TWG 4/8/98

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CONCLUSIONS

DURING THE MONTHS OF AUGUST AND SEPTEMBER, $7.6x10^5$ m^3 (2.2 MILLION TONS) OF SAND AND $9.2x10^5$ m^3 (2.7 MILLION TONS) OF SILT & CLAY WERE INPUT TO UPPER MARBLE CANYON BY THE PARIA RIVER

SEDIMENT INPUT DURING TRIBUTARY FLOODS TRAVELS DOWNSTREAM AS "SEDIMENT WAVES"

SEDIMENT WAVES HAVE COMPONENTS IN THE SUSPENDED LOAD, BEDLOAD, AND BED

SEDIMENT WAVES ELONGATE IN THE STREAMWISE DIRECTION WITH FINEST SIZE TRAVELING THE FASTEST

AS A SEDIMENT WAVE PASSES A GIVEN LOCATION, SEDIMENT ON THE BED AND IN SUSPENSION COARSENS, THUS DECREASING THE DOWNSTREAM SEDIMENT-TRANSPORT RATES

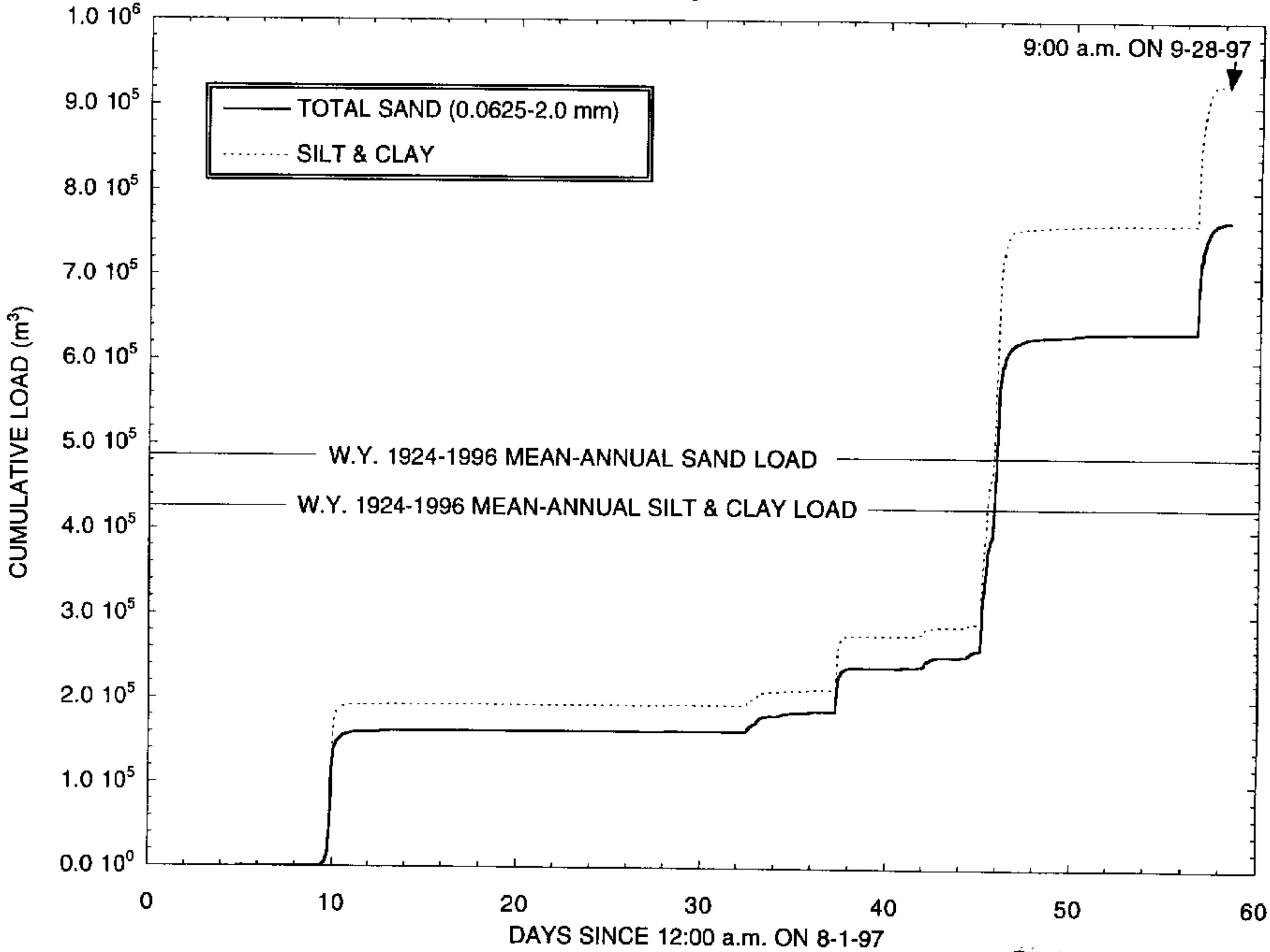
THIS STYLE OF GRAIN-SIZE EVOLUTION OCCURS DURING MAINSTEM FLOODS AS FINES ARE PREFERENTIALLY DEPOSITED IN EDDIES; FLOODS CAN THEREFORE DECREASE THE DOWNSTREAM TRANSPORT RATES BY COARSENING THE CHANNEL

CHANGE IN MAINSTEM SEDIMENT-TRANSPORT RATES ON ORDER OF 10-100x IS POSSIBLE FOLLOWING TRIBUTARY FLOODS

10-20% OF SAND AND 100% OF SILT&CLAY INPUT DURING TRIBUTARY FLOODS ARE EXPORTED IN APPROXIMATELY 2 WEEKS; REMAINING SAND IS PROBABLY EXPORTED OVER 1-2 YEARS

WORK IS PROGRESSING ON DEVELOPING A MODEL THAT CAN PREDICT RATES AT WHICH THE GRAIN-SZIE OF SEDIMENT IN THE SYSTEM EVOLVES

MODEL-PREDICTED CUMULATIVE LOADS OF THE PARIA RIVER @ LEES FERRY, AZ
8-1-97 through 9-27-97



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after Topping (1997)

CAPTIONS FOR FIGURES FROM TOPPING AND OTHERS (WRR, in review)

Figure 4: **(a)** Daily mean grain-size distributions of the bed material at the Grand-Canyon-gage measurement cableway during the 1996 flood experiment. During the rising limb of the flood, the median size in the bed fined from 0.4 to 0.3 mm. During the 7 days of high discharge, the median size of the bed coarsened from 0.3 to 0.3 mm, most of this coarsening occurred during the first 2 days of high discharge. The number of samples in each spatially averaged measurement is indicated by n in the legend; the heavy vertical lines indicate the median grain sizes for each day. **(b)** Grain-size distributions of: the calculated 1923-1996 Paria River input of sand to the Colorado River (after Topping, 1997); the bed material at the Grand-Canyon-gage measurement cableway on 4-12-56, during the rising limb of the 1956 snowmelt flood (U.S. Geological Survey, 1961); the bed material at the Grand-Canyon-gage measurement cableway on 5-31-56, near the peak of the 1956 snowmelt flood (U.S. Geological Survey, 1961); and, the bed material at the Grand-Canyon-gage measurement cableway on 6-25-83 (Garrett and others, 1993).

