

# Hydraulic resistance in open-channel flows over self-affine rough beds

## Supplementary data

### Hydraulic conditions covered during experiments

Table S1 Summary of hydraulic conditions in the AOCF flume (for R1 and  $S = 0.1\%$ )

$S^{\dagger\dagger}$ (-)	$H$ (mm)	$U$ (ms <sup>-1</sup> )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
1.1E-03	29.7	0.138	39.7	5.0	0.26	93	0.132	0.126
1.0E-03	34.5	0.155	34.2	5.8	0.27	98	0.117	0.111
1.0E-03	39.9	0.172	29.6	6.7	0.27	103	0.106	0.099
1.0E-03	49.5	0.207	23.9	8.2	0.30	117	0.094	0.086
9.6E-04	59.7	0.232	19.8	9.9	0.30	123	0.083	0.076
9.8E-04	69.8	0.264	16.9	11.6	0.32	135	0.077	0.069
9.7E-04	79.5	0.290	14.8	13.2	0.33	143	0.072	0.063
1.0E-03	89.8	0.325	13.1	15.0	0.35	155	0.067	0.058
1.0E-03	99.4	0.351	11.9	16.6	0.36	164	0.064	0.055
1.0E-03	109.6	0.375	10.8	18.3	0.36	170	0.061	0.051
1.0E-03	119.7	0.401	9.9	19.9	0.37	178	0.059	0.049
9.9E-04	140.1	0.447	8.4	23.3	0.38	192	0.055	0.044
1.0E-03	159.8	0.494	7.4	26.6	0.39	207	0.052	0.041

$\dagger\dagger$   $S$  is the mean water surface slope;  $H$  is the mean flow depth;  $U=Q/BH$  is the bulk velocity,  $Q$  is the volumetric flowrate and  $B$  is the flume width;  $B/H$  is the aspect ratio;  $H/\Delta$  is the relative submergence and  $\Delta=4\sigma_z$  is the roughness height;  $F=U/(gH)^{0.5}$  is the Froude number and  $g=9.81$  (ms<sup>-2</sup>) is the acceleration due to gravity;  $\Delta^+=\Delta u_* / \nu$  is the roughness Reynolds number,  $\nu$  is the kinematic viscosity and  $u_*=(gSH)^{0.5}$  is the shear velocity;  $f_H=8gHS/U^2$ ;  $f_R=8gRS/U^2$  where  $R=BH/(B+2H)$  is the hydraulic radius.

Table S2 Summary of hydraulic conditions in the AOCF flume (for R1 and  $S = 0.2\%$ )

$S$ (-)	$H$ (mm)	$U$ ( $\text{ms}^{-1}$ )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
2.0E-03	25.2	0.161	46.9	4.2	0.32	117	0.154	0.147
2.1E-03	30.0	0.190	39.4	5.0	0.35	129	0.135	0.129
2.0E-03	35.1	0.217	33.6	5.8	0.37	139	0.119	0.113
2.0E-03	40.0	0.241	29.5	6.7	0.38	147	0.109	0.102
2.0E-03	49.8	0.289	23.7	8.3	0.41	163	0.094	0.086
2.0E-03	59.7	0.333	19.8	10.0	0.43	178	0.084	0.077
2.0E-03	70.0	0.376	16.9	11.7	0.45	193	0.077	0.069
2.0E-03	79.6	0.416	14.8	13.3	0.47	206	0.072	0.063
2.0E-03	89.5	0.455	13.2	14.9	0.49	218	0.068	0.059
2.0E-03	99.1	0.494	11.9	16.5	0.50	231	0.064	0.055
2.0E-03	110.0	0.530	10.7	18.3	0.51	241	0.061	0.051
2.0E-03	119.3	0.567	9.9	19.9	0.52	253	0.059	0.049
2.0E-03	139.4	0.633	8.5	23.2	0.54	273	0.055	0.045

Table S3 Summary of hydraulic conditions in the AOCF flume (for R1 and  $S = 0.3\%$ )

