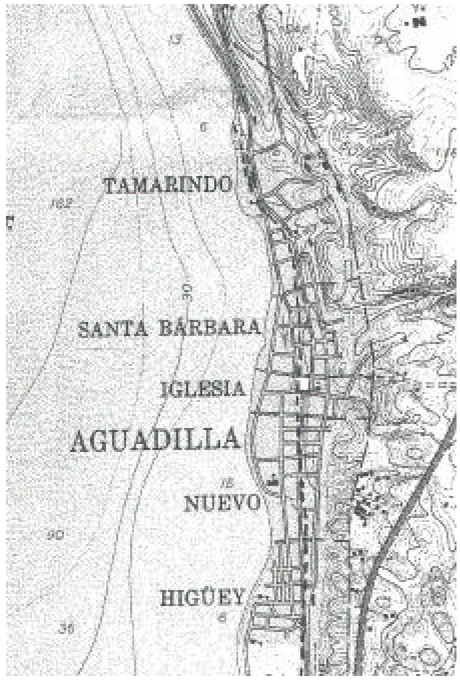
Probabilistic Tsunami Hazard Analysis
Aguadilla, Puerto Rico



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THE DETERMINATION OF THE TSUNAMI HAZARD FOR WESTERN PUERTO RICO FROM LOCAL SOURCES

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Executive Summary

This study presents the results of a probabilistic analysis of earthquake-generated tsunami runups for the coast of Aguadilla, Puerto Rico using synthetic runup-frequency calculations based on the hydrodynamic modeling of potential tsunami source zones in the Mona Passage region, west of Puerto Rico. Tsunami runups are mapped at an interval of approximately 90 meters along the coast and probabilities of exceedance for runups of 1, 2, and 3 meters are calculated for return times of 50, 100, 500, and 1000 years. Runups for specific probabilities of exceedance (0.01 annual, and 0.05, 0.10, and 0.25 in 50 years) are also presented. The 10-percent probability of exceedance in 50-year runups range from 0.5 to 1.4 meters in the study area and the 1-percent annual probability of exceedance (equivalent to the 100 year return time) runups range from 0.3 to 0.7 meters.

The principal tsunami hazard for the city of Aguadilla from the Mona Passage region is related to a repeat of the 1918 M 7.3 earthquake. Tsunami runup heights from fault segments that are believed to have ruptured in 1918 range from 1.5 to 3 meters within the study area and are a factor of two or more larger than the modeled runups from the 30 other fault segments included in this analysis. Modeled runups for the majority of potential tsunami sources in the Mona Passage are similar to those seen from hurricane storm surge.

Introduction

Fifty tsunamis have been observed in the Caribbean region since 1530 and have accounted for more fatalities than the sum of all tsunamis in Alaska, Hawaii, and the west coast of the United States in the last 500 years (Lander, 1977). Caribbean tsunamis are caused by a number of physical mechanisms including local submarine earthquakes (e.g., 1867 Anegada Passage, 1918 M 7.3 Mona Passage), volcanic activity and landslides (Nevis Peak, 1690), and the eruption of mud volcanoes (Trinidad, 1911). Tsunamis from distant sources in the Atlantic, such as 1755 Lisbon, Portugal earthquake, also pose a threat. While the tsunami hazard is not as great as other hazards in the Caribbean region (i.e., tropical storms and hurricanes), no fewer than six have caused damage in the last century and a repeat of one of these historic tsunami events would be disastrous due to increased coastal population and development in the region.

Tsunami hazards need to be characterized in terms that are applicable to coastal construction, as well as policy and land-use decisions. The most common reference for storm surges associated with tropical storms and hurricanes is the elevation of the coastal flood that has a 1-percent chance of being exceeded in any given year, also known as the 100-year flood (FEMA, 1997). The 1-percent chance annual flood is derived from statistical hydrologic analyses to establish stage-frequency relationships of the water surface based on historic data.

In areas where there are a number of observations, information about the size and frequency of tsunami runups can also be used to map potential flooding zones in terms of the probability of exceedance in a specific period of time. (e.g., Gusiakov, 1997). Maps showing predicted tsunami elevations with both 10-perecent chance of being exceeded in 50 years (475 year return time) and a 1-percent chance annual runup (100 year return time) have been prepared for the western United States, Alaska, and Hawaii. Similar maps have not been published for Puerto Rico, however, due to limited historic data and the infrequency of events (FEMA, 1997).

Comparison of computer models of tsunami runups with actual observations from the few historic earthquakes that do exist (e.g., Mercado and McCann, 1999, 1918 Mona Passage earthquake) provides valuable information for hazard identification and planning purposes. Modeled results are calibrated with historic observations and can be used to map flooding at a much finer scale than is available from eyewitness accounts or tide gauge records. While these studies only address specific earthquakes, they form the foundation for a more comprehensive suite of analyses that consider a population of potential tsunami sources in a region. These detailed analyses can be used to construct synthetic tsunami runup-frequency relationships and estimates of the probabilities of exceedance of flood levels.

This study presents the results of a probabilistic analysis of earthquake-generated tsunami runups for the coast of Aguadilla, Puerto Rico using synthetic runup-frequency calculations based on the hydrodynamic modeling of potential tsunami source zones in the Mona Passage region, west of Puerto Rico. Tsunami runups are mapped at a interval of approximately 90 meters along the coast. Probabilities of exceedance for runups of 1, 2, and 3 meters are calculated for return times of 50, 100, 500, and 1000 years. Runups for specific probabilities of exceedance (0.01 annual, and 0.05, 0.10, and 0.25 in 50 years) are also presented.

Methodology

The methodology for the probabilistic tsunami hazard analysis is summarized in the following five steps.

1. Measure fault parameters (strike, length, dip) for a suite of submarine faults in the Mona Passage.
2. Develop fault length-fault displacement-seismic moment and return time estimates for each fault segment.
3. For each fault segment (using inputs from 1 and 2), propagate tsunami waves to the study region and compute runup values.
4. Develop cumulative tsunami runup – frequency distributions for each coastal segment using the earthquake return time and runups (from 2 and 3).
5. Develop tsunami hazard equations (based on 4) that provide
   - **a.** the probability of exceeding runup heights of 1, 2, and 3 meters for exposure periods of 50, 100, 500, 1000 years.
   - **b.** runup heights for probabilities of exceedance of 0.01 per year and 0.25, 0.10, and 0.05 in 50 years.

Data from steps 1 through 3 serve as input to the probabilistic hazard analysis, and the procedures and methodology to develop those estimates are described elsewhere (e.g. McCann, 1998). This report addresses the final steps in this process (steps 4 and 5) and the following sections discuss the procedures used to conduct the analysis.

Step 4 - Develop cumulative tsunami runup – frequency distributions for each coastal segment using estimated earthquake return times and modeled runups.

Coastal segments are spaced every 0.05 minute of latitude, or approximately 90 meters, from 18° 25.11' to 18° 26.91' N along the coast of northwestern Puerto Rico near Aguadilla (see Figure 1). For each site, runup- frequency relationships were developed based on a synthetic catalog of tsunami activity. The number of tsunami runups in 10,000 years was calculated for each fault segment based on the estimated frequency of occurrence for that fault segment. The number of runups from all 31 fault segments in 10,000 years are then aggregated to construct a synthetic tsunami catalog for each of the 37 sites along the coast of Aguadilla. Data in each synthetic catalog were binned in 0.1 m increments of runup and the cumulative number of runups in 10,000 years are plotted as function of the runup size on a log-log scale for further analysis. Figure 2 shows the cumulative tsunami runup- frequency relationship at 18° 25.11' N. See Worksheet … for the catalog parameters for all 37 coastal sites.

Step 5 - Develop tsunami hazard equations that provide

1. *the probability of exceeding runup heights of 1, 2, and 3 meters for exposure periods of 50, 100, 500, 1000 years.*
2. *runup heights for probabilities of exceedance of 0.01 per year and 0.25, 0.10, and 0.05 in 50 years.*

Two techniques were used to analyze the synthetic tsunami catalog for Aguadilla. The first was based on a traditional cumulative runup-frequency distribution (see Figure 2) and the second is based on rank-order statistics (see Figure 3). The rank-order plot is the same as the cumulative runup-frequency distribution, but with an interchange of axes. Both plots illustrate the underlying power law distribution of the runup data, however, the two techniques provide different perspectives on that distribution. Rank-order statistics provide emphasis on extreme tails of distribution (which in this study is dominated by runups from 1918) and can be constrained by only a small number of the largest events. Cumulative distributions, on the other hand, are constrained by the distribution of the more numerous smaller events (Sornette et al., 1996).

Least Squares fits to the cumulative runup-frequency distributions are of the form

$$N = aH^{-b} \qquad [1]$$

where N, is the cumulative number of events greater than or equal to a runup H, b is the slope of the distribution, and a is a constant related to the overall number of events per unit time. The minimum or cutoff runup used for all analysis was 0.25 meters. Values of b for the cumulative distribution range from -1.9 to -2.4, and values of a range from 6.5 to 44, both reflecting the localized variations in runup frequency behavior along the coast. r^2 values for the least squares fits range from 0.83 to 0.99. (see Worksheets for a detailed description of regression equations for each coastal segment)

Using the same notation as in Equation 1, least squares fits to the rank-order statistics are of the form

$$H = aN^{-b} \qquad [2]$$

Probabilities for a specific runup and exposure period, P_T, are computed using the results of the least squares regression and a Poisson model,

$$P_T = 1 - \exp^{-\lambda T} \qquad [3]$$

where λ is the frequency of occurrence of a specific runup height, H, and T is the period of exposure. Tables 2 and 3 present probabilities for the exceedance of computed tsunami heights, H, of 1, 2, and 3 meters for exposure periods, T, of 50, 100, 500, and

1000 years. As seen in Figure 4, the highest probabilities for exceedance of 1 meter runups in 50 years (0.20) exist in the southern part of the study area near 18° 25.11. There is a relatively steep gradient in probability (from 0.20 to 0.09) from 18° 25.11 to 18° 25.31, followed by a more gradual decease (from 0.09 to 0.04) to the northern part of the study area at 18° 26.91.