Figure 5: **(a)** Hydrograph of the 1996 flood experiment and spatially averaged, depth-integrated sand and silt & clay concentrations measured at the Grand Canyon gage and Mile-122 sites. Error bars are one standard deviation. The travel-time of the flood between the main-channel and eddy sites has been removed in this figure such that the beginning of day one at each site corresponds to the time of the first arrival of the flood wave at each site. [Values of the means and error bars for the Grand-Canyon-gage data shown in this plot are the same as reported in Rubin and others (1998). Values of the means and error bars for the 122-mile data shown in this plot, and in (c), differ from those in Rubin and others (1998) in 3 ways: (1) The sand fraction in this plot is composed of sediment with a settling velocity greater than that for 0.0625 mm sediment with a Corey shape factor of 0.7 and Powers index of 3.0; in this plot, platy material

larger than 0.0625 mm with lower settling velocities is grouped with the silt and clay. (2) Error bars reported for the 122-mile data in Rubin and others (1998) were one standard error, not one standard deviation. (3) One sample used by Rubin and others (1997) to define the mean concentration on day 7 of the flood was excluded from this analysis because of probable bed contamination.] **(b)** Daily mean concentrations by size class of the suspended sand depicted in (a) measured with the P-61 sampler at the Grand Canyon gage. The number of samples in each spatially averaged measurement is indicated by n in the legend. The heavy vertical lines indicate the median grain sizes for each day; during the 7 days of high discharge, the median size of the suspended sand increased from 0.14 to 0.21 mm. **(c)** Daily mean concentrations by size class of the suspended sand depicted in (a) measured with the D-74 sampler at the 122-mile site. The number of samples in each spatially averaged measurement is indicated by n in the legend. The heavy vertical lines indicate the median grain sizes for each day; during the 7 days of high discharge, the median size of the suspended sand in the eddy increased from 0.11 to 0.16 mm.

Figure 6: **(a)** Sediment discharge (Q_S) as a function time for 8 size classes of sediment in the Paria River during the August-September sampling period. Instantaneous sediment discharge for each size class are calculated by the method of Topping (1997). [Julian time is defined such that 0 equals midnight preceding January 1.] **(b)** Measured sediment discharge as a function of time for 8 size classes of sediment at the above LCR gage. In addition to the two rises in sediment discharge associated with the two Paria River floods, two other rises in sediment discharge also occurred during the sampling period. Except for the fours days (Julian time from 241 through 246) of lower discharge described in the text, changes in sediment discharge were relatively unaffected by changes in water discharge and mainly reflected changes in sediment concentration.

Figure 7: Measurements made during the 2 days of steady, high flow during the 1997 test flow. **(a)** Hydrograph of the 1997 test flow, cross-sectionally integrated suspended-sand and silt & clay concentrations, and median size (D_{50}) of the suspended sand at the Lees Ferry gage (located 1.1 km upstream from the Paria River). **(b)** Hydrograph of the 1997 test flow, cross-sectionally integrated suspended-sand and silt & clay concentrations, median size of the suspended sand, and median size of the sand, silt, and clay at the above LCR gage. Each reported median size of the sand, silt, and clay on the bed is defined by a sample collected at only 1 station under the measurement cableway. **(c)** Hydrograph of the 1997 test flow, cross-sectionally integrated suspended-sand and silt & clay concentrations, and median size of the suspended sand at the Grand Canyon gage. **(d)** Hydrograph of the 1997 test flow, cross-sectionally integrated suspended-sand and silt & clay concentrations, median size of the suspended sand, and median size of the sand, silt, and clay on the bed at the above Diamond Creek gage. Each reported median size of the sand, silt, and clay on the bed is defined by samples collected at 3 stations under the measurement cableway; error bars are 1 standard deviation.

Figure 8: **(a)** Water-surface stage and bed stage as a function of time at the Grand Canyon gage during the 1983 sampling period; stage is that at the lower, not upper, gage. Shaded area indicates the range of values [depicted in 3(b)] of the bed stage at the measurement cableway during the pre-dam, 1923-1962 era. [Julian time is defined such that 0 equals midnight preceding January 1.] **(b)** Suspended-sand and suspended-silt & clay concentration as a function of time at the Grand Canyon gage during the 1983 sampling period. Also shown are the instantaneous discharges of the LCR (at the near Cameron gage) and the Paria River (at the Lees Ferry gage). Three samples, in which the median size of the suspended sand exceeded 0.4 mm, were excluded from this plot; these samples were likely to have significant bed contamination. **(c)** Median size of suspended sand and a 21-point running average of the median size of suspended sand as a function of time at the Grand Canyon gage during the 1983 sampling period.

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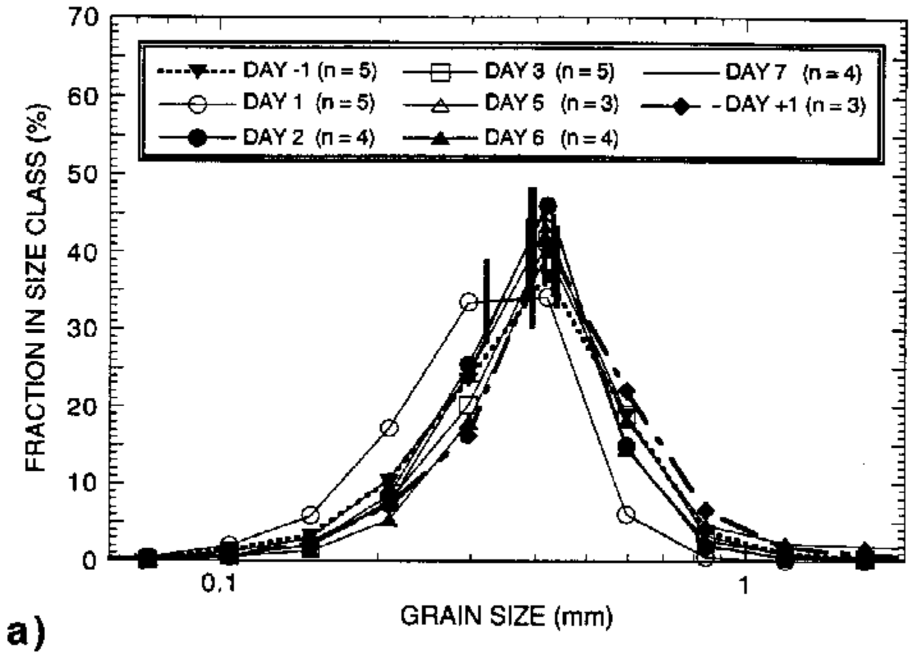
Also shown are the instantaneous discharges of the LCR (at the near Cameron gage) and the Paria River (at the Lees Ferry gage). Three samples, in which the median size of the suspended sand exceeded 0.4 mm, were excluded from this plot; these samples were likely to have significant bed-material contamination. **(d)** Median size of fine sediment (i.e., sand, silt, and clay) on the bed as a function of time at the Grand Canyon gage during the 1983 sampling period; error bars are 1 standard deviation. All measurements that were made in the center portion of the channel (from station 170 to station 315) that included samples at two or more stations are shown. Because most bed-material samples were collected near the banks during the 1983 sampling period, and to avoid biasing the plot toward the grain sizes of bank sediment, samples from the near-bank regions, i.e., the left and right 25% of the channel, were excluded from this plot. **(e)** Fraction of the fine sediment on the bed composed of 0.0615-0.125 mm sand as a function of time at the Grand Canyon gage during the 1983 sampling period; error bars are 1 standard deviation. All measurements that were made in the center portion of the channel (from station 170 to station 315) that included two or more samples are shown. Because most bed-material samples were collected near the banks during the 1983 sampling period, and to avoid biasing the plot toward the grain sizes of bank sediment, samples from the near-bank regions, i.e., the left and right 25% of the channel, were excluded from this plot. Data from Garrett and others (1993).

Figure 9: Median grain size as a function of relative height within flood deposits (1996 flood deposit at five sites and four pre-dam flood deposits). Grain size nearly doubled during both the 1996 and the pre-dam floods.

