



Map Atlas

Rainwater Harvesting Phase II

A Geographic Information System-based method for Estimation of Rainwater Capture Potential in St. John's, Antigua

An initiative financed by the United Nations Environment Programme (UNEP)

Division of Environmental Policy Implementation (DEPI)

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Implemented by the

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In partnership with the

Antigua Public Utilities Authority (APUA)

Cassada Gardens

St. John's, Antigua

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The information presented in this Atlas is intended to assist water resources managers, municipal officials, town and country planners in applying simple Geographical Information System (GIS)-based mapping methods and approaches to evaluate rainwater harvesting (RWH) potential in enhancing water security at the community level.

This effort is a Phase 2 United Nations Environment Programme (UNEP)-financed / Caribbean Environmental Health Institute (CEHI) collaboration to promote rainwater harvesting in the Caribbean. One of the components of this second phase was the generation of GIS map outputs that reflect the potential impact of climate change on rainwater harvesting potential and water availability in a select community in Antigua and Barbuda, the pilot country for this initiative.

Overview:

The community of Ottos, in the southern suburbs of St. John's Antigua was chosen as the study area for the spatial analysis of RWH harvesting potential. The selection of this particular community was due to the fact that a RWH demonstration model (one of four) was built under this project to serve as a teaching tool for best practices in rainwater harvesting, with emphasis on improving the quality of harvested rainwater.

Estimation of RWH capture potential was conducted for (1) building roof catchments, (2) non-built areas and (3) roads on the basis of rainfall data for one of the closest rainfall stations (data was provided by the Antigua and Barbuda Meteorological Services).

Rainwater capture potential was estimated for three rainfall scenarios; (1) mean rainfall, (2) actual rainfall for a meteorological drought year (year 2000) and (3) a 30% rainfall reduction from the mean, which corresponds to the projected decline in average rainfall based on the down-scaled Japanese global climatic models (Cashman et al., 2007).

Household water supply deficits were also estimated based on average water consumption and potable supply reliability scenarios. The deficit maps could assist in guiding targeting support within communities to identify households that are most vulnerable and require investment in RWH supply solutions.

Data sources and guidance resources:

- **Antigua and Barbuda Drought Hazard Mapping (2001).** USAID/OAS Post-Georges Disaster Mitigation: <http://www.oas.org/pgdm>
- **Exploring the Water Management Implications of Potential Climate Change (2007),** Dr Adrian Cashman, Dr John Charlery, Dr Leonard Nurse, University of the West Indies
- **Potential for Rain Water Harvesting in Ten African Cities: A GIS Overview (2005)** RELMA in ICRAF & UNEP
- **Water Resources Assessment of Dominica, Antigua, Barbuda, St. Kitts And Nevis (2004).** US Army Corps of Engineers Mobile District & Topographic Engineering Center. Available on-line at http://www.sam.usace.army.mil/en/wra/N_Caribbean/N%20CARIBBEAN%20WRA%201%20DEC%202004.pdf

Acknowledgements:

Hastin Barnes, Planning Engineer at the Antigua Public Utilities Authority and Mr. Keithley Meade, Chief Meteorological Services Officer, with the Antigua and Barbuda Meteorological Services for GIS input data and rainfall data provision respectively.

The atlas is available on the Caribbean Environmental Health Institute's website at www.cehi.org.lc and UNEP's website at www.xxxxxx.com . For more information contact CEHI in St. Lucia at Tel: (758) 452-2501, Fax: (758) 453-2721; e-mail: cehi@candw.lc

Ottos, St. John's, Antigua

This community is the location of a household rainwater harvesting demonstration project. The house is situated on Tindall Road. It is a typical 3-bedroom, 2-bathroom single-storey structure occupying 96 m² of floor space, with 4 residents. The house has a connection to the potable municipal supply (Antigua Public Utilities Authority) but the residents have traditionally relied on rainwater for potable needs. The estimated daily household water consumption is 0.5 m³/day (500 litres/day). This household has 1,000 gallons (4.5 m³) storage capacity dedicated to RWH.

This household represents the typical home found in the suburbs around St. John's, and in this mapping application the households in the study area were assumed to have similar profiles.

NOTE: for purposes of demonstration all building structures were treated as households; in reality several of these were actually commercial properties particularly in the northern area).

This level of characterization to discern households from non-households, was not carried out in



Study area – red outline



Aerial photo of study area (2000 image)

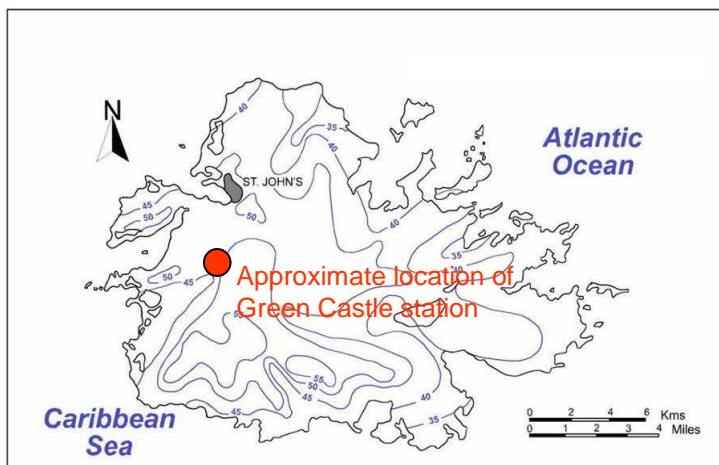
Rainfall data from the Green Castle station was used in this rainwater capture analysis given its relatively close proximity to the study area. Green Castle is situated approximately 4 km from the Ottos area.

Three rainfall scenarios