Runup heights for specific probabilities of exceedance are computed using the parameters in Eqn. 1, where

$$H = 10^{[\log (N/a)/b]} \qquad [3]$$

And are calculated directly from Eqn. 2.

Tables 4 and 5 list tsunami runup heights for probabilities of exceedance of 0.01per year and 0.25, 0.10, and 0.05 in 50 years, equivalent to events with return times of 100, 175, 475, and 1000 years, respectively.   As seen in Figure 5, the largest values for the 10-percent in 50 years runup (1.4 m) occur in the southern part of the study zone in the vicinity of 18° 25.11' N. As with the distribution of probabilities in Figure 4, there is a step gradient from 1.4 to 0.9 m from 18° 25.11 to 18° 25.31, followed by a more gradual decease (from 0.9 to 0.5 m) to the northern part of the study area at 18° 26.91. Modeled tsunami runup profiles from the 1918 event (Fig 7, Mercado and McCann, 1998) show a similar gradient from south to north in the area of Aguadilla.   At the scale of this study, computed runups vary by a factor of three throughout the study area, ranging from 0.3 to 0.9 m for 175 year return times, 0.5 to 1.4 m for 475 year return times, and 0.7 to 2 m for 1000 year return times. Annual runups (1-percent per year) in Figure 5 exhibit similar characteristics but are much reduced in overall amplitude, ranging from 0.7 to 0.3 m.

Summary

Analysis of submarine faulting and modeled tsunami runups originating from the Mona Passage area indicate that the principal tsunami hazard for the city of Aguadilla, Puerto Rico is related to a repeat of the 1918 earthquake. Tsunami runup heights from fault segments that are believed to have ruptured in 1918 range from 1.5 to 3 meters and are a factor of two or more larger than the modeled runups from 30 other fault segments included in this analysis. Modeled runups for the majority of potential earthquake sources in the Mona Passage area are similar to those seen from storm surge in hurricanes.

Based on estimated 3116 yr recurrence time for the 1918 source alone, the probability for a repeat of this size tsunami in the future ranges from 1.6% in 50 yrs; 3.2% in 100 yrs; 14.8% in 500 yrs; 27.4% in 1000 yrs (see Table 1). Using a synthetic catalog of all possible tsunami sources from the Mona Passage region, the probability of a 3 meter runup is slightly larger and ranges from 2% in 50 yrs; 4% in 100 yrs; 18% in 500 yrs; 34% in 1000 yrs.

The use of synthetic tsunami catalogs to examine tsunami hazards provides a degree of spatial resolution not available from historic observations. Tsunami runups and their corresponding probabilities show strong spatial variation related to changes in submarine topography and shoreline along the coast of Aguadilla, with the largest values along the southern part of the study area.

Information of this type and scale is valuable for land use planning and coastal zone management. The 1-percent annual chance flood has been widely adopted as the common design and regulatory standard in the United States and is used to delineate areas of storm surge flooding in coastal areas. Integration of the probabilistic Mona Passage runup values with those due to hurricane storm surge provide the foundation for an integrated coastal hazards model along the coast of Aguadilla and northwestern Puerto Rico.

Future improvements to the overall tsunami hazard analysis for western Puerto Rico include-

- Better estimates of the return period of 1918 type tsunamis. Geologic observations supporting a large tsunami prior to 1918 are undated as of this writing (W. McCann, personal comm., 1997)
- Improved bathymetric and topographic maps to model runup along the coast and in populated urban areas.

Electronic Databases

The accompanying Microsoft Excel2000 spreadsheet contains the following project information:

Worksheet 1 (Base Data)

- Segment identifications and estimated recurrence times for 31 fault segments in the Mona Passage region
- Runup estimates for 37 sites (spaced every 90 m) along the northwestern coast of Puerto Rico at Aguadilla.

Worksheet 2 (Tsunami Catalog)

- Tsunami Runup and frequency data for each coastal segment

Worksheet 3 (Data Analysis)

- Runup-frequency analysis of 37 coastal segments

Worksheet 4 (Probability – Runup Values)

- Runup-frequency distribution parameters
- Probabilities of exceedance of 1, 2, and 3 meter events for time periods of 50, 100, 500, and 1000 years.
- Runup heights for probabilities of exceedance of 0.01 per year and 0.25, 0.10 and 0.05 in 50 years

Figure 1. Study area

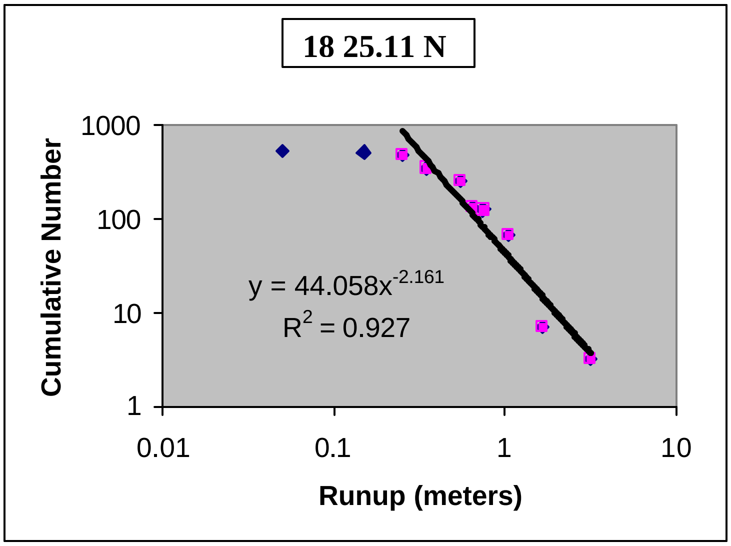

Figure 2. Cumulative Tsunami Runup-Frequency Relationship
Squares represent the subset of the data used for the cumulative power law regression equation at site located at 18° 25.11 N, where y (cumulative number of events in 10,000 years) is a function of x (runup height). R^2 is the correlation coefficient.

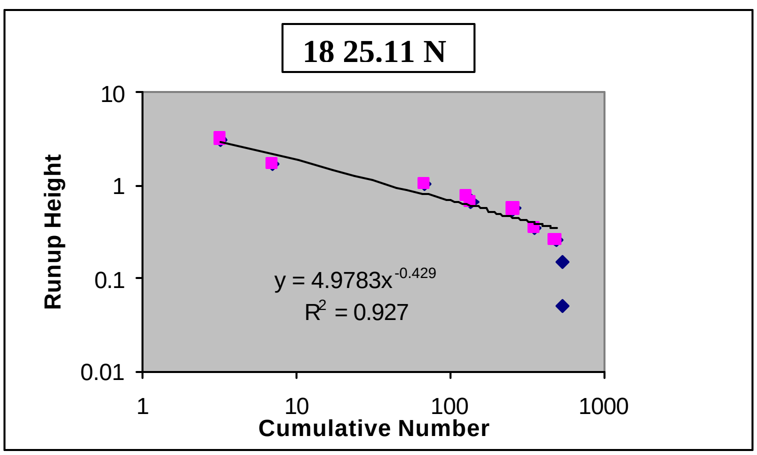

Figure 3. Rank-Order Tsunami Runup-Frequency Distribution
Squares represent the subset of the data used for the rank-order power law regression equation at site located at 18° 25.11 N, where y (cumulative number of events in 10,000 years) is a function of x (runup height). R^2 is the correlation coefficient.

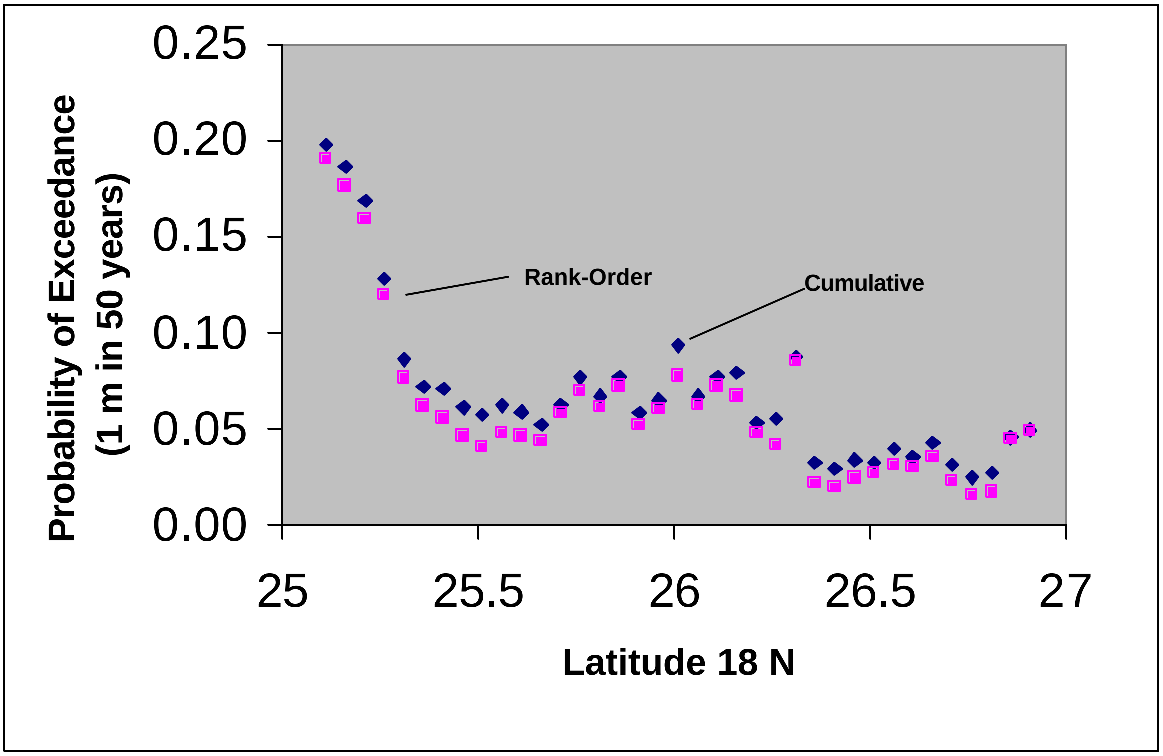

Figure 4 Probability of exceeding 1-meter runups in 50 years along the coast of Aguadilla, Puerto Rico. Probabilities calculated using cumulative statistics are shown as diamonds, values calculated using rank-order statistics are shown as squares.