Figure 10: **(a)** Median grain size as a function of relative height within the deposits of the 1997 test flow at 9 sites between Lees Ferry and the Grand Canyon gage. The sites at river-miles less than 62 are above the Little Colorado River in Marble Canyon, and the sites at river-miles greater

than 62 are below the Little Colorado River in upper Grand Canyon. The numbers in italics refer to the lateral distance of the sample site (in meters) from the test-flow high-water mark. **(b)** Cumulative grain-size distributions of the samples collected at 22-mile bar. Also shown are the coarsest sizes present at the 5 sampled elevations within the deposit. These samples were collected 14.3 m from the test-flow high-water mark; the deposit thickness at this location was 1.23 m. **(c)** Cumulative grain-size distributions of the most-riverward samples collected at the Tanner site. Also shown are the coarsest sizes present at the 3 sampled elevations within the deposit. These samples were collected 11.2 m from the test-flow high-water mark; the deposit thickness at this location was 0.23 m.



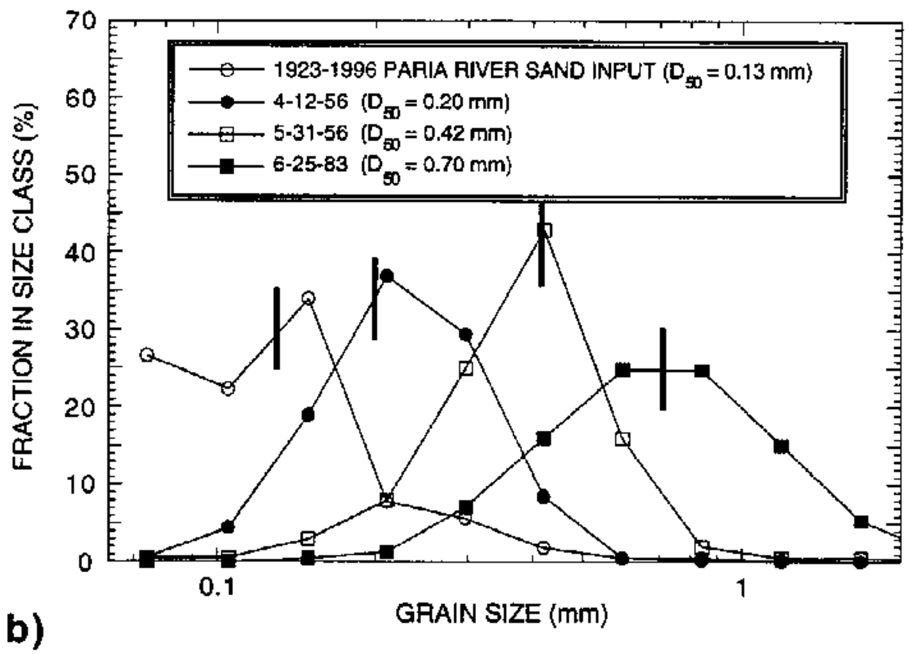


Figure 4

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from Topping and others (WRR, in review)

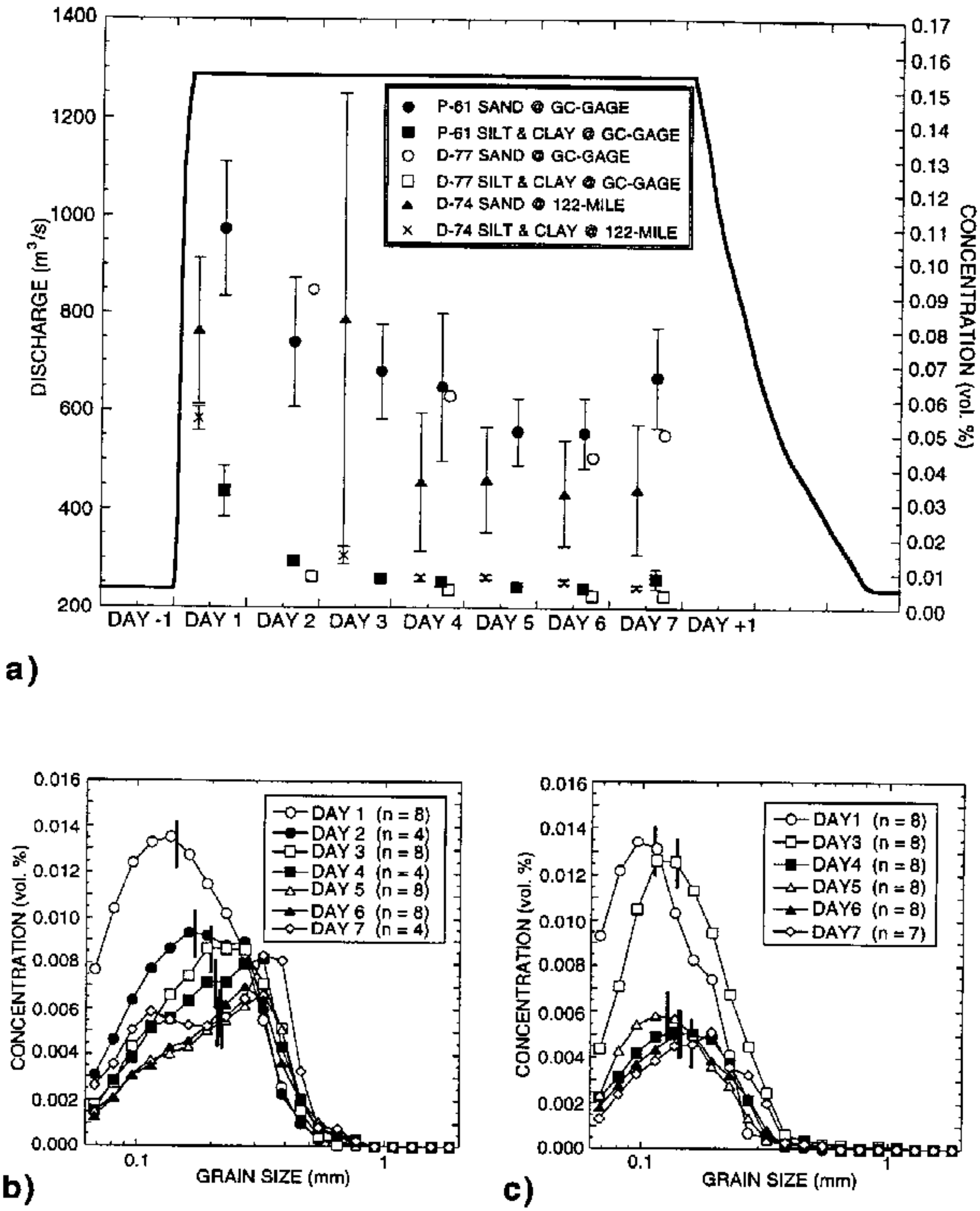

Figure 5

from Topping and others (WRR, in review)

