GUIDELINES FOR IMPROVED IRRIGATION PRACTICES FOR CITRUS GROWN ON THE SANDY SOILS OF THE YUMA MESA IRRIGATION DISTRICT

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EXECUTIVE SUMMARY

Basins are widely used to irrigate citrus in the coarse textured soils of the Yuma Mesa. Irrigation in the mesa district is characterized by low performance, application efficiency for basin irrigated citrus groves is typically below 40 %. The inefficient irrigation practices as well as their attendant water quality and drainage problems are sources of major environmental concern in the region. Recently, researchers have identified the lack of management guidelines as the main cause of low irrigation performance in the desert southwestern US. In 1997, the Yuma Agricultural Center initiated a project aimed at developing a management package (management tools as well as guidelines) for improved irrigation practices for basin irrigated citrus groves of the Yuma Mesa irrigation district. The project had field experimental, modeling, and outreach/educational components. The field experimental study was conducted over a period of twenty-one months (4/98 – 1/2000), the principal objective of which was to develop a database for model calibration as well as validation. The modeling components included model calibration, validation, as well as simulation experiments. The database generated using simulation experiments was used to develop management tools (performance charts and tables) for level basins as well as for basins with 0.1 % slope – typical bed slope used in the Yuma Mesa irrigation district. In addition, management guidelines that facilitate effective use of the performance charts and tables have been developed.

INTRODUCTION

Large basins are commonly used to irrigate citrus on the coarse textured soils of the Yuma Mesa. The minimal labor requirement associated with large basins, availability of large flow rates, crop type, and the exceptionally conducive topography (which requires only minimal land grading) have contributed to the wide spread use of large basins in the area.

In the desert southwestern United States in general and Yuma in particular, irrigation is the only source of water for agriculture. Irrigation, in the Yuma Mesa and Valley irrigation districts, is characterized by low performance. Simulation studies conducted by the authors indicate that typical application efficiency for basin irrigated citrus groves in the Yuma Mesa is below 40 %. Although water scarcity is not yet a problem, it is expected that the increasing demand for fresh water from the municipal and industrial sectors of the region will significantly reduce the share of fresh water supply available for irrigation. The inefficient irrigation practices as well as their attendant water quality problems are sources of major environmental concern in the region (Fedkiw, 1991; USBR, 1991). In general, efficient irrigation not only saves water but also impacts positively on the environment and enhances the physical as well as the economic well-being of the agricultural system of the region by (1) reducing the transfer of pollutants (nutrients and pesticides) from irrigated lands to the groundwater and surface-water resources of the region and (2) enhancing on-site use of resources (fertilizers and pesticides) thereby minimizing the quantity of agricultural inputs required for optimal crop yield. Improvements in irrigation performance can be realized through the use of sound irrigation systems design and management practices. In the Yuma Mesa irrigation district reconfiguring (redesigning) most existing systems entails significant capital expenditure, hence improvements in basin performance can best be realised through improved management practices. Lack of management guidelines has in fact been identified as the most important factor contributing to the low performance of basin irrigation systems in the Yuma Mesa (Sanchez and Bali, 1997).

The principal objective of this study was to develop management tools as well as guidelines for optimal basin irrigation management for the citrus groves of the Yuma Mesa irrigation district. The development of management tools and guidelines had been undertaken in four stages: (1) experimental studies (4/1998 – 1/2000), (2) model[1] calibration and validation (1/2000), (3) simulation experiments to develop management tools [i.e., performance charts and lookup tables (2/2000)], and (4) development of guidelines that facilitates effective use of the management tools (3/2000).

LITERATURE REVIEW

Basin irrigation processes are governed by universal physical laws: conservation of mass, energy, and momentum; which in turn can be expressed as a function of a number of physical quantities. The physical quantities affecting the outcomes of an irrigation event are generally of two types: (1) *system variables* - those physical quantities whose magnitude can be varied, within a relatively wide band, by the decision maker; and (2) *system parameters* - those physical quantities that measure the intrinsic physical characteristics of the system under study and hence little or no modification is practically possible. Generally, basin dimension (basin length, L, and basin width, W), unit inlet flow rate, Q_o, cutoff criteria (cutoff time, t_{co}, or cutoff length, L_{co}) are considered as system variables, while the net irrigation requirement, Z_r, hydraulic roughness coefficient, n, bed slope, S_o, and infiltration parameters, I, can be considered as system parameters. A description of surface irrigation system variables and parameters as related to their influence, methods of quantification, and their dimensions are presented in the sequel.

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[1] The model used in this study is SRFR (Strelkoff et al., 1998). SRFR is commonly used by researchers in real-life applications. SRFR has been extensively validated, has a well-developed user-interface, and has capabilities to analyze the effects of various management scenarios. In addition, SRFR has capabilities to simulate processes in any of the three primary surface irrigation systems at two levels of complexity and accuracy (zero-inertia and kinematic-wave models) in the framework of a single integrated model.

System parameters and variables

System parameters

Required amount of application (Z_r): this parameter represents the amount of water that needs to be stored in the crop root zone reservoir, during every irrigation event, in order to sustain normal crop growth and obtain satisfactory yield. The following simple expression can be used to estimate Z_r.

$$Z_r = TAW(P)D_r \tag{1}$$

where TAW = total available soil moisture (L/L. e.g. cm/m, mm/m, inch/ft) which represents the amount of water that a soil takes into storage as its water content rises from wilting coefficient to field capacity; P = represents the fraction of TAW held between field capacity and a certain management allowed deficit level, its value ranges from 0 to 1 (-); D_r = effective crop root depth (L). Z_r can be expressed in depth units (e.g. millimetre, inch) or in units of area (e.g. m^3/m, ft^3/ft). Z_r expressed in depth units can be converted to area units by multiplying it by the characteristic width of the channel. For basins the characteristic width is a unit width, e.g. 1 ft.

Among other things crop type, stage of growth, presence or absence of shallow water table and limiting soil horizons (such as hard pans) determine the effective crop root depth, D_r. Soil physical properties such as texture and structure are the factors that determine the quantity of water that can be stored per unit depth of soil. The parameter P in Eq. 1, also known as P-factor, is an index that symbolizes the fraction of the total available water that a plant can extract from its root-zone without experiencing water stress and unacceptable levels of yield loss. Crop water stress is dependent on soil moisture content, soil type (i.e., the unsaturated hydraulic conductivity of the soil), crop type and stage of growth, and atmospheric demand. Therefore, the P-factor is a function of all these factors. Given the complex interrelationship between these factors, the determination of D_r and P is not a simple matter. In addition, for a specific soil-crop-atmosphere continuum experimental determination of D_r and P requires a costly experiment that spans over the life cycle of the crop. In case of citrus, the subject crop in this study, it might take a couple of years to collect one complete data set on D_r and P. It is therefore practical and makes economic sense to use literature data from the same irrigation district or an irrigation district that is in a similar agro-climatological zone for management purposes.

The procedure for the determination of TAW on the other hand is straightforward. Standard soil moisture determination techniques can be used to determine the moisture content at field capacity and at wilting coefficient and the difference yields TAW. TAW values for different soil textural classes can also be obtained from literature sources (e.g. NRCS, 1998).

Manning's roughness coefficient (n): Manning's equation is among the most commonly used equations for estimating the friction slope, S_f, of water flow in a hydraulic conduit:

$$S_f = \frac{q^2 \left(\frac{n}{c_u} \right)^2}{y^{\frac{10}{3}}} \qquad (2)$$

where q = unit flow rate (m^3/sec/m), n = Manning's roughness coefficient ($m^{1/6}$), c_u = dimensional constant (1 $m^{1/2}$/sec), and y = depth of flow (m). Manning's *n* is used as a measure of the resistance effects that flow might encounter as it moves down a channel, which is in fact a representation, in a lumped form, of the effects of the roughness of the physical boundaries of the flow as well as irregularities caused by tillage and vegetative growth. Recommended n values can be obtained from literature sources or can be estimated based on field measurements (e.g. Strelkoff et al., 1999).

C*hannel bed slope (*S_o): bed slope is the average slope in the direction of irrigation and is an easy to measure quantity. In graded basins, bed slope represents the component of the gravitational force that acts on the surface stream in the direction of irrigation, expressed per unit weight and per unit length of the stream. Recommended slopes for surface irrigation systems depend on soil (type and profile depth) and crop combination (Hart et al., 1980).

Infiltration parameters (I): infiltration affects not only the quantity of water that enters the soil profile and its rate of entry but also the overland flow processes itself. Over the years several infiltration models have been developed. Owing to their simplicity and minimal data requirement the most commonly used infiltration equations are those based on empirical relationships, particularly those of the Kostiakov-Lewis, modified Kostiakov-Lewis equations, and their variants. The advantages, limitations as well as ways of estimating parameters of these two equations is briefly discussed in the sequel:

The Kostiakov-Lewis equation, Eq. 3, was developed by Kostiakov (1932) and has a form in which infiltration rate is expressed as a single term monotonic decreasing power function of time.

$$I(\tau) = ak\tau^{a-1} \qquad (3)$$

where I(t) = infiltration rate (m^3/m/min), k and a are Kostiakov's model parameters. Although these two parameters do not possess any specific physical meaning, the values they take however reflects, in lumped form, the effects of soil physical properties of influence on infiltration as well as antecedent soil moisture content and surface conditions.

The Kostiakov-Lewis equation is simple, the model contains only two parameters and the determination of these parameters does not require prior knowledge of soil physical properties. This might partly explain the popularity of the equation in surface irrigation applications. According to Philip (1957) the Kostiakov-Lewis equation describes both the actual and theoretical infiltration very well on small to medium time scales. It nonetheless has two major disadvantages: (1) it can not be adjusted for different field conditions known to have profound effects on infiltration, such as soil water content and (2) after long periods of application the Kostiakov-Lewis equation predicts an infiltration rate which approaches zero, which is not always correct. To correct the latter limitation a constant term has been introduced to Eq. 3. This resulted in a modified form of the original Kostiakov-Lewis equation:

$$I(\tau) = ak\tau^{a-1} + f_o \qquad (4)$$

The new term represents the final, near constant, infiltration rate that occurs after long time of application. It is generally referred to as the basic infiltration (intake) rate. Eq. 4 is more versatile than Eq. 3 (Elliott and Walker, 1982; Hartley et al., 1992).

The other empirical infiltration function of importance from convenience and practical application perspectives is the branch infiltration function proposed independently by Kostiakov (1932) and Clemmens (1981). The branch function can be stated as (Strelkoff et al., 1999):

$$Z(\tau) = k\tau^{a} + c \quad \text{for} \quad \tau \# \tau_B \qquad \text{and} \qquad Z(\tau) = c_B + b\tau \quad \text{for} \quad \tau > \tau_B \qquad \mathbf{(5)}$$

where k (in/hr^{a}), a (-), c (in), b (in/hr), and c_B (in/hr) = infiltration parameters, Z = depth of application (in), ϑ = infiltration opportunity time (min), and ϑ_B = inundation time (min). Observe that these equation avoids the slow gradual approach to the basic rate of Eq. 4, branching instead from the power-law monomial to the constant final rate, b, at the inundation time, τ_B.

Estimation of soil infiltration parameters: estimation of soil infiltration parameters are conducted in two stages:

(1) *Field measurement:* the type of data to be collected depends on the method of measurement used. The most important field measurement techniques include: ring infiltrometers, blocked furrow infiltrometer, recirculating infiltrometer, and inflow-outflow methods (Merriam et al., 1980; Walker and Skogerboe, 1987; Reddy and Clyma, 1993). With the exception of the ring infiltrometer method, all these methods are inappropriate for basin irrigation. An indirect method that is gaining popularity is the use of advance and/or water surface profile data in parameter estimation (Elliott and Walker, 1982; Katopodes et al., 1990; Walker and Busman, 1992; Bautista and Wallender, 1994; Strelkoff et al., 1999).

(2) *Parameter estimation*: data collected from point measurements, like ring infiltrometers, can be used to estimate infiltration parameters using curve fitting techniques (Merriam and Keller, 1978). More representative estimates of model intake parameters can be obtained by the inverse solution of the governing equations of surface irrigation phenomena (Elliott and Walker, 1982; Katopodes et al., 1990; Bautista and Wallender, 1994; Strelkoff et al., 1999). This approach requires data on advance and/or water surface profile.

System variables

Channel length (L): the length of a basin needs to be known in order to estimate advance and recession over the length of run of the channel and the ultimate distribution of infiltrated water and system performance. Generally, too long a basin may result in too slow advance hence leads to a decline in uniformity and efficiency of irrigation water application. On the other hand, too short a basin could be uneconomical due mainly to increased farm machinery idle runs, increased number of field supply/drainage canals as well as access roads, and reduced area of cultivation.

Unit inlet flow rate (Q_o): inlet flow rate is the discharge diverted into a unit width basin. Inflow rate is one of the key variables that influences the out come of an irrigation event, it affects the rate of advance to a significant degree and also recession to a lesser but appreciable extent. It has a significant effect on uniformity, efficiency, and adequacy of irrigation. Like length, flow rate is a variable whose value can be fixed by the irrigator at the deign phase or prior to or following the initiation of every irrigation event such that system performance is maximized. The inlet flow rate should generally be constrained within a certain range. It should not be too high as to cause scouring and should not be too small as otherwise the water will not advance to the downstream end. The unit flow rate must also exceed a certain minimum value needed for adequate spread.

Cutoff length (L_{co}): cutoff length is the length of the portion of the basin that is under water when the supply is turned off. It is one of the three decision variables, the other two being L and Q_o, over which the engineer and irrigator has a degree of control. The most important effect of cutoff time is reflected on the quantity of deep percolation loss and efficiency as well as adequacy of irrigation. In general, for any given factor level combination the selection of an appropriate value of L_{co} is made on the basis of the target application depth and acceptable level of deficit.

Basin irrigation management criteria and objectives

Equations that describe the physical laws (i.e., mass, momentum, and energy conservation) or field experiments can be used to evaluate the dependent surface-irrigation variables as functions of the system parameters and variables. There are various types of dependent irrigation variables, the most important category being the performance indices. In basin irrigation, performance indices measure how close an irrigation event (scenario) is to an ideal one (Zerihun et al. 1997). A complete picture of the performance of an irrigation event can be obtained using three performance indices: (1) application efficiency, E_a[2]; (2) water requirement efficiency, E_r[3]; and (3) distribution uniformity, D_u[4]. The objective of basin irrigation management is to maximize application efficiency, E_a; while closely satisfying the irrigation requirement ($Z_r \sim Z_{min}$, which means $E_r = 100\%$) and maintaining satisfactory levels of uniformity (D_u). Generally, basin irrigation systems management involves the selection of Q_o-L_{co} pairs for maximum E_a prior to the initiation of every irrigation event.

Economic and practical considerations limit the scope of application of field experiments in system design and management. On the other hand, mathematical models are far more flexible, less expensive, and more general than field experiments. This feature of mathematical models makes them the primary research as well as design, management, and analytical tools in many engineered systems including surface irrigation systems, such as basins.

During the last couple of decades surface irrigation hydraulic modeling has been an area of intensive research. Depending on the form of the momentum/energy equation used, surface irrigation models can broadly be classified into three major groups: the hydrodynamic, zero-inertia, and kinematic-wave models, all of which are based on the numerical solution of the continuity and a variant of the momentum/energy conservation equation (Bassett and Ftzsimons, 1976; Sakkas and Strelkofff, 1974; Strelkoff and Katopodes, 1977; Katopodes and Strelkoff, 1977; Elliott et al., 1982; Walker and Humphereys, 1983; Bautista and Wallender, 1992; Strelkoff et al., 1998). A fourth class of surface irrigation model is the volume-balance model, which is based on the analytical or numerical solution of the spatially and temporally lumped form of the continuity equation, while the dynamic equation is supplanted by gross assumptions (Lewis and Milne, 1938; Davis, 1961; Hall, 1956; Philip and Farrel, 1964; Christiansen et al., 1966; Walker and Skogerboe, 1987). Among these four classes of models, strictly speaking, only

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[2] Application efficiency is a measure the how effective an irrigation event (system) is in minimizing unavoidable losses.

[3] Water requirement efficiency is a measure the adequacy of irrigation. It is expressed as the ratio of the average depth of water stored in the crop root zone to the target depth of application.

[4] Distribution uniformity measures the evenness of irrigation water application along the length of run of a basin.

the hydrodynamic and the zero-inertia models are applicable to basin irrigation processes. The selection of a model, for any application, involves a process of reconciling the conflict between accuracy on the one hand, and cost and complexity on the other. Work to date suggests that models based on the theory of zero-inertia are the most preferred choice of modelers for both theoretical as well as practical studies. The potential for accuracy is good, because Froude numbers in surface irrigation are typically quite low, at the same time the diffusive character of the governing equations is conducive to stability of computation. Moreover, computation times are much less than that incurred with the fully dynamic model.

