APPENDIX IV-A

CHARACTERIZATION OF THE STREAM NETWORK IN ST. JOHN

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Purpose

The storage and transport capacity of sediment along stream channels is an important component of a sediment budget (Reid and Dunne, 1996). The routing component of the St. John sediment budget model (STJ-EROS) is based on sediment delivery ratios. The use of this method requires making some assumptions related to processes controlling the storage and transport of sediment through the fluvial network on St. John. The purpose of this appendix is to present a qualitative and quantitative geomorphic description of several stream reaches on the island that support the assumptions made for STJ-EROS.

Methods

Three first-order streams on the Reef Bay basin, and two second- to third-order streams in the Main Fish Bay and Greater Lameshur Bay guts are described in this Appendix. Longitudinal profiles and channel cross-sections were measured with a measuring tape and hand level (Ramos, 1996). The particle-size distribution of the streambed surface was determined on several stream reaches by the pebble-count method (Wolman, 1954). The location and height of eroding banks and the channel type (Montgomery and Buffington, 1997) were also noted. These surveys were used to determine channel slope, sediment transport capacity, and the total volume of fine sediment ($\leq$ 2 mm) stored on the surface of the streambed.

Results

The three first-order in the Reef Bay basin had average slopes ranging of 20 to 30%, a predominantly cobble and boulder streambed, and a cascade-type morphology with pools that have been completely filled in by clay to medium gravel-sized sediment (Figures 1a-1c). These characteristics make them highly capable of transporting additional fine sediment (roughly $\leq$ 2 mm) delivered to them (Montgomery and Buffington, 1997). This suggests that fine sediments being delivered to low-order (first to second order) channels in St. John have a high potential of being transported downstream to higher order streams.

A longitudinal profile was surveyed along the third to fourth-order Main Fish Bay Gut and its tributary, Battery Gut (Figure 2). The Main Fish Bay and Battery guts can be divided into three distinct sections based on breaks in slope and changes in channel morphology. The first section is in the lower Fish Bay area where a 0.37-km long channel with an average slope of 2% cuts through alluvial fan deposits. This portion of the channel appears to have been created in the 1970's when the Fish Bay Estate area was starting to be developed. The apparent goal of this work was to prevent flooding of the low-lying areas by channeling the runoff directly into Fish Bay. The channel appears to have developed morphologies that can be described as step-pool and planar (Montgomery and Bufffington, 1997).

The 1.6-km middle portion of the channel is characterized by an average slope of 7%, cascade and step-pool morphologies, a general absence of fine sediment deposits, and an abundance of bedrock exposures and large boulders. The change from a gently-sloped channel in the low-lying areas to a steep channel in the headwater areas is considered to be representative of the third-order streams draining to the southern coast of St. John.

The 1.4-km uppermost section of the channel has an average slope of 4%, step-pool and plane-bed morphologies, and a streambed dominated by cobbles and boulders with occasional patches of fine sediment.

Figure 2 shows the location of stream segments where the particle-size distribution of the streambed surface was determined. Points with significant sediment inputs are also shown. On average, 21% of the streambed surface in the upper and lower reaches is composed of particles finer than 2 mm (Figures 3a and 3b). The volume of fine sediment stored on the streambed was calculated assuming: (1) sediment storage only occurred along the 0.37-km lower reaches and 1.4-km upper reaches of the channel; (2) fine sediment occupies 21% of the 1.8-km of streambed where sediment was present; (3) a channel average width of 9 m can be approximated as the mean width of the surveyed cross-sections; and (4) the depth of the fine sediment deposits is 0.08 m, which equals the mean D_{84} of the streambed sediment. On this basis an estimated 270 m^3 of fine sediment is stored on the streambed surface. Assuming a dry bulk density of 1.4 tons m^{-3}, this converts to 380 tons of fine sediment.

A closer look at the spatial distribution of fine sediment stored on the channel streambed shows that it is not evenly distributed throughout the entire length of the fluvial network and that these deposits are likely to be only temporary features of the channel. Channels in steady-state experience no net deposition or scour as the amount of sediment being delivered is balanced by the mass being transported out. An increase in the amount of fine sediment being stored on the streambed indicates an increase in the amount of sediment being delivered into the fluvial system (Kinnerson, 1990).