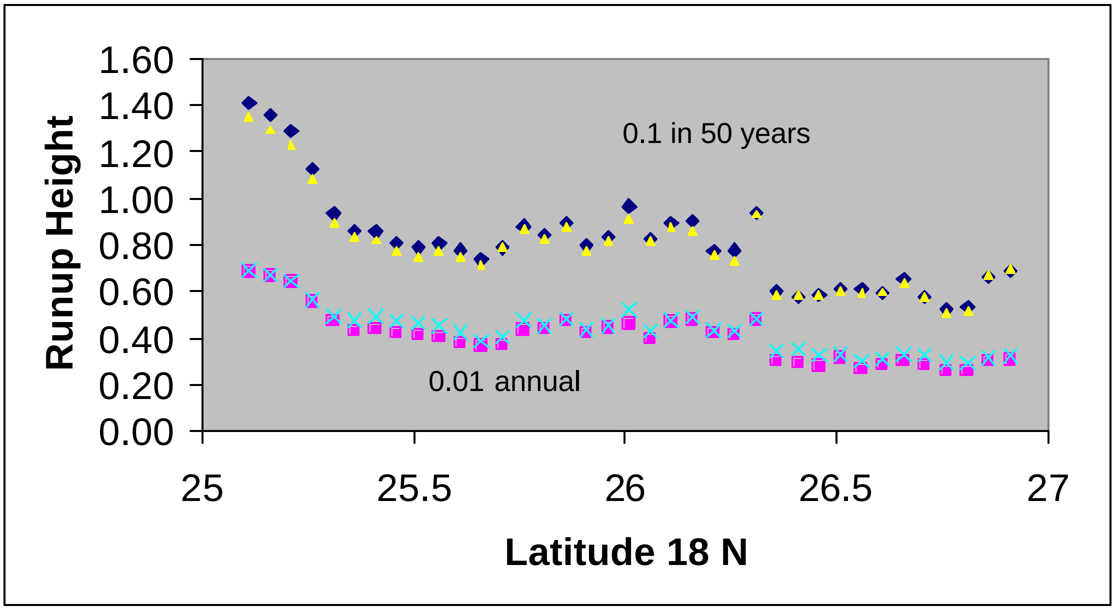

Figure 5 Runup heights with probabilities of exceedance of 0.01 per year and 0.10 in 50 years along the coast of Aguadilla, Puerto Rico. Runup heights based on cumulative statistics are shown as diamonds and squares for 0.1 in 50 year and 0.01 per year events. Runup heights based on rank-order statistics are shown as triangles and crosses for 0.1 in 50 year and 0.01 per year events.

Table 1. Poisson probabilities for the recurrence of the 1918 Mona Passage earthquake.

Return Time	Exposure Period			
3115 years	50 yrs	100 yrs	500 yrs	1000 yrs
Probability	0.016	0.032	0.148	0.274

Table 2. Probabilities of exceedance for tsunami runups of 1, 2, and 3 meters during exposure periods of 50, 100, 500, and 1000 years along the coast of Aguadilla, Puerto Rico based on cumulative statistics

	Probability of Exceedance											
Zone	P50/1m	P50/2m	P50/3m	P100/1m	P100/2m	P100/3m	P500/1m	P500/2m	P500/3m	P1000/1m	P1000/2m	P1000/3m
25.11	0.198	0.048	0.020	0.356	0.094	0.040	0.890	0.389	0.185	0.988	0.627	0.336
25.16	0.186	0.044	0.018	0.338	0.086	0.036	0.873	0.363	0.169	0.984	0.594	0.309
25.21	0.169	0.039	0.016	0.309	0.076	0.032	0.842	0.326	0.148	0.975	0.546	0.274
25.26	0.128	0.030	0.012	0.240	0.058	0.025	0.746	0.260	0.117	0.936	0.452	0.220
25.31	0.086	0.018	0.007	0.164	0.036	0.014	0.592	0.166	0.068	0.834	0.304	0.132
25.36	0.072	0.015	0.006	0.138	0.031	0.012	0.525	0.144	0.061	0.775	0.268	0.117
25.41	0.071	0.014	0.006	0.137	0.029	0.011	0.520	0.135	0.055	0.770	0.252	0.106
25.46	0.061	0.012	0.004	0.118	0.024	0.009	0.467	0.112	0.044	0.716	0.212	0.086
25.51	0.057	0.011	0.004	0.111	0.022	0.008	0.445	0.104	0.040	0.692	0.196	0.078
25.56	0.062	0.013	0.005	0.120	0.026	0.010	0.472	0.123	0.051	0.722	0.231	0.099
25.61	0.059	0.013	0.005	0.114	0.026	0.011	0.454	0.123	0.053	0.702	0.232	0.102
25.66	0.052	0.011	0.005	0.101	0.023	0.009	0.414	0.109	0.046	0.656	0.206	0.090
25.71	0.062	0.015	0.007	0.121	0.030	0.013	0.474	0.141	0.063	0.723	0.262	0.123
25.76	0.077	0.017	0.007	0.147	0.034	0.014	0.549	0.158	0.068	0.797	0.292	0.131
25.81	0.067	0.013	0.005	0.129	0.026	0.010	0.500	0.122	0.047	0.750	0.228	0.093
25.86	0.077	0.015	0.005	0.148	0.029	0.011	0.550	0.137	0.054	0.798	0.256	0.104
25.91	0.058	0.011	0.004	0.113	0.022	0.008	0.451	0.103	0.039	0.698	0.195	0.077
25.96	0.065	0.012	0.004	0.126	0.024	0.009	0.489	0.114	0.043	0.739	0.215	0.085
26.01	0.093	0.022	0.010	0.178	0.044	0.019	0.624	0.203	0.092	0.858	0.364	0.175
26.06	0.067	0.016	0.007	0.130	0.031	0.013	0.500	0.146	0.065	0.750	0.272	0.125
26.11	0.077	0.015	0.006	0.148	0.029	0.011	0.551	0.139	0.054	0.799	0.258	0.106
26.16	0.079	0.015	0.006	0.151	0.030	0.011	0.560	0.141	0.055	0.806	0.262	0.107
26.21	0.053	0.009	0.003	0.103	0.018	0.006	0.420	0.087	0.031	0.664	0.167	0.062
26.26	0.055	0.010	0.004	0.107	0.021	0.008	0.433	0.099	0.038	0.679	0.187	0.074
26.31	0.087	0.018	0.007	0.167	0.036	0.014	0.598	0.169	0.070	0.839	0.310	0.136
26.36	0.032	0.007	0.003	0.063	0.013	0.005	0.279	0.065	0.026	0.480	0.126	0.052
26.41	0.029	0.006	0.002	0.058	0.012	0.005	0.257	0.059	0.024	0.449	0.114	0.046
26.46	0.034	0.008	0.003	0.066	0.016	0.007	0.289	0.076	0.033	0.494	0.147	0.065
26.51	0.032	0.006	0.002	0.063	0.013	0.005	0.279	0.062	0.024	0.479	0.119	0.048
26.56	0.040	0.011	0.005	0.078	0.021	0.010	0.333	0.101	0.048	0.555	0.192	0.093
26.61	0.035	0.008	0.004	0.069	0.017	0.007	0.300	0.080	0.035	0.509	0.154	0.069
26.66	0.043	0.011	0.005	0.084	0.021	0.009	0.356	0.101	0.046	0.585	0.193	0.089
26.71	0.031	0.007	0.003	0.062	0.014	0.006	0.273	0.068	0.028	0.472	0.131	0.056
26.76	0.025	0.005	0.002	0.049	0.011	0.004	0.220	0.052	0.022	0.392	0.102	0.043
26.81	0.027	0.006	0.003	0.053	0.012	0.005	0.238	0.060	0.025	0.420	0.116	0.050
26.86	0.045	0.012	0.005	0.088	0.023	0.010	0.371	0.111	0.051	0.604	0.209	0.100
26.91	0.049	0.013	0.006	0.096	0.026	0.012	0.397	0.123	0.058	0.636	0.231	0.113

Table 3. Probabilities of exceedance for tsunami runups of 1, 2, and 3 meters during exposure periods of 50, 100, 500, and 1000 years along the coast of Aguadilla, Puerto Rico based on rank-order statistics.