Although the literature in surface irrigation is voluminous, currently only a few surface irrigation models are widely used by researchers in real-life applications. SRFR (Strelkoff et al., 1998) is perhaps the most commonly used surface irrigation model. SRFR has been extensively validated, has a well developed user-interface, and has capabilities to analyze the effects of various management scenarios. In addition, SRFR has capabilities to simulate processes in any of the primary surface irrigation systems at two levels of complexity and accuracy (the zero-inertia and the kinematic-wave models) in the framework of a single integrated model.

METHODOLOGY

The development of a management package for the basin irrigated citrus groves of the Yuma Mesa area had been undertaken in four stages: (1) experimental studies (4/1998 – 1/2000), (2) model[5] calibration and validation (1/2000), (3) simulation experiment and development of management tools [i.e., performance charts and lookup tables (2/2000)], and (4) development of management guidelines that facilitate effective use of the management tools (3/2000). The primary objective of the field experimental study was to develop a complete database that would be used in the modeling studies (i.e., model calibration and

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[5] That is SRFR

validation). A complete data set for calibration and validation of a basin irrigation model includes data on: basin length, L; unit inlet flow rate, Q_o; cutoff distance, L_{co}; Manning's roughness coefficient, n; infiltration parameters; target application depth, Z_r; and advance and recession trajectories

Field experimentation

Description of the experimental site and procedure: the field experimental study had been undertaken in two phases over a period of 22 months on a 13 acre facility at the University of Arizona Yuma Mesa experimental farm. The layout of the experimental basins is depicted in Figure 1. The experimental farm has eight basins, each 583 ft long and 110 ft wide. Each basin is planted with lemon trees at a spacing of 23.5 ft × 23.5 ft. The soils of the experimental site is superstition sand, in which the sand fraction accounts for over 90 percent of the textural class. The soil of the Yuma Mesa irrigation district is relatively uniform. The experimental farm obtains its supply from canal 89w20 (Figure 1). Canal 89w20 itself obtains its water supply from the Colorado river at the Imperial dam.

The first phase of the experimental study lasted for 17 months (4/1998 - 8/1999). During each irrigation event, data on Q_o, L_{co}, advance, and recession had been collected on eight experimental basins, i.e., basins A through H (Figure 1). Phase II spanned over a period of five months (9/1999 – 1/2000), during which five irrigation events had taken place. In addition to the types of data items collected in phase I, flow depths have been measured at regular spatial and temporal intervals during phase II. Only four basins (basins A, C, E, and G) had been used in the second phase of the experimental study. Changes in soil moisture content had been monitored using neutron probe measurements throughout the experimental period.

Determination of system variables: all system variables (Q_o, L_{co}, L, and basin width, W) were determined based on direct field measurements (Table 1). L and W represent known physical dimensions of the basins. The flow rate in the field supply channel had been measured using a flume built into the head end of the field supply channel. Throughout the duration of the experimental study the entire discharge in the field supply channel had been used to irrigate a single basin. t_{co} is monitored using a stop watch and L_{co} is known.

Determination of system parameters: among the system parameters, S_o and Z_r are relatively easy to quantify. In the Yuma Mesa irrigation district, bed slope of basins range from zero (level bed) to a couple of inches drop over one-hundred feet distance. Bed slopes were determined based on levelling runs conducted using standard surveyor's level along the centre line of each experimental basin prior to the initiation of every irrigation event. The target amount of application, Z_r, was calculated using equation 1 as a function of the total available water holding capacity of the soil, TAW; the P-factor; and crop root depth, D_r. A TAW value given in the NRCS handbook (1998) for the superstition sand of the Yuma Mesa area was used in this study. According to the NRCS irrigation handbook, the TAW for the superstition sand of the Yuma Mesa area is 0.9 in/ft. Typical D_r for citrus crop is about 3.28 ft (1 m) and the optimal P value for citrus crop in the Yuma mesa area has been found out to be 0.5 (Sanchez et al., 1998). Substituting these values in equation 1 resulted in the target depth of application used in this study, which is 1.476 in.

While the determination of the system variables and some of the system parameters such as S_o and Z_r is straightforward, the estimation of such parameters as hydraulic resistance, n, and infiltration is not. There are a variety of methods that can be used to estimate infiltration and roughness parameters for basin irrigation modeling. These include approaches that require input data on advance, recession, and/or flow depth (Katopodes et al., 1990; Strelkoff et al., 1999). In this study the method of Strelkoff et al. (1999) had been used. The reasons for the adoption of Strelkoff et al.'s approach are: (1) simplicity, (2) their method has already been used in a practical setting in Egypt and satisfactory results have been reported (Strelkoff et al., 1999), and (3) there already exists an operational parameter estimation model (i.e., EVALUE, Strelkoff et al., 1999), that has the aforementioned advantageous features.

EVALUE requires input data on basin bed profile, advance, flow depth measured at regular temporal and spatial intervals, and inlet flow rate. The following is an outline of the field measurement procedure used in the second phase of the experimental study:

1. In order to induce a uniform distribution of flow rate over the width of the basin a barrier that runs across the direction of irrigation had been constructed at the inlet end of the experimental basins.
2. The field had been staked out at regular intervals of 58 ft in the longitudinal direction, which resulted in eleven measurement stations. Staff gauges[6] had been setup at each of the eleven measuring stations (Figure 1).
3. The elevation of the measurement stations had been determined using standard surveyor's level prior to every irrigation event and the staff gauges had been set such that their zero mark lies at the ground surface. Figure 2, depicts longitudinal profile for four experimental basins.
4. Flow rate into the basins had been monitored regularly using a flume located at the head end of the field supply channel.
5. Advance and recession had been recorded at each of the measurement stations. Stopwatches were used to determine advance and recession times.
6. During advance water surface depths had been recorded whenever the advancing front arrives at a new measurement station. Once advance is completed, flow depth had been measured at each station every 3 minutes. Notice that flow depths had been measured at the same times at all the measurement stations. This resulted in a data set that shows the temporal growth of the water surface profile.
7. Soil moisture content had been monitored using neutron probe measurements taken at four points along the centerline of the basins. The neutron probe readings were taken one day before and one day after each irrigation event.

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[6] The staff gauges were used to measure flow depths at each measuring station.

A similar field measurement procedure had been used in the first phase of the experimental study, except that in phase I flow depths were not measured.

Modeling

Model calibration: model calibration involves estimation of infiltration and roughness parameters. Data from phase II of the experimental study had been used in estimating infiltration and roughness parameters using EVALUE. The type of infiltration function implemented in EVALUE is the branch infiltration function. The parameters of the branch infiltration function are: k, a, b, c and c_B (Eq. 5). EVALUE employs a simple inverse solution technique in which the infiltration parameters are estimated by matching the observed temporal growth of the volume of infiltration calculated using a volume balance approach with the growth of the volume of infiltration calculated on the basis of measured opportunity times. EVALUE uses a simple approach for the determination of Manning's roughness parameter as well. For level basins or basins with flat slopes, common in the Yuma Mesa area, EVALUE assumes that water velocities are small; hence water surface slopes, My/Mx, can be equated with friction slopes, S_f. EVALUE calculates the mean water surface slope associated with any given time step from water depths measured at regular intervals along the length of the basin. Since the water surface slope is assumed to be equal to S_f, and Q_o, A, and R are known; n can be determined using equation 2 after rearranging terms.

EVALUE (Strelkoff et al., 1999) was used to generate the initial estimates for the infiltration parameters and Manning's roughness coefficient for a total of twenty data sets (four basins and five irrigation events, Phase II of the experimental study). The initial estimates of the parameters have then been tuned up such that advance predicted by SRFR matches reasonably well with field observed advance. The resulting infiltration and roughness parameters for each of the experimental basins and irrigation combination are given in Tables 2a and 2b. For each experimental basin (basins A, C, E, and G, Tables 2a and 2b), temporally averaged infiltration and roughness parameters have been calculated by taking the arithmetic mean of the parameter estimates of all the five irrigation events. This parameters set has been used in model validation (Figure 3- 30). In addition, five sets of spatially averaged infiltration and roughness parameters, each corresponding to an irrigation event, have been calculated based on the parameter estimates for each basin (Tables 2a and 2b). Significant differences can be noted between the spatially averaged parameter estimates for the first irrigation event and the parameter estimates for the other four irrigation events (Tables 2a and 2b). Therefore, only the parameters set from the last four irrigations have been used in calculating a spatially and temporally averaged infiltration and roughness parameters set (Tables 2a and 2b). The significant difference in the parameter estimates of the first irrigation and the other four irrigations could be attributed to problems encountered in implementing the field measurement procedure and inexperience of the irrigation crew in the first irrigation event. In subsequent irrigations, however, data collection went smoothly.

Model validation: the capability of the SRFR model to simulate basin irrigation processes[7] with an acceptable level of accuracy had been evaluated by comparing its output with field data. Twenty-eight independent data sets randomly selected from the data pool developed in the first phase of the experimental study had been used in the model verification exercise. The temporally averaged infiltration and roughness parameters have been used in this application (Table 2b). Comparison of model predicted and field observed advance for the 28 data sets is shown in Figures 3-30. The mean error in the advance predicted by SRFR is ∀2.6 minute at the 5% confidence level and the average of the maximum residuals in the model predicted advance is ∀6.9 minute at the 5% confidence level. The results of model verification clearly demonstrate that SRFR is capable of simulating the basin irrigation processes in the Yuma Mesa irrigation district with acceptable accuracy. In addition, it shows that the spatially and temporally averaged parameter estimates resulted in a consistent and reasonably accurate estimate of advance.

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[7] These particularly refer to basins used to irrigate lemon on the coarse textured soils of the Yuma mesa.

Simulation experiments

In the Yuma Mesa irrigation district reconfiguring (redesigning) most existing systems entails significant capital expenditure, hence improvements in basin performance can best be realised through improved management practices. Management tools (performance charts and lookup tables) are central to the management package developed for the Yuma Mesa irrigation district. A prime consideration in developing the management tools had been that they should be simple enough to be understood and used by growers without the aid of trained irrigation technicians or experts. This practical constraint requires a direct and simplified graphical and tabular presentation of the relationships between performance indicators and system variables. In the management tools developed in this study, irrigation performance indicators are expressed as direct functions of the two management variables: unit inlet flow rate, Q_o, and cut off distance, L_{co}. Q_o was calculated as the quotient of the total inlet flow rate delivered into a basin and basin width and the system parameters and variables have been set at typical values given in Table 1.

Selection of typical values for system variables and parameters: in the Yuma Mesa irrigation district a standard irrigation block[8] constitutes a tract of land that is 0.5 mile wide and about 660 ft long. After making allowances for canals and access roads, the average length of a basin in the mesa area is about 600 ft. Therefore, 600 ft has been taken as the typical length of a basin throughout the simulation experiment. Spatially and temporally averaged infiltration and roughness parameters have been used in the simulation experiment (Table 2b). This implies that temporal and spatial variation in infiltration and roughness parameters are insignificant. The fact that (1) soil is relatively uniform over the mesa area, (2) more or less similar cultural practices and land grading methods/tools are used in the area, (3) measured advance times for the same basins in different irrigation events did not show significant variations (Figures 3-30), and (4) the management tools are developed for a specific type of

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[8] One that receives its supply from the same field supply channel.

crop (citrus), make the forgoing assumption plausible. Throughout the simulation experiment the target depth of application have been maintained at 1.476 in. Although the crop root depth generally varies between 0-3.28 ft (1 m) during the life cycle of the crop, given the simplification that have already been made, the development of management tools for different target application depths is unwarranted.

Both level and graded basins are commonly used to irrigate citrus crops in the Yuma Mesa irrigation district. Apparently, the main reason for the use of graded basins is the anticipation by growers that some gradient in the direction of irrigation might improve uniformity and efficiency. The relationships between performance indices and bed slope for three inlet flow rate levels are shown in Figure 31. The results summarized in Figure 31 clearly demonstrate that level basins perform better than graded basins for the range of flow rates commonly used in the mesa area. Therefore, the authors recommend the gradual replacement of graded basins by level basins. For management applications in the interim period, however, two sets of performance charts and lookup tables, one for level basin and another for a basin with a bed slope of 0.1 %, have been developed (Figures 32-37). 0.1 % is typical bed slope used in the Yuma Mesa area.

Simulation experiments had been performed to generate the database required to develop the management tools. Systematic variation of unit inlet flow rate and cutoff distance combinations within the range indicated in Tables 3a-3k and 4a-4k results in a database summarized in a series of graphs and tables (Figures 32-37 and Tables 3 and 4). Figure 32 presents the application efficiency contours expressed as a function of unit inlet flow rate and cutoff distance for level basins. Figure 33 is application efficiency chart, for level basins, expressed as a function of cutoff time and unit inlet flow. In management decision-making applications, Figures 32 and 33 have to be used in conjunction with Tables 3 and 5 (See management guidelines section). Figures 34, 35, and 36 present charts for application efficiency, water requirement efficiency, and low quarter distribution uniformity all expressed as a function of unit inlet flow rate and cut off distance, respectively. Figure 37 is application efficiency chart, in which E_a is expressed as a function unit inlet flow rate and cutoff time. Figures 34-37 are all developed for a basin with 0.1 % slope. Figures 34-37 have to be used along with Tables 4 and 5 in management decision-making applications.

Notice that all irrigation scenarios summarized in Figures 32 and 33 and Table 3a-3k (i.e., level basin option) replenish the root zone fully, which means the corresponding water requirement efficiency is 100 %. On the other hand, such a stringent requirement is impossible to satisfy with graded basins without causing a significant decline in application efficiency. A good compromise is to accept a degree of under-irrigation (i.e., E_r < 100 %) so that acceptably high levels of application efficiency can be realized. The adoption of such a compromise requires the presentation of water requirement efficiency and distribution uniformity, for a basin with 0.1 % slope, in separate charts (Figures 35 and 36).

In general, the lookup tables are more comprehensive than the charts in terms of the type of information they provide. They contain information on application efficiency, low quarter distribution uniformity, water requirement efficiency, maximum, average, as well as applied depths, and maximum surface depth. The performance charts have to be used in conjunction with the lookup tables in making management decisions. A guideline on how to make effective use of the management tools is outlined in the next section.

Management guidelines

The following procedure is proposed to facilitate effective use of the management tools (i.e., performance curves and lookup tables) in making management decisions. In order to avoid injudicious use of the management tools, it is important to recognize the assumptions based on which the management tools are developed. Therefore, pertinent assumptions are stated first:

1. It has been assumed that the basins are graded to a uniform gentle slope in the direction of irrigation. This implies that the presence of micro-topographic deviations from the theoretically assumed surfaces, which are common in real-life situations, might introduce some error in the predictions of the management charts and tables. So periodic land levelling is important to minimize the prediction error associated with micro-topographic variations.
2. It is important to recognize that the management tools had been developed based on spatially and temporally averaged infiltration and roughness parameters. Discrepancies between actual infiltration and roughness parameters and the assumed spatial and temporal average values will introduce some error to the estimated performance indices.
3. The field procedure commonly used to construct basins in the Yuma Mesa area results in the formation of two furrows that run along the edges of each basin. During irrigation some of the water diverted into a basin gets trapped in the furrows and becomes unavailable for plant use. The management tools do not take into account the volume of water lost in the furrows, hence the presence of side-furrows introduces an error in the estimated performance of basins.
4. It is assumed that the flumes used to measure flow rates into a field supply channel and the individual basins is well maintained and regularly calibrated. Deviation from these assumptions might contribute to flow measurement errors that are not accounted for in the management tools.

A procedure for level basin management

1. Determine the duration for which a specified amount of inlet flow rate can be withdrawn from the main canal, t_i. t_i is determined based on agreements between individual growers and irrigation district personnel.
2. Set a minimum target application efficiency, E_a. A minimum E_a value of 70 % is realistic in most situations.

3. Determine the feasible range of inlet flow rate, i.e, the maximum (Q_{max}) and minimum inlet flow rates (Q_{min}).

i. The maximum flow rate that can be withdrawn from the main canal for a specified duration can be taken as Q_{max}.

ii. The minimum inlet flow rate can be determined using the procedure outlined next.

- Determine the fraction of t_i that is actually used to irrigate the basins, t_{ai}:

$$t_{ai} = \frac{t_i}{\mathbf{1} + SF} \qquad (\mathbf{6})$$

where SF = a safety factor that represents a fraction of t_i that is used as downtime; i.e., time used to open and close gates and perform other unforeseen operations. Experience in the YAC experimental farm indicates that SF might range from 0.1-0.15 of t_{ai}. Notice that this is just a guideline, depending on their experience individual growers can use values of SF other than those given here.