$S$ (-)	$H$ (mm)	$U$ ( $\text{ms}^{-1}$ )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
3.0E-03	19.6	0.157	60.1	3.3	0.36	125	0.189	0.183
3.0E-03	24.1	0.191	48.9	4.0	0.39	137	0.156	0.149
3.0E-03	28.7	0.224	41.2	4.8	0.42	151	0.136	0.130
3.0E-03	33.6	0.259	35.1	5.6	0.45	163	0.120	0.114
3.0E-03	38.8	0.293	30.4	6.5	0.47	176	0.108	0.101
3.0E-03	49.5	0.351	23.9	8.2	0.50	198	0.095	0.088
3.0E-03	59.0	0.404	20.0	9.8	0.53	216	0.086	0.078
3.0E-03	69.2	0.456	17.1	11.5	0.55	232	0.078	0.070
3.0E-03	79.2	0.506	14.9	13.2	0.57	249	0.073	0.064
3.0E-03	89.2	0.557	13.2	14.9	0.60	266	0.069	0.060
3.0E-03	99.7	0.603	11.8	16.6	0.61	278	0.064	0.055
3.0E-03	109.7	0.647	10.8	18.3	0.62	293	0.062	0.052
3.0E-03	119.5	0.689	9.9	19.9	0.64	305	0.059	0.049

Table S4 Summary of hydraulic conditions in the AOCF flume (for R2 and  $S = 0.1\%$ )

$S$ (-)	$H$ (mm)	$U$ (ms <sup>-1</sup> )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
1.0E-03	30.0	0.146	39.3	5.0	0.27	91	0.115	0.110
1.0E-03	34.7	0.163	34.0	5.8	0.28	97	0.105	0.099
1.0E-03	39.8	0.181	29.6	6.6	0.29	104	0.099	0.093
1.0E-03	49.9	0.214	23.6	8.3	0.31	116	0.088	0.081
1.0E-03	59.5	0.246	19.8	9.9	0.32	127	0.079	0.072
9.9E-04	70.3	0.276	16.8	11.7	0.33	135	0.072	0.064
1.0E-03	79.7	0.310	14.8	13.3	0.35	147	0.068	0.060
1.0E-03	89.4	0.337	13.2	14.9	0.36	156	0.064	0.056
1.0E-03	99.8	0.362	11.8	16.6	0.37	163	0.061	0.052
1.0E-03	110.3	0.390	10.7	18.4	0.37	171	0.058	0.049
1.0E-03	119.8	0.413	9.8	20.0	0.38	178	0.056	0.047
1.0E-03	140.4	0.461	8.4	23.4	0.39	193	0.053	0.043
1.0E-03	160.4	0.506	7.4	26.7	0.40	207	0.051	0.040

Table S5 Summary of hydraulic conditions in the AOCF flume (for R2 and  $S = 0.2\%$ )

$S$ (-)	$H$ (mm)	$U$ (ms <sup>-1</sup> )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
2.0E-03	25.6	0.174	46.1	4.3	0.35	114	0.130	0.125
2.0E-03	30.5	0.204	38.7	5.1	0.37	126	0.116	0.110
2.0E-03	35.2	0.228	33.5	5.9	0.39	134	0.107	0.101
2.0E-03	39.9	0.251	29.6	6.6	0.40	143	0.099	0.093
2.0E-03	49.4	0.298	23.9	8.2	0.43	160	0.088	0.081
2.0E-03	59.4	0.343	19.9	9.9	0.45	175	0.079	0.072
2.0E-03	69.7	0.386	16.9	11.6	0.47	192	0.073	0.065
2.0E-03	79.7	0.426	14.8	13.3	0.48	204	0.068	0.060
2.0E-03	89.6	0.469	13.2	14.9	0.50	219	0.064	0.056
2.0E-03	99.5	0.508	11.9	16.6	0.51	231	0.061	0.052
2.0E-03	109.8	0.543	10.7	18.3	0.52	241	0.058	0.049
2.0E-03	119.9	0.581	9.8	20.0	0.54	252	0.056	0.047
2.0E-03	140.7	0.646	8.4	23.4	0.55	271	0.052	0.042

Table S6 Summary of hydraulic conditions in the AOCF flume (for R2 and  $S = 0.3\%$ )

