0.79	26 – 28	70	6	97.11
0.79 – 0.85	28 – 30	75	8	98.16
0.85 – 0.91	30 – 32	80	4	98.68
0.91 – 0.96	32 – 34	85	3	99.08
0.96 – 1.04	34 – 36	90	4	99.61
1.04 – 1.08	36 – 38	95	2	99.87
1.08 – 1.13	38 – 40	100	1	100.00

*Number of flows of 6-h duration having an average flow rate within the specified range.

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TABLE 2. WATER USE DATA FROM IRRIGATION RETURN FLOW STREAMS IN SOUTHERN IDAHO

Stream	Annual diversion		Qmax*		Area	
	ha-m/ha	ac-ft/ac	m^3/s	ft^3/s	ha	acres
1	1.10	3.61	0.34	12.1	1554	3840
2	2.70	8.85	2.66	94.1	14488	35800
3	1.32	4.34	0.10	3.4	40	100
4	1.32	4.34	0.94	33.1	2104	5200
5	2.70	8.85	11.45	404.5	4533	11200
6	2.45	8.05	1.68	59.2	202	500
7	4.29	14.09	0.84	29.7	656	1620
8	1.32	4.34	0.08	2.7	49	120
9	2.11	6.92	0.74	26.0	809	2000
10	2.11	6.92	0.79	28.0	809	2000
11	2.11	6.92	0.74	26.0	809	2000
12	2.11	6.92	0.99	35.0	4047	10000
13	2.11	6.92	1.13	40.0	4047	10000
14	1.83	6.00	0.04	1.5	30	75
15	1.83	6.00	0.05	1.6	30	75

*Runoff.

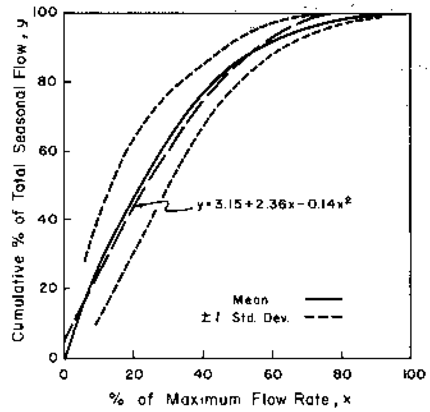

FIG. 2 Cumulative percent of total seasonal flow vs percent of maximum flow rate for 15 irrigation return flow streams.

studies in eastern Idaho (3, Table 2). Fifteen years of data from 11 return flow streams were used to develop the relationship shown in Fig. 2. This relationship is:

$$y = 3.15 + 2.36\,x - 0.14\,x^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

where

y = percent of annual flow volume

x = percent of annual maximum flow rate

Also shown is ± one standard deviation from the mean value line. This shows, for example, that at a flow rate of 50 percent of maximum 86 ± 6 percent of the total annual flow would have occurred.

DISCUSSION

The data in Fig. 2 came from irrigation districts throughout southern Idaho and represent widely varying management and efficiency. These data represent annual diversions ranging from 1.10 to 4.29 ha-m/ha (3.6 to 14.1 acre feet per acre), total contributing area from about 30 to 14,500 ha (75 to 35,300 acres), and maximum runoff rates from 0.04 to 11.5 m^3/s (1.5 to 404 ft^3/s), Table 2. Irrigation efficiencies ranged from 20 to 65 percent. The flow in irrigation return streams was both direct runoff and regulation waste water. These are difficult to separate in southern Idaho irrigation systems because runoff from most farms returns to the distribution system and becomes part of the supply for downstream diversions. The contributing area affecting the return stream is similarly difficult to determine accurately. Areas listed in Table 2 are the total for the given canal or lateral system.

The relationship of percent annual flow volume occurring at a given percent of maximum flow rate in the given stream allows a stream size to be selected for a sediment pond design. Knowing the flow rate, velocities may be computed for settling out specified particle sizes (Bondurant et al., 1975).

Maximum flow rates in return flow channels can be estimated using slope-area techniques. Velocities can be estimated using Manning's formula. Canal check structures can sometimes be used as measuring structures and maximum flow rates can be estimated from high water marks.

Many irrigated areas in western United States are converting from surface to sprinkler irrigation. Flow data from three return streams from such areas in southern Idaho were analyzed. The summation curves from these streams were more linear and also more variable than those used to develop equation [1]. One such return stream, the S-Coulee, is compared with one not affected by sprinkler conversion, the K-Lateral, in Fig. 1. Both streams are in the same irrigation district. Conversion to sprinklers may cause less runoff than surface irrigation, but may also cause more regulation waste. To maintain efficiency and prevent pump burn out, it is necessary to have the design water supply at the farm turnout at all times. When power outages occur on these sprinkler systems, all water reverts to the canal and can cause large regulation waste flows where surface systems will not be affected at all.

SUMMARY

Return flows from irrigated areas in southern Idaho have been analyzed and a relationship developed that characterizes flows by relating the cumulative percent of total seasonal flow to maximum flow rate. Since maximum flow rate can be estimated from channel characteristics and flow evidence, design flow rates sediment ponds can be selected where flow records are not available.

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