- Determine the maximum possible cutoff time for the individual basins:

$$t_{co} = \frac{t_{ai}}{N_b} \qquad (7)$$

where N_b = number of basins in a block that are to be irrigated in a single irrigation session.

iii. In order to determine the minimum inlet flow rate, mark the cutoff time axis in Figure 38 at the t_{co} value calculated in step ii and then draw a horizontal line through it. At the intersection of the horizontal line with the minimum E_a contour (see step 2) drop a vertical line. The

Q_o value at the intersection of the vertical line and the x-axis is Q_{min}.

4. Identify the maximum application efficiency contour that is within a physically realistic range (Figure 32). It is advisable to avoid operating along the very edge of the E_a chart. A maximum feasible E_a value of about 90 % is realistic in most situations.
5. Steps 1-4 lead to the delineation of a region in the E_a graph from which a near "optimum" irrigation scenario can be identified (Figure 38).

6. The “optimal” region is a parallelogram. A few efficiency contours pass through the “optimal” region. Along a contour E_a is constant and only L_{co} and Q_o combinations vary. For any given inlet flow rate E_a declines with an increase in L_{co} and vice-versa. The selection of an irrigation scenario (L_{co} and Q_o combinations) within the “optimal” region has to done based on practical considerations, such as:
   - Reliability of the maximum available flow rate.
   - The maximum flow depth associated with the selected irrigation scenario compared with the maximum ridge height (Table 3a-3k).
   - The low quarter distribution uniformity associated with the chosen irrigation scenario (Table 3a-3k).
7. L_{co} and t_{co} determined in step 6 have to be modified to take into account deviations of actual field conditions (such as micro-topography, infiltration, roughness, the presence of furrows running along the edges of the basins, etc.) from the assumed average field conditions. Field tests conducted in the YAC experimental farm at the Yuma Mesa had shown that in order to take into account the deviation of actual surface roughness, infiltration, and micro-topography from assumed average field conditions a correction of about 20 % needs to be added to the L_{co} calculated in step 6. This correction takes into account inaccuracies in flow rate measurement as well. In addition, if there are furrows running along the edges of the basin a correction of about 20 % needs to be added to the adjusted L_{co}.
8. Check if the cutoff time associated with the revised L_{co} is less than the maximum t_{co} calculated in step 3. Assuming a power-law advance function calculate the advance time to L_{co} (which is also the revised cutoff time) as follows:

$$t_a(L_{co}) = t_{co} = \alpha L_{co}^{\gamma} \tag{8}$$

where $t_a(L_{co})$ = advance time to L_{co} (min), ∀ (min/$L^{($) and ((-) = coefficient and exponent of the assumed power-law advance function. Values of ∀ and (can be obtained from Table 5 as a function inlet flow rate. If the t_{co} calculated using equation 8 is greater than the t_{co} calculated in step 3, the management computation needs to be revised. Options are: (1) use a higher flow rate within the “optimal” set (Figure 39); if this does not work then (1) decrease the number of basins irrigated in a session or (2) if possible increase the maximum available inlet flow rate.

An example problem for level basin management

Given: A farmer uses 20 basins, each 600 ft H 110 ft, to irrigate his citrus grove in the Yuma Mesa area. The maximum flow rate that can be withdrawn from the main canal are Q_{max} = 16 cfs. The farmer is allowed to withdraw water from the main canal for a period of 6 hrs at any one irrigation session. All the 20 basins are to be irrigated in a single session. Each basin has two furrows that run along the edges of the basin. Downtime can be taken as 15% of the actual time used to irrigate the basins.

Required: to determine the inlet flow rate and cutoff distance combination that yields optimal performance.

Solution

1. From the given data, t_i = 6 hrs or 360 min.
2. Let the minimum acceptable E_a be 70 %.
3. Determine the feasible range of inlet flow rate
   - i. Q_{max} = 16 cfs
   - ii. Determine Q_{min}
     - calculate t_{ai}:

$$t_{ai} = \frac{t_i}{SF} = \frac{\mathbf{360}}{\mathbf{1.15}} = \mathbf{313}\ min$$

- calculate t_{co}

$$t_{co} = \frac{t_{ai}}{N_b} = \frac{313}{20} = 15.65\,min \approx 16\,min$$

iii. From Figure 38, the unit inlet flow rate value that corresponds to a t_{co} of 16 min is 0.12 cfs/ft. This corresponds to a Q_{min} of 13.2 cfs.

3. Let the maximum attainable E_a = 88 %.
4. The “optimal” set is shown in Figure 39 (region A-B-C-D).
5. Within the “optimal” set the maximum E_a can be maintained if one moves from point A to point B along the 88 % contour, Figure 39. From Table 4, Du_{lq} is 0.98 for both points A and B. What this means is that points A and B basically offer the same level of uniformity. In addition, Y_{max} is 6.4 in and 7.3 in for points A and B, respectively (Table 4). The difference in Y_{max} is not significant enough as to favour one point over the other. All the points, between A and B, along the 88 % contour (Figure 39) are equally valid management options. Selection of any given combination of Q_o and L_{co} could be done on the basis of personal preferences and other local considerations. If for instance point A is selected, the corresponding L_{co} is 248 ft.

7. Adjustments to L_{co}

   - *To take into account the deviations of field conditions from the assumed average conditions add 20% correction to L_{co}.*

     $$L_{co1} = \mathbf{248} + \mathbf{248(0.2)} = \mathbf{298}\ ft$$

   - *To take into account the volume of water trapped in the furrows at the edges of the basins add about 20 % correction to the adjusted L_{co}.*

     $$L_{co} = \mathbf{298} + \mathbf{298(0.2)} = \mathbf{358}\ ft$$

8. Determine the cutoff time associated with L_{co} = 358 ft:

   - From Table 5, for Q_o = 0.12, $\forall$ = 0.0119 min/ft$^{(}$ and (= 1.2472. t_{co} can therefore be calculated as follows:

     $$t_{co} = \mathbf{0.0119(358)}^{1.2472} = \mathbf{18.322}\,min \approx \mathbf{18}\,min$$

   - The revised t_{co} is higher than the t_{co} calculated in step 2. Therefore, revise the management scenario.

     Increase inlet flow rate to say 0.14 cfs/ft. From Figure 39, for E_a = 88 % the corresponding L_{co} is 232 ft. The adjusted L_{co} would be 334 ft. The revised t_{co} that *corresponds to an L_{co} of 334 ft and a Q_o of 0.14 cfs/ft is 15 min. Since the revised cutoff time is less than the cutoff time calculated in step 2, this is a feasible management scenario.*

9. In summary, each basin is to be irrigated with an inlet flow rate of 15.4 cfs for about 15 minutes. The corresponding L_{co} = 334 ft. With this management scenario, the entire farm will be irrigated in 6 hrs. The resulting performance is: E_a = 88 % , E_r = 100 %, and Du_{lq} = 0.99.

A procedure for graded basin management

The procedure for the management of graded basins would be more or less the same as the procedure outlined above for level basins. However, unlike the management tools developed for level basins, deficit irrigation is permissible for the management tools developed for graded basins. Therefore, before selecting an irrigation scenario the extent of under irrigation as well as level of uniformity associated with it have to be determined using Figures 36 and 37.

OUTREACH AND EDUCATION

The outreach component of this project included the construction and maintenance of a field experiment-demonstration facility, organization of field day events, and setting up an irrigation and water quality web site. Construction of the experimental facility was completed in 1998. Over the last two years the facility had been used to conduct field experiments. It has also been used for irrigation management demonstrations to local growers. Field day presentations and demonstrations had been organized for growers throughout the project period and we plan on organizing another field day presentation on May 16, 2000. In the framework of this project an irrigation and water quality web site has been established. The web site is still evolving and hopefully in the future it might serve as an important resource for stakeholders as far as water management and water quality issues of the area are concerned.

SUMMARY

A management package (tools and guidelines) have been developed for the basin irrigated citrus groves of the Yuma Mesa. Field experiment had been performed over a period of twenty-one months. The experimental study had been undertaken in two phases. The first phase of the experimental study lasted for 17 months (4/1998 - 8/1999). Data on Q_o, L_{co}, advance, and recession had been collected on eight experimental basins. Phase II spanned over a period of five months (9/1999 – 1/2000), during which five irrigation events had taken place. In addition to the types of data items collected in phase I, during the second phase of the experiment, flow depths have been measured at regular spatial and temporal intervals. Four instrumented basins have been used in the second phase of the experimental study. Changes in soil moisture content had been monitored using neutron probe measurements throughout the experimental period.

Twenty data sets from the second phase of the experimental study had been used in model calibration. Twenty-eight randomly selected data sets from the database developed in the first phase of the experimental study had been used to validate SRFR – i.e., the simulation model used in the study reported herein. The validation results indicate that SRFR is capable of simulating the surface irrigation process with acceptable levels of accuracy. The mean error in the advance time predicted by SRFR is ∀2.57 min at the 5 % confidence level.

Simulation experiments had been performed using the SRFR model and the results are summarized in the form of management charts and tables, collectively referred to as management tools. The management tools have been tested in the experimental basins of the University of Arizona, Yuma Mesa experimental farm. Limitations of the tools have been identified and ways of taking in to account the limitations of the management tools have been proposed. Management guidelines that facilitate effective use of the management tools have been developed.

RECOMMENDATION

1. An extensive test of the management tools in real-life settings (i.e., in selected growers fields) is needed. Such tests would help gather feed back information, which will be useful to refine and improve the management package and enhance its practical utility.
2. Once the management package is tested in growers' fields and the necessary improvements are incorporated, it can be implemented in real-life irrigation management practices. Implementation needs to be preceded by training and field demonstration. In addition, a manual of practices that describes the management package proposed herein must be developed and distributed among local growers. The manual of practices must be prepared in a format and language that is simple enough to be understood and used by growers in their day-to-day management decisions without the aid of trained technicians and experts.
3. Impact monitoring and evaluation needs to be an important component of the implementation phase.
4. The principal problems of irrigation system management could be summed up using the following questions: (1) how much to irrigate? (2) when to irrigate ? (3) at what rate to irrigate? and (4) for how long to irrigate? Questions 3 and 4 can be answered using the management package developed in this project. However, the first two questions are the domains of irrigation scheduling and cannot be addressed by the management package under discussion. In order for the management package developed herein to have maximum impact, it needs to be complemented by an irrigation scheduling decision support system. Future research must therefore address this aspect of irrigation management. The development of a decision support system that integrates an irrigation scheduling model, like AZSCHED, with the management packages developed herein in a GIS environment could be the way forward.

5. Problems associated with the presence of furrows that run along the edges of the basins have been discussed earlier. This problem can be remedied in two ways (1) during the land preparation phase the basins can be prepared without the furrows or (2) the volume of water trapped in the furrows has to be estimated and allowances have to be made for it in estimating the volume of water that would be diverted into the basins.
6. Effective management of irrigation systems requires satisfactory control over discharge delivered to the field supply channel and to the individual basins. Therefore, growers must place emphasise on installing water measuring devices that have satisfactory levels of accuracy. Periodic calibration and recalibration of water measuring devices must be part of a sound irrigation management practice.
7. Periodic land levelling would help maintain high levels of irrigation performance. It should therefore be part of an effective irrigation management strategy.
8. Establishing a regular publication, both electronic and hard-copy versions, that addresses current and potential water management and water quality issues of the Yuma area is necessary. This would promote water resources and environmental stewardship and awareness among local growers, thereby facilitating and enhancing collaboration[9] between researchers and extension workers on one hand and stakeholders on the other.
9. The management tools developed in this study are based on assumed average field conditions (spatially and temporally averaged infiltration and roughness parameters and average bed slope). Although soils in the Yuma Mesa area are relatively uniform and laser levelling is common, deviations of actual field conditions from assumed spatial and temporal averages would naturally exist. Meaning, the performance predictions of the management tools would invariable contain a degree of error. Therefore, a sound management strategy must involve the use of the management packages proposed herein in conjunction with good judgement and experience. In fact, it is crucially important for

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[9] Collaboration promotes and facilitates the adoption and implementation of research results, such as the basin irrigation management package proposed herein, by local growers.

growers to recognize that the management packages proposed herein are meant to complement and reinforce experience and good judgement instead of replacing them.

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Table 5. Power-law advance parameters

Table 1. Input variables and parameters used in the simulation experiment

Variables and parameters	Unit	Level basin
Length	ft	600
Width	ft	100
Depth of application	in	1.476
c^1	in	0.197
k^1	in/hr^a	0.432
a^1	-	0.5
b^1	in/hr	0.075
Manning's n	-	0.08
Bed slope	ft/ft	0.000/0.001

[1] Exponent and coefficients of the branch infiltration function (Eq. 5). Inlet flow rate and cutoff distance combinations used in the simulation experiments are given in Tables 3a-3k and Tables 4a-4k.

Table 2a. Estimates of infiltration and roughness parameters

Basin	Irrigation I, Phase II, 10/13/99				
	Infiltration and roughness parameters				
	c (mm/hr)	k (mm/hr^{a})	a (-)	b (mm/hr)	n (-)
A	0.46	37.129	25.555	4.199	0.069
C	0.50	39.600	25.500	5.430	0.031
E	0.55	30.000	14.500	1.775	0.054
G	0.50	50.050	26.600	4.935	0.029
Spatial average	0.50	39.1954	23.039	4.085	0.046
Basin	Irrigation II, Phase II, 11/09/99				
	Infiltration and roughness parameters				
	a (-)	k (mm/hr^{a})	c (mm/hr)	b (mm/hr)	n (-)
A	0.50	9.50	2.24	1.40	0.139
C	0.51	11.30	7.20	1.30	0.064
E	0.50	12.80	5.80	0.95	0.070
G	0.49	10.30	4.80	3.95	0.066
Spatial average	0.50	10.975	5.01	1.900	0.085
Basin	Irrigation III, Phase II, / /				
	Infiltration and roughness parameters				
	a (-)	k (mm/hr^{a})	c (mm/hr)	b (mm/hr)	n (-)
A	0.50	12.0	6.2	1.53	0.077
C	0.45	11.0	5.1	1.90	0.060
E	0.50	12.4	4.2	1.61	0.100
G	0.50	9.3	5.5	2.30	0.075
Spatial average	0.49	11.175	5.25	1.835	0.078
Basin	Irrigation IV, Phase II, 12 /22/99				
	Infiltration and roughness parameters				
	a (-)	k (mm/hr^{a})	c (mm/hr)	b (mm/hr)	n (-)
A	0.50	13.5	1.75	2.10	0.080
C	0.50	12.0	1.50	1.80	0.090
E	0.50	12.2	1.45	1.76	0.100
G	0.50	10.1	1.20	1.85	0.080
Spatial average	0.50	11.95	1.475	1.878	0.088

Table 2b. Estimates of infiltration and roughness parameters

Basin	Irrigation V, Phase II, 1 / /00				
	Infiltration and roughness parameters				
	a (-)	k (mm/hr^a)	c (mm/hr)	b (mm/hr)	n (-)
A	0.50	6.000	3.90	0.755	0.100
C	0.50	6.525	3.75	1.358	0.060
E	0.50	17.976	20.40	4.230	0.050
G	0.50	8.700	5.20	1.610	0.070
	0.50	9.800	8.3125	1.988	0.07
Basin	Temporally averaged infiltration and roughness parameters				
	a (-)	k (mm/hr^a)	c (mm/hr)	b (mm/hr)	n (-)
A	0.50	10.25	3.52	1.45	0.099
C	0.49	10.21	4.39	1.59	0.069
E	0.50	13.84	13.84	2.13	0.080
G	0.50	09.6	9.6	2.43	0.073

Spatially and temporally averaged infiltration and roughness parameters				
c (mm/hr)	k (mm/hr^a)	a (-)	b (mm/hr)	n (-)
5.0	10.975	0.496	1.90	0.08