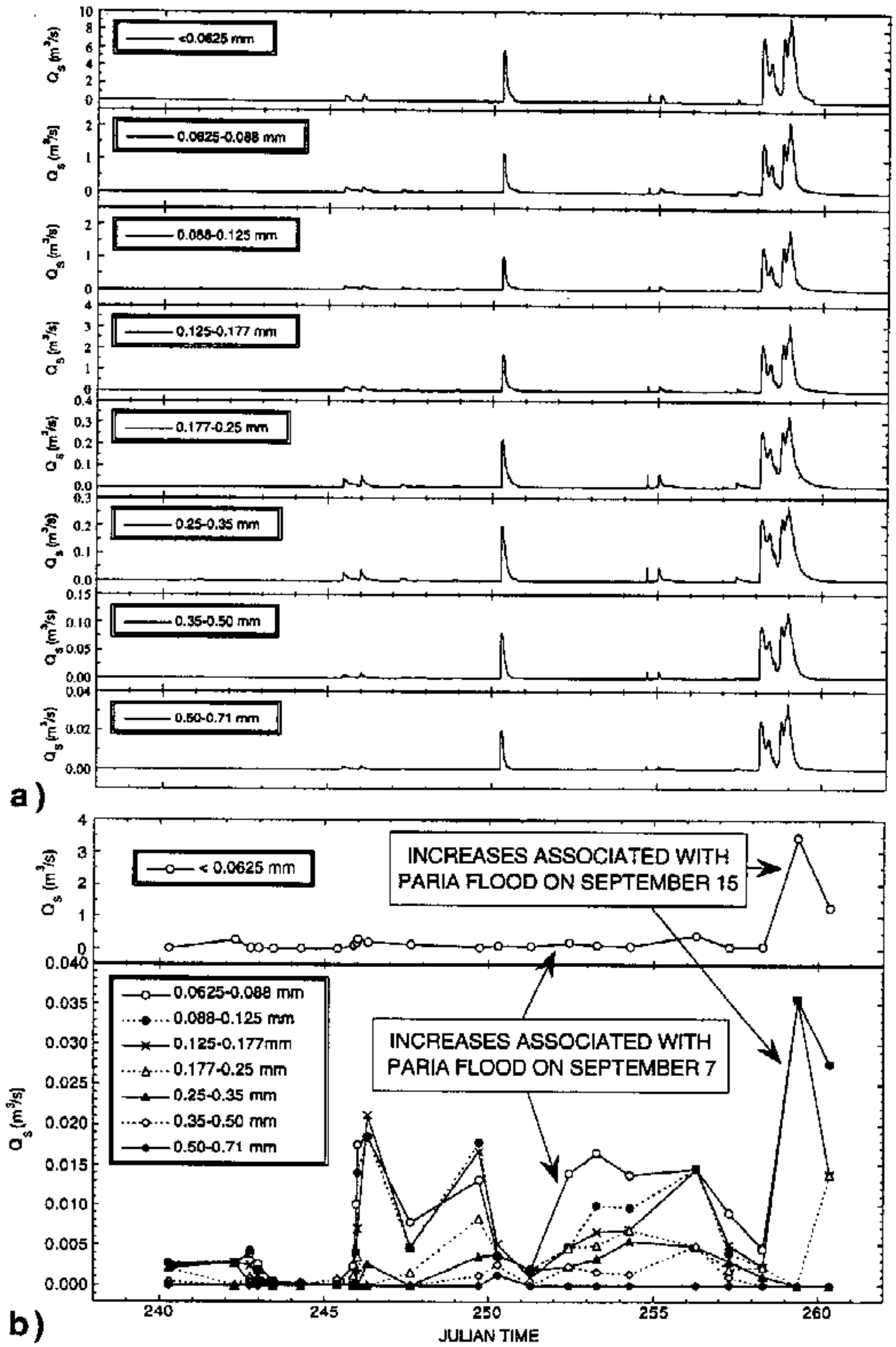

Figure 6

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from Topping and others (WRR, in review)