Sections with anomalously high quantities of fine sediment can be identified by plotting selected particle-size percentiles against stream gradient. Figure 4 shows the relationship between three particle-size percentiles (D_{16}, D_{50}, and D_{84}) and channel slope for the Main Fish Bay Gut and Battery Gut. This shows that the expected positive relationship between slope and particle size is disrupted at three locations. At these three sites the streambed is finer than other sites with similar slopes. The excess of fine sediment in these reaches appears to be related to their downstream location relative to very important inputs of sediment into the main channel. These inputs include sediment produced from several steep and unpaved roads on the upper portions of the Fish Bay basin.

The storage of fine sediment along the channel reaches with anomalously fine streambeds is expected to be temporary due to the ephemeral nature of channel flows tat permits the accumulation of sediment during periods with little or no flow. The sediment transport capacity was estimated at 12 different stream reaches from the ratio of particle settling velocities (ω_o) to shear flow velocities (u*). While settling velocities are proportional to particle size, shear velocities equal the square root of the product of gravitational acceleration, flow depth, and channel slope. Laboratory experiments have shown that when ω_o/u* equals or exceeds 1.0, flows can suspend those particles with settling velocities slower than ω_o (Middleton, 1976) . Settling velocities for coarse sand (2 mm) and medium gravel (8 mm) at water temperatures of 20º Celsius are 0.112 and 0.338 m s^{-1}, respectively (Julien, 1995). Calculated u* values calculated for 12 reaches stream segments along the Main Fish Bay and Battery Guts show that even on stream segments with a 1% slope, a flow depth of 0.10 m is sufficient to keep material finer than coarse sand in suspension (Table 1). For the 12 stream reaches these flow depths represent on average only 12% of the channel depth at bankfull stage, which indicates that the entire fluvial network is capable of transporting sediment finer than 2 mm in suspension even during low flows. The relatively low flows required to transport fine sediment (< 2 mm) along the entire stream network leads to the conclusion that the anomalous abundance of fine sediments along several stream segments represent only temporary storage of sediment that has occurred after the last flow event.

Table 1 also shows that critical flow depths needed to transport medium gravel in suspension are much higher than those for coarse sand and they generally represent flow depths greater than bankfull. Hence particles coarser than 2 mm will tend to be transported as bed load and are likely to remain in the fluvial system for much longer than the sediment finer than 2 mm.

References cited

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Wolman, G. (1954) A method of sampling coarse river-bed material. *Transactions American Geophysical Union* 35(6):951-956.

Figure 1a. Longitudinal profile of Reef Bay 1st-order Gut-A.