Table 3a. Lookup table for level basins

Q_o	**L_{co}**	**t_{co}**	**E_a**	**Du_{lq}**	**E_r**	**D_p**	**D_{av}**	**D_{min}**	**D_{app}**	**Y_{max}**
cfs/ft	**ft**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.04	**312.5**	30.40	99.5	0.96	100	0.0	1.4	1.40	1.51	3.8
	337.5	33.50	91.6	0.97	100	0.1	1.6	1.50	1.65	3.8
	362.5	36.30	84.6	0.97	100	0.2	1.7	1.60	1.68	3.8
	387.5	39.58	77.6	0.97	100	0.4	1.8	1.75	1.85	3.8
	412.5	42.90	71.6	0.98	100	0.5	2.0	2.00	2.05	3.8
	437.5	46.20	66.5	0.98	100	0.7	2.1	2.10	2.25	3.8
	462.5	49.63	61.9	0.98	100	0.9	2.3	2.30	2.42	3.8
	487.5	53.10	57.9	0.98	100	1.0	2.4	2.50	2.51	3.8
	512.5	56.11	54.7	0.98	100	1.2	2.6	2.60	2.72	3.8
	537.5	59.68	51.5	0.98	100	1.3	2.8	2.80	2.90	3.8
	562.5	63.50	48.5	0.98	100	1.5	2.9	3.00	3.15	3.8
	587.5	66.88	45.8	0.98	100	1.7	3.1	3.20	3.23	3.8
	600.0	68.48	44.9	0.98	100	1.8	3.2	3.20	3.25	3.8
0.05	**312.5**	26.40	93.1	0.97	100	0.1	1.5	1.5	1.62	4.2
	337.5	29.13	84.4	0.97	100	0.2	1.7	1.6	1.78	4.2
	362.5	31.51	78.0	0.98	100	0.4	1.8	1.8	1.85	4.2
	387.5	34.33	71.6	0.98	100	0.5	2.0	2.0	2.12	4.2
	412.5	37.25	66.0	0.98	100	0.7	2.2	2.1	2.28	4.2
	437.5	40.11	61.3	0.98	100	0.9	2.4	2.3	2.45	4.2
	462.5	43.08	57.1	0.98	100	1.1	2.5	2.5	2.61	4.2
	487.5	46.06	53.4	0.98	100	1.2	2.7	2.7	2.80	4.2
	512.5	48.68	50.5	0.98	100	1.4	2.9	2.8	2.95	4.2
	537.5	51.78	47.5	0.99	100	1.6	3.1	3.0	3.14	4.2
	562.5	54.91	44.8	0.99	100	1.8	3.2	3.2	3.25	4.2
	587.5	58.00	42.4	0.99	100	2.0	3.4	3.4	3.50	4.2
	600.0	59.38	41.4	0.99	100	2.0	3.5	3.5	3.60	4.2

Table 3b. Lookup table for level basins

Q_o	**L_{co}**	**t_{co}**	**E_a**	**Du_{lq}**	**E_r**	**D_p**	**D_{av}**	**D_{min}**	**D_{app}**	**Ymax**
cfs/ft	**ft**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.06	**287.5**	21.18	96.6	0.96	100	0.0	1.5	1.4	1.57	4.6
	312.5	23.56	86.9	0.97	100	0.2	1.6	1.6	1.73	4.6
	337.5	26.00	78.8	0.98	100	0.3	1.8	1.8	1.90	4.6
	362.5	28.13	72.8	0.98	100	0.5	2.0	1.9	2.05	4.6
	387.5	30.66	66.8	0.98	100	0.7	2.2	2.1	2.25	4.6
	412.5	33.23	61.6	0.98	100	0.9	2.3	2.3	2.41	4.6
	437.5	35.80	57.2	0.98	100	1.1	2.5	2.5	2.60	4.6
	462.5	38.43	53.3	0.99	100	1.2	2.7	2.7	2.75	4.6
	487.5	41.10	49.8	0.99	100	1.4	2.9	2.9	3.00	4.6
	512.5	43.43	47.2	0.99	100	1.6	3.0	3.0	3.17	4.6
	537.5	46.18	44.3	0.99	100	1.8	3.3	3.2	3.37	4.6
	562.5	48.96	41.8	0.99	100	2.0	3.5	3.4	3.47	4.6
	587.5	51.73	39.6	0.99	100	2.2	3.7	3.6	3.77	4.6
	600.0	52.96	38.7	0.99	100	2.3	3.8	3.7	3.82	4.6
0.07	**287.5**	19.26	91.20	0.97	100	0.1	1.6	1.5	1.65	4.9
	312.5	21.43	81.90	0.98	100	0.3	1.8	1.7	1.75	4.9
	337.5	23.65	74.30	0.98	100	0.5	1.9	1.9	2.02	4.9
	362.5	25.58	68.60	0.98	100	0.6	2.1	2.1	2.18	4.9
	387.5	27.88	63.00	0.98	100	0.8	2.3	2.3	2.36	4.9
	412.5	30.21	58.11	0.98	100	1.0	2.5	2.4	2.56	4.9
	437.5	32.55	53.99	0.99	100	1.2	2.7	2.6	2.76	4.9
	462.5	34.95	50.22	0.99	100	1.4	2.9	2.9	2.98	4.9
	487.5	37.36	47.00	0.99	100	1.6	3.1	3.1	3.18	4.9
	512.5	39.48	44.50	0.99	100	1.8	3.3	3.2	3.27	4.9
	537.5	41.98	41.80	0.99	100	2.0	3.5	3.4	3.47	4.9
	562.5	44.51	39.40	0.99	100	2.2	3.7	3.7	3.77	4.9
	587.5	47.01	37.30	0.99	100	2.4	3.9	3.9	3.98	4.9
	600.0	48.13	36.50	0.99	100	2.5	4.0	4.0	4.08	4.9

Table 3c. Lookup table for level basins

Q_o	**L_{co}**	**t_{co}**	**E_a**	**Du_{lq}**	**E_r**	**D_p**	**D_{av}**	**D_{min}**	**D_{app}**	**Y_{max}**
cfs/ft	**ft**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.08	**262.5**	15.83	96.9	0.97	100	0.0	1.5	1.4	1.60	5.3
	287.5	17.76	86.5	0.97	100	0.2	1.7	1.6	1.74	5.3
	312.5	19.76	77.7	0.98	100	0.4	1.8	1.8	1.83	5.3
	337.5	21.80	70.5	0.98	100	0.6	2.0	2.0	2.12	5.3
	362.5	23.58	65.1	0.98	100	0.7	2.2	2.2	2.30	5.3
	387.5	25.70	59.8	0.99	100	0.9	2.4	2.4	2.50	5.3
	412.5	27.85	55.2	0.99	100	1.1	2.6	2.6	2.70	5.3
	437.5	30.00	51.2	0.99	100	1.4	2.8	2.8	2.90	5.3
	462.5	32.30	47.7	0.99	100	1.6	3.0	3.0	3.10	5.3
	487.5	34.43	44.6	0.99	100	1.8	3.3	3.2	3.16	5.3
	512.5	36.38	42.2	0.99	100	2.0	3.4	3.4	3.50	5.3
	537.5	38.68	39.7	0.99	100	2.2	3.7	3.6	3.73	5.3
	562.5	41.01	37.4	0.99	100	2.4	3.9	3.9	3.95	5.3
	587.5	43.31	35.4	0.99	100	2.6	4.1	4.1	4.10	5.3
	600.0	44.35	34.6	0.99	100	2.7	4.2	4.2	4.20	5.3
0.09	**262.5**	14.75	92.60	0.97	100	0.1	1.5	1.5	1.62	5.6
	287.5	16.54	82.60	0.98	100	0.3	1.7	1.7	1.81	5.6
	312.5	18.40	74.20	0.98	100	0.5	1.9	1.9	2.01	5.6
	337.5	20.30	67.30	0.98	100	0.7	2.1	2.1	2.20	5.6
	362.5	21.96	62.20	0.98	100	0.8	2.3	2.3	2.40	5.6
	387.5	23.93	54.10	0.99	100	1.1	2.5	2.5	2.60	5.6
	412.5	25.93	52.60	0.99	100	1.3	2.7	2.7	2.82	5.6
	437.5	27.93	48.90	0.99	100	1.5	2.9	2.9	3.05	5.6
	462.5	29.98	45.50	0.99	100	1.7	3.2	3.2	3.25	5.6
	487.5	32.06	42.60	0.99	100	1.9	3.4	3.4	3.50	5.6
	512.5	33.86	41.75	0.99	100	2.1	3.6	3.6	3.70	5.6
	537.5	36.01	37.90	0.99	100	2.4	3.8	3.8	3.90	5.6
	562.5	38.18	35.70	0.99	100	2.6	4.1	4.1	4.15	5.6
	587.5	40.33	33.80	0.99	100	2.8	4.3	4.3	4.40	5.6
	600.0	41.28	33.10	0.99	100	2.9	4.4	4.4	4.50	5.6

Table 3d. Lookup table for level basins

Q_o	**L_{co}**	**t_{co}**	**E_a**	**Du_{lq}**	**E_r**	**D_p**	**D_{av}**	**D_{min}**	**D_{app}**	**Y_{max}**
cfs/ft	**ft**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.10	**237.5**	12.16	99.7	0.96	95	0.0	1.4	1.3	1.50	5.8
	262.5	13.84	88.8	0.97	100	0.1	1.6	1.5	1.69	5.8
	287.5	15.52	79.2	0.98	100	0.3	1.8	1.8	1.89	5.8
	312.5	17.28	71.2	0.98	100	0.5	2.0	2.0	2.10	5.8
	337.5	19.05	64.5	0.98	100	0.8	2.2	2.2	2.31	5.8
	362.5	20.61	59.6	0.99	100	0.9	2.4	2.4	2.50	5.8
	387.5	22.46	54.7	0.99	100	1.2	2.6	2.6	2.61	5.8
	412.5	24.35	50.5	0.99	100	1.4	2.9	2.8	2.92	5.8
	437.5	26.21	46.9	0.99	100	1.6	3.1	3.1	3.19	5.8
	462.5	28.13	43.7	0.99	100	1.9	3.3	3.3	3.40	5.8
	487.5	30.08	40.8	0.99	100	2.1	3.6	3.5	3.62	5.8
	512.5	31.78	38.7	0.99	100	2.3	3.8	3.7	3.82	5.8
	537.5	33.80	36.3	0.99	100	2.5	4.0	4.0	4.10	5.8
	562.5	35.83	34.3	0.99	100	2.8	4.2	4.2	4.25	5.8
	587.5	37.83	32.5	0.99	100	3.0	4.5	4.5	4.58	5.8
	600.0	38.73	31.7	0.99	100	3.1	4.6	4.6	4.63	5.8
0.11	**237.5**	11.49	97.1	0.97	100	0.0	1.5	1.4	1.55	6.1
	262.5	13.07	85.5	0.98	100	0.2	1.7	1.6	1.75	6.1
	287.5	14.66	76.2	0.98	100	0.4	1.8	1.8	1.95	6.1
	312.5	16.31	68.5	0.98	100	0.6	2.1	2.1	2.17	6.1
	337.5	18.00	62.1	0.99	100	0.8	2.3	2.3	2.40	6.1
	362.5	19.46	57.4	0.99	100	1.0	2.5	2.5	2.60	6.1
	387.5	21.21	52.7	0.99	100	1.3	2.7	2.7	2.82	6.1
	412.5	23.00	48.6	0.99	100	1.5	3.0	3.0	3.10	6.1
	437.5	24.75	45.1	0.99	100	1.7	3.2	3.2	3.30	6.1
	462.5	26.58	42.0	0.99	100	2.0	3.4	3.4	3.52	6.1
	487.5	28.41	39.3	0.99	100	2.2	3.7	3.7	3.79	6.1
	512.5	30.01	37.2	0.99	100	2.4	3.9	3.9	4.00	6.1
	537.5	31.91	35.0	0.99	100	2.7	4.2	4.1	4.22	6.1
	562.5	33.83	33.0	0.99	100	2.9	4.4	4.4	4.50	6.1
	587.5	35.73	31.2	0.99	100	3.2	4.7	4.6	4.72	6.1
	600.0	36.58	30.5	0.99	100	3.3	4.8	4.8	4.90	6.1

Table 3e. Lookup table for level basins

Q_o	**L_{co}**	**t_{co}**	**E_a**	**Du_{lq}**	**E_r**	**D_p**	**D_{av}**	**D_{min}**	**D_{app}**	**Y_{max}**
cfs/ft	**ft**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.12	**237.5**	10.91	93.9	0.97	100	0.0	1.5	1.4	1.60	6.4
	262.5	12.41	82.5	0.98	100	0.3	1.7	1.7	1.82	6.4
	287.5	13.92	73.6	0.98	100	0.5	2.0	1.9	2.20	6.4
	312.5	15.49	66.1	0.98	100	0.7	2.2	2.1	2.25	6.4
	337.5	17.08	59.9	0.99	100	0.9	2.4	2.4	2.49	6.4
	362.5	18.48	55.4	0.99	100	1.1	2.6	2.6	2.68	6.4
	387.5	20.15	50.8	0.99	100	1.4	2.9	2.8	2.92	6.4
	412.5	21.83	46.9	0.99	100	1.6	3.1	3.1	3.18	6.4
	437.5	23.50	43.6	0.99	100	1.9	3.3	3.3	3.41	6.4
	462.5	25.23	40.6	0.99	100	2.1	3.6	3.6	3.65	6.4
	487.5	26.98	37.9	0.99	100	2.4	3.8	3.8	3.90	6.4
	512.5	28.50	35.9	0.99	100	2.6	4.1	4.0	4.10	6.4
	537.5	30.30	33.8	0.99	100	2.8	4.3	4.3	4.40	6.4
	562.5	32.11	31.9	0.99	100	3.1	4.6	4.6	4.62	6.4
	587.5	33.93	30.2	0.99	100	3.4	4.8	4.8	4.90	6.4
	600.0	34.73	29.5	0.99	100	3.5	4.9	4.9	5.04	6.4
0.13	**237.5**	10.40	90.9	0.98	100	0.1	1.6	1.5	1.65	6.6
	262.5	11.84	79.9	0.98	100	0.3	1.8	1.7	1.87	6.6
	287.5	13.28	71.2	0.98	100	0.5	2.0	2.0	2.10	6.6
	312.5	14.77	64.0	0.99	100	0.8	2.3	2.2	2.32	6.6
	337.5	16.29	58.0	0.99	100	1.0	2.5	2.5	2.55	6.6
	362.5	17.63	53.6	0.99	100	1.2	2.7	2.7	2.77	6.6
	387.5	19.21	49.2	0.99	100	1.5	2.9	2.9	3.01	6.6
	412.5	20.81	45.4	0.99	100	1.7	3.2	3.2	3.22	6.6
	437.5	22.41	42.2	0.99	100	2.0	3.4	3.4	3.50	6.6
	462.5	24.06	39.3	0.99	100	2.2	3.7	3.7	3.78	6.6
	487.5	25.73	36.7	0.99	100	2.5	4.0	3.9	4.23	6.6
	512.5	27.18	34.8	0.99	100	2.7	4.2	4.2	4.27	6.6
	537.5	28.90	32.7	0.99	100	3.0	4.5	4.4	4.52	6.6
	562.5	30.63	30.8	0.99	100	3.3	4.7	4.7	4.80	6.6
	587.5	32.35	29.2	0.99	100	3.5	5.0	5.0	5.09	6.6
	600.0	33.11	28.5	0.99	100	3.6	5.1	5.1	5.20	6.6

Table 3f. Lookup table for level basins

Q_o	**L_{co}**	**t_{co}**	**E_a**	**Du_{lq}**	**E_r**	**D_p**	**D_{av}**	**D_{min}**	**D_{app}**	**Y_{max}**
cfs/ft	**ft**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.14	**212.5**	8.62	99.9	0.96	100	0.0	1.4	1.3	1.47	6.8
	237.5	9.96	88.2	0.97	100	0.1	1.6	1.6	1.70	6.8
	262.5	11.33	77.5	0.98	100	0.4	1.9	1.8	1.92	6.8
	287.5	12.71	69.1	0.98	100	0.6	2.1	2.0	2.15	6.8
	312.5	14.14	62.1	0.99	100	0.8	2.3	2.3	2.40	6.8
	337.5	15.59	56.3	0.99	100	1.1	2.6	2.5	2.62	6.8
	362.5	16.86	52.0	0.99	100	1.3	2.8	2.8	2.85	6.8
	387.5	18.38	47.7	0.99	100	1.6	3.0	3.0	3.10	6.8
	412.5	19.93	44.0	0.99	100	1.8	3.3	3.3	3.38	6.8
	437.5	21.45	40.9	0.99	100	2.1	3.6	3.5	3.61	6.8
	462.5	23.03	38.1	0.99	100	2.3	3.8	3.8	3.90	6.8
	487.5	24.63	35.6	0.99	100	2.6	4.1	4.1	4.18	6.8
	512.5	26.01	33.7	0.99	100	2.8	4.3	4.3	4.40	6.8
	537.5	37.65	31.7	0.99	100	3.1	4.6	4.6	4.70	6.8
	562.5	29.31	29.9	0.99	100	3.4	4.9	4.9	4.96	6.8
	587.5	30.96	28.3	0.99	100	3.7	5.2	5.1	5.22	6.8
	600.0	31.70	27.7	0.99	100	3.8	5.3	5.3	5.33	6.8
0.15	**212.5**	8.28	98.5	0.98	100	0.0	1.4	1.4	1.52	7.1
	237.5	9.56	85.7	0.98	100	0.2	1.7	1.6	1.75	7.1
	262.5	10.88	75.3	0.98	100	0.4	1.9	1.9	1.98	7.1
	287.5	12.20	67.1	0.98	100	0.7	2.1	2.1	2.22	7.1
	312.5	13.58	60.3	0.99	100	0.9	2.4	2.4	2.47	7.1
	337.5	14.97	54.7	0.99	100	1.2	2.6	2.6	2.71	7.1
	362.5	16.20	50.6	0.99	100	1.4	2.9	2.8	2.93	7.1
	387.5	17.65	46.4	0.99	100	1.7	3.1	3.1	3.20	7.1
	412.5	19.13	42.8	0.99	100	1.9	3.4	3.4	3.44	7.1
	437.5	20.60	39.8	0.99	100	2.2	3.7	3.6	3.73	7.1
	462.5	22.77	37.0	0.99	100	2.5	3.9	3.9	4.00	7.1
	487.5	23.65	34.6	0.99	100	2.7	4.2	4.2	4.28	7.1
	512.5	24.96	32.8	0.99	100	3.0	4.4	4.4	4.50	7.1
	537.5	26.55	30.8	0.99	100	3.3	4.7	4.7	4.80	7.1
	562.5	28.15	29.1	0.99	100	3.5	5.0	5.0	5.18	7.1
	587.5	29.73	27.5	0.99	100	3.8	5.3	5.3	5.38	7.1
	600.0	30.43	26.9	0.99	100	3.9	5.4	5.4	5.50	7.1