$S$ (-)	$H$ (mm)	$U$ (ms <sup>-1</sup> )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
3.0E-03	20.0	0.176	59.0	3.3	0.40	126	0.154	0.149
3.0E-03	24.3	0.206	48.6	4.0	0.42	138	0.134	0.128
3.0E-03	29.3	0.243	40.2	4.9	0.45	153	0.118	0.112
3.0E-03	34.2	0.276	34.5	5.7	0.48	165	0.106	0.101
3.0E-03	39.0	0.307	30.2	6.5	0.50	176	0.098	0.092
3.0E-03	49.6	0.363	23.8	8.3	0.52	197	0.088	0.081
3.0E-03	59.3	0.414	19.9	9.9	0.54	218	0.081	0.074
3.0E-03	69.0	0.466	17.1	11.5	0.57	234	0.074	0.066
3.0E-03	79.4	0.520	14.9	13.2	0.59	252	0.069	0.061
3.0E-03	89.5	0.572	13.2	14.9	0.61	269	0.065	0.056
3.0E-03	99.8	0.619	11.8	16.6	0.63	283	0.061	0.052
3.1E-03	109.9	0.667	10.7	18.3	0.64	299	0.059	0.050
3.0E-03	120.3	0.711	9.8	20.1	0.65	312	0.056	0.047

Table S7 Summary of hydraulic conditions in the AOCF flume (for R3 and  $S = 0.1\%$ )

$S$ (-)	$H$ (mm)	$U$ (ms <sup>-1</sup> )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
1.0E-03	29.9	0.161	39.4	5.0	0.30	90	0.091	0.087
1.0E-03	34.5	0.180	34.2	5.8	0.31	97	0.084	0.080
1.0E-03	39.4	0.201	30.0	6.6	0.32	104	0.078	0.073
1.0E-03	49.5	0.239	23.9	8.2	0.34	116	0.069	0.064
9.8E-04	59.7	0.272	19.8	10.0	0.36	125	0.062	0.056
1.0E-03	69.8	0.311	16.9	11.6	0.38	138	0.058	0.052
1.0E-03	79.6	0.342	14.8	13.3	0.39	147	0.055	0.048
1.0E-03	89.0	0.371	13.3	14.8	0.40	156	0.052	0.045
1.0E-03	99.1	0.398	11.9	16.5	0.40	163	0.050	0.043
1.0E-03	108.8	0.428	10.8	18.1	0.41	172	0.048	0.041
1.0E-03	119.4	0.456	9.9	19.9	0.42	180	0.046	0.038
1.0E-03	139.7	0.503	8.4	23.3	0.43	193	0.044	0.035
1.0E-03	159.8	0.552	7.4	26.6	0.44	208	0.042	0.033

Table S8 Summary of hydraulic conditions in the AOCF flume (for R3 and  $S = 0.2\%$ )

$S$ (-)	$H$ (mm)	$U$ ( $\text{ms}^{-1}$ )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
2.0E-03	25.6	0.204	46.0	4.3	0.41	119	0.097	0.093
2.0E-03	30.2	0.232	39.0	5.0	0.43	128	0.088	0.084
2.0E-03	35.2	0.263	33.5	5.9	0.45	139	0.081	0.076
2.0E-03	40.0	0.288	29.5	6.7	0.46	147	0.076	0.071
2.0E-03	50.0	0.341	23.6	8.3	0.49	166	0.068	0.063
2.0E-03	59.4	0.389	19.9	9.9	0.51	178	0.061	0.055
2.0E-03	69.5	0.438	17.0	11.6	0.53	193	0.057	0.051
2.0E-03	79.0	0.484	14.9	13.2	0.55	208	0.054	0.047
2.0E-03	89.4	0.528	13.2	14.9	0.56	220	0.051	0.044
2.0E-03	99.6	0.567	11.8	16.6	0.57	231	0.049	0.042
2.0E-03	109.3	0.606	10.8	18.2	0.59	242	0.047	0.040
2.0E-03	119.6	0.645	9.9	19.9	0.60	256	0.046	0.038

Table S9 Summary of hydraulic conditions in the AOCF flume (for R3 and  $S = 0.3\%$ )