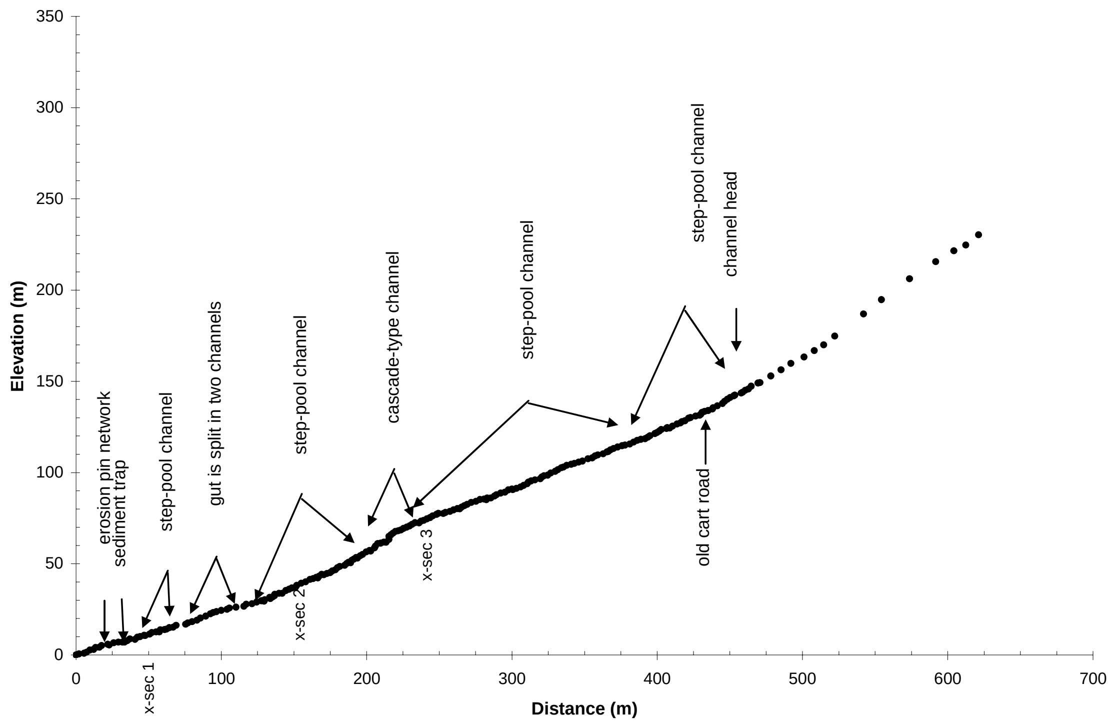

Figure 1b. Longitudinal profile of Reef Bay 1st-order Gut-B.

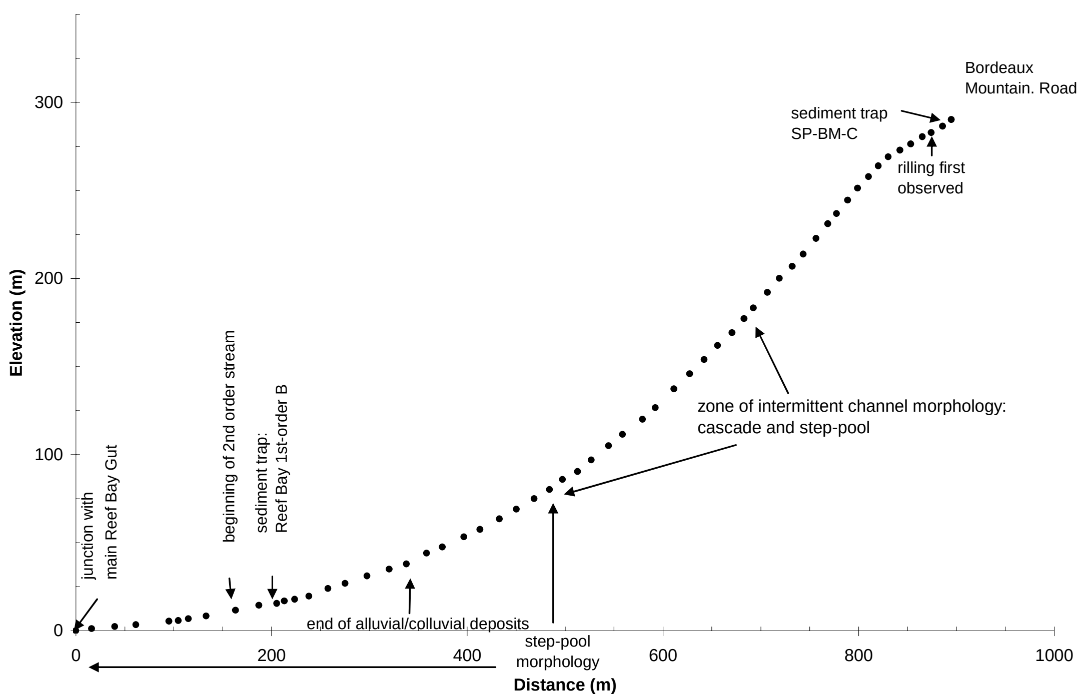

Figure 1c. Longitudinal profile of Reef Bay 1st-order Gut-C.