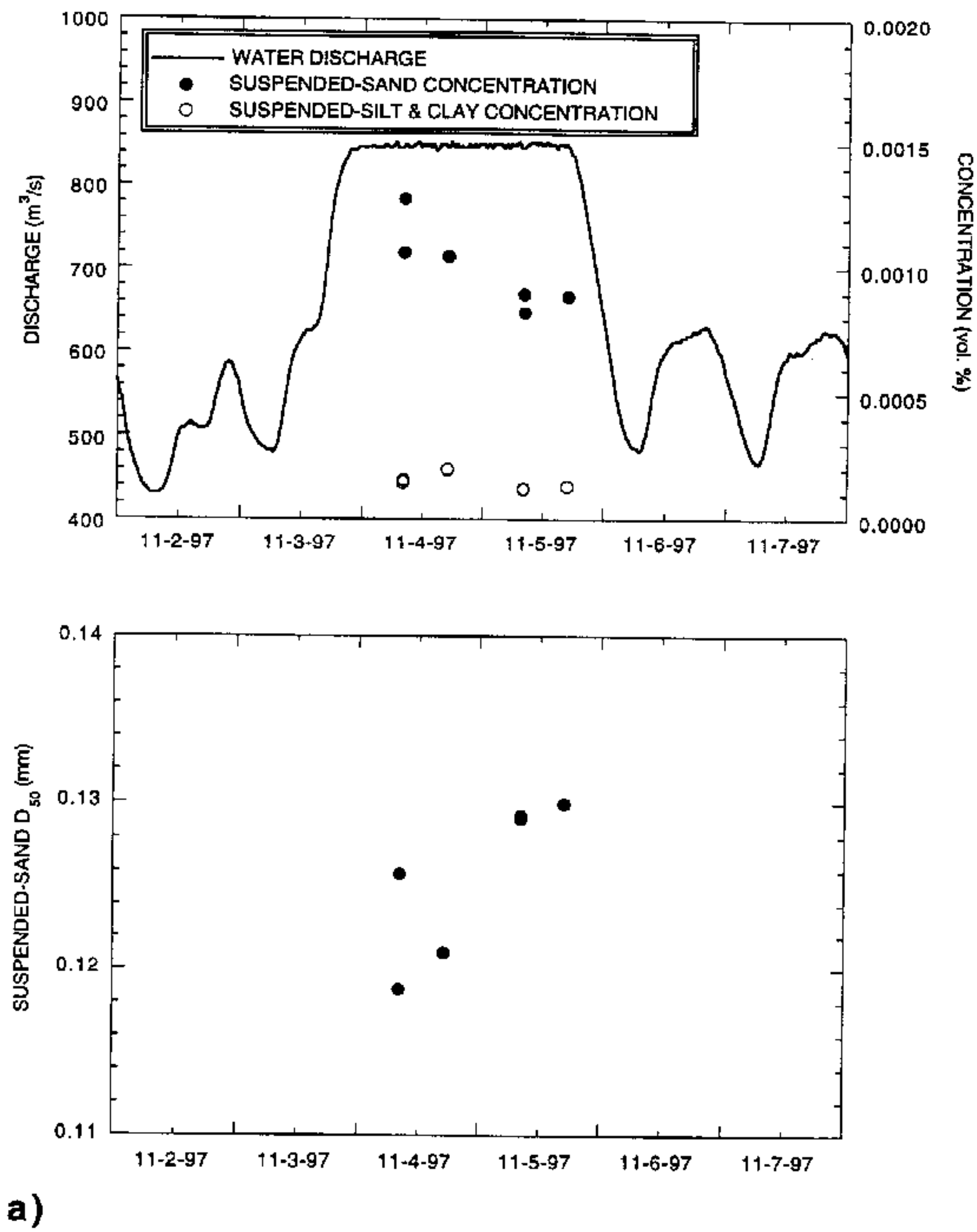

Figure 7a

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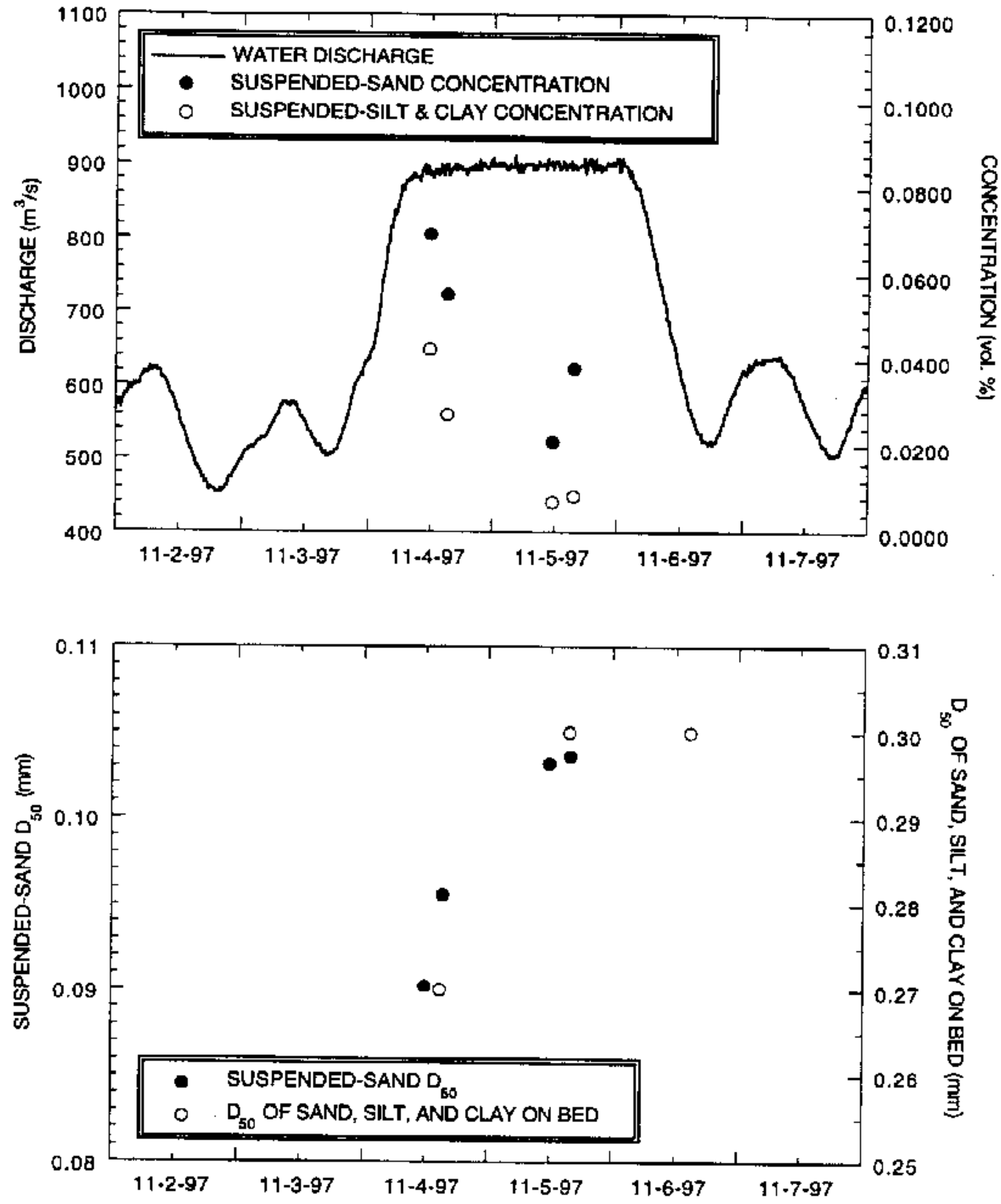
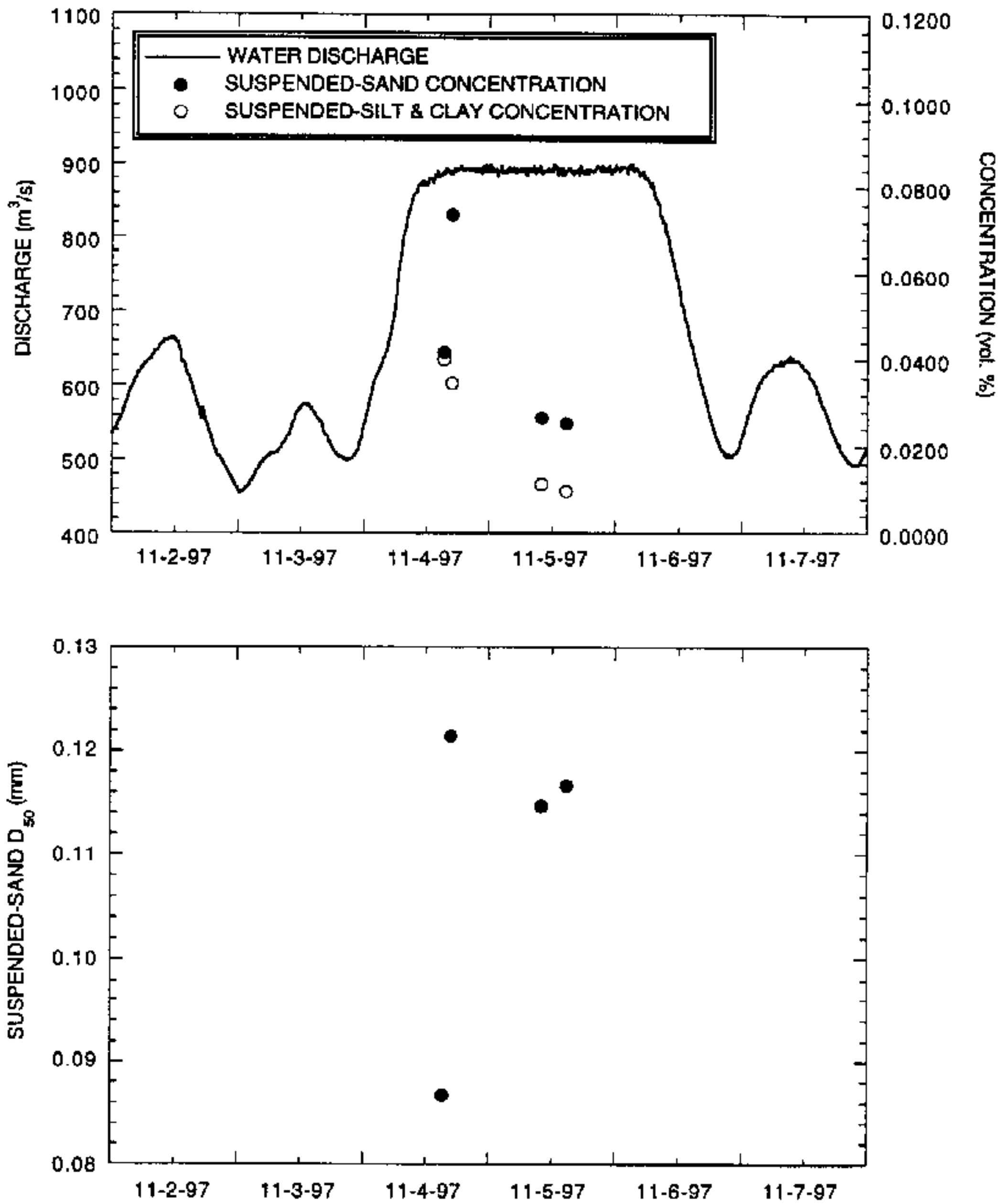
from Topping and others (WRR, in review)



b)

Figure 7b

from Topping and others (WRR, in review)



c)

Figure 7c

from Topping and others (WRR, in review)