$S$ (-)	$H$ (mm)	$U$ ( $\text{ms}^{-1}$ )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
3.0E-03	18.9	0.193	62.5	3.1	0.45	126	0.120	0.116
3.0E-03	23.7	0.240	49.8	3.9	0.50	141	0.097	0.093
3.0E-03	29.2	0.280	40.5	4.9	0.52	157	0.088	0.084
3.0E-03	34.3	0.317	34.4	5.7	0.55	169	0.080	0.076
3.0E-03	39.3	0.350	30.0	6.5	0.56	181	0.075	0.070
3.0E-03	49.2	0.413	24.0	8.2	0.60	202	0.067	0.062
3.0E-03	59.2	0.480	19.9	9.9	0.63	222	0.060	0.055
3.0E-03	69.2	0.538	17.1	11.5	0.65	239	0.056	0.050
3.0E-03	79.2	0.594	14.9	13.2	0.67	255	0.052	0.046
3.0E-03	89.3	0.649	13.2	14.9	0.69	273	0.050	0.044
3.0E-03	99.5	0.700	11.9	16.6	0.71	287	0.048	0.041
3.0E-03	109.6	0.748	10.8	18.3	0.72	300	0.046	0.039
3.0E-03	119.2	0.791	9.9	19.9	0.73	311	0.045	0.037

Table S10 Summary of hydraulic conditions in the RS flume (for R1 and  $S = 0.1\%$ )

$S$ (-)	$H$ (mm)	$U$ (ms <sup>-1</sup> )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
9.3E-04	35.9	0.146	11.1	6.0	0.25	102	0.122	0.103
9.6E-04	40.1	0.165	10.0	6.7	0.26	109	0.110	0.092
9.2E-04	45.5	0.181	8.8	7.6	0.27	114	0.100	0.082
9.3E-04	50.5	0.198	7.9	8.4	0.28	121	0.094	0.075
9.5E-04	55.5	0.215	7.2	9.3	0.29	128	0.090	0.071
9.3E-04	60.5	0.230	6.6	10.1	0.30	132	0.084	0.064
9.3E-04	66.0	0.241	6.1	11.0	0.30	137	0.083	0.062
8.9E-04	70.0	0.251	5.7	11.7	0.30	139	0.077	0.057
8.6E-04	75.4	0.263	5.3	12.6	0.31	141	0.074	0.053
8.5E-04	80.9	0.271	4.9	13.5	0.30	146	0.073	0.052
8.6E-04	86.3	0.289	4.6	14.4	0.31	151	0.070	0.049
8.6E-04	90.2	0.292	4.4	15.0	0.31	154	0.071	0.049
8.6E-04	95.0	0.310	4.2	15.8	0.32	158	0.067	0.045
9.6E-04	100.6	0.335	4.0	16.8	0.34	172	0.067	0.045
9.3E-04	105.0	0.340	3.8	17.5	0.34	173	0.066	0.043
8.6E-04	110.4	0.339	3.6	18.4	0.33	170	0.065	0.042
8.5E-04	115.6	0.353	3.5	19.3	0.33	173	0.062	0.039
8.6E-04	119.9	0.357	3.3	20.0	0.33	177	0.064	0.040

Table S11 Summary of hydraulic conditions in the RS flume (for R1 and  $S = 0.2\%$ )

$S$ (-)	$H$ (mm)	$U$ (ms <sup>-1</sup> )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
1.9E-03	30.7	0.181	13.0	5.1	0.33	128	0.136	0.118
1.9E-03	35.6	0.207	11.2	5.9	0.35	139	0.124	0.105
1.9E-03	40.4	0.233	9.9	6.7	0.37	148	0.111	0.092
1.9E-03	45.9	0.260	8.7	7.6	0.39	163	0.103	0.084
1.9E-03	50.8	0.283	7.9	8.5	0.40	167	0.096	0.077
1.9E-03	55.6	0.302	7.2	9.3	0.41	178	0.092	0.072
1.9E-03	60.4	0.323	6.6	10.1	0.42	180	0.086	0.066
1.9E-03	65.9	0.342	6.1	11.0	0.43	194	0.083	0.063
1.9E-03	70.8	0.369	5.7	11.8	0.44	196	0.078	0.058
1.9E-03	75.8	0.382	5.3	12.6	0.44	207	0.077	0.056
1.9E-03	80.8	0.400	4.9	13.5	0.45	207	0.074	0.053
1.9E-03	86.5	0.420	4.6	14.4	0.46	225	0.074	0.052
1.8E-03	90.9	0.431	4.4	15.2	0.46	217	0.071	0.049
2.0E-03	96.0	0.461	4.2	16.0	0.48	237	0.069	0.047
1.9E-03	100.7	0.471	4.0	16.8	0.47	238	0.067	0.045