	Probability of Exceedance											
Zone	P50/1m	P50/2m	P50/3m	P100/1m	P100/2m	P100/3m	P500/1m	P500/2m	P500/3m	P1000/1m	P1000/2m	P1000/3m
2511	0.190	0.041	0.016	0.344	0.080	0.032	0.879	0.342	0.150	0.985	0.567	0.278
2516	0.176	0.037	0.014	0.322	0.072	0.028	0.856	0.311	0.133	0.979	0.526	0.248
2521	0.160	0.032	0.012	0.294	0.064	0.025	0.824	0.280	0.117	0.969	0.482	0.220
2526	0.120	0.024	0.009	0.226	0.048	0.018	0.721	0.217	0.089	0.922	0.387	0.170
2531	0.076	0.013	0.005	0.147	0.026	0.009	0.549	0.122	0.044	0.796	0.230	0.087
2536	0.062	0.009	0.003	0.120	0.018	0.006	0.472	0.088	0.029	0.721	0.168	0.058
2541	0.056	0.007	0.002	0.108	0.014	0.004	0.436	0.066	0.019	0.682	0.127	0.038
2546	0.046	0.005	0.002	0.090	0.011	0.003	0.376	0.052	0.015	0.611	0.102	0.030
2551	0.040	0.004	0.001	0.079	0.009	0.002	0.337	0.042	0.011	0.560	0.083	0.023
2556	0.048	0.006	0.002	0.093	0.013	0.004	0.388	0.063	0.020	0.625	0.121	0.039
2561	0.046	0.007	0.002	0.090	0.014	0.005	0.378	0.068	0.023	0.613	0.131	0.045
2566	0.044	0.008	0.003	0.085	0.015	0.005	0.360	0.073	0.026	0.591	0.140	0.052
2571	0.058	0.012	0.005	0.113	0.024	0.009	0.452	0.112	0.045	0.699	0.212	0.088
2576	0.070	0.012	0.004	0.135	0.023	0.008	0.515	0.111	0.040	0.765	0.210	0.078
2581	0.061	0.010	0.004	0.119	0.021	0.007	0.470	0.099	0.035	0.719	0.187	0.069
2586	0.072	0.012	0.004	0.139	0.025	0.009	0.527	0.117	0.043	0.776	0.221	0.084
2591	0.052	0.008	0.003	0.101	0.016	0.005	0.413	0.079	0.027	0.655	0.151	0.054
2596	0.060	0.010	0.003	0.117	0.020	0.007	0.463	0.095	0.034	0.711	0.181	0.066
2601	0.078	0.012	0.004	0.149	0.023	0.007	0.555	0.109	0.037	0.802	0.207	0.072
2606	0.062	0.012	0.004	0.121	0.023	0.009	0.474	0.112	0.043	0.724	0.211	0.084
2611	0.072	0.013	0.004	0.140	0.025	0.009	0.528	0.120	0.044	0.778	0.225	0.086
2616	0.067	0.010	0.003	0.130	0.020	0.007	0.500	0.098	0.033	0.750	0.186	0.065
2621	0.048	0.007	0.002	0.094	0.014	0.005	0.388	0.069	0.023	0.626	0.133	0.045
2626	0.042	0.006	0.002	0.081	0.011	0.003	0.346	0.054	0.017	0.573	0.105	0.033
2631	0.085	0.017	0.007	0.163	0.035	0.014	0.590	0.161	0.066	0.832	0.297	0.127
2636	0.022	0.003	0.001	0.043	0.006	0.002	0.199	0.029	0.009	0.358	0.057	0.018
2641	0.020	0.002	0.001	0.039	0.005	0.001	0.182	0.023	0.007	0.330	0.046	0.014
2646	0.025	0.004	0.001	0.049	0.008	0.003	0.221	0.038	0.013	0.393	0.075	0.026
2651	0.027	0.004	0.002	0.054	0.009	0.003	0.241	0.044	0.015	0.423	0.085	0.030
2656	0.031	0.006	0.002	0.061	0.013	0.005	0.270	0.062	0.025	0.467	0.119	0.049
2661	0.030	0.006	0.002	0.059	0.012	0.004	0.264	0.057	0.022	0.458	0.110	0.043
2666	0.036	0.007	0.003	0.070	0.014	0.005	0.304	0.067	0.026	0.516	0.130	0.052
2671	0.023	0.003	0.001	0.046	0.007	0.002	0.208	0.034	0.011	0.373	0.067	0.022
2676	0.015	0.002	0.001	0.030	0.004	0.001	0.142	0.021	0.006	0.263	0.041	0.013
2681	0.017	0.003	0.001	0.034	0.005	0.002	0.159	0.025	0.008	0.292	0.050	0.017
2686	0.045	0.011	0.005	0.088	0.021	0.009	0.368	0.103	0.046	0.600	0.195	0.089
2691	0.049	0.012	0.005	0.096	0.024	0.011	0.395	0.115	0.052	0.634	0.217	0.102

Table 4 Computed tsunami runup heights for probabilities of exceedance of 0.01 per year and 0.25, 0.10, and 0.05 in 50 years based on cumulative statistics

Run Ups				
25%/50 years	**10%/50 years**	**5%/50 years**	**1%/year**	**Zone**
0.89	1.41	1.99	0.68	**25.11**
0.86	1.36	1.91	0.67	**25.16**
0.82	1.29	1.80	0.64	**25.21**
0.72	1.13	1.59	0.55	**25.26**
0.61	0.93	1.29	0.48	**25.31**
0.55	0.86	1.19	0.43	**25.36**
0.56	0.86	1.18	0.44	**25.41**
0.53	0.81	1.10	0.42	**25.46**
0.52	0.79	1.07	0.41	**25.51**
0.52	0.80	1.11	0.41	**25.56**
0.49	0.78	1.09	0.38	**25.61**
0.47	0.74	1.03	0.36	**25.66**
0.49	0.79	1.13	0.37	**25.71**
0.56	0.88	1.23	0.44	**25.76**
0.56	0.84	1.14	0.44	**25.81**
0.59	0.89	1.21	0.47	**25.86**
0.53	0.80	1.08	0.42	**25.91**
0.56	0.83	1.13	0.44	**25.96**
0.60	0.97	1.37	0.46	**26.01**
0.51	0.82	1.17	0.40	**26.06**
0.59	0.89	1.21	0.47	**26.11**
0.60	0.90	1.23	0.48	**26.16**
0.53	0.78	1.03	0.42	**26.21**
0.52	0.78	1.05	0.41	**26.26**
0.61	0.94	1.30	0.48	**26.31**
0.39	0.60	0.83	0.30	**26.36**
0.37	0.58	0.80	0.29	**26.41**
0.36	0.59	0.83	0.28	**26.46**
0.40	0.61	0.83	0.31	**26.51**
0.36	0.61	0.90	0.27	**26.56**
0.37	0.60	0.85	0.28	**26.61**
0.40	0.65	0.94	0.30	**26.66**
0.37	0.58	0.81	0.28	**26.71**
0.33	0.52	0.73	0.26	**26.76**
0.33	0.53	0.75	0.26	**26.81**
0.40	0.66	0.96	0.30	**26.86**
0.41	0.68	1.01	0.31	**26.91**

Table 5 Computed tsunami runup heights for probabilities of exceedance of 0.01 per year and 0.25, 0.10, and 0.05 in 50 years based on rank-order statistics

Run Ups				
25%/50 years	10%/50 years	5%/50 years	1%/year	Zone
0.88	1.35	1.85	0.69	**25.11**
0.85	1.29	1.77	0.67	**25.16**
0.81	1.23	1.68	0.64	**25.21**
0.71	1.08	1.48	0.56	**25.26**
0.61	0.90	1.19	0.49	**25.31**
0.58	0.84	1.09	0.48	**25.36**
0.59	0.82	1.04	0.49	**25.41**
0.56	0.77	0.98	0.47	**25.46**
0.55	0.75	0.94	0.46	**25.51**
0.55	0.77	0.99	0.45	**25.56**
0.52	0.75	0.98	0.42	**25.61**
0.49	0.72	0.96	0.39	**25.66**
0.51	0.79	1.08	0.40	**25.71**
0.59	0.87	1.15	0.48	**25.76**
0.56	0.82	1.10	0.45	**25.81**
0.60	0.88	1.17	0.48	**25.86**
0.54	0.78	1.02	0.44	**25.91**
0.56	0.82	1.09	0.45	**25.96**
0.64	0.91	1.19	0.52	**26.01**
0.54	0.82	1.11	0.43	**26.06**
0.59	0.88	1.17	0.48	**26.11**
0.60	0.86	1.13	0.49	**26.16**
0.53	0.76	0.99	0.43	**26.21**
0.52	0.73	0.95	0.43	**26.26**
0.61	0.93	1.28	0.48	**26.31**
0.42	0.59	0.76	0.34	**26.36**
0.42	0.58	0.74	0.35	**26.41**
0.40	0.58	0.77	0.33	**26.46**
0.41	0.60	0.80	0.33	**26.51**
0.38	0.59	0.82	0.30	**26.56**
0.39	0.60	0.81	0.31	**26.61**
0.42	0.64	0.87	0.33	**26.66**
0.40	0.58	0.76	0.33	**26.71**
0.36	0.51	0.66	0.30	**26.76**
0.36	0.52	0.68	0.29	**26.81**
0.41	0.67	0.96	0.32	**26.86**
0.43	0.70	1.00	0.32	**26.91**

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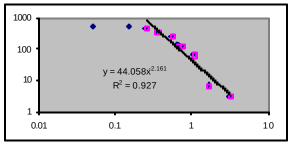
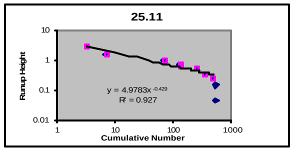
WORKSHEET DATA

Location 25.110

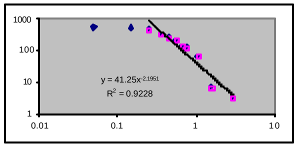
Height	N	Cum #	A*B		
				cum N=	490.428
0.05	12.628	539.865	0.6314177		
0.15	36.809	527.237	5.5212752	cum A*B=	265.65593
0.25	**137.576**	**490.428**	34.393992		
0.35	**93.903**	**352.853**	32.86597	cumAB/cun	0.5416813
0.55	**122.215**	**258.950**	67.218425		
0.65	**9.468**	**136.734**	6.1544893	b=.4343[1/(	0.801763
0.75	**58.812**	**127.266**	44.10874		
1.05	**61.415**	**68.454**	64.486116	95%CI=b*1.	0.0709601
1.65	**3.830**	**7.039**	6.3190831		
3.15	**3.209**	**3.209**	10.109114	**b values**	
				95%	0.873
				mean	0.802
				-95%	0.731
				a values	
				95%	2.909
				mean	2.891
				-95%	2.873