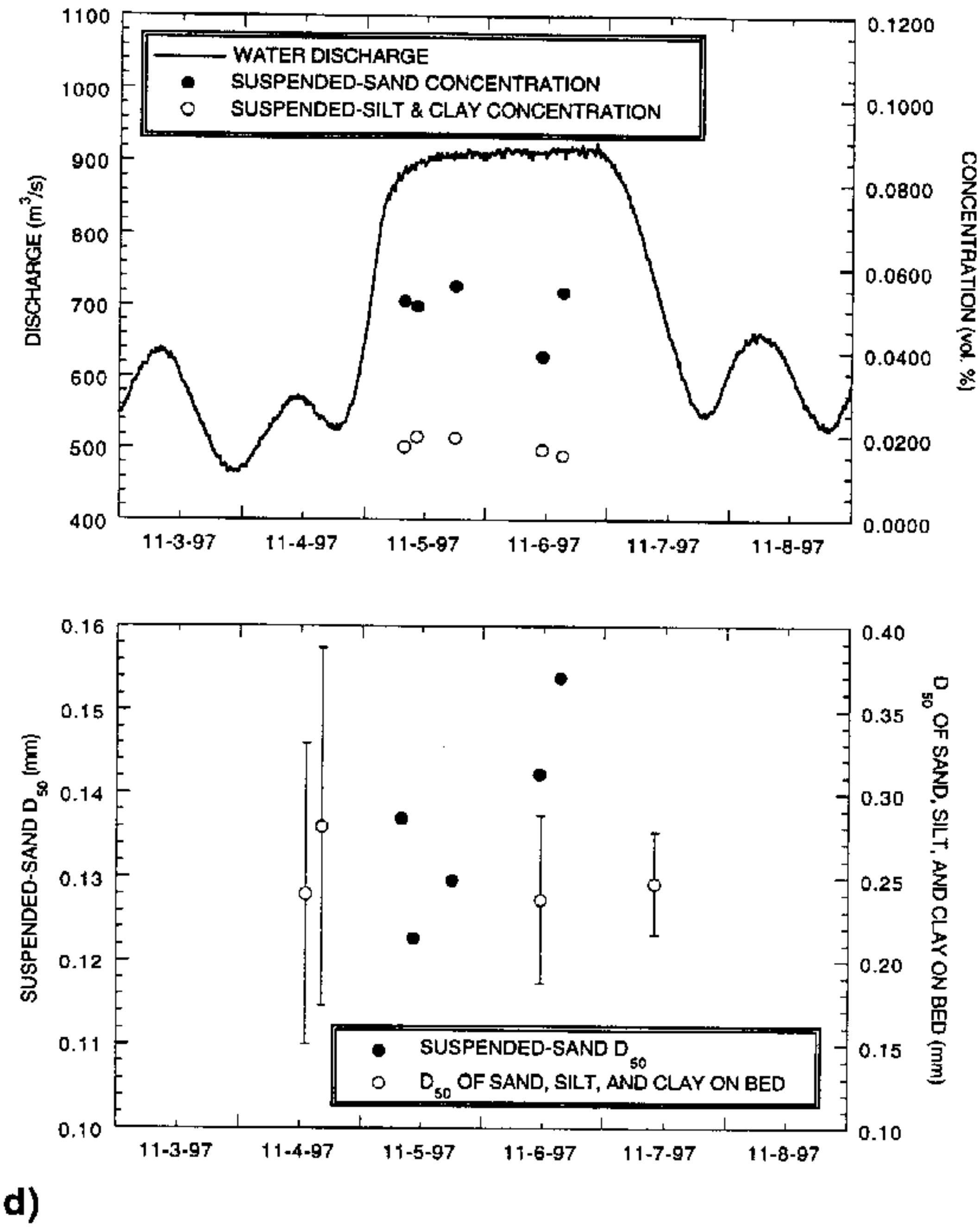


Figure 7d

from Topping and others (WRR, in review)

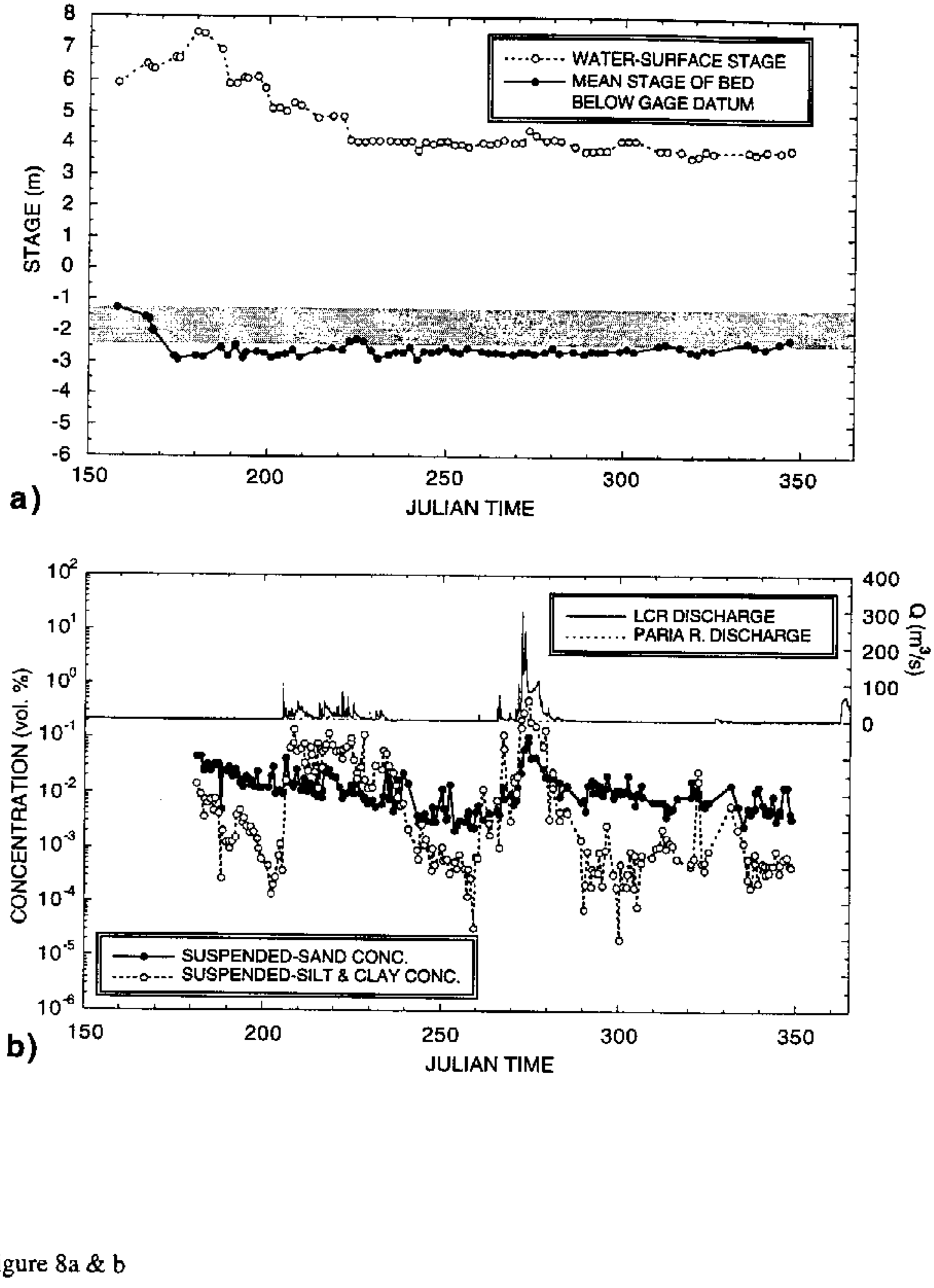


Figure 8a & b

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from Topping and others (WRR, in review)