Table 3g. Lookup table for level basins

Q_o	**L_{co}**	**t_{co}**	**E_a**	**Du_{lq}**	**E_r**	**D_p**	**D_{av}**	**D_{min}**	**D_{app}**	**Y_{max}**
cfs/ft	**ft**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.16	**212.5**	7.97	96.3	0.97	100	0.0	1.5	1.4	1.60	7.3
	237.5	9.21	83.4	0.98	100	0.2	1.7	1.7	1.80	7.3
	262.5	10.47	73.3	0.98	100	0.5	2.0	1.9	2.08	7.3
	287.5	11.75	65.4	0.99	100	0.7	2.2	2.2	2.28	7.3
	312.5	13.07	58.7	0.99	100	1.0	2.5	2.4	2.52	7.3
	337.5	14.42	53.3	0.99	100	1.2	2.7	2.7	2.80	7.3
	362.5	15.59	49.2	0.99	100	1.5	2.9	2.9	3.01	7.3
	387.5	17.00	45.2	0.99	100	1.7	3.2	3.2	3.30	7.3
	412.5	18.41	41.7	0.99	100	2.0	3.5	3.5	3.55	7.3
	437.5	19.83	38.7	0.99	100	2.3	3.8	3.7	3.82	7.3
	462.5	21.30	36.1	0.99	100	2.6	4.0	4.0	4.10	7.3
	487.5	22.76	33.7	0.99	100	2.8	4.3	4.3	4.40	7.3
	512.5	24.05	31.9	0.99	100	3.1	4.6	4.5	4.62	7.3
	537.5	25.56	30.0	0.99	100	3.4	4.9	4.8	4.94	7.3
	562.5	27.10	28.3	0.99	100	3.7	5.2	5.1	5.21	7.3
	587.5	28.61	26.8	0.99	100	4.0	5.4	5.4	5.50	7.3
	600.0	29.30	26.2	0.99	100	4.1	5.6	5.6	5.62	7.3
0.17	**212.5**	7.69	94.0	0.97	100	0.0	1.5	1.4	1.60	7.5
	237.5	8.88	81.4	0.98	100	0.3	1.8	1.7	1.85	7.5
	262.5	10.11	71.5	0.98	100	0.5	2.0	2.0	2.18	7.5
	287.5	11.34	63.8	0.99	100	0.8	2.3	2.2	2.35	7.5
	312.5	12.62	57.3	0.99	100	1.0	2.5	2.5	2.60	7.5
	337.5	13.91	51.9	0.99	100	1.3	2.8	2.8	2.85	7.5
	362.5	15.05	48.0	0.99	100	1.5	3.0	3.0	3.10	7.5
	387.5	16.40	44.1	0.99	100	1.8	3.3	3.3	3.37	7.5
	412.5	17.78	40.7	0.99	100	2.1	3.6	3.6	3.62	7.5
	437.5	19.13	37.8	0.99	100	2.4	3.9	3.8	3.92	7.5
	462.5	20.55	35.2	0.99	100	2.7	4.1	4.1	4.20	7.5
	487.5	21.96	32.9	0.99	100	3.0	4.4	4.4	4.50	7.5
	512.5	23.20	31.1	0.99	100	3.2	4.7	4.7	4.75	7.5
	537.5	24.66	29.3	0.99	100	3.5	5.0	5.0	5.02	7.5
	562.5	26.15	27.6	0.99	100	3.8	5.3	5.3	5.37	7.5
	587.5	27.61	26.2	0.99	100	4.1	5.6	5.6	5.62	7.5
	600.0	28.26	25.5	0.99	100	4.2	5.7	5.7	5.80	7.5

Table 3h. Lookup table for level basins

Q_o	**L_{co}**	**t_{co}**	**E_a**	**Du_{lq}**	**E_r**	**D_p**	**D_{av}**	**D_{min}**	**D_{app}**	**Y_{max}**
cfs/ft	**ft**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.18	**212.5**	7.44	91.8	0.97	100	0.1	1.6	1.5	1.68	7.7
	237.5	8.57	79.7	0.98	100	0.3	1.8	1.7	1.88	7.7
	262.5	9.78	69.8	0.98	100	0.6	2.1	2.0	2.12	7.7
	287.5	10.96	62.3	0.99	100	0.8	2.3	2.3	2.40	7.7
	312.5	12.20	55.9	0.99	100	1.1	2.6	2.6	2.65	7.7
	337.5	13.46	50.7	0.99	100	1.4	2.9	2.8	2.91	7.7
	362.5	14.56	46.9	0.99	100	1.6	3.1	3.1	3.16	7.7
	387.5	15.86	43.0	0.99	100	1.9	3.4	3.4	3.42	7.7
	412.5	17.20	39.7	0.99	100	2.2	3.7	3.6	3.72	7.7
	437.5	18.31	37.3	0.99	100	2.4	3.9	3.9	3.98	7.7
	462.5	19.86	34.3	0.99	100	2.8	4.2	4.2	4.30	7.7
	487.5	21.25	32.1	0.99	100	3.1	4.5	4.5	4.60	7.7
	512.5	22.45	30.4	0.99	100	3.3	4.8	4.8	4.82	7.7
	537.5	23.86	28.6	0.99	100	3.6	5.1	5.1	5.18	7.7
	562.5	25.30	27.0	0.99	100	3.9	5.4	5.4	5.50	7.7
	587.5	26.71	25.5	0.99	100	4.2	5.7	5.7	5.80	7.7
	600.0	27.33	24.9	0.99	100	4.4	5.9	5.8	5.94	7.7
0.19	**212.5**	7.21	89.7	0.97	100	0.1	1.6	1.5	1.67	7.9
	237.5	8.33	77.7	0.98	100	0.4	1.8	1.8	1.92	7.9
	262.5	9.47	68.3	0.98	100	0.6	2.1	2.1	2.18	7.9
	287.5	10.62	60.9	0.99	100	0.9	2.4	2.3	2.45	7.9
	312.5	11.82	54.7	0.99	100	1.2	2.6	2.6	2.72	7.9
	337.5	13.04	49.6	0.99	100	1.4	2.9	2.9	3.00	7.9
	362.5	14.10	45.8	0.99	100	1.7	3.2	3.2	3.22	7.9
	387.5	15.37	42.1	0.99	100	2.0	3.5	3.4	3.52	7.9
	412.5	16.66	38.8	0.99	100	2.3	3.7	3.7	3.80	7.9
	437.5	17.93	36.0	0.99	100	2.6	4.0	4.0	4.10	7.9
	462.5	19.25	33.6	0.99	100	2.9	4.3	4.3	4.40	7.9
	487.5	20.58	31.4	0.99	100	3.2	4.6	4.6	4.70	7.9
	512.5	21.75	29.7	0.99	100	3.4	4.9	4.9	5.00	7.9
	537.5	23.11	28.0	0.99	100	3.7	5.2	5.2	5.25	7.9
	562.5	24.50	26.4	0.99	100	4.1	5.5	5.5	5.50	7.9
	587.5	25.88	25.0	0.99	100	4.4	5.9	5.8	5.95	7.9
	600.0	26.48	24.4	0.99	100	4.5	6.0	6.0	6.20	7.9

Table 3i. Lookup table for level basins

Q_o	L_{co}	t_{co}	E_a	Du_{lq}	E_r	D_p	D_{av}	D_{min}	D_{app}	Y_{max}
cfs/ft	**ft**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.20	**187.5**	6.08	99.7	0.96	100	0.0	1.4	1.3	1.49	8.1
	212.5	6.99	87.8	0.97	100	0.2	1.6	1.6	1.70	8.1
	237.5	8.08	76.0	0.98	100	0.4	1.9	1.8	1.95	8.1
	262.5	9.20	66.8	0.99	100	0.7	2.2	2.1	2.22	8.1
	287.5	10.31	59.6	0.99	100	0.9	2.4	2.4	2.50	8.1
	312.5	11.47	53.5	0.99	100	1.2	2.7	2.7	2.79	8.1
	337.5	12.85	48.5	0.99	100	1.5	3.0	3.0	3.07	8.1
	362.5	13.69	44.9	0.99	100	1.8	3.2	3.2	3.30	8.1
	387.5	14.92	41.2	0.99	100	2.1	3.5	3.5	3.60	8.1
	412.5	16.17	38.0	0.99	100	2.4	3.8	3.8	3.90	8.1
	437.5	17.41	35.3	0.99	100	2.7	4.1	4.1	4.20	8.1
	462.5	18.68	32.9	0.99	100	3.0	4.4	4.4	4.50	8.1
	487.5	19.98	30.7	0.99	100	3.3	4.7	4.7	4.80	8.1
	512.5	21.10	29.1	0.99	100	3.5	5.0	5.0	5.08	8.1
	537.5	22.43	27.4	0.99	100	3.9	5.3	5.3	5.40	8.1
	562.5	23.78	25.8	0.99	100	4.2	5.7	5.6	5.80	8.1
	587.5	25.11	24.4	0.99	100	4.5	6.0	6.0	6.03	8.1
	600.0	25.71	23.9	0.99	100	4.6	6.1	6.1	6.15	8.1
0.21	**187.5**	5.91	98.4	0.97	100	0.0	1.4	1.4	1.52	8.2
	212.5	6.80	86.0	0.98	100	0.2	1.7	1.6	1.75	8.2
	237.5	7.85	74.5	0.98	100	0.5	1.9	1.9	2.00	8.2
	262.5	8.94	65.5	0.99	100	0.7	2.2	2.2	2.28	8.2
	287.5	10.02	58.4	0.99	100	1.0	2.5	2.4	2.55	8.2
	312.5	11.15	52.4	0.99	100	1.3	2.8	2.7	2.82	8.2
	337.5	12.30	47.6	0.99	100	1.6	3.1	3.0	3.12	8.2
	362.5	13.31	44.0	0.99	100	1.8	3.3	3.3	3.38	8.2
	387.5	14.50	40.3	0.99	100	2.1	3.6	3.6	3.63	8.2
	412.5	15.71	37.2	0.99	100	2.4	3.9	3.9	3.97	8.2
	437.5	16.91	34.6	0.99	100	2.7	4.2	4.2	4.23	8.2
	462.5	18.16	32.2	0.99	100	3.1	4.5	4.5	4.60	8.2
	487.5	19.41	30.1	0.99	100	3.4	4.8	4.8	4.90	8.2
	512.5	20.51	28.5	0.99	100	3.6	5.1	5.1	5.20	8.2
	537.5	21.81	26.8	0.99	100	4.0	5.4	5.4	5.50	8.2
	562.5	23.11	25.3	0.99	100	4.3	5.8	5.8	5.85	8.2
	587.5	24.41	23.9	0.99	100	4.6	6.1	6.1	6.15	8.2
	600.0	25.00	23.4	0.99	100	4.8	6.2	6.2	6.22	8.2

Table 3j. Lookup table for level basins

Q_o	**L_{co}**	**t_{co}**	**E_a**	**Du_{lq}**	**E_r**	**D_p**	**D_{av}**	**D_{min}**	**D_{app}**	**Y_{max}**
cfs/ft	**ft**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.22	**187.5**	5.76	96.9	0.97	100	0.0	1.5	1.4	1.60	8.4
	212.5	6.62	84.4	0.98	100	0.2	1.7	1.6	1.77	8.4
	237.5	7.65	73.0	0.98	100	0.5	1.9	1.9	2.03	8.4
	262.5	8.70	64.2	0.98	100	0.8	2.2	2.2	2.31	8.4
	287.5	9.76	57.2	0.99	100	1.1	2.5	2.5	2.60	8.4
	312.5	10.86	51.4	0.99	100	1.3	2.8	2.8	2.85	8.4
	337.5	11.97	46.6	0.99	100	1.6	3.1	3.1	3.19	8.4
	362.5	12.95	43.1	0.99	100	1.9	3.4	3.3	3.42	8.4
	387.5	14.12	39.6	0.99	100	2.2	3.7	3.7	3.72	8.4
	412.5	15.30	36.5	0.99	100	2.5	4.0	4.0	4.02	8.4
	437.5	16.47	33.9	0.99	100	2.8	4.3	4.3	4.38	8.4
	462.5	17.68	31.6	0.99	100	3.1	4.6	4.6	4.70	8.4
	487.5	18.90	29.5	0.99	100	3.5	4.9	4.9	5.00	8.4
	512.5	19.96	27.9	0.99	100	3.7	5.2	5.2	5.30	8.4
	537.5	21.23	26.3	0.99	100	4.1	5.6	5.5	5.61	8.4
	562.5	22.50	24.8	0.99	100	4.4	5.9	5.9	5.97	8.4
	587.5	23.76	23.5	0.99	100	4.7	6.2	6.2	6.30	8.4
	600.0	24.33	22.9	0.99	100	4.9	6.4	6.4	6.18	8.4
0.23	**187.5**	5.61	95.2	0.97	100	0.0	1.5	1.4	1.58	8.6
	212.5	6.45	82.8	0.98	100	0.3	1.7	1.7	1.80	8.6
	237.5	7.45	71.7	0.98	100	0.5	2.0	2.0	2.18	8.6
	262.5	8.48	63.0	0.99	100	0.8	2.3	2.3	2.35	8.6
	287.5	9.51	56.2	0.99	100	1.1	2.6	2.5	2.65	8.6
	312.5	10.58	50.5	0.99	100	1.4	2.9	2.8	2.92	8.6
	337.5	11.67	45.8	0.99	100	1.7	3.2	3.1	3.22	8.6
	362.5	12.62	42.3	0.99	100	2.0	3.4	3.4	3.50	8.6
	387.5	13.76	38.8	0.99	100	2.3	3.7	3.7	3.80	8.6
	412.5	14.91	35.8	0.99	100	2.6	4.1	4.0	4.15	8.6
	437.5	16.05	33.3	0.99	100	2.9	4.4	4.4	4.44	8.6
	462.5	17.23	31.0	0.99	100	3.2	4.7	4.7	4.78	8.6
	487.5	18.43	29.0	0.99	100	3.6	5.0	5.0	5.10	8.6
	512.5	19.46	27.4	0.99	100	3.8	5.3	5.3	5.40	8.6
	537.5	20.10	25.8	0.99	100	4.2	5.7	5.6	5.80	8.6
	562.5	21.93	24.3	0.99	100	4.5	6.0	6.0	6.03	8.6
	587.5	23.16	23.0	0.99	100	4.9	6.3	6.3	6.30	8.6
	600.0	23.71	22.5	0.99	100	5.0	6.5	6.5	6.52	8.6