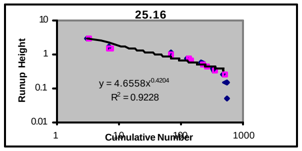




Location 25.160

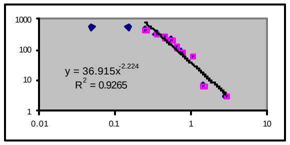
Height	N	Cum #	A*B		
				cum N=	480.100
0.05	12.628	539.87	0.6314177		
0.15	47.138	527.24	7.0706705	cum A*B=	255.84107
0.25	145.375	480.10	36.34381		
0.35	75.774	334.72	26.520968	cumAB/cun	0.5328913
0.45	43.995	258.95	19.7977		
0.55	78.216	214.96	43.018594	b=.4343[1/(	1.3046302
0.65	9.470	136.74	6.1555		
0.75	58.810	127.27	44.1075	95%CI=b*1	0.1167018
1.05	61.420	68.46	64.491		
1.55	3.830	7.04	5.9365	**b values**	
2.95	3.210	3.21	9.4695	**95%**	1.421
				mean	1.305
				-95%	1.188
				a values	
				95%	3.037
				mean	3.007
				-95%	2.978

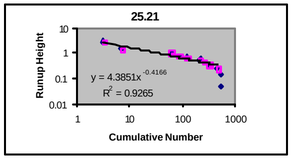




Location 25.210

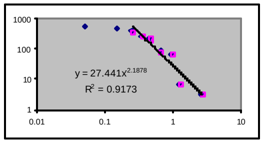
Height	N	Cum #	A*B		
				cum N=	457.209
0.05	12.628	539.866	0.6314177		
0.15	70.029	527.238	10.504301	cum A*B=	240.67585
0.25	**133.940**	**457.209**	33.485044		
0.35	**64.318**	**323.269**	22.511437	cumAB/cun	0.5264019
0.45	**43.995**	**258.951**	19.7977		
0.55	**91.807**	**214.956**	50.493701	b=.4343[1/(	0.8250351
0.65	**37.099**	**123.149**	24.1143		
0.75	**24.630**	**86.050**	18.472669	95%CI=b*1.	0.075626
1.05	**54.380**	**61.420**	57.099		
1.45	**3.830**	**7.040**	5.5535	**b values**	
2.85	**3.210**	3.210	9.1485	**95%**	0.901
				mean	0.825
				-95%	0.749
				a values	
				95%	2.885
				mean	2.866
				-95%	2.847

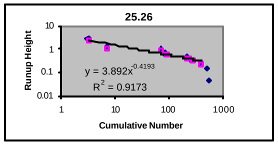




Location 25.260

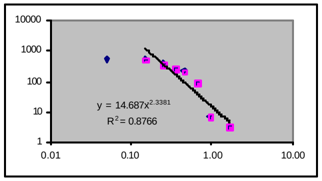
Height	N	Cum #	A*B		
				cum N=	384.559
0.05	49.437	539.866	2.4718427		
0.15	105.870	490.429	15.880485	cum A*B=	188.32028
0.25	**121.791**	**384.559**	30.447662		
0.35	**47.813**	**262.769**	16.734576	cumAB/cun	0.489704
0.45	**128.906**	**214.956**	58.007544		
0.65	**17.410**	**86.050**	11.3165	b=.4343[1/(	1.4991161
0.95	**61.600**	**68.640**	58.52		
1.25	**3.830**	**7.040**	4.7875	95%CI=b*1	0.1498337
2.65	**3.210**	**3.210**	8.5065		
			0	**b values**	
				95%	1.649
				mean	1.499
				-95%	1.349
				a values	
				95%	2.997
				mean	2.960
				-95%	2.922

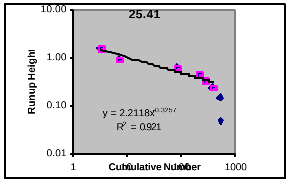




Location 25.410

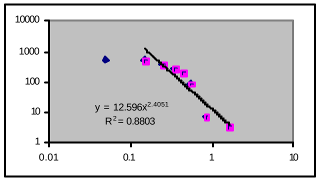
Height	N	Cum #	A*B		
				cum N=	527.238
0.05	12.628	539.866	0.631418		
0.15	147.296	527.238	22.09437	cum A*B=	187.5328
0.25	**106.060**	**379.942**	26.51493		
0.35	**58.927**	**273.882**	20.62432	cumAB/cur	0.355689
0.45	**128.906**	**214.956**	58.00764		
0.65	**79.010**	**86.050**	51.3565	b=.4343[1/	2.789535
0.95	**3.830**	**7.040**	3.6385		
1.65	**3.210**	**3.210**	5.2965	95%CI=b*1	0.238114
			0		
			0	**b values**	
				95%	3.028
				mean	2.790
				-95%	2.551
				a values	
				95%	3.479
				mean	3.419
				-95%	3.360

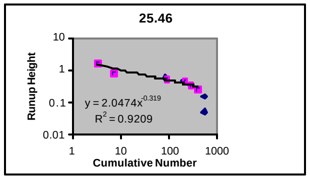




Location 25.460

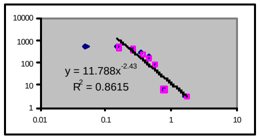
Height	N	Cum #	A*B		
				cum N=	527.238
0.05	12.628	539.866	0.631418		
0.15	147.310	527.238	22.09644	cum A*B=	177.8071
0.25	**110.980**	**379.928**	27.74502		
0.35	**63.461**	**268.948**	22.21131	cumAB/cur	0.337243
0.45	**119.437**	**205.487**	53.74674		
0.55	**79.010**	**86.050**	43.45562	b=.4343[1/(	3.164468
0.85	**3.830**	**7.040**	3.2555		
1.65	**3.210**	**3.210**	5.2965	95%CI=b*1	0.270118
			0		
			0	**b values**	
				95%	3.435
				mean	3.164
				-95%	2.894
				a values	
				95%	3.581
				mean	3.513
				-95%	3.446

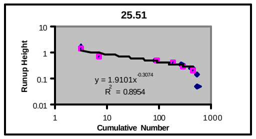




Location 25.510

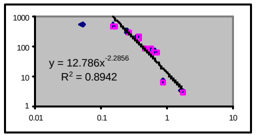
Height	N	Cum #	A*B		
				cum N=	527.238
0.05	12.628	539.866	0.6314177		
0.15	105.625	527.238	15.843692	cum A*B=	179.09739
0.25	**152.665**	**421.613**	38.166269		
0.35	**88.413**	**268.948**	30.944685	cumAB/cun	0.3396898
0.45	**94.485**	**180.535**	42.518118		
0.55	**79.010**	**86.050**	43.455624	b=.4343[1/(	1.811925
0.75	**3.830**	**7.040**	2.8725		
1.65	**3.210**	**3.210**	5.2965	95%CI=b*1.	0.1546653
			0		
			0	**b values**	
				95%	1.967
				mean	1.812
				-95%	1.657
				a values	
				95%	3.214
				mean	3.175
				-95%	3.136

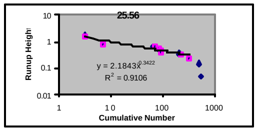




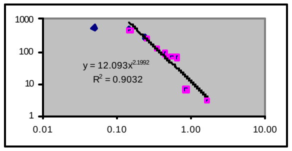
Location 25.560

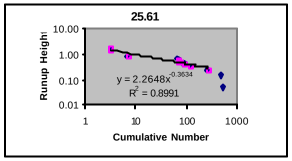
Height	N	Cum #	A*B		
				cum N=	514.975
0.05	24.891	539.866	1.2445691		
0.15	191.706	514.975	28.755873	cum A*B=	159.51212
0.25	**108.313**	**323.269**	27.07832		
0.35	**124.788**	**214.956**	43.67573	cumAB/cun	0.3097473
0.45	**4.118**	**90.168**	1.8530341		
0.55	**17.595**	**86.050**	9.6771819	b=.4343[1/(	2.0705867
0.65	**61.415**	**68.455**	39.919977		
0.85	**3.830**	**7.040**	3.2555	95%CI=b*1	0.1788366
1.65	**3.210**	**3.210**	5.2965		
			0	**b values**	
				95%	2.249
				mean	2.071
				-95%	1.892
				a values	
				95%	3.274
				mean	3.229
				-95%	3.185



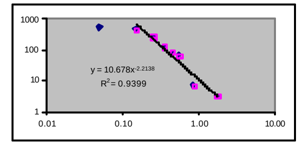


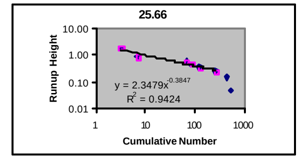
Location	25.610				
Height	**N**	**Cum #**	**A*B**	cum N=	490.339
0.05	49.532	539.871	2.4765936		
0.15	221.386	490.339	33.207925	cum A*B=	140.00259
0.25	**144.359**	**268.953**	36.089823		
0.35	**34.421**	**124.594**	12.047331	cumAB/cum	0.285522
0.45	**17.595**	**90.173**	7.9176943		
0.55	**4.118**	**72.578**	2.2648195	b=.4343[1/(	2.3409627
0.65	**61.420**	**68.460**	39.923		
0.85	**3.830**	**7.040**	3.2555	95%CI=b*1.	0.207206
1.65	**3.210**	**3.210**	5.2965		
			0	**b values**	
				95%	2.548
				mean	2.341
				-95%	2.134
				a values	
				95%	3.328
				mean	3.276
				-95%	3.224



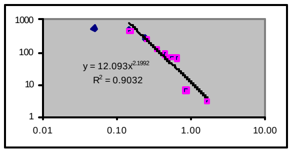


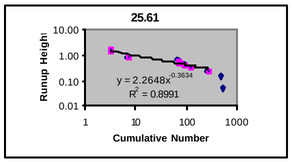
Location	25.660				
Height	**N**	**Cum #**	**A*B**	cum N=	465.183
0.05	74.684	539.866	3.73418		
0.15	196.234	465.183	29.435166	cum A*B=	129.8505
0.25	**141.681**	**268.948**	35.420329		
0.35	**41.217**	**127.267**	14.425872	cumAB/cur	0.2791387
0.45	**17.595**	**86.050**	7.9176943		
0.55	**61.415**	**68.455**	33.778442	b=.4343[1/(	5.4878345
0.85	**3.830**	**7.040**	3.2555		
1.75	**3.210**	**3.210**	5.6175	95%CI=b*1	0.4987068
			0		
			0	**b values**	
				95%	5.987
				mean	5.488
				-95%	4.989
				a values	
				95%	4.164
				mean	4.040
				-95%	3.915