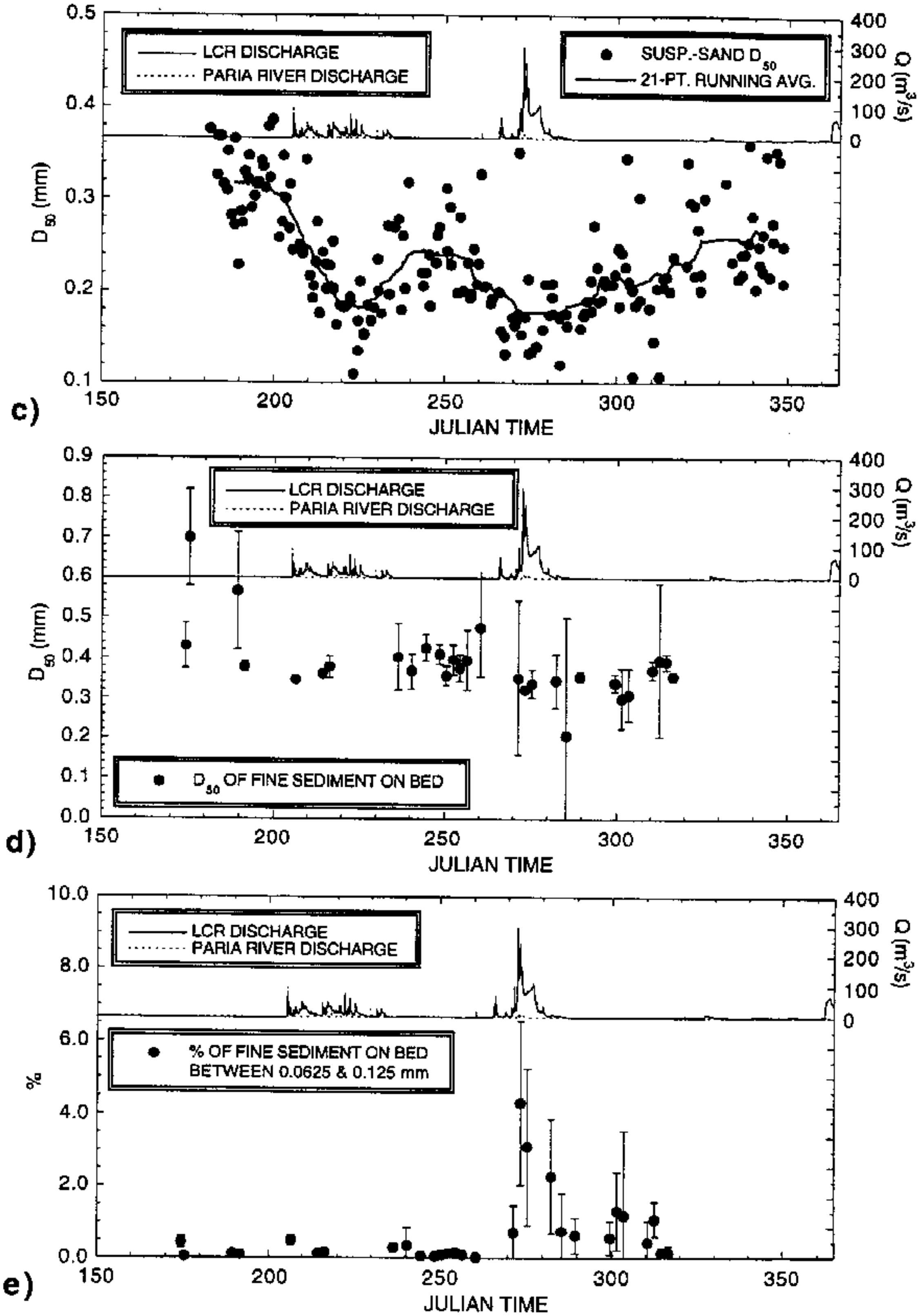

Figure 8c, d, e

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from Topping and others (WRR, in review)

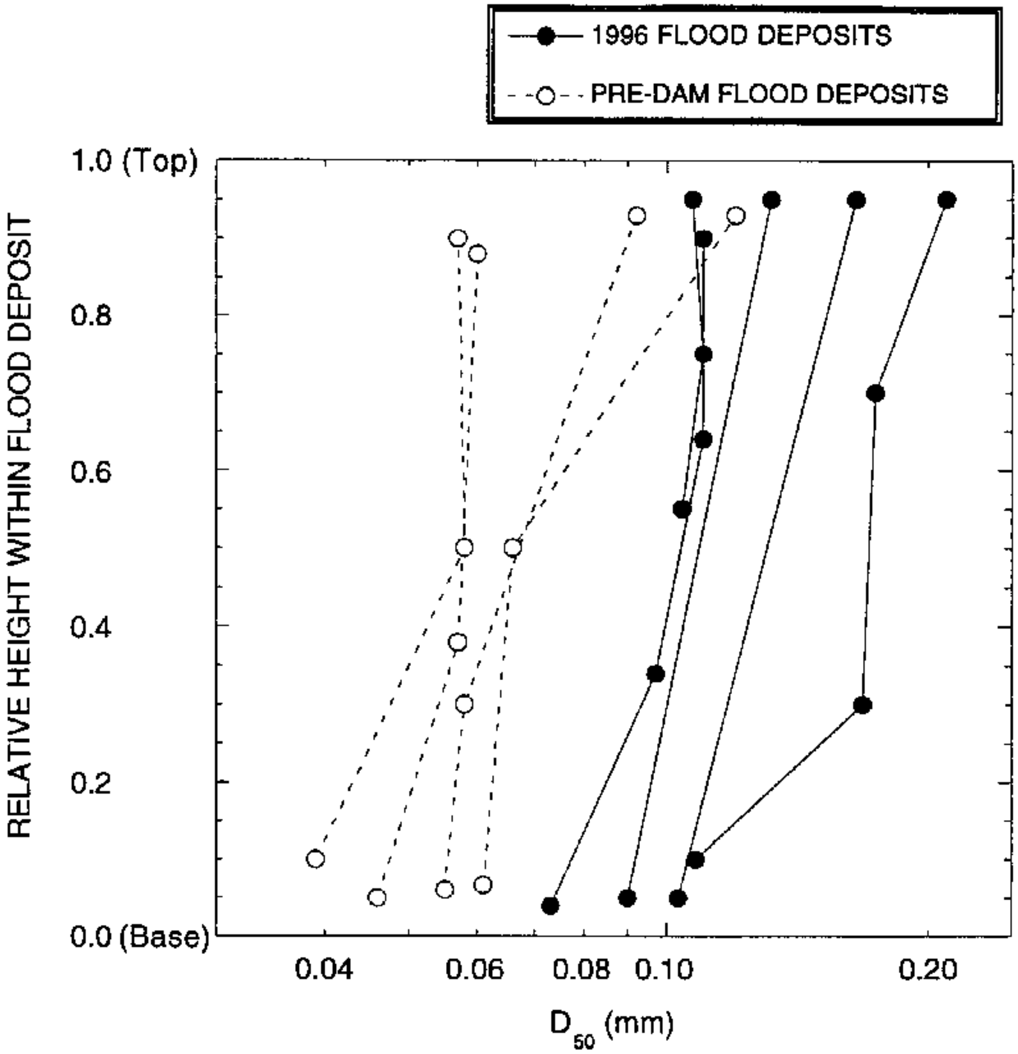

Figure 9

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from Topping and others (WRR, in review)

