and is the downstream direction), which reduces the river's ability to transport the coarser fraction of the sediment load, resulting in deposition. Selective deposition can occur through loss of competency (i.e., the river's inability to mobilize certain particles because they are too large) [., 1992a] or loss of capacity (i.e., the river's inability to transport the supplied sediment load) [, 1991; , 1994]. Modeling the loss of capacity while coupling bed load, suspended load, and wash load is not straightforward [, 2014], and wash load in particular depends on the sediment supply, which is dif cult to constrain. Although it is likely an oversimpli cation, here we model downstream ning by loss of competency because ning can be predicted as a simple function of bed shear stress and transport thresholds. Following . [1992a], we assume that downstream ning occurs due to deposition of the coarsest fraction of the sediment load where bed shear stresses fall below the threshold of motion for that size class.

The threshold for sediment motion is typically formulated as a critical Shields number (τ^{*}) that is a function of particle Reynolds number ( ) [, 1936],

$$\tau^{*} = \frac{\quad^{2}}{\quad} \tag{1}$$

$$= \frac{(\quad)^{1/2}}{\nu} \tag{2}$$

in which $= \sqrt{\tau/\rho}$ is bed shear velocity, ρ is uid density,

[1990], and $_{90}$/ $_{50}$ = 3, which is typical of gravel-bedded rivers and consistent with our data compilation in section 3.

Finally, given that most riverbed grain-size distributions can be t with a lognormal distribution, we calculate $_{50}$ as the geometric mean of the two predicted bounds on the bed-material grain-size distribution (i.e., $_{90}$ and $_{10}$). We make no assumption about the transport stage of $_{50}$ at bankfull, except that implicitly it must be above the threshold of motion (since that is set for $_{90}$) and below the threshold of wash load (which is set for $_{10}$). Importantly, we set all parameters such as and γ to be constants for all sediment sizes such that we make no explicit distinctions in bed forms, form drag, or sorting between sand and gravel, or any other size classes that could in uence the emergence of a grain size gap. Model sensitivity to these parameters is discussed in section 5.

3. Data Compilation

We use the compiled bed grain-size distributions and bankfull measurements of formative bed shear velocity as for a worldwide compilation of rivers [., 2014] (Figure 1b). We also compare the model against several rivers in Western Canada that cross the grain size gap (Figure 1a). In the Fraser River, B.C., we use observations of bed shear stress reported in [2014] for bankfull ow in the gravel and sand bed reaches, which have been shown to entrain the gravel bed surface and move sand as wash load in the gravel reach [., 1999]. For the Alberta rivers, we require a continuous downstream pro le of total boundary shear stress to estimate the shear velocity at the bed-material sampling sites (Figure 1a). . [1972] reported shear stress for 2 year and 5 year return interval ood ows (= 36) at discharge gauging stations in each river system shown in Figure 1a, and less frequently for the 10 year and bankfull ood ows. In these formerly glaciated drainage basins, reported bankfull ows have return periods of 2.5 (1 site), ~10 (5 sites), ~25 (2 sites) and 100 (7 sites) years. We elected to use exponential ts to 5 year return interval shear stress and downstream distance to provide continuous downstream pro les of shear stress, which could be matched to bed-material samples.

4. Results

β as large as 8. A smaller hiding coef cient, γ

References

Bagnold, R. A. (1966), An approach to the sediment transport problem from general physics, 37 pp., U.S. Geological Survey Professional Paper, *422-* Washington, D. C.

Bennett, S. J., J. S. Bridge, and J. L. Best (1998), Fluid and sediment dynamics of upper stage plane beds, ., *103*(C1), 1239–1274, doi:10.1029/97JC02764.

Bridge, J. S. (2003), , , , 491 pp., Wiley-Blackwell, Oxford.

Brownlie, W. R. (1983), Flow depth in sand-bed channels, . , (7), 959–990.

Cui, Y. T., and G. Parker (1998), The arrested gravel front: Stable gravel-sand transitions in rivers - Part 2: General numerical solution, . ., *36*(2), 159–182.