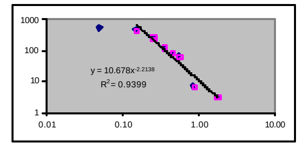


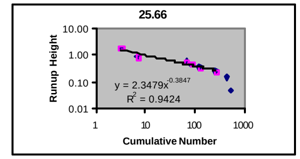
Location	25.610				
Height	**N**	**Cum #**	**A*B**	cum N=	490.339
0.05	49.532	539.871	2.4765936		
0.15	221.386	490.339	33.207925	cum A*B=	140.00259
0.25	**144.359**	**268.953**	36.089823		
0.35	**34.421**	**124.594**	12.047331	cumAB/cum	0.285522
0.45	**17.595**	**90.173**	7.9176943		
0.55	**4.118**	**72.578**	2.2648195	b=.4343[1/(	2.3409627
0.65	**61.420**	**68.460**	39.923		
0.85	**3.830**	**7.040**	3.2555	95%CI=b*1.	0.207206
1.65	**3.210**	**3.210**	5.2965		
			0	**b values**	
				95%	2.548
				mean	2.341
				-95%	2.134
				a values	
				95%	3.328
				mean	3.276
				-95%	3.224



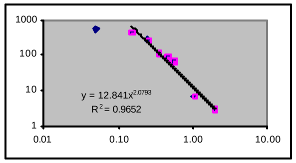


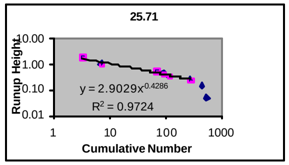
Location	25.660				
Height	**N**	**Cum #**	**A*B**	cum N=	465.183
0.05	74.684	539.866	3.73418		
0.15	196.234	465.183	29.435166	cum A*B=	129.8505
0.25	**141.681**	**268.948**	35.420329		
0.35	**41.217**	**127.267**	14.425872	cumAB/cur	0.2791387
0.45	**17.595**	**86.050**	7.9176943		
0.55	**61.415**	**68.455**	33.778442	b=.4343[1/(	5.4878345
0.85	**3.830**	**7.040**	3.2555		
1.75	**3.210**	**3.210**	5.6175	95%CI=b*1	0.4987068
			0		
			0	**b values**	
				95%	5.987
				mean	5.488
				-95%	4.989
				a values	
				95%	4.164
				mean	4.040
				-95%	3.915



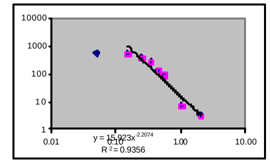


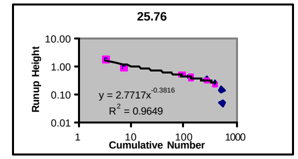
Location	25.710				
Height	**N**	**Cum #**	**A*B**	cum N=	448.555
0.05	91.312	539.866	4.5655909		
0.15	179.606	448.555	26.940933	cum A*B=	127.96141
0.25	**153.828**	**268.948**	38.456934		
0.35	**24.953**	**115.121**	8.7333757	cumAB/cun	0.285275
0.45	**21.713**	**90.168**	9.7707284		
0.55	**61.415**	**68.455**	33.778442	b=.4343[1/(	2.3440826
1.05	**3.830**	**7.040**	4.0215		
1.95	**3.210**	**3.210**	6.2595	95%CI=b*1	0.2169309
			0		
			0	**b values**	
				95%	2.561
				mean	2.344
				-95%	2.127
				a values	
				95%	3.292
				mean	3.238
				-95%	3.184



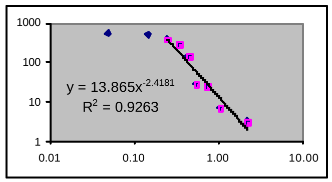


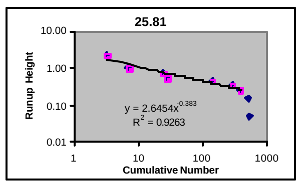
Location	25.760				
Height	**N**	**Cum #**	**A*B**	cum N=	391.662
0.05	12.628	539.866	0.631418		
0.15	135.576	527.238	20.33639	cum A*B=	153.7456
0.25	**121.598**	**391.662**	30.39945		
0.35	**139.296**	**270.064**	48.75357	cumAB/cun	0.392547
0.45	**40.600**	**130.768**	18.27014		
0.55	**83.128**	**90.168**	45.72044	b=.4343[1/(	2.255559
1.05	**3.830**	**7.040**	4.0215		
2.05	**3.210**	**3.210**	6.5805	95%CI=b*1	0.223385
			0		
			0	**b values**	
				95%	2.479
				mean	2.256
				-95%	2.032
				a values	
				95%	3.213
				mean	3.157
				-95%	3.101



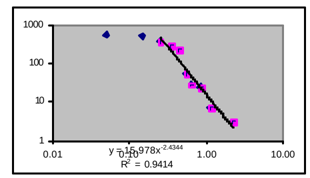


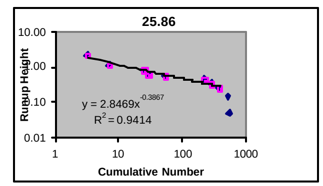
Location	25.810				
Height	**N**	**Cum #**	**A*B**	cum N=	391.657
0.05	12.628	539.861	0.631418		
0.15	135.576	527.233	20.33639	cum A*B=	155.1724
0.25	**99.634**	**391.657**	24.90846		
0.35	**149.113**	**292.023**	52.18971	cumAB/cur	0.396194
0.45	**114.162**	**142.910**	51.37294		
0.55	**4.118**	**28.748**	2.264819	b=.4343[1/(	2.21362
0.75	**17.590**	**24.630**	13.1925		
1.05	**3.830**	**7.040**	4.0215	95%CI=b*1	0.219233
2.25	**3.210**	**3.210**	7.2225		
			0	**b values**	
				95%	2.433
				mean	2.214
				-95%	1.994
				a values	
				95%	3.201
				mean	3.146
				-95%	3.092



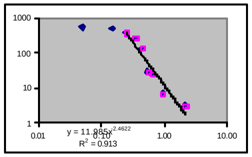


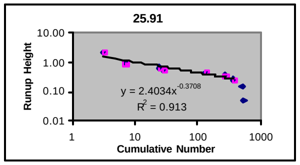
Location	25.860				
Height	**N**	**Cum #**	**A*B**	cum N=	374.817
0.05	24.891	539.866	1.244569		
0.15	140.157	514.975	21.02362	cum A*B=	162.7847
0.25	**93.297**	**374.817**	23.32434		
0.35	**60.385**	**281.520**	21.1347	cumAB/cur	0.434304
0.45	**167.430**	**221.135**	75.3435		
0.55	**24.953**	**53.705**	13.72388	b=.4343[1/(	1.853575
0.65	**4.123**	**28.753**	2.679774		
0.85	**17.590**	**24.630**	14.9515	95%CI=b*1	0.187653
1.15	**3.830**	**7.040**	4.4045		
2.25	**3.210**	**3.210**	7.2225	**b values**	
				95%	2.041
				mean	1.854
				-95%	1.666
				a values	
				95%	3.084
				mean	3.037
				-95%	2.990



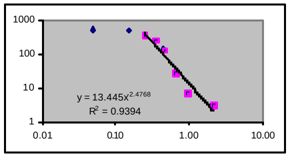


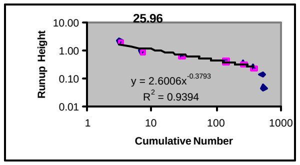
Location	25.910				
Height	**N**	**Cum #**	**A*B**	cum N=	374.817
0.05	24.891	539.866	1.244569		
0.15	140.157	514.975	21.02362	cum A*B=	145.6869
0.25	**104.753**	**374.817**	26.18829		
0.35	**133.329**	**270.064**	46.6651	cumAB/cun	0.388688
0.45	**107.983**	**136.735**	48.59222		
0.55	**4.118**	**28.752**	2.264819	b=.4343[1/(	2.301684
0.65	**17.595**	**24.635**	11.43651		
0.95	**3.830**	**7.040**	3.6385	95%CI=b*1	0.233019
2.15	**3.210**	**3.210**	6.9015		
			0	**b values**	
				95%	2.535
				mean	2.302
				-95%	2.069
				a values	
				95%	3.207
				mean	3.149
				-95%	3.091



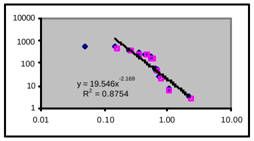


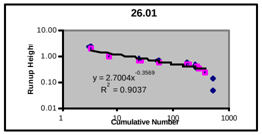
Location	25.960				
Height	**N**	**Cum #**	**A*B**	cum N=	374.817
0.05	24.891	539.866	1.244569		
0.15	140.157	514.975	21.02362	cum A*B=	145.6053
0.25	**109.687**	**374.817**	27.42184		
0.35	**128.395**	**265.130**	44.93814	cumAB/cui	0.38847
0.45	**107.983**	**136.735**	48.59222		
0.65	**21.712**	**28.752**	14.11311	b=.4343[1/	2.304344
0.95	**3.830**	**7.040**	3.6385		
2.15	**3.210**	**3.210**	6.9015	95%CI=b*1	0.233289
			0		
			0	**b values**	
				95%	2.538
				mean	2.304
				-95%	2.071
				a values	
				95%	3.208
				mean	3.150
				-95%	3.092