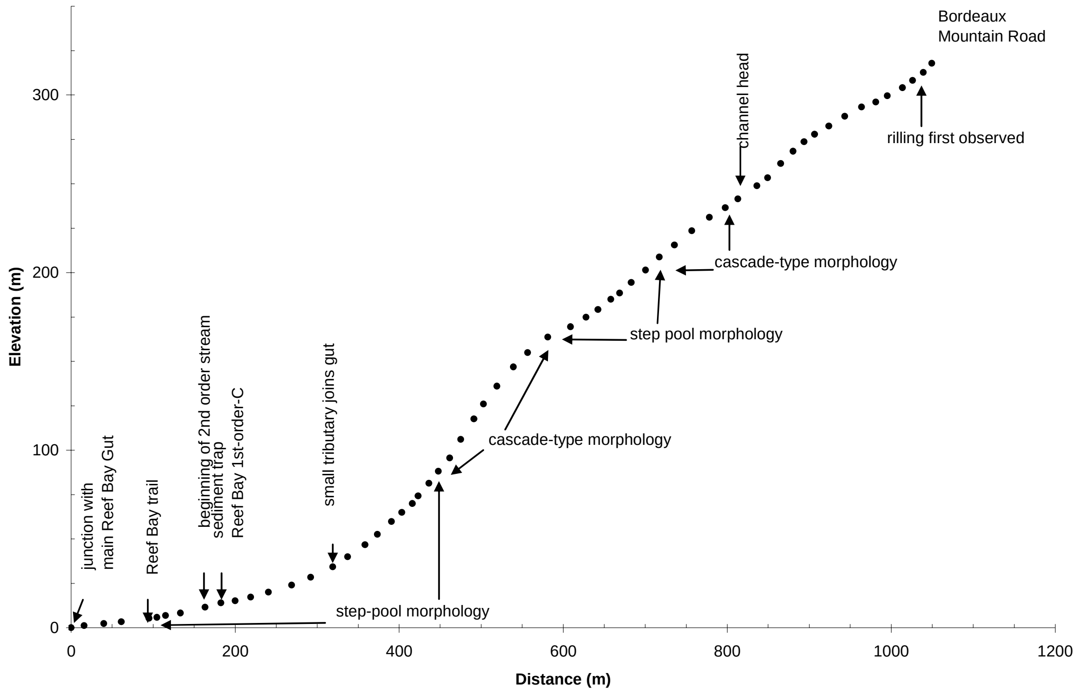

Figure 2. Longitudinal profile of Fish Bay Gut and Battery Gut. Solid arrows indicate points where the particle-size distribution of the streambed surface was determined, while dashed arrows signal the location of important sediment inputs.

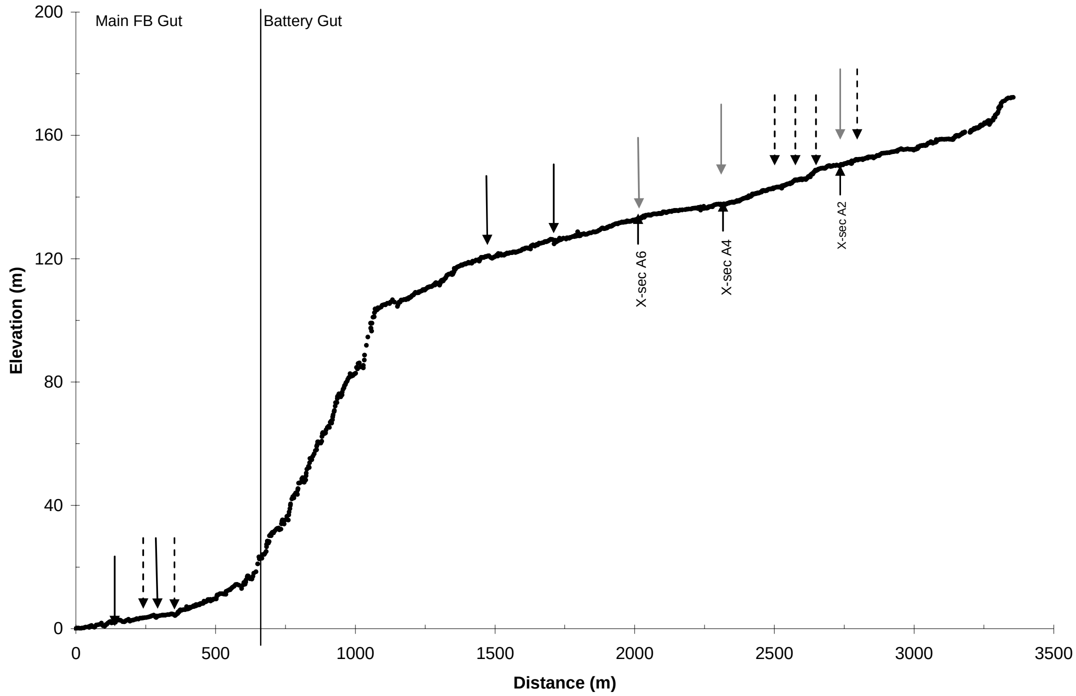

Figure 3a. Streambed surface particle-size distribution measured at several cross-sections along the Main Fish Bay Gut and Battery Gut. Distributions shown in this figure appear to be correlated with channel slope (Figure 4).