Table S12 Summary of hydraulic conditions in the RS flume (for R1 and  $S = 0.3\%$ )

$S$ (-)	$H$ (mm)	$U$ (ms <sup>-1</sup> )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
2.9E-03	26.0	0.199	15.4	4.3	0.39	151	0.148	0.131
2.9E-03	30.5	0.223	13.1	5.1	0.41	164	0.139	0.120
2.9E-03	35.6	0.257	11.2	5.9	0.44	178	0.122	0.104
2.9E-03	40.7	0.287	9.8	6.8	0.45	192	0.115	0.095
3.0E-03	45.7	0.322	8.8	7.6	0.48	203	0.102	0.083
2.9E-03	50.8	0.346	7.9	8.5	0.49	211	0.096	0.077
2.9E-03	55.8	0.375	7.2	9.3	0.51	221	0.090	0.070
2.9E-03	61.3	0.401	6.5	10.2	0.52	232	0.087	0.066
2.9E-03	66.3	0.423	6.0	11.1	0.52	242	0.085	0.064
2.9E-03	71.0	0.450	5.6	11.8	0.54	250	0.081	0.060
3.0E-03	76.1	0.477	5.3	12.7	0.55	261	0.078	0.056
3.0E-03	80.6	0.501	5.0	13.4	0.56	268	0.075	0.053
3.0E-03	86.6	0.529	4.6	14.4	0.57	278	0.072	0.050
2.9E-03	90.5	0.534	4.4	15.1	0.57	280	0.072	0.049

Table S13 Summary of hydraulic conditions in the RS flume (for R2 and  $S = 0.1\%$ )

$S$ (-)	$H$ (mm)	$U$ (ms <sup>-1</sup> )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
9.2E-04	30.5	0.134	13.1	5.1	0.24	90	0.123	0.107
9.5E-04	36.0	0.158	11.1	6.0	0.27	99	0.107	0.091
9.2E-04	40.4	0.173	9.9	6.7	0.27	105	0.098	0.082
9.5E-04	45.8	0.189	8.7	7.6	0.28	112	0.096	0.078
8.6E-04	50.0	0.193	8.0	8.3	0.28	111	0.091	0.073
8.9E-04	55.2	0.214	7.2	9.2	0.29	118	0.084	0.066
9.5E-04	60.3	0.233	6.6	10.1	0.30	128	0.083	0.064
9.1E-04	65.4	0.241	6.1	10.9	0.30	130	0.081	0.061
9.3E-04	69.9	0.255	5.7	11.6	0.31	137	0.079	0.058
9.4E-04	75.5	0.272	5.3	12.6	0.32	142	0.075	0.055
9.2E-04	80.3	0.285	5.0	13.4	0.32	146	0.071	0.051
9.6E-04	85.8	0.297	4.7	14.3	0.32	153	0.073	0.051
9.5E-04	90.8	0.312	4.4	15.1	0.33	157	0.069	0.048
9.1E-04	96.2	0.319	4.2	16.0	0.33	158	0.067	0.045
9.6E-04	100.5	0.341	4.0	16.8	0.34	167	0.065	0.044
8.9E-04	105.6	0.340	3.8	17.6	0.33	163	0.064	0.042
9.4E-04	110.7	0.356	3.6	18.4	0.34	173	0.064	0.042
9.4E-04	115.2	0.366	3.5	19.2	0.34	176	0.063	0.040
8.9E-04	119.6	0.364	3.3	19.9	0.34	176	0.063	0.039