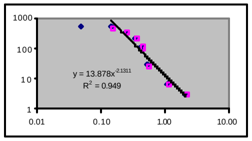


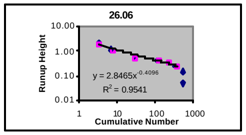
Location	26.010				
Height	**N**	**Cum #**	**A*B**	cum N=	527.238
0.05	12.628	539.866	0.6314177		
0.15	152.421	527.238	22.863079	cum A*B=	201.99216
0.25	**98.232**	**374.817**	24.557887		
0.35	**17.635**	**276.586**	6.1723087	cumAB/cur	0.3831138
0.45	**78.220**	**258.951**	35.199194		
0.55	**127.025**	**180.730**	69.863807	b=.4343[1/(	1.534012
0.65	**29.070**	**53.705**	18.895731		
0.75	**17.595**	**24.635**	13.196157	95%CI=b*1.	0.1309428
1.05	**3.830**	**7.040**	4.0215		
2.25	**3.210**	**3.210**	7.2225	**b values**	
				95%	1.665
				mean	1.534
				-95%	1.403
				a values	
				95%	3.138
				mean	3.106
				-95%	3.073



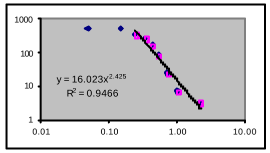


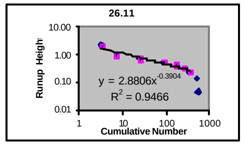
Location	26.060				
Height	**N**	**Cum #**	**A*B**	cum N=	504.650
0.05	35.217	539.87	1.7608315		
0.15	158.063	504.65	23.709434	cum A*B=	154.291
0.25	**125.452**	346.59	31.362898		
0.35	**106.015**	221.14	37.105132	cumAB/cum	0.3057388
0.45	**86.368**	115.12	38.865533		
0.55	**21.713**	28.75	11.942001	b=.4343[1/(	2.1109291
1.15	**3.830**	7.04	4.4045		
2.15	**3.210**	3.21	6.9015	95%CI=b*1.	0.1841767
			0		
			0	**b values**	
				95%	2.295
				mean	2.111
				-95%	1.927
				a values	
				95%	3.277
				mean	3.231
				-95%	3.185



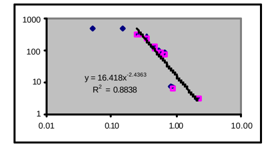


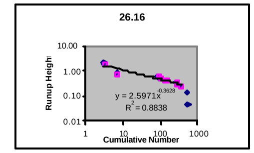
Location	26.110				
Height	**N**	**Cum #**	**A*B**	cum N=	346.587
0.05	24.891	539.87	1.2445691		
0.15	168.388	514.97	25.258221	cum A*B=	149.163
0.25	**87.636**	346.59	21.909017		
0.35	**87.689**	258.95	30.691106	cumAB/cum	0.430377
0.45	**85.212**	171.26	38.345249		
0.55	**61.420**	86.05	33.781124	b=.4343[1/(I	1.885171
0.75	**17.590**	24.63	13.1925		
1.05	**3.830**	7.04	4.0215	95%CI=b*1.	0.1984727
2.25	**3.210**	3.21	7.2225		
			0	**b values**	
				95%	2.084
				mean	1.885
				-95%	1.687
				a values	
				95%	3.061
				mean	3.011
				-95%	2.961



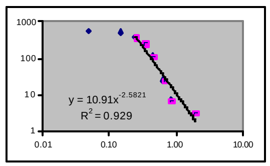


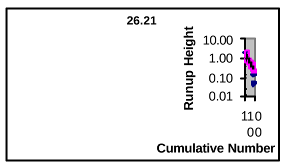
Location	26.160				
Height	**N**	**Cum #**	**A*B**	cum N=	346.587
0.05	24.891	539.87	1.2445691		
0.15	168.388	514.97	25.258221	cum A*B=	150.83895
0.25	**81.457**	346.59	20.364176		
0.35	**128.395**	265.13	44.938139	cumAB/cur	0.4352126
0.45	**38.539**	136.74	17.34246		
0.55	**12.146**	98.20	6.6805318	b=.4343[1/(	1.8464148
0.65	**79.010**	86.05	51.356646		
0.85	**3.830**	7.04	3.2555	95%CI=b*1	0.1943924
2.15	**3.210**	3.21	6.9015		
			0	**b values**	
				95%	2.041
				mean	1.846
				-95%	1.652
				a values	
				95%	3.050
				mean	3.001
				-95%	2.953



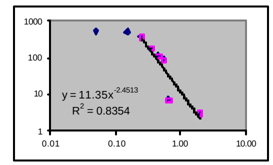


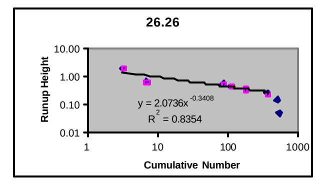
Location	26.210				
Height	**N**	**Cum #**	**A*B**	cum N=	368.546
0.05	35.122	539.86	1.7560806		
0.15	136.194	504.74	20.429095	cum A*B=	138.99585
0.25	**109.600**	368.55	27.400003		
0.35	**147.948**	258.95	51.781814	cumAB/cun	0.3771466
0.45	**86.368**	111.00	38.865533		
0.65	**17.590**	24.63	11.4335	b=.4343[1/(	2.4516412
0.85	**3.830**	7.04	3.2555		
1.95	**3.210**	3.21	6.2595	95%CI=b*1	0.2503036
			0		
			0	**b values**	
				95%	2.702
				mean	2.452
				-95%	2.201
				a values	
				95%	3.242
				mean	3.179
				-95%	3.117



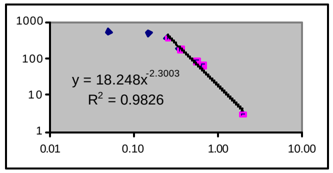


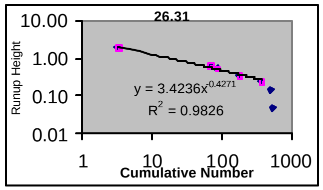
Location	26.260				
Height	**N**	**Cum #**	**A*B**	cum N=	368.551
0.05	35.122	539.87	1.756081		
0.15	136.194	504.74	20.42909	cum A*B=	134.793
0.25	**187.820**	368.55	46.95511		
0.35	**69.728**	180.73	24.40466	cumAB/cun	0.365738
0.45	**24.953**	111.00	11.22863		
0.55	**79.010**	86.05	43.45562	b=.4343[1/(	2.620401
0.65	**3.830**	7.04	2.4895		
1.95	**3.210**	3.21	6.2595	95%CI=b*1	0.267532
			0		
			0	**b values**	
				95%	2.888
				mean	2.620
				-95%	2.353
				a values	
				95%	3.288
				mean	3.222
				-95%	3.155



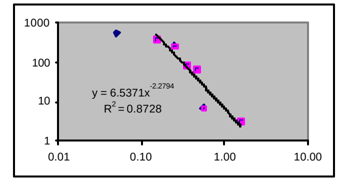


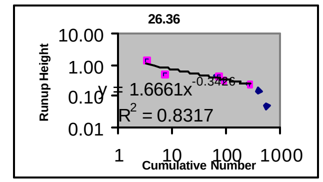
Location	26.310				
Height	**N**	**Cum #**	**A*B**	cum N=	368.551
0.05	35.122	539.87	1.756081		
0.15	136.194	504.74	20.42909	cum A*B=	138.4398
0.25	**187.820**	368.55	46.95511		
0.35	**94.680**	180.73	33.13804	cumAB/cur	0.375633
0.55	**17.590**	86.05	9.674624		
0.65	**65.250**	68.46	42.4125	b=.4343[1/	2.472772
1.95	**3.210**	3.21	6.2595		
			0	95%CI=b*1	0.252459
			0		
			0	**b values**	
				95%	2.725
				mean	2.473
				-95%	2.220
				a values	
				95%	3.248
				mean	3.185
				-95%	3.122



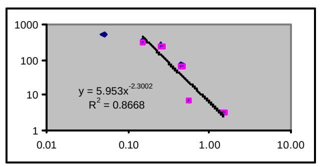


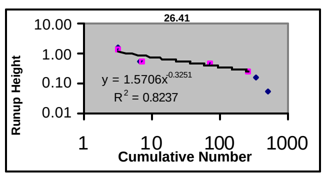
Location	26.360				
Height	**N**	**Cum #**	**A*B**	cum N=	258.955
0.05	148.204	539.87	7.410213		
0.15	132.711	391.67	19.9067	cum A*B=	84.10434
0.25	**172.901**	258.96	43.22514		
0.35	**17.595**	86.05	6.158207	cumAB/cur	0.324783
0.45	**61.420**	68.46	27.639		
0.55	**3.830**	7.04	2.1065	b=.4343[1/(	3.480439
1.55	**3.210**	3.21	4.9755		
			0	95%CI=b*1	0.423914
			0		
			0	**b values**	
				95%	3.904
				mean	3.480
				-95%	3.057
				a values	
				95%	3.389
				mean	3.283
				-95%	3.177





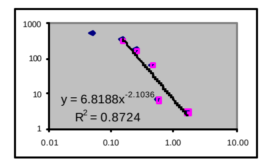
Location	26.410				
Height	**N**	**Cum #**	**A*B**	cum N=	350.417
0.05	180.651	531.07	9.032559		
0.15	87.636	350.42	13.14541	cum A*B=	96.89154
0.25	**190.491**	262.78	47.62263		
0.45	**65.250**	72.29	29.3625	cumAB/cun	0.276504
0.55	**3.830**	7.04	2.1065		
1.45	**3.210**	3.21	4.6545	b=.4343[1/(	2.460569
			0		
			0	95%CI=b*1	0.257632
			0		
			0	**b values**	
				95%	2.718
				mean	2.461
				-95%	2.203
				a values	
				95%	3.224
				mean	3.160
				-95%	3.095