Table 3k. Lookup table for level basins

Q_o	L_{co}	t_{co}	E_a	Du_{lq}	E_r	D_p	D_{av}	D_{min}	D_{app}	Y_{max}
cfs/ft	**ft**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.24	**187.5**	5.47	93.5	0.97	100	0.1	1.5	1.5	1.60	8.8
	212.5	6.29	81.3	0.98	100	0.3	1.7	1.7	1.82	8.8
	237.5	7.27	70.4	0.98	100	0.6	2.0	2.0	2.12	8.8
	262.5	8.27	61.9	0.99	100	0.9	2.3	2.3	2.40	8.8
	287.5	9.28	55.2	0.99	100	1.1	2.6	2.6	2.70	8.8
	312.5	10.32	49.6	0.99	100	1.4	2.9	2.9	3.00	8.8
	337.5	11.39	44.9	0.99	100	1.8	3.2	3.2	3.30	8.8
	362.5	12.32	41.5	0.99	100	2.0	3.5	3.5	3.48	8.8
	387.5	13.42	38.1	0.99	100	2.3	3.8	3.8	3.90	8.8
	412.5	14.55	35.2	0.99	100	2.7	4.1	4.1	4.20	8.8
	437.5	15.66	32.7	0.99	100	3.0	4.5	4.4	4.55	8.8
	462.5	16.81	30.4	0.99	100	3.3	4.8	4.8	4.84	8.8
	487.5	17.88	28.5	0.99	100	3.7	5.1	5.1	5.20	8.8
	512.5	18.98	26.9	0.99	100	3.9	5.4	5.4	5.50	8.8
	537.5	20.18	25.3	0.99	100	4.3	5.8	5.7	5.90	8.8
	562.5	21.40	23.9	0.99	100	4.6	6.1	6.1	6.15	8.8
	587.5	22.60	22.6	0.99	100	5.0	6.5	6.4	6.50	8.8
	600.0	23.13	22.1	0.99	100	5.1	6.6	6.6	6.70	8.8
0.25	**187.5**	5.4	91.9	0.97	100	0.1	1.6	1.5	1.62	8.9
	212.5	6.2	79.9	0.98	100	0.3	1.8	1.7	1.86	8.9
	237.5	7.1	69.2	0.98	100	0.6	2.1	2.0	2.15	8.9
	262.5	8.1	60.8	0.99	100	0.9	2.4	2.3	2.45	8.9
	287.5	9.1	54.2	0.99	100	1.2	2.7	2.6	2.75	8.9
	312.5	10.1	48.7	0.99	100	1.5	3.0	3.0	3.10	8.9
	337.5	11.1	44.2	0.99	100	1.8	3.3	3.3	3.35	8.9
	362.5	12.0	40.8	0.99	100	2.1	3.6	3.5	3.61	8.9
	387.5	13.1	37.5	0.99	100	2.4	3.9	3.9	3.95	8.9
	412.5	14.2	34.6	0.99	100	2.7	4.2	4.2	4.30	8.9
	437.5	15.3	32.1	0.99	100	3.1	4.5	4.5	4.60	8.9
	462.5	16.4	29.9	0.99	100	3.4	4.9	4.9	4.95	8.9
	487.5	17.6	28.0	0.99	100	3.7	5.2	5.2	5.25	8.9
	512.5	18.6	26.5	0.99	100	4.0	5.5	5.5	5.60	8.9
	537.5	19.7	24.9	0.99	100	4.4	5.9	5.9	5.97	8.9
	562.5	20.9	23.5	0.99	100	4.7	6.2	6.2	6.25	8.9
	587.5	22.1	22.2	0.99	100	5.1	6.6	6.6	6.60	8.9
	600.0	22.6	21.7	0.99	100	5.3	6.7	6.7	6.75	8.9

Table 4a. Lookup table for basins with a bed slope of 0.1%

Qo	**Lco**	**tco**	**Ea**	**Dulq**	**Er**	**Dp**	**Dav**	**Dmin**	**Dapp**	**Ymax**
cfs/ft	**-**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.04	**212.5**	16.48	99.6	0.82	53.4	0.0	0.7	0.5	0.7	2.3
	237.5	18.80	95.6	0.72	58.4	0.0	0.9	0.6	0.9	2.3
	262.5	21.13	89.6	0.65	61.6	0.1	1.0	0.6	1.0	2.3
	287.5	23.45	84.6	0.59	64.5	0.1	1.1	0.6	1.1	2.3
	312.5	25.83	79.2	0.55	66.5	0.2	1.2	0.6	1.2	2.6
	337.5	28.23	75.0	0.51	68.9	0.3	1.3	0.6	1.3	2.9
	362.5	30.60	69.2	0.41	68.9	0.4	1.4	0.1	1.4	3.2
	387.5	33.03	66.5	0.42	71.4	0.5	1.5	0.5	1.5	3.4
	412.5	35.21	64.2	0.41	73.5	0.5	1.6	0.6	1.6	3.7
	437.5	37.63	61.0	0.39	74.6	0.6	1.7	0.5	1.8	3.9
	462.5	40.11	58.3	0.36	76.0	0.7	1.9	0.4	1.9	4.1
	487.5	42.60	56.7	0.36	78.6	0.8	2.0	0.6	2.0	4.3
	512.5	45.05	53.8	0.33	78.8	0.9	2.1	0.5	2.1	4.5
	537.5	47.56	52.2	0.32	80.7	1.0	2.2	0.6	2.2	4.7
	562.5	50.08	50.4	0.32	82.1	1.1	2.3	0.7	2.4	4.9
	587.5	52.56	48.9	0.31	83.6	1.2	2.5	0.7	2.5	5.0
	600.0	53.68	48.1	0.30	84.0	1.3	2.5	0.7	2.5	5.1
0.05	**187.5**	12.49	101.3	0.80	51.4	0.0	0.7	0.4	0.7	2.6
	212.5	14.46	96.0	0.72	56.4	0.0	0.8	0.4	0.8	2.6
	237.5	16.51	89.8	0.65	60.3	0.0	0.9	0.4	0.9	2.6
	262.5	18.58	84.5	0.60	63.8	0.1	1.1	0.6	1.1	2.6
	287.5	20.63	78.9	0.54	66.2	0.2	1.2	0.6	1.2	2.6
	312.5	22.73	73.7	0.48	68.1	0.3	1.3	0.5	1.3	3.0
	337.5	24.85	69.4	0.45	70.1	0.4	1.4	0.5	1.4	3.3
	362.5	26.95	64.9	0.36	71.1	0.5	1.6	0.1	1.6	3.5
	387.5	29.10	62.0	0.38	73.3	0.6	1.7	0.4	1.7	3.8
	412.5	31.03	60.3	0.38	76.1	0.7	1.8	0.6	1.8	4.0
	437.5	33.16	56.7	0.34	76.4	0.8	1.9	0.5	1.9	4.2
	462.5	35.36	54.8	0.35	78.8	0.9	2.1	0.6	2.1	4.4
	487.5	37.56	52.9	0.32	80.8	1.0	2.2	0.6	2.2	4.7
	512.5	39.73	50.1	0.29	80.9	1.1	2.3	0.5	2.3	4.9
	537.5	41.95	48.7	0.29	83.0	1.2	2.5	0.7	2.5	5.1
	562.5	44.18	46.6	0.27	83.7	1.4	2.6	0.5	2.6	5.2
	587.5	46.36	45.2	0.26	85.2	1.5	2.7	0.7	2.7	5.4
	600.0	47.36	44.6	0.26	85.9	1.5	2.8	0.7	2.8	5.5

Table 4b. Lookup table for basins with a bed slope of 0.1%

Q_o	**L_{co}**	**t_{co}**	**E_a**	**Du_{lq}**	**E_r**	**D_p**	**D_{av}**	**D_{min}**	**D_{app}**	**Y_{max}**
cfs/ft	**-**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.06	**187.5**	11.24	101.1	0.75	55.4	0.0	0.8	0.5	0.8	2.8
	212.5	13.02	92.7	0.68	58.9	0.0	0.9	0.5	0.9	2.9
	237.5	14.87	86.4	0.60	62.7	0.1	1.0	0.5	1.0	2.9
	262.5	16.75	79.9	0.54	65.3	0.2	1.2	0.6	1.2	2.9
	287.5	18.60	74.6	0.49	67.7	0.3	1.3	0.5	1.3	2.9
	312.5	20.50	70.1	0.45	70.1	0.4	1.4	0.6	1.4	3.2
	337.5	22.41	64.7	0.36	70.7	0.5	1.6	0.1	1.6	3.5
	362.5	24.31	61.6	0.37	73.0	0.6	1.7	0.5	1.7	3.8
	387.5	26.26	58.5	0.34	74.9	0.7	1.8	0.4	1.8	4.1
	412.5	28.01	56.3	0.34	76.9	0.8	2.0	0.5	2.0	4.3
	437.5	29.95	53.0	0.28	77.4	1.0	2.1	0.3	2.1	4.5
	462.5	31.93	51.1	0.29	79.6	1.1	2.2	0.4	2.2	4.8
	487.5	33.93	49.6	0.29	82.1	1.2	2.4	0.6	2.4	5.0
	512.5	35.90	47.5	0.28	83.2	1.3	2.5	0.6	2.5	5.2
	537.5	37.91	45.8	0.27	84.7	1.4	2.7	0.6	2.7	5.4
	562.5	39.93	43.9	0.24	85.5	1.6	2.8	0.5	2.8	5.6
	587.5	42.81	41.7	0.24	87.1	1.7	3.0	0.5	3.0	5.8
0.07	**187.5**	10.28	97.3	0.69	56.9	0.0	0.8	0.4	0.8	3.1
	212.5	11.92	89.0	0.62	60.4	0.1	1.0	0.4	1.0	3.1
	237.5	13.62	82.8	0.56	64.2	0.2	1.1	0.5	1.1	3.1
	262.5	15.34	76.7	0.50	67.0	0.3	1.3	0.5	1.2	3.2
	287.5	17.05	71.0	0.45	68.9	0.4	1.4	0.5	1.4	3.2
	312.5	18.80	66.7	0.43	71.4	0.5	1.5	0.6	1.5	3.5
	337.5	20.56	62.2	0.37	72.8	0.6	1.7	0.4	1.7	3.8
	362.5	22.31	58.7	0.34	74.5	0.7	1.8	0.4	1.8	4.1
	387.5	24.10	56.4	0.34	77.4	0.8	2.0	0.6	2.0	4.3
	412.5	25.71	53.4	0.31	78.1	1.0	2.1	0.5	2.1	4.5
	437.5	27.50	50.8	0.28	79.5	1.1	2.3	0.4	2.3	4.8
	462.5	29.33	48.6	0.26	81.1	1.2	2.4	0.4	2.4	5.0
	487.5	31.16	46.7	0.26	82.8	1.3	2.6	0.5	2.6	5.2
	512.5	32.98	45.1	0.25	84.6	1.5	2.7	0.6	2.7	5.4
	537.5	34.83	43.6	0.25	86.4	1.6	2.9	0.6	2.9	5.7
	562.5	36.70	41.7	0.24	87.1	1.7	3.0	0.5	3.0	5.9
	587.5	38.53	40.6	0.25	89.0	1.9	3.2	0.7	3.2	6.0
	600.0	39.35	39.9	0.26	89.4	1.9	3.2	0.7	3.3	6.1

Table 4c. Lookup table for basins with a bed slope of 0.1%

Q_o	**L_{co}**	**t_{co}**	**E_a**	**Du_{lq}**	**E_r**	**D_p**	**D_{av}**	**D_{min}**	**D_{app}**	**Y_{max}**
cfs/ft	**-**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.08	**162.5**	8.00	99.7	0.73	51.9	0.0	0.7	0.3	0.7	3.3
	187.5	9.53	94.6	0.65	58.6	0.0	0.9	0.4	0.9	3.3
	212.5	11.05	85.3	0.57	61.3	0.1	1.0	0.3	1.0	3.4
	237.5	12.63	78.2	0.50	64.2	0.2	1.2	0.3	1.2	3.4
	262.5	14.22	73.5	0.47	68.0	0.3	1.3	0.5	1.3	3.4
	287.5	15.81	68.4	0.43	70.3	0.4	1.5	0.5	1.5	3.4
	312.5	17.45	63.2	0.37	71.7	0.6	1.6	0.4	1.6	3.7
	337.5	19.10	59.8	0.36	74.3	0.7	1.8	0.5	1.8	4.0
	362.5	20.71	56.3	0.33	75.8	0.8	1.9	0.5	1.9	4.3
	387.5	22.38	53.4	0.30	77.7	0.9	2.1	0.5	2.1	4.5
	412.5	23.88	51.0	0.28	79.2	1.1	2.2	0.4	2.2	4.8
	437.5	25.55	48.7	0.26	80.9	1.2	2.4	0.3	2.4	5.0
	462.5	27.25	46.7	0.26	82.8	1.3	2.6	0.5	2.6	5.2
	487.5	28.96	44.6	0.24	84.0	1.5	2.7	0.4	2.7	5.5
	512.5	30.66	42.9	0.23	85.5	1.6	2.9	0.4	2.9	5.7
	537.5	32.40	41.8	0.25	88.1	1.8	3.1	0.6	3.1	5.9
	562.5	34.13	40.1	0.25	89.0	1.9	3.2	0.6	3.2	6.1
	587.5	35.83	38.7	0.26	90.2	2.1	3.4	0.5	3.4	6.3
	600.0	36.60	38.3	0.27	91.2	2.1	3.5	0.6	3.5	6.4
0.09	**162.5**	7.48	100.2	0.71	54.8	0.0	0.8	0.4	0.8	3.5
	187.5	8.91	91.6	0.62	59.7	0.1	0.9	0.4	0.9	3.5
	212.5	10.33	83.7	0.56	63.3	0.1	1.1	0.5	1.1	3.6
	237.5	11.81	76.7	0.50	66.3	0.3	1.2	0.5	1.2	3.6
	262.5	13.32	70.4	0.44	68.6	0.4	1.4	0.4	1.4	3.7
	287.5	14.80	66.1	0.41	71.6	0.5	1.6	0.6	1.5	3.7
	312.5	16.34	61.0	0.36	72.9	0.6	1.7	0.5	1.7	3.9
	337.5	17.88	56.7	0.30	74.2	0.8	1.9	0.2	1.9	4.2
	362.5	19.41	54.2	0.30	77.0	0.9	2.0	0.4	2.0	4.5
	387.5	20.98	51.2	0.28	78.6	1.0	2.2	0.4	2.2	4.7
	412.5	22.38	49.3	0.28	80.7	1.2	2.4	0.5	2.4	5.0
	437.5	23.95	46.8	0.25	82.0	1.3	2.5	0.5	2.5	5.2
	462.5	25.55	44.8	0.23	83.8	1.5	2.7	0.4	2.7	5.5
	487.5	27.16	43.2	0.24	85.9	1.6	2.9	0.6	2.9	5.7
	512.5	28.76	41.8	0.25	88.0	1.8	3.1	0.6	3.1	5.9
	537.5	30.38	39.8	0.24	88.5	1.9	3.2	0.4	3.2	6.1
	562.5	32.01	38.7	0.27	90.6	2.1	3.4	0.6	3.4	6.3
	587.5	33.63	37.5	0.28	92.3	2.2	3.6	0.6	3.6	6.5
	600.0	34.35	36.9	0.29	92.7	2.3	3.7	0.6	3.7	6.6

Table 4d. Lookup table for basins with a bed slope of 0.1%

Q_o	**L_{co}**	**t_{co}**	**E_a**	**Du_{lq}**	**E_r**	**D_p**	**D_{av}**	**D_{min}**	**D_{app}**	**Y_{max}**
cfs/ft	**-**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.10	**162.5**	7.04	96.0	0.64	54.9	0.0	0.8	0.2	0.8	3.7
	187.5	8.39	87.7	0.57	59.8	0.1	1.0	0.3	1.0	3.8
	212.5	9.74	81.3	0.52	64.4	0.2	1.1	0.4	1.1	3.8
	237.5	11.14	74.4	0.47	67.4	0.3	1.3	0.5	1.3	3.8
	262.5	13.93	63.8	0.37	72.3	0.6	1.6	0.5	1.6	3.9
	287.5	13.96	63.6	0.37	72.2	0.6	1.6	0.5	1.6	3.9
	312.5	15.41	58.9	0.33	73.8	0.7	1.8	0.4	1.8	4.0
	337.5	16.88	56.1	0.33	77.0	0.9	2.0	0.6	2.0	4.3
	362.5	18.31	52.6	0.30	78.3	1.0	2.1	0.5	2.1	4.6
	387.5	19.80	49.6	0.27	79.8	1.1	2.3	0.5	2.3	4.9
	412.5	21.13	47.4	0.25	81.4	1.3	2.5	0.4	2.5	5.1
	437.5	22.61	45.3	0.23	83.3	1.4	2.7	0.4	2.7	5.4
	462.5	24.13	43.9	0.25	86.1	1.6	2.9	0.6	2.8	5.6
	487.5	25.60	41.5	0.23	86.4	1.7	3.0	0.5	3.0	5.9
	512.5	27.16	40.2	0.25	88.8	1.9	3.2	0.6	3.2	6.1
	537.5	28.70	38.8	0.26	90.5	2.1	3.4	0.6	3.4	6.3
	562.5	30.25	37.4	0.28	92.0	2.2	3.6	0.6	3.6	6.6
	587.5	31.78	36.1	0.30	93.3	2.4	3.8	0.6	3.8	6.8
	600.0	32.46	35.5	0.31	93.7	2.5	3.8	0.4	3.8	6.8
0.11	**162.5**	6.72	93.5	0.60	56.2	0.0	0.8	0.2	0.8	3.9
	187.5	8.01	86.4	0.55	61.9	0.1	1.0	0.4	1.0	4.0
	212.5	9.15	79.2	0.50	64.8	0.2	1.2	0.4	1.2	4.0
	237.5	10.49	72.1	0.45	67.6	0.3	1.3	0.4	1.3	4.0
	262.5	11.85	66.6	0.40	70.6	0.5	1.5	0.4	1.5	4.1
	287.5	13.21	61.9	0.36	73.1	0.6	1.7	0.5	1.7	4.1
	312.5	14.60	57.2	0.32	74.7	0.8	1.9	0.4	1.9	4.2
	337.5	16.01	53.5	0.29	76.6	0.9	2.1	0.3	2.1	4.5
	362.5	17.23	51.6	0.29	79.5	1.1	2.2	0.6	2.2	4.7
	387.5	18.66	48.3	0.26	80.6	1.2	2.4	0.4	2.4	5.0
	412.5	20.11	45.8	0.24	82.4	1.4	2.6	0.4	2.6	5.3
	437.5	21.53	43.7	0.22	74.1	1.5	2.8	0.3	2.8	5.6
	462.5	23.00	42.4	0.24	87.2	1.7	3.0	0.6	3.0	5.8
	487.5	24.46	40.1	0.23	87.7	1.9	3.2	0.4	3.2	6.1
	512.5	25.73	39.0	0.25	89.7	2.0	3.3	0.5	3.3	6.3
	537.5	27.21	37.7	0.28	91.7	2.2	3.6	0.6	3.5	6.5
	562.5	28.71	36.2	0.30	92.9	2.4	3.7	0.6	3.7	6.7
	587.5	30.18	35.1	0.33	94.7	2.5	3.9	0.6	3.9	7.0
	600.0	30.83	34.6	0.34	95.4	2.6	4.0	0.6	4.0	7.0