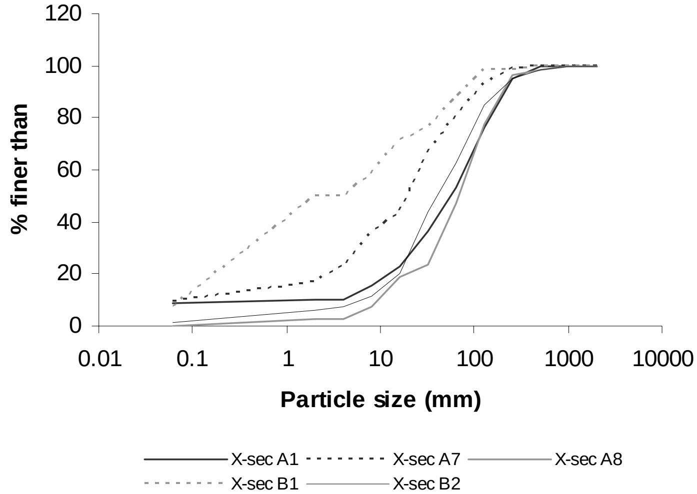

Figure 3b. Streambed surface particle-size distribution measured at several cross-sections along the Main Fish Bay Gut and Battery Gut. Distributions shown in this figure appear to be anomalously fine for their channel slope (Figure 4).

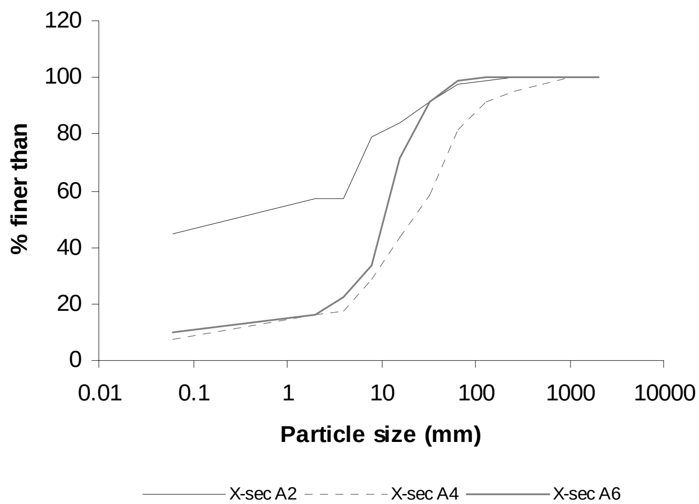

Figure 4. Relationship between slope and the 16th, 50th, and 84th percentile of the particle-size distributions from Main Fish Bay Gut. Points in gray refer to the gray arrows in Figure 2.

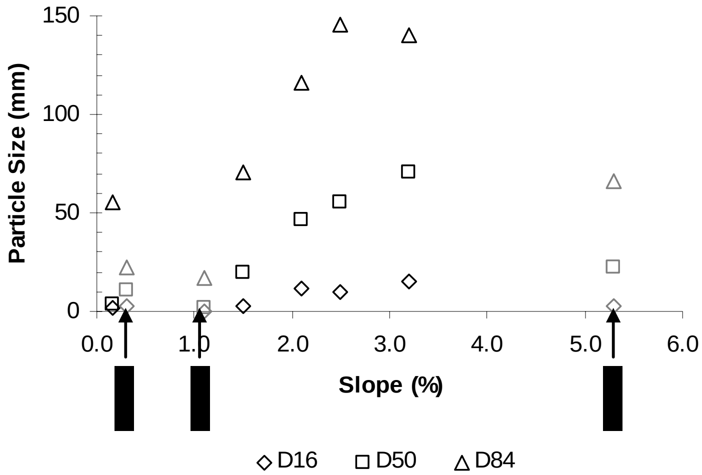

Figure 5. Longitudinal profile for the Greater Lameshur Bay Gut.

