posed by the two governing equations (e.g., sediment transport and flow resistance). Chang (1988) combined sediment transport and flow resistance formulas with flow continuity and minimization of stream power at each cross section and through a reach to generate a numerical model of flow and sediment transport. Special relationships for flow and transverse sediment transport in bends were also derived. The model was used to make repeated computations of channel geometry with various values for input variables. Results of the analysis were used to construct a family of design curves that yield d (bankfull depth) and w (bankfull width), given bankfull Q, S, and D_{50}. Separate sets of curves are provided for sand and gravel bed rivers. Regime-type formulas have been fit to the curves, as shown in **Table 8.3.** These relationships should be used with tractive stress analyses to develop converging data that increase the designer's confidence that the appropriate channel dimensions have been selected.

Subsequent work by Thorne et al. (1988) modified these formulas to account for effects of bank vegetation along gravel-bed rivers. The Thorne et al. (1988) formulas in Table 8.3 are based on the data presented by Hey and Thorne (1986) in Table 7.6.

Channels with Moving Beds and Known Sediment Concentration

White et al. (1982) present an analytical approach based on the Ackers and White sediment transport function, a companion flow resistance relationship, and maximization of sediment transport for a specified sediment concentration. Tables (White et al. 1981) are available to assist users in implementing this procedure. The tables contain entries for sediment sizes from 0.06 to 100 millimeters, discharges up to 35,000 cubic feet per second, and sedi-

Table 8.3: Equations for river width and depth.

Author	Year	Data	Domain	k_1	k_2	k_4	k_5
Chang	1988		Meandering or braided sand-bed rivers with:				
		Equiwidth point-bar streams and stable canals	$0.00238 < SD_{50}^{-0.5}\,Q^{-0.51}$ and $SD_{50}^{-0.5}\,Q^{-0.55} < 0.05$	$3.49k_1$*		$3.51k_4$*	0.47
		Straight braided streams	$0.05 < SD_{50}^{-0.5}\,Q^{-0.55}$ and $SD_{50}^{-0.5}\,Q^{-0.51} < 0.047$	Unknown and unusual			
		Braided point-bar and wide-bend point-bar streams; beyond upper limit lie steep, braided streams	$0.047 < SD_{50}^{-0.5}\,Q^{-0.51} <$ indefinite upper limit	$33.2k_1$**	0.93	$1.0k_4$**	0.45
Thorne et al.	1988	Same as for Thorne and Hey 1986	Gravel-bed rivers	$1.905 + k_1$***	0.47	$0.2077 + k_4$***	0.42
		Adjustments for bank vegetation[a]	Grassy banks with no trees or shrubs	$w = 1.46\,w_c - 0.8317$		$d = 0.8815\,d_c + 0.2106$	
			1-5% tree and shrub cover	$w = 1.306\,w_c - 8.7307$		$d = 0.5026\,d_c + 1.7553$	
			5-50% tree and shrub cover	$w = 1.161\,w_c - 16.8307$		$d = 0.5413\,d_c + 2.7159$	
			Greater than 50% tree and shrub cover, or incised into flood plain	$w = 0.9656\,w_c - 10.6102$		$d = 0.7648\,d_c + 1.4554$	

Chang equations for determining river width and depth. Coefficients for equations of the form $w = k_1 Q^{K_2}$; $d = K_4 Q^{K5}$; where w is mean bankfull width (ft), Q is the bankfull or dominant discharge ($ft^3/_s$), d is mean bankfull depth (ft), D_{50} is median bed-material size (mm), and S is slope (ft/ft).

[a] w_c and d_c in these equations are calculated using exponents and coefficients from the row labeled "gravel-bed rivers".

$k_1* = (S\,D_{50}^{-0.5} - 0.00238Q^{-0.51})^{0.02}$.

$k_4* = \exp[-0.38\,(420.17S\,D_{50}^{-0.5}Q^{-0.51} - 1)^{0.4}]$.

$k_1** = (S\,D_{50}^{-0.5})^{0.84}$.

$k_4** = 0.015 - 0.025\,\ln Q - 0.049\,\ln(S\,D_{50}^{-0.5})$.

$k_1*** = 0.2490[\ln(0.0010647D_{50}^{1.15}/SQ^{0.42})]^2$.

$k_4*** = 0.0418\,\ln(0.0004419D_{50}^{1.15}/SQ^{0.42})$.