Table 4e. Lookup table for basins with a bed slope of 0.1%

Q_o	L_{co}	t_{co}	E_a	Du_{lq}	E_r	D_p	D_{av}	D_{min}	D_{app}	Y_{max}
cfs/ft	**-**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.12	**137.5**	5.19	102.6	0.73	52.0	0.0	0.7	0.3	0.7	4.0
	162.5	6.40	92.7	0.60	57.9	0.0	0.9	0.3	0.9	4.1
	187.5	7.63	82.7	0.50	61.6	0.1	1.1	0.2	1.0	4.1
	212.5	8.71	76.8	0.46	65.3	0.3	1.2	0.3	1.2	4.2
	237.5	9.99	69.3	0.40	67.5	0.4	1.4	0.2	1.4	4.2
	262.5	11.29	64.6	0.37	71.2	0.6	1.6	0.4	1.6	4.3
	287.5	12.59	59.8	0.35	73.5	0.7	1.8	0.5	1.8	4.3
	312.5	13.92	55.6	0.31	75.5	0.8	1.9	0.5	2.0	4.4
	337.5	15.26	52.2	0.29	77.7	1.0	2.1	0.4	2.1	4.6
	362.5	16.42	49.4	0.26	79.1	1.1	2.3	0.4	2.3	4.9
	387.5	17.80	46.8	0.24	81.3	1.3	2.5	0.3	2.5	5.2
	412.5	19.18	44.8	0.24	83.8	1.5	2.7	0.5	2.7	5.5
	437.5	20.55	42.5	0.22	85.2	1.6	2.9	0.4	2.9	5.7
	462.5	21.93	40.6	0.23	86.9	1.8	3.1	0.3	3.1	6.0
	487.5	23.33	38.9	0.24	88.5	2.0	3.3	0.2	3.3	6.2
	512.5	24.55	37.7	0.26	90.3	2.1	3.5	0.4	3.5	6.4
	537.5	25.96	36.6	0.29	92.7	2.3	3.7	0.6	3.7	6.7
	562.5	27.40	35.3	0.32	94.4	2.5	3.9	0.6	3.9	6.9
	587.5	28.80	34.1	0.35	95.8	2.7	4.1	0.6	4.1	7.1
	600.0	29.43	33.7	0.36	96.8	2.8	4.2	0.6	4.2	7.2
0.13	**137.5**	4.96	101.4	0.70	53.2	0.0	0.7	0.3	0.7	4.1
	162.5	6.11	91.4	0.58	59.0	0.1	0.9	0.3	0.9	4.2
	187.5	7.29	80.9	0.48	62.3	0.2	1.1	0.2	1.1	4.3
	212.5	8.33	74.8	0.45	65.9	0.3	1.3	0.3	1.2	4.4
	237.5	9.56	68.1	0.40	68.8	0.4	1.4	0.3	1.4	4.4
	262.5	10.80	62.5	0.35	71.3	0.6	1.6	0.3	1.6	4.5
	287.5	12.04	58.0	0.32	73.8	0.7	1.8	0.3	1.8	4.5
	312.5	13.32	53.9	0.29	75.9	0.9	2.0	0.3	2.0	4.6
	337.5	14.60	51.5	0.29	79.5	1.1	2.2	0.6	2.2	4.8
	362.5	15.72	48.5	0.26	80.6	1.2	2.4	0.4	2.4	5.0
	387.5	17.03	45.7	0.23	82.3	1.4	2.6	0.4	2.6	5.3
	412.5	18.36	43.4	0.22	84.2	1.6	2.8	0.3	2.8	5.6
	437.5	19.66	41.4	0.22	86.0	1.7	3.0	0.3	3.0	5.9
	462.5	21.01	39.7	0.24	88.2	1.9	3.2	0.4	3.2	6.1
	487.5	22.35	38.3	0.26	90.5	2.1	3.4	0.6	2.1	6.4
	512.5	23.51	37.1	0.29	92.2	2.3	3.6	0.6	3.6	6.6
	537.5	24.88	35.6	0.31	93.6	2.4	3.8	0.4	3.8	6.9
	562.5	26.25	34.4	0.34	95.4	2.6	4.0	0.6	4.0	7.1
	587.5	27.60	33.3	0.37	97.1	2.8	4.3	0.7	4.3	7.3
	600.0	28.20	32.8	0.38	97.8	2.9	4.3	0.8	4.3	7.4

Table 4f. Lookup table for basins with a bed slope of 0.1%

Q_o	**L_{co}**	**t_{co}**	**E_a**	**Du_{lq}**	**E_r**	**D_p**	**D_{av}**	**D_{min}**	**D_{app}**	**Y_{max}**
cfs/ft	**-**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.14	**137.5**	4.76	100.2	0.68	54.3	0.0	0.8	0.3	0.7	4.3
	162.5	5.86	88.5	0.54	59.0	0.1	1.0	0.2	0.9	4.4
	187.5	6.99	79.4	0.48	63.2	0.2	1.1	0.2	1.1	4.5
	212.5	7.99	73.4	0.45	66.8	0.3	1.3	0.4	1.3	4.6
	237.5	9.17	66.6	0.38	69.5	0.5	1.5	0.3	1.5	4.6
	262.5	10.37	61.8	0.36	72.9	0.6	1.7	0.5	1.7	4.7
	287.5	11.56	56.7	0.31	74.6	0.8	1.9	0.4	1.9	4.7
	312.5	12.79	52.8	0.28	76.9	1.0	2.1	0.4	2.1	4.7
	337.5	14.02	49.6	0.26	79.2	1.1	2.3	0.3	2.3	4.9
	362.5	15.10	47.0	0.23	80.8	1.3	2.5	0.3	2.5	5.2
	387.5	16.36	44.9	0.23	83.6	1.5	2.7	0.5	2.7	5.5
	412.5	17.65	42.4	0.22	85.2	1.6	2.9	0.4	2.9	5.7
	437.5	18.90	40.4	0.23	86.9	1.8	3.1	0.3	3.1	6.0
	462.5	20.18	38.9	0.25	89.3	2.0	3.3	0.5	3.3	6.3
	487.5	21.48	37.5	0.28	91.7	2.2	3.6	0.6	3.6	6.5
	512.5	22.60	36.2	0.30	93.1	2.4	3.7	0.6	3.7	6.8
	537.5	23.91	34.9	0.33	95.0	2.6	4.0	0.6	4.0	7.0
	562.5	25.23	33.6	0.36	96.5	2.8	4.2	0.6	4.2	7.2
	587.5	26.53	32.5	0.39	98.1	3.0	4.4	0.8	4.4	7.5
	600.0	27.11	31.9	0.41	98.4	3.0	4.5	0.9	4.5	7.6
0.15	**137.5**	4.57	97.9	0.65	54.6	0.0	0.8	0.2	0.8	4.5
	162.5	5.64	86.7	0.53	59.6	0.1	1.0	0.2	1.0	4.6
	187.5	6.73	79.2	0.49	65.0	0.2	1.2	0.4	1.2	4.7
	212.5	7.69	72.0	0.42	67.5	0.4	1.4	0.3	1.3	4.7
	237.5	8.83	65.4	0.36	70.4	0.5	1.6	0.3	1.5	4.8
	262.5	9.98	59.3	0.31	72.2	0.7	1.7	0.2	1.7	4.8
	287.5	11.13	55.8	0.31	75.7	0.8	1.9	0.5	2.0	4.9
	312.5	12.31	51.8	0.28	77.8	1.0	2.2	0.4	2.2	4.9
	337.5	13.50	48.5	0.25	79.8	1.2	2.4	0.4	2.4	5.0
	362.5	14.54	46.1	0.23	81.7	1.4	2.6	0.4	2.6	5.3
	387.5	15.76	43.6	0.22	83.8	1.5	2.8	0.3	2.8	5.6
	412.5	17.00	41.4	0.22	85.8	1.7	3.0	0.2	3.0	5.9
	437.5	18.21	39.7	0.24	88.2	1.9	3.2	0.4	3.2	6.2
	462.5	19.45	37.8	0.25	89.7	2.1	3.4	0.3	3.5	6.4
	487.5	20.70	36.6	0.29	92.4	2.3	3.7	0.5	3.7	6.7
	512.5	21.78	35.5	0.32	94.3	2.5	3.9	0.6	3.9	6.9
	537.5	23.05	34.1	0.35	95.9	2.7	4.1	0.6	4.1	7.2
	562.5	24.33	32.9	0.38	97.6	2.9	4.3	0.8	4.3	7.4
	587.5	25.58	31.7	0.41	98.9	3.1	4.6	1.0	4.6	7.6
	600.0	26.13	31.1	0.42	99.1	3.2	4.7	1.1	4.7	7.7

Table 4g. Lookup table for basins with a bed slope of 0.1%

Q_o	L_{co}	t_{co}	E_a	Du_{lq}	E_r	D_p	D_{av}	D_{min}	D_{app}	Y_{max}
cfs/ft	**-**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.16	**137.5**	4.41	96.7	0.59	55.5	0.0	0.8	0.2	0.8	4.6
	162.5	5.44	85.3	0.53	60.4	0.1	1.0	0.2	1.0	4.7
	187.5	6.49	77.6	0.47	65.5	0.3	1.2	0.3	1.2	4.8
	212.5	7.42	69.3	0.37	66.9	0.4	1.4	0.1	1.4	4.9
	237.5	8.52	64.2	0.36	71.2	0.6	1.6	0.4	1.6	5.0
	262.5	9.63	59.0	0.32	73.9	0.7	1.8	0.4	1.8	5.0
	287.5	10.74	54.2	0.28	75.7	0.9	2.0	0.3	2.0	5.1
	312.5	11.88	50.4	0.25	77.9	1.1	2.2	0.3	2.2	5.1
	337.5	13.04	48.1	0.26	81.6	1.3	2.5	0.6	2.5	5.1
	362.5	14.04	45.3	0.23	82.7	1.4	2.6	0.4	2.6	5.4
	387.5	15.22	42.8	0.22	84.7	1.6	2.9	0.4	2.9	5.7
	412.5	16.41	40.6	0.22	86.7	1.8	3.1	0.3	3.1	6.0
	437.5	17.58	38.7	0.24	88.5	2.0	3.3	0.2	3.3	6.3
	462.5	18.80	37.5	0.28	91.7	2.2	3.6	0.6	3.6	6.6
	487.5	20.00	35.8	0.30	93.1	2.4	3.8	0.3	3.8	6.8
	512.5	21.03	34.8	0.33	95.2	2.6	4.0	0.6	4.0	7.0
	537.5	22.26	33.5	0.37	97.0	2.8	4.2	0.7	4.2	7.3
	562.5	23.50	32.2	0.40	98.4	3.0	4.5	0.9	4.5	7.5
	587.5	24.71	30.9	0.43	99.3	3.2	4.7	1.1	4.7	7.8
	600.0	25.25	30.3	0.44	99.5	3.3	4.8	1.2	4.8	7.9
0.17	**137.5**	4.26	95.6	0.60	56.3	0.0	0.9	0.2	0.8	4.8
	162.5	5.26	85.1	0.52	61.9	0.1	1.1	0.3	1.0	4.9
	187.5	6.27	75.2	0.43	65.2	0.3	1.3	0.2	1.2	5.0
	212.5	7.17	69.2	0.40	68.6	0.4	1.4	0.3	1.4	5.1
	237.5	8.23	63.2	0.36	71.9	0.6	1.7	0.4	1.6	5.1
	262.5	9.32	57.4	0.31	73.9	0.8	1.8	0.3	1.9	5.2
	287.5	10.39	53.3	0.28	76.5	0.9	2.1	0.4	2.1	5.2
	312.5	11.50	49.6	0.25	78.8	1.1	2.3	0.3	2.3	5.3
	337.5	12.61	46.5	0.23	81.0	1.3	2.5	0.3	2.5	5.3
	362.5	13.58	44.9	0.24	84.3	1.5	2.7	0.6	2.7	5.5
	387.5	14.73	42.1	0.22	85.7	1.7	3.0	0.4	3.0	5.8
	412.5	15.88	39.9	0.23	87.6	1.9	3.2	0.4	3.2	6.1
	437.5	17.01	38.0	0.25	89.3	2.1	3.4	0.3	3.4	6.4
	462.5	18.18	36.6	0.28	92.0	2.3	3.7	0.2	3.7	6.7
	487.5	19.36	35.3	0.32	94.5	2.5	3.9	0.6	3.9	6.9
	512.5	20.36	34.1	0.35	96.0	2.7	4.1	0.6	4.1	7.2
	537.5	21.56	32.8	0.38	97.7	2.9	4.3	0.8	4.3	7.4
	562.5	22.76	31.5	0.42	99.1	3.1	4.6	1.0	4.6	7.7
	587.5	23.93	30.1	0.44	99.6	3.4	4.8	1.2	4.8	7.9
	600.0	24.45	29.5	0.46	99.7	3.5	4.9	1.4	4.9	8.0

Table 4h. Lookup table for basins with a bed slope of 0.1%

Q_o	**L_{co}**	**t_{co}**	**E_a**	**Du_{lq}**	**E_r**	**D_p**	**D_{av}**	**D_{min}**	**D_{app}**	**Y_{max}**
cfs/ft	**-**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.18	**137.5**	4.13	93.2	0.57	56.3	0.0	0.9	0.1	0.8	4.9
	162.5	5.09	82.8	0.49	61.7	0.2	1.1	0.2	1.1	5.0
	187.5	6.08	73.6	0.41	65.5	0.3	1.3	0.2	1.3	5.1
	212.5	6.95	67.3	0.38	68.4	0.4	1.5	0.2	1.5	5.2
	237.5	7.98	61.6	0.32	71.9	0.6	1.7	0.3	1.7	5.3
	262.5	9.03	55.7	0.27	73.6	0.8	1.9	0.2	1.9	5.3
	287.5	10.07	52.4	0.28	77.2	1.0	2.1	0.4	2.1	5.4
	312.5	11.14	48.7	0.25	79.4	1.2	2.3	0.4	2.4	5.4
	337.5	12.23	45.8	0.23	82.0	1.4	2.6	0.4	2.6	5.5
	362.5	13.17	43.5	0.22	83.8	1.6	2.8	0.3	2.8	5.6
	387.5	14.28	41.1	0.21	85.9	1.8	3.0	0.3	3.0	5.9
	412.5	15.40	39.7	0.25	89.5	2.0	3.3	0.6	3.3	6.2
	437.5	16.50	37.5	0.26	90.5	2.2	3.5	0.4	3.5	6.5
	462.5	17.63	36.0	0.30	92.9	2.4	3.8	0.3	3.8	6.8
	487.5	18.78	34.7	0.33	95.4	2.6	4.0	0.6	4.0	7.1
	512.5	19.76	33.5	0.37	96.9	2.8	4.2	0.7	4.2	7.3
	537.5	20.91	32.1	0.40	98.2	3.0	4.5	0.9	4.5	7.6
	562.5	22.08	30.8	0.43	99.5	3.3	4.7	1.1	4.7	7.8
	587.5	23.21	29.4	0.46	99.9	3.5	5.0	1.4	5.0	8.1
	600.0	23.73	28.8	0.47	100.0	3.6	5.1	1.5	5.1	8.2
0.19	**137.5**	4.00	93.3	0.57	57.6	0.0	0.9	0.2	0.9	5.0
	162.5	4.94	81.8	0.46	62.4	0.2	1.1	0.2	1.1	5.2
	187.5	5.90	72.7	0.40	66.3	0.3	1.3	0.2	1.3	5.3
	212.5	6.74	65.8	0.34	68.5	0.5	1.5	0.1	1.5	5.4
	237.5	7.74	60.7	0.32	72.6	0.7	1.7	0.3	1.7	5.4
	262.5	8.76	54.9	0.26	74.3	0.9	2.0	0.0	1.9	5.5
	287.5	9.77	51.7	0.28	78.0	1.0	2.2	0.5	2.2	5.6
	312.5	10.82	48.2	0.25	80.6	1.2	2.4	0.4	2.4	5.6
	337.5	11.87	45.2	0.23	82.9	1.4	2.7	0.4	2.7	5.7
	362.5	12.79	42.8	0.22	84.6	1.6	2.9	0.4	2.9	5.7
	387.5	13.87	40.4	0.22	86.6	1.8	3.1	0.3	3.1	6.0
	412.5	14.96	38.4	0.24	88.7	2.0	3.4	0.3	3.4	6.3
	437.5	16.03	37.0	0.28	91.6	2.2	3.6	0.5	3.6	6.6
	462.5	17.13	35.5	0.31	93.9	2.5	3.9	0.6	3.9	6.9
	487.5	18.25	34.1	0.35	96.1	2.7	4.1	0.6	4.1	7.2
	512.5	19.20	32.9	0.38	97.6	2.9	4.3	0.8	4.3	7.4
	537.5	20.31	31.5	0.41	98.8	3.1	4.6	1.0	4.6	7.7
	562.5	21.45	30.0	0.45	99.4	3.4	4.8	1.3	4.8	7.9
	587.5	22.56	28.6	0.47	99.7	3.6	5.1	1.5	5.1	8.2
	600.0	23.06	28.0	0.48	99.7	3.7	5.2	1.6	5.2	8.3