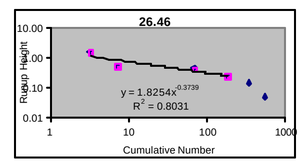




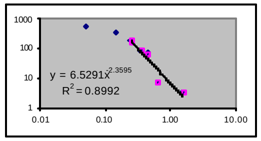
Location	26.460				
Height	**N**	**Cum #**	**A*B**	cum N=	346.587
0.05	193.280	539.87	9.663976		
0.15	165.856	346.59	24.87847	cum A*B=	87.98806
0.25	112.270	180.73	28.06758		
0.45	**61.420**	68.46	27.639	cumAB/cur	0.25387
0.55	**3.830**	7.04	2.1065		
1.65	**3.210**	3.21	5.2965	b=.4343[1/	2.822509
			0		
			0	95%CI=b*1	0.297157
			0		
			0	**b values**	
				95%	3.120
				mean	2.823
				-95%	2.525
				a values	
				95%	3.320
				mean	3.245
				-95%	3.171

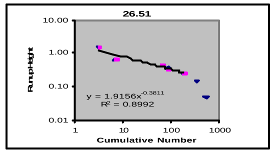
Least Squares	
a	6.8188
b	2.1036



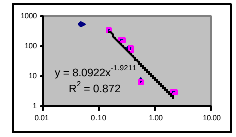


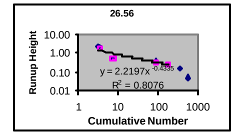
Location	26.510				
Height	**N**	**Cum #**	**A*B**	cum N=	180.730
0.05	193.280	539.87	9.6639762		
0.15	165.856	346.59	24.878475	cum A*B=	64.930141
0.25	**94.680**	180.73	23.670028		
0.35	**17.595**	86.05	6.1582067	cumAB/cur	0.3592653
0.45	**61.415**	68.46	27.636907		
0.65	**3.830**	7.04	2.4895	b=.4343[1/(	2.7268963
1.55	**3.210**	3.21	4.9755		
			0	95%CI=b*1.	0.3975659
			0		
			0	**b values**	
				95%	3.124
				mean	2.727
				-95%	2.329
				a values	
				95%	3.038
				mean	2.939
				-95%	2.839



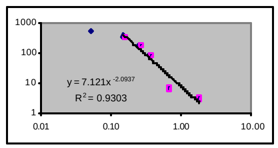


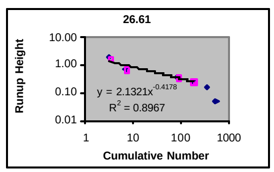
Location	26.560				
Height	**N**	**Cum #**	**A*B**	cum N=	168.584
0.05	193.280	539.87	9.6639762		
0.15	178.003	346.59	26.700438	cum A*B=	56.974001
0.25	**82.534**	168.58	20.633422		
0.35	**79.010**	86.05	27.653579	cumAB/cum	0.3379563
0.55	**3.830**	7.04	2.1065		
2.05	**3.210**	3.21	6.5805	b=.4343[1/(	3.1480976
			0		
			0	95%CI=b*1.	0.4752216
			0		
			0	**b values**	
				95%	3.623
				mean	3.148
				-95%	2.673
				a values	
				95%	3.133
				mean	3.014
				-95%	2.895



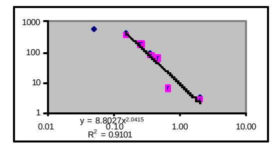


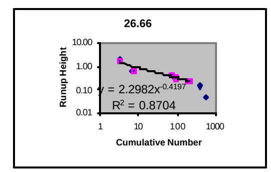
Location	26.610				
Height	**N**	**Cum #**	**A*B**	cum N=	346.587
0.05	193.280	539.87	9.6639762		
0.15	165.856	346.59	24.878475	cum A*B=	84.309081
0.25	**94.680**	180.73	23.670028		
0.35	**79.010**	86.05	27.653579	cumAB/cum	0.2432553
0.65	**3.830**	7.04	2.4895		
1.75	**3.210**	3.21	5.6175	b=.4343[1/(l	3.0316507
			0		
			0	95%CI=b*1.	0.3191752
			0		
			0	**b values**	
				95%	3.351
				mean	3.032
				-95%	2.712
				a values	
				95%	3.378
				mean	3.298
				-95%	3.218



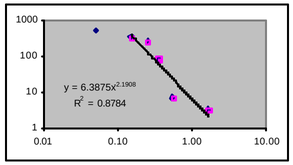


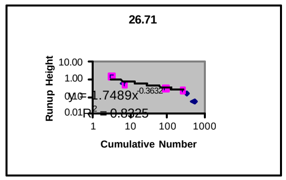
Location	26.660				
Height	**N**	**Cum #**	**A*B**	cum N=	397.626
0.05	142.245	539.87	7.1122428		
0.15	205.435	397.63	30.815304	cum A*B=	99.895489
0.25	**106.136**	192.19	26.533978		
0.35	**17.595**	86.05	6.1582067	cumAB/cur	0.2512297
0.45	**61.420**	68.46	27.639		
0.65	**3.830**	7.04	2.4895	b=.4343[1/(	2.8717909
1.95	**3.210**	3.21	6.2595		
			0	95%CI=b*1	0.2822743
			0		
			0	**b values**	
				95%	3.154
				mean	2.872
				-95%	2.590
				a values	
				95%	3.073
				mean	3.030
				-95%	2.988



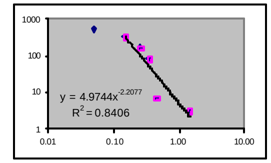


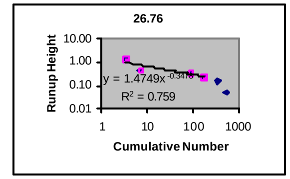
Location		26.710				
Height	**N**		**Cum #**	**A*B**	cum N=	346.587
0.05		193.280	539.87	9.6639762		
0.15		87.636	346.59	13.14541	cum A*B=	91.427124
0.25		**172.901**	258.95	43.225135		
0.35		**79.010**	86.05	27.653579	cumAB/cun	0.2637928
0.55		**3.830**	7.04	2.1065		
1.65		**3.210**	3.21	5.2965	b=.4343[1/(	2.6515201
				0		
				0	95%CI=b*1	0.2791547
				0		
				0	**b values**	
					95%	2.931
					mean	2.652
					-95%	2.372
					a values	
					95%	2.979
					mean	2.938
					-95%	2.896



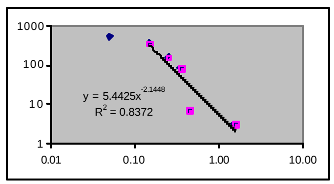


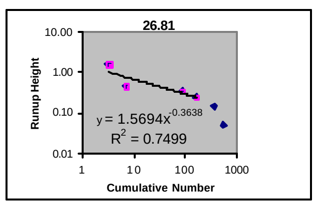
Location		26.760				
Height	**N**		**Cum #**	**A*B**	cum N=	340.407
0.05		199.459	539.87	9.972944		
0.15		171.824	340.41	25.77353	cum A*B=	80.43853
0.25		**82.534**	168.58	20.63342		
0.35		**79.010**	86.05	27.65358	cumAB/cun	0.236301
0.45		**3.830**	7.04	1.7235		
1.45		**3.210**	3.21	4.6545	b=.4343[1/(	3.186337
				0		
				0	95%CI=b*1	0.338492
				0		
				0	**b values**	
					95%	3.525
					mean	3.186
					-95%	2.848
					a values	
					95%	3.061
					mean	3.010
					-95%	2.959



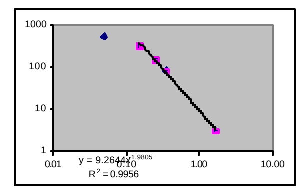


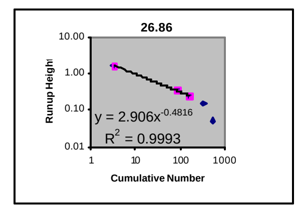
Location		26.810				
Height	**N**		**Cum #**	**A*B**	cum N=	363.431
0.05		176.435	539.87	8.821745		
0.15		204.316	363.43	30.6474	cum A*B=	83.26629
0.25		**73.065**	159.12	18.26631		
0.35		**79.010**	86.05	27.65358	cumAB/cur	0.229111
0.45		**3.830**	7.04	1.7235		
1.55		**3.210**	3.21	4.9755	b=.4343[1/	3.363762
				0		
				0	95%CI=b*1	0.345836
				0		
				0	**b values**	
					95%	3.710
					mean	3.364
					-95%	3.018
					a values	
					95%	3.117
					mean	3.065
					-95%	3.013





Location		26.860				
Height	**N**		**Cum #**	**A*B**	cum N=	340.407
0.05		199.459	539.87	9.972944		
0.15		185.410	340.41	27.81148	cum A*B=	79.33882
0.25		**68.947**	155.00	17.23685		
0.35		**82.840**	86.05	28.99399	cumAB/cur	0.23307
1.65		**3.210**	3.21	5.2965		
				0	b=.4343[1/(	3.263688
				0		
				0	95%CI=b*1	0.346709
				0		
				0	**b values**	
					95%	3.610
					mean	3.264
					-95%	2.917
					a values	
					95%	3.074
					mean	3.022
					-95%	2.970





Location	26.910				
Height	**N**	**Cum #**	**A*B**	cum N=	340.407
0.05	199.459	539.87	9.972944		
0.15	173.263	340.41	25.98951	cum A*B=	80.87446
0.25	**81.094**	167.14	20.27345		
0.35	**82.840**	86.05	28.99399	cumAB/cur	0.237582
1.75	**3.210**	3.21	5.6175		
			0	b=.4343[1/(	3.156674
			0		
			0	95%CI=b*1	0.335341
			0		
			0	**b values**	
				95%	3.492
				mean	3.157
				-95%	2.821
				a values	
				95%	3.056
				mean	3.005
				-95%	2.955