Einstein, H. A. (1950), The bedload function for bedload transportation in open channel ows, 71 pp., U.S.D.A. Soil Conservation Service Report, Technical Bulletin 1026.

Einstein, H. A. (1968), Deposition of suspended particles in a gravel bed, . . *4*(5), 1197–1205.

Ferguson, R. I. (2003), Emergence of abrupt gravel to sand transitions along rivers through sorting processes, , *31*(2), 159–162, doi:10.1130/0091-7613(2003)031 0159:eoagts 2.0.co;2.

Ferguson, R. I., and M. Church (2004), A simple universal equation for grain settling velocity, . ., *74*(6), 933–937, doi:10.1306/051204740933.

Ferguson, R., and M. Church (2009), A critical perspective on 1-D modeling of river processes: Gravel load and aggradation in lower Fraser River, ., *45*, W11424, doi:10.1029/2009WR007740.

Ferguson, R. I., T. B. Hoey, S. J. Wathen, A. Werritty, R. I. Hardwick, and G. H. Sambrook Smith (1998), Downstream ning of river gravels: integrated eld, laboratory and modeling study, in - , edited by P. C. Klingman et al., pp. 85–114, Water Resources Publications, Highlands Ranch, Colo.

Garcia, M. H. (2008), , , , , , vol. 110, 1132 pp., American Society of Civil Engineers, Reston, Va.

Grams, P. E., and P. R. Wilcock (2014), Transport of ne sediment over a coarse, immobile riverbed, ..., , 188–211, doi:10.1002/2013jf002925.

Grotzinger, J. P., A. G. Hayes, M. P. Lamb, and S. M. McLennan (2013), Sedimentary processes on Earth, Mars, Titan and Venus, in , 47210, 22 Arizona, oce bye

Scheingross, J. S., F. Brun, D. Y. Lo, K. Omerdin, and M. P. Lamb (2014), Experimental evidence for uvial bedrock incision by suspended and bedload sediment, , *42*(6), 523–526, doi:10.1130/g35432.1.

Seal, R., C. Paola, G. Parker, J. B. Southard, and P. R. Wilcock (1997), Experiments on downstream ning of gravel. 1. Narrow-channel runs, . . . , *123*(10), 874–884, doi:10.1061/(asce)0733-9429(1997)123:10(874).

Shaw, J., and R. Kellerhals (1982), The composition of recent alluvial gravels in alberta river beds, . . ., *41*, 151.

Shields, A. (1936), Anwendung der Ähnlichkeitsmechanik auf die Geschiebebewegung: Berlin, Preussische Versuchanstalt für Wasserbau und Schiffbau, Mitteilungen, *26*, 25 p.

Sternberg, H. (1875), Untersuchungen über längen- und querpro l geschiebeführender üss, . , *25*, 483–506.

Sundborg, A. (1956), The River Klarålven: Chapter 2. The morphological activity of owing water—erosion of the stream bed, . ., *3* , 165–221.

Toro-Escobar, C. M., C. Paola, G. Parker, P. R. Wilcock, and J. B. Southard (2000), Experiments on downstream ning of gravel. Ii: Wide and sandy runs, . . . , *126*(3), 198–208, doi:10.1061/(asce)0733-9429(2000)126:3(198).

Trampush, S. M., S. Huzurbazar, and B. McElroy (2014), Emperical assesment of theory for bankfull characterisitics of alluvial channels, . ., *50*, 9211–9220, doi:10.1002/2014WR015597.

Udden, J. A. (1914), Mechanical composition of clastic sediments, ..., *25*, 655–744, doi:10.1130/GSAB-25-655.

van Rijn, L. C. (1984), Sediment transport, Part II: Suspended load transport, . . ., *110*, 1613–1641.

Venditti, J. G., and M. Church (2014), Morphology and controls on the position of a gravel-sand transition: Fraser River, British Columbia, ..., , 1959–1976, doi:10.1002/2014JF003147.