Table 4i. Lookup table for basins with a bed slope of 0.1%

Q_o	**L_{co}**	**t_{co}**	**E_a**	**Du_{lq}**	**E_r**	**D_p**	**D_{av}**	**D_{min}**	**D_{app}**	**Y_{max}**
cfs/ft	**-**	**Min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.20	**112.5**	3.02	101.9	0.63	50.0	0.0	0.7	0.1	0.7	5.0
	137.5	3.89	92.0	0.57	58.2	0.1	0.9	0.2	0.9	5.2
	162.5	4.80	80.1	0.45	62.5	0.2	1.1	0.1	1.1	5.3
	187.5	5.73	71.3	0.39	66.4	0.4	1.4	0.2	1.3	5.4
	212.5	6.55	65.0	0.34	69.2	0.5	1.5	0.1	1.5	5.5
	237.5	7.53	59.8	0.32	73.2	0.7	1.8	0.4	1.8	5.6
	262.5	8.52	55.0	0.29	76.2	0.9	2.0	0.4	2.0	5.7
	287.5	9.50	50.4	0.25	77.9	1.1	2.2	0.3	2.2	5.7
	312.5	10.52	47.0	0.23	80.4	1.3	2.5	0.3	2.5	5.8
	337.5	11.55	44.8	0.24	84.1	1.5	2.7	0.6	2.7	5.8
	362.5	12.44	42.2	0.22	85.4	1.7	2.9	0.4	2.9	5.9
	387.5	13.49	40.0	0.23	87.7	1.9	3.2	0.4	3.2	6.1
	412.5	14.55	37.9	0.25	89.7	2.1	3.4	0.3	3.4	6.4
	437.5	15.60	36.3	0.29	92.1	2.3	3.7	0.3	3.7	6.7
	462.5	16.66	35.0	0.33	94.8	2.5	3.9	0.5	3.9	7.0
	487.5	17.75	33.5	0.36	96.7	2.8	4.2	0.6	4.2	7.3
	512.5	18.68	32.3	0.40	98.1	3.0	4.4	0.9	4.4	7.5
	537.5	19.78	30.9	0.43	99.4	3.2	4.7	1.1	4.7	7.8
	562.5	20.88	29.4	0.46	99.8	3.5	5.0	1.4	5.0	8.1
	587.5	21.96	28.0	0.48	100.0	3.7	5.2	1.6	5.2	8.3
	600.0	22.45	27.4	0.50	100.0	3.9	5.3	1.7	5.3	8.5
0.21	**112.5**	2.94	104.0	0.66	52.2	0.0	0.7	0.2	0.7	5.1
	137.5	3.78	88.1	0.49	56.9	0.1	0.9	0.0	0.9	5.3
	162.5	4.67	78.8	0.43	62.8	0.2	1.2	0.1	1.1	5.4
	187.5	5.58	70.2	0.36	66.9	0.4	1.4	0.1	1.4	5.6
	212.5	6.38	64.3	0.34	70.0	0.5	1.6	0.2	1.6	5.6
	237.5	7.33	59.0	0.32	73.8	0.7	1.8	0.4	1.8	5.7
	262.5	8.29	53.7	0.28	76.0	0.9	2.0	0.3	2.0	5.8
	287.5	9.25	49.8	0.25	78.6	1.1	2.3	0.3	2.3	5.9
	312.5	10.24	46.4	0.23	81.1	1.3	2.5	0.3	2.5	5.9
	337.5	11.24	43.6	0.21	83.7	1.5	2.8	0.3	2.8	6.0
	362.5	12.11	41.3	0.21	85.4	1.7	3.0	0.2	3.0	6.0
	387.5	13.14	39.7	0.25	89.1	2.0	3.3	0.5	3.3	6.2
	412.5	14.17	37.4	0.26	90.5	2.2	3.5	0.4	3.5	6.5
	437.5	15.19	35.8	0.30	92.8	2.4	3.8	0.3	3.8	6.8
	462.5	16.24	34.4	0.34	95.4	2.6	4.0	0.5	4.0	7.1
	487.5	17.30	33.0	0.38	97.5	2.9	4.3	0.7	4.3	7.4
	512.5	18.20	31.8	0.41	98.8	3.1	4.5	1.0	4.5	7.6
	537.5	19.26	30.2	0.44	99.3	3.3	4.8	1.2	4.8	7.9
	562.5	20.35	28.7	0.47	99.7	3.6	5.1	1.5	5.1	8.2
	587.5	21.40	27.3	0.50	99.7	3.9	5.3	1.8	5.3	8.5
	600.0	21.86	26.7	0.51	99.7	4.0	5.5	1.9	5.5	8.6

Table 4j. Lookup table for basins with a bed slope of 0.1%

Q_o	L_{co}	t_{co}	E_a	Du_{lq}	E_r	D_p	D_{av}	D_{min}	D_{app}	Y_{max}
cfs/ft	**-**	**Min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.22	**112.5**	2.87	101.5	0.59	52.1	0.0	0.7	0.1	0.7	5.2
	137.5	3.68	88.6	0.49	58.3	0.1	1.0	0.1	0.9	5.4
	162.5	4.55	76.9	0.39	62.6	0.3	1.2	0.0	1.2	5.6
	187.5	5.43	68.7	0.36	66.7	0.4	1.4	0.1	1.4	5.7
	212.5	6.22	63.3	0.32	70.4	0.6	1.6	0.2	1.6	5.8
	237.5	7.14	57.6	0.29	73.6	0.8	1.9	0.2	1.8	5.9
	262.5	8.08	52.9	0.28	76.5	0.9	2.1	0.4	2.1	5.9
	287.5	9.02	49.0	0.25	79.1	1.2	2.3	0.4	2.3	6.0
	312.5	9.99	45.7	0.23	81.7	1.4	2.6	0.4	2.6	6.1
	337.5	10.96	43.0	0.21	84.3	1.6	2.8	0.3	2.8	6.1
	362.5	11.81	40.8	0.22	86.2	1.8	3.1	0.3	3.1	6.2
	387.5	12.81	38.6	0.23	88.4	2.0	3.3	0.2	3.3	6.3
	412.5	13.82	37.2	0.28	92.0	2.3	3.6	0.3	3.6	6.6
	437.5	14.82	35.5	0.32	94.1	2.5	3.9	0.6	3.9	6.9
	462.5	15.84	33.9	0.35	96.0	2.7	4.1	0.6	4.1	7.2
	487.5	16.86	32.5	0.39	98.0	3.0	4.4	0.8	4.4	7.5
	512.5	17.75	31.2	0.42	99.1	3.2	4.6	1.1	4.6	7.7
	537.5	18.80	29.6	0.45	99.5	3.4	4.9	1.3	4.9	8.0
	562.5	19.85	28.1	0.48	99.8	3.7	5.2	1.6	5.2	8.3
	587.5	20.88	26.7	0.51	99.8	4.0	5.5	1.9	5.5	8.6
	600.0	21.35	26.2	0.52	100.0	4.1	5.6	2.0	5.6	8.7
0.23	**112.5**	2.79	100.7	0.60	52.5	0.0	0.8	0.1	0.7	5.4
	137.5	3.59	87.5	0.50	58.7	0.1	1.0	0.1	0.9	5.6
	162.5	4.44	75.4	0.38	62.6	0.3	1.2	0.0	1.2	5.7
	187.5	5.30	68.4	0.37	67.8	0.4	1.4	0.2	1.4	5.8
	212.5	6.06	62.5	0.32	70.8	0.6	1.7	0.3	1.6	5.9
	237.5	6.97	56.1	0.27	73.1	0.8	1.9	0.2	1.9	6.0
	262.5	7.89	52.3	0.28	77.2	1.0	2.1	0.4	2.1	6.1
	287.5	8.80	48.5	0.25	79.8	1.2	2.4	0.4	2.4	6.2
	312.5	9.75	45.3	0.23	82.6	1.4	2.6	0.4	2.6	6.2
	337.5	10.70	42.5	0.22	85.0	1.6	2.9	0.4	2.9	6.3
	362.5	11.53	40.3	0.22	86.9	1.8	3.1	0.3	3.1	6.3
	387.5	12.51	38.1	0.24	89.1	2.1	3.4	0.3	3.4	6.4
	412.5	13.50	36.5	0.28	92.1	2.3	3.7	0.2	3.7	6.7
	437.5	14.47	35.0	0.33	94.7	2.5	3.9	0.5	3.9	7.0
	462.5	15.47	33.5	0.37	96.9	2.8	4.2	0.7	4.2	7.3
	487.5	16.47	32.0	0.40	98.6	3.0	4.5	0.9	4.5	7.6
	512.5	17.33	30.6	0.43	99.2	3.3	4.7	1.2	4.7	7.9
	537.5	18.36	29.1	0.46	99.9	3.5	5.0	1.4	5.0	8.1
	562.5	19.38	27.5	0.49	99.7	3.8	5.3	1.7	5.3	8.4
	587.5	20.40	26.2	0.52	99.9	4.1	5.6	2.0	5.6	8.7
	600.0	20.85	25.6	0.53	99.9	4.2	5.7	2.1	5.7	8.8

Table 4k. Lookup table for basins with a bed slope of 0.1%

Q_o	**L_{co}**	**t_{co}**	**E_a**	**Du_{lq}**	**E_r**	**D_p**	**D_{av}**	**D_{min}**	**D_{app}**	**Y_{max}**
cfs/ft	**-**	**min**	**%**	**%**	**%**	**in**	**in**	**in**	**in**	**in**
0.24	**112.5**	2.73	97.0	0.53	51.7	0.0	0.7	0.0	0.7	5.5
	137.5	3.51	85.7	0.46	58.4	0.1	1.0	0.0	1.0	5.7
	162.5	4.33	74.9	0.37	63.3	0.3	1.2	0.0	1.2	5.8
	187.5	5.18	66.9	0.34	67.6	0.5	1.5	0.1	1.4	6.0
	212.5	5.92	61.9	0.32	71.5	0.6	1.7	0.3	1.7	6.1
	237.5	6.81	56.4	0.29	84.9	0.8	1.9	0.3	1.9	6.2
	262.5	7.71	51.0	0.23	96.7	1.1	2.2	0.0	2.2	6.2
	287.5	8.60	48.7	0.26	81.7	1.3	2.5	0.5	2.4	6.3
	312.5	9.53	45.1	0.26	83.9	1.5	2.7	0.5	2.7	6.4
	337.5	10.46	42.3	0.23	86.3	1.7	3.0	0.5	3.0	6.4
	362.5	11.27	39.9	0.23	87.7	1.9	3.2	0.4	3.2	6.5
	387.5	12.23	37.7	0.26	90.0	2.1	3.5	0.3	3.5	6.5
	412.5	13.19	35.9	0.29	92.4	2.4	3.7	0.3	3.7	6.8
	437.5	14.14	34.5	0.34	95.2	2.6	4.0	0.5	4.0	7.1
	462.5	15.12	33.0	0.38	97.4	2.9	4.3	0.7	4.3	7.4
	487.5	16.10	31.5	0.42	99.0	3.1	4.6	1.0	4.6	7.7
	512.5	16.95	30.1	0.44	99.6	3.4	4.8	1.2	4.8	8.0
	537.5	17.95	28.5	0.47	99.8	3.6	5.1	1.5	5.1	8.2
	562.5	18.96	27.0	0.50	99.9	3.9	5.4	1.8	5.4	8.5
	600.0	20.38	2.5	0.54	100.0	4.3	5.8	2.2	5.8	9.0
0.25	**112.5**	2.67	98.6	0.56	53.5	0.0	0.8	0.1	0.8	5.6
	137.5	3.43	85.6	0.47	59.7	0.1	1.0	0.1	1.0	5.8
	162.5	4.24	74.1	0.39	63.9	0.3	1.2	0.0	1.2	5.9
	187.5	5.06	65.6	0.32	67.5	0.5	1.5	0.0	1.5	6.1
	212.5	5.79	61.2	0.32	72.0	0.7	1.7	0.3	1.7	6.2
	237.5	6.66	55.6	0.29	75.03	0.9	2.0	0.3	1.9	6.3
	262.5	7.54	51.2	0.26	78.5	1.1	2.2	0.4	2.2	6.4
	287.5	8.41	47.0	0.23	80.3	1.3	2.5	0.3	2.5	6.4
	312.5	9.32	43.8	0.21	83.0	1.5	2.7	0.3	2.7	6.5
	337.5	10.23	41.2	0.21	85.7	1.8	3.0	0.2	3.0	6.6
	362.5	11.02	39.7	0.24	88.9	2.0	3.3	0.5	3.3	6.6
	387.5	11.96	37.3	0.26	90.7	2.2	3.5	0.4	3.5	6.7
	412.5	12.90	35.6	0.30	93.3	2.4	3.8	0.3	3.8	6.9
	437.5	13.84	34.1	0.35	95.9	2.7	4.1	0.5	4.1	7.2
	462.5	14.79	32.6	0.39	98.0	2.9	4.4	0.8	4.4	7.5
	487.5	15.75	31.0	0.43	99.2	3.2	4.7	1.1	4.7	7.8
	512.5	16.59	29.6	0.45	99.8	3.5	4.9	1.3	4.9	8.1
	537.5	17.56	28.0	0.48	99.9	3.7	5.2	1.6	5.2	8.4
	562.5	18.55	26.5	0.51	99.9	4.0	5.5	1.9	5.5	8.7
	587.5	19.51	25.2	0.54	99.9	4.3	5.8	2.2	5.8	8.9
	600.0	19.95	24.6	0.55	99.9	4.5	5.9	2.3	5.9	9.1

Table 5. Power-law advance parameters

Unit inlet flow rate (cfs/ft)	Level basin		1% bed slope	
	∀ (min/ft$^{(}$)[10]	((-)	∀ (min/ft$^{(}$)	((-)
0.04	0.0231	1.2502	0.0382	1.1339
0.05	0.0204	1.2474	0.0318	1.1429
0.06	0.0183	1.2465	0.0143	1.2465
0.07	0.0217	1.2045	0.0251	1.1509
0.08	0.0155	1.2448	0.0222	1.1594
0.09	0.0144	1.2449	0.0204	1.1625
0.10	0.0133	1.2474	0.0204	1.1537
0.11	0.0126	1.2472	0.0178	1.1672
0.12	0.0119	1.2472	0.0163	1.1739
0.13	0.0114	1.2470	0.0154	1.1761
0.14	0.0107	1.2505	0.0146	1.1778
0.15	0.0101	1.2532	0.0139	1.1798
0.16	0.0099	1.2503	0.0133	1.1809
0.17	0.0095	1.2501	0.0128	1.1826
0.18	0.0092	1.2504	0.0123	1.1836
0.19	0.0089	1.2500	0.0118	1.1854
0.20	0.0088	1.2475	0.0110	1.1925
0.21	0.0086	1.2466	0.0107	1.1934
0.22	0.0084	1.2468	0.0104	1.1944
0.23	0.0081	1.2474	0.0100	1.1960
0.24	0.0079	1.2476	0.0099	1.1942
0.25	0.0078	1.2470	0.0095	1.1968

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[10] $t_a = \forall x^{(}$, where t_a = advance time (min), x = advance distance (ft), ∀ and (= coefficient and exponent of the power function, respectively.

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