Table S14 Summary of hydraulic conditions in the RS flume (for R2 and  $S = 0.2\%$ )

$S$ (-)	$H$ (mm)	$U$ ( $\text{ms}^{-1}$ )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
1.8E-03	25.6	0.162	15.6	4.3	0.32	119	0.140	0.124
1.9E-03	31.1	0.199	12.8	5.2	0.36	135	0.119	0.103
1.9E-03	35.7	0.220	11.2	5.9	0.37	142	0.109	0.093
1.9E-03	40.4	0.242	9.9	6.7	0.38	150	0.101	0.084
1.9E-03	45.6	0.266	8.8	7.6	0.40	160	0.097	0.079
1.9E-03	51.2	0.287	7.8	8.5	0.40	170	0.091	0.073
1.9E-03	55.8	0.314	7.2	9.3	0.42	181	0.086	0.067
1.9E-03	61.0	0.333	6.6	10.2	0.43	188	0.083	0.064
1.9E-03	65.5	0.352	6.1	10.9	0.44	195	0.079	0.060
1.9E-03	70.9	0.375	5.6	11.8	0.45	202	0.076	0.056
1.9E-03	75.8	0.391	5.3	12.6	0.45	211	0.075	0.054
1.9E-03	80.8	0.409	5.0	13.5	0.46	214	0.072	0.051
1.9E-03	86.2	0.427	4.6	14.4	0.46	224	0.071	0.050
1.9E-03	91.2	0.450	4.4	15.2	0.48	227	0.068	0.047
1.9E-03	96.0	0.458	4.2	16.0	0.47	235	0.068	0.046
2.0E-03	101.0	0.484	4.0	16.8	0.49	242	0.067	0.045

Table S15 Summary of hydraulic conditions in the RS flume (for R2 and  $S = 0.3\%$ )

$S$ (-)	$H$ (mm)	$U$ ( $\text{ms}^{-1}$ )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
2.9E-03	21.2	0.169	18.8	3.5	0.37	135	0.171	0.154
3.0E-03	26.5	0.205	15.1	4.4	0.40	151	0.145	0.128
2.9E-03	30.8	0.239	13.0	5.1	0.44	162	0.123	0.107
2.9E-03	36.2	0.270	11.1	6.0	0.45	176	0.113	0.096
3.0E-03	41.2	0.301	9.7	6.9	0.47	189	0.106	0.088
2.9E-03	46.2	0.327	8.7	7.7	0.49	199	0.100	0.081
3.0E-03	51.0	0.355	7.8	8.5	0.50	210	0.094	0.075
2.9E-03	56.7	0.384	7.1	9.4	0.51	219	0.089	0.069
3.0E-03	61.1	0.413	6.5	10.2	0.53	231	0.084	0.064
2.9E-03	66.3	0.435	6.0	11.0	0.54	237	0.081	0.061
3.0E-03	70.9	0.456	5.6	11.8	0.55	247	0.079	0.059
2.9E-03	76.5	0.478	5.2	12.7	0.55	251	0.075	0.054
3.0E-03	81.2	0.505	4.9	13.5	0.57	265	0.074	0.053
2.9E-03	86.2	0.521	4.6	14.4	0.57	266	0.071	0.050
2.9E-03	90.3	0.540	4.4	15.0	0.57	274	0.070	0.048

Table S16 Summary of hydraulic conditions in the RS flume (for R3 and  $S = 0.1\%$ )