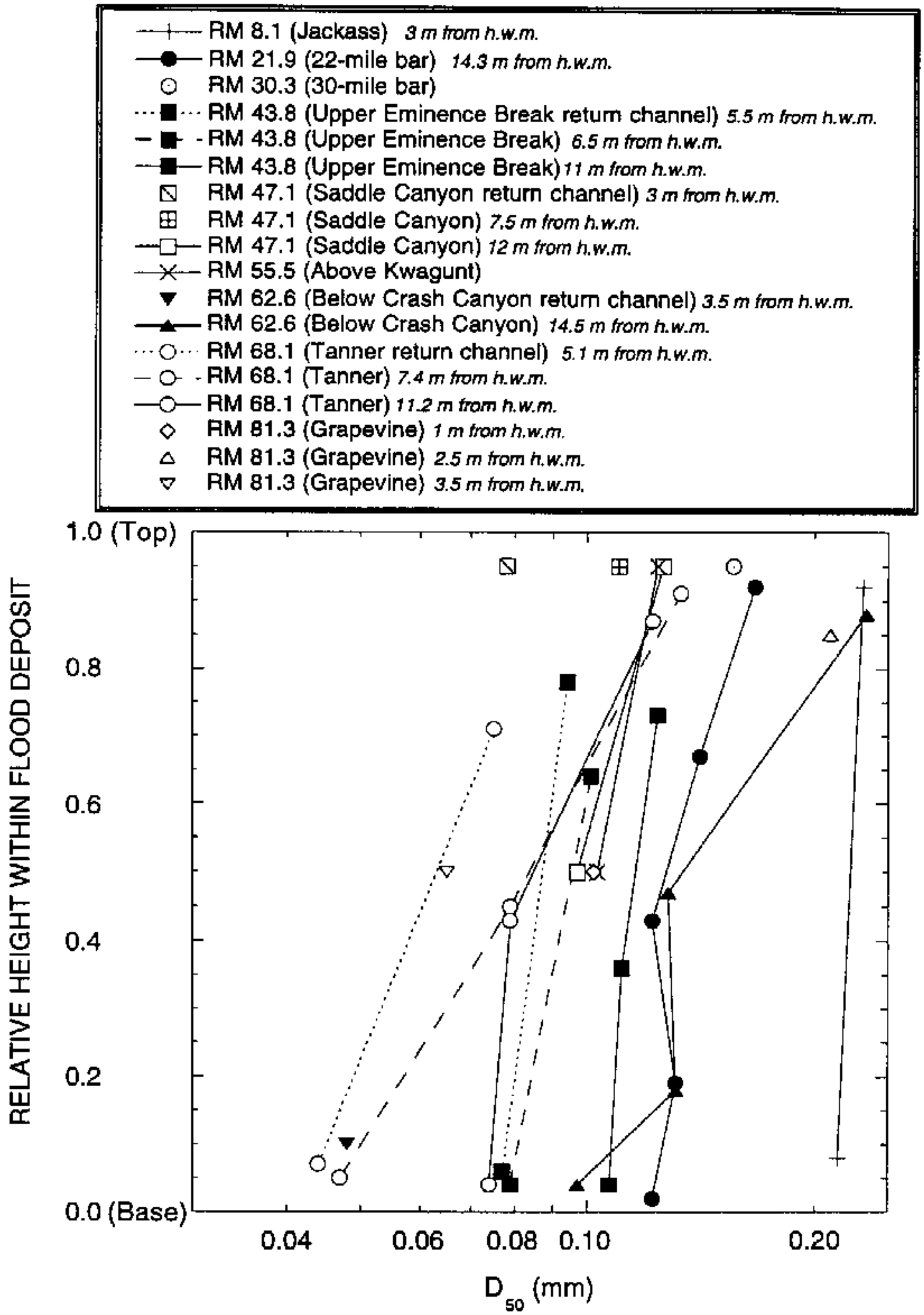

Figure 10a

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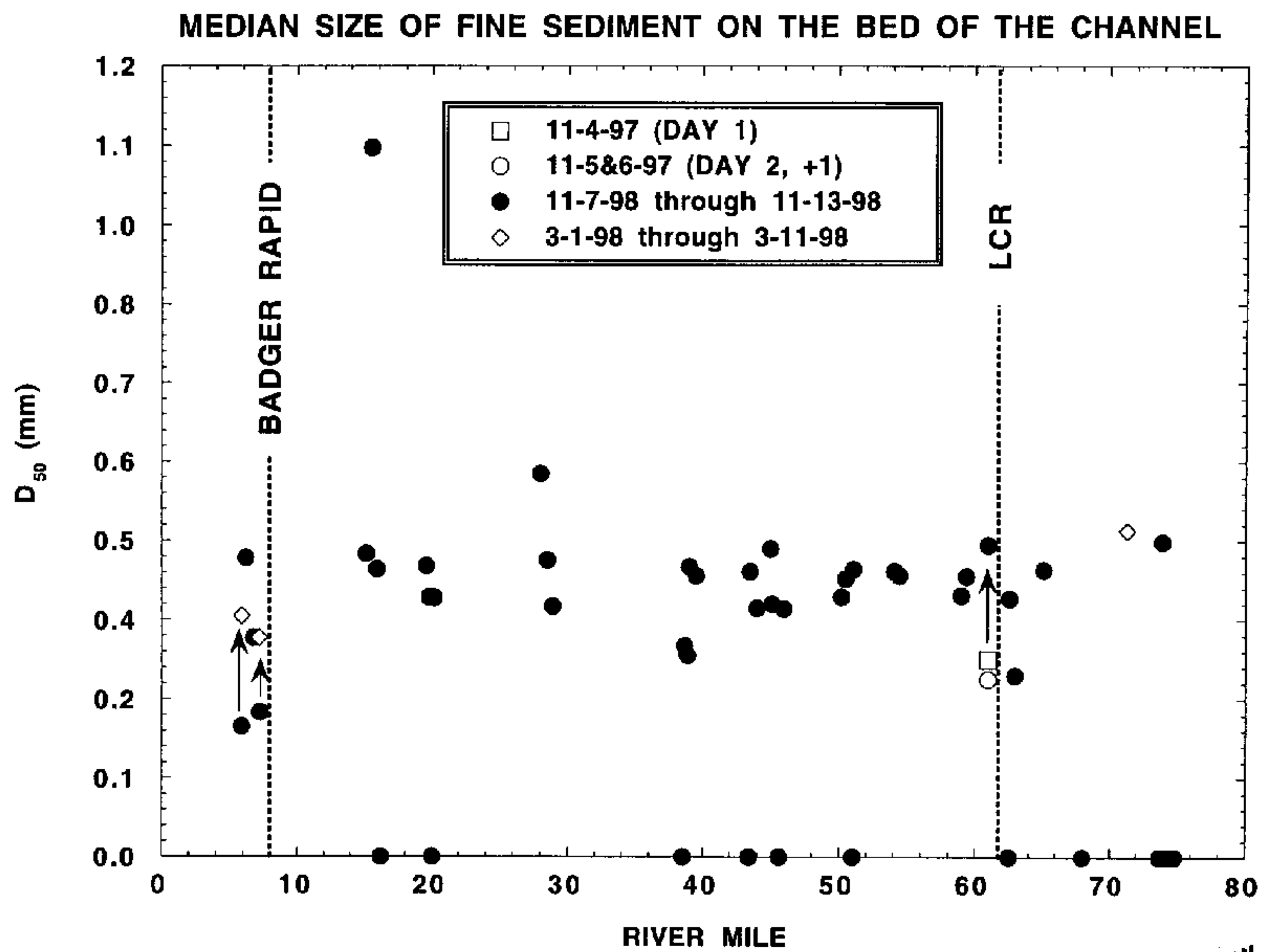
from Topping and others (WRR, in review)



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from Topping, Wiele, Rubin (in prep.)

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