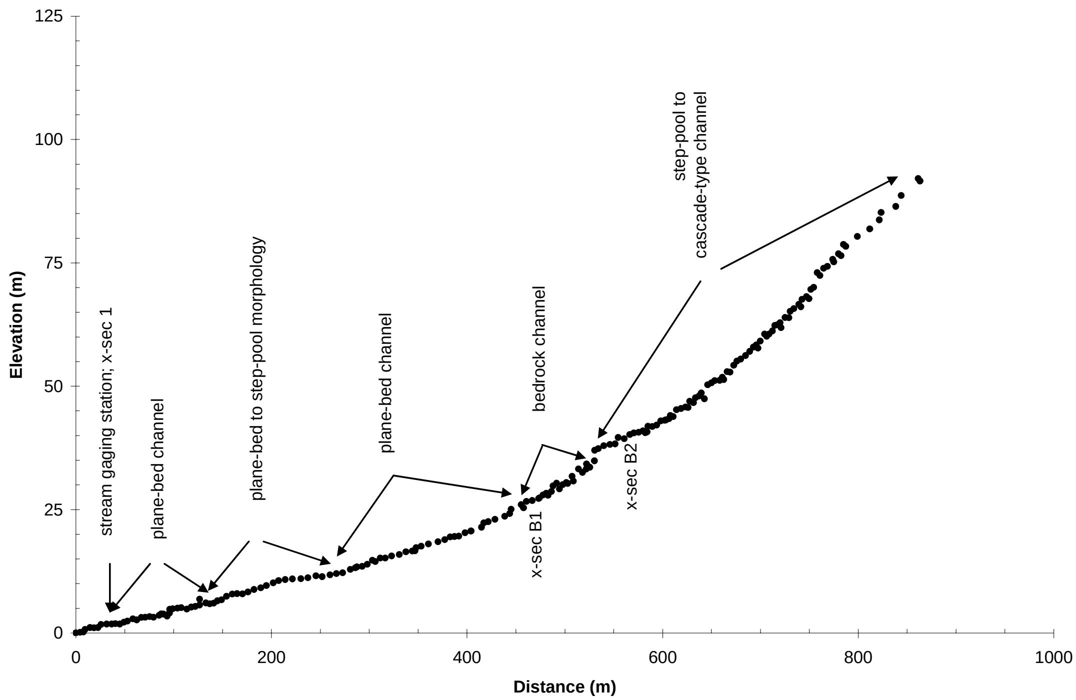

Figure 6. Particle-size distribution at three cross-sections surveyed along Greater Lameshur Bay Gut.

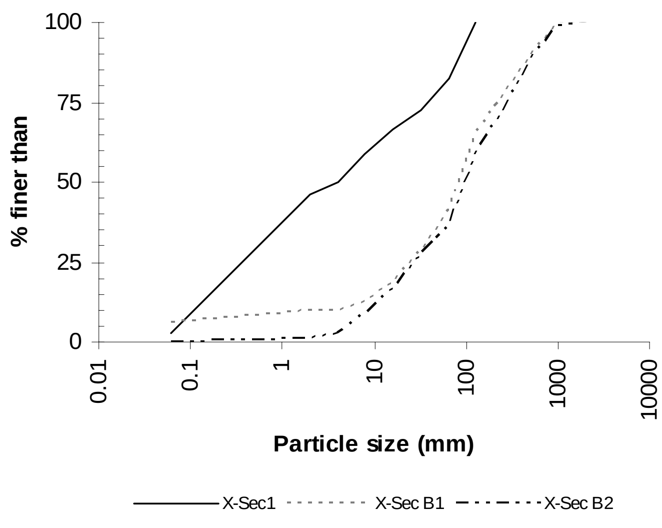

Table 1. Channel characteristics and critical flow depths for twelve reaches along the Main Fish Bay Gut and Battery Gut.

Long-Profile distance* (km)	**Slope ($m\ m^{-1}$)**	**Channel depth at bankfull (m)**	**Critical flow depth to maintain sand in suspension (m)**	**Critical flow depth to maintain medium gravel in suspension (m)**
3.26	0.03	0.64	0.05	0.47
3.12	0.01	0.42	0.12	1.06
2.80	0.01	0.38	0.09	0.83
2.65	0.05	0.51	0.02	0.22
2.48	0.02	0.34	0.05	0.49
2.30	0.01	0.46	0.10	0.90
1.98	0.02	0.44	0.06	0.56
1.70	0.04	0.38	0.03	0.31
1.33	0.08	0.50	0.02	0.14
0.73	0.13	1.04	0.01	0.10
0.36	0.02	0.81	0.06	0.56
0.18	0.02	1.21	0.08	0.73

*Distances refer to those in Figure 2.