$S$ (-)	$H$ (mm)	$U$ ( $\text{ms}^{-1}$ )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
9.7E-04	29.4	0.158	13.6	4.9	0.29	85	0.090	0.078
9.7E-04	35.0	0.182	11.4	5.8	0.31	92	0.081	0.069
9.7E-04	39.8	0.198	10.1	6.6	0.32	98	0.078	0.065
9.7E-04	45.5	0.223	8.8	7.6	0.33	105	0.070	0.057
9.7E-04	49.5	0.234	8.1	8.2	0.34	114	0.069	0.055
9.7E-04	55.6	0.257	7.2	9.3	0.35	121	0.064	0.050
9.7E-04	59.9	0.272	6.7	10.0	0.35	126	0.062	0.048
9.7E-04	65.5	0.289	6.1	10.9	0.36	132	0.060	0.045
9.7E-04	69.9	0.301	5.7	11.7	0.36	136	0.059	0.044
9.7E-04	75.1	0.317	5.3	12.5	0.37	141	0.057	0.041
9.7E-04	80.4	0.328	5.0	13.4	0.37	146	0.057	0.041
9.7E-04	85.4	0.341	4.7	14.2	0.37	150	0.056	0.039
9.7E-04	89.6	0.353	4.5	14.9	0.38	154	0.055	0.038
9.7E-04	95.7	0.371	4.2	15.9	0.38	159	0.053	0.036
9.7E-04	100.4	0.383	4.0	16.7	0.39	163	0.052	0.035
9.7E-04	104.8	0.392	3.8	17.5	0.39	168	0.052	0.034
9.7E-04	109.4	0.403	3.7	18.2	0.39	169	0.052	0.033
9.7E-04	113.9	0.411	3.5	19.0	0.39	172	0.051	0.033

Table S17 Summary of hydraulic conditions in the RS flume (for R3 and  $S = 0.2\%$ )

$S$ (-)	$H$ (mm)	$U$ (ms <sup>-1</sup> )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
2.0E-03	25.3	0.199	15.8	4.2	0.40	117	0.101	0.090
2.0E-03	29.9	0.227	13.4	5.0	0.42	127	0.091	0.079
2.0E-03	35.1	0.259	11.4	5.8	0.44	137	0.083	0.070
2.0E-03	40.1	0.287	10.0	6.7	0.46	147	0.077	0.064
2.0E-03	45.0	0.311	8.9	7.5	0.47	156	0.074	0.060
2.0E-03	50.1	0.338	8.0	8.3	0.48	164	0.069	0.055
2.0E-03	55.1	0.363	7.3	9.2	0.49	173	0.066	0.052
2.0E-03	59.9	0.387	6.7	10.0	0.50	180	0.063	0.049
2.0E-03	65.3	0.411	6.1	10.9	0.51	188	0.061	0.046
2.0E-03	69.4	0.434	5.8	11.6	0.53	195	0.058	0.043
2.0E-03	75.7	0.453	5.3	12.6	0.53	208	0.058	0.042
2.0E-03	80.5	0.473	5.0	13.4	0.53	215	0.057	0.041
2.0E-03	85.8	0.495	4.7	14.3	0.54	221	0.055	0.039
2.0E-03	90.8	0.506	4.4	15.1	0.54	227	0.056	0.039
2.0E-03	94.3	0.523	4.2	15.7	0.54	230	0.055	0.037

Table S18 Summary of hydraulic conditions in the RS flume (for R3 and  $S = 0.3\%$ )

$S$ (-)	$H$ (mm)	$U$ (ms <sup>-1</sup> )	$B/H$ (-)	$H/\Delta$ (-)	$F$ (-)	$\Delta^+$ (-)	$f_H$ (-)	$f_R$ (-)
2.9E-03	19.2	0.191	20.9	3.2	0.44	123	0.121	0.111
2.9E-03	25.1	0.245	15.9	4.2	0.49	141	0.096	0.085
2.9E-03	30.1	0.282	13.3	5.0	0.52	154	0.087	0.076
2.9E-03	35.1	0.316	11.4	5.9	0.54	166	0.081	0.069
2.9E-03	40.3	0.355	9.9	6.7	0.56	177	0.074	0.061
2.9E-03	45.5	0.388	8.8	7.6	0.58	188	0.070	0.057
2.9E-03	50.3	0.412	8.0	8.4	0.59	198	0.068	0.054
2.9E-03	54.3	0.438	7.4	9.0	0.60	205	0.065	0.051
2.9E-03	60.6	0.474	6.6	10.1	0.61	215	0.062	0.048
2.9E-03	65.3	0.492	6.1	10.9	0.61	223	0.062	0.047
2.9E-03	70.4	0.517	5.7	11.7	0.62	239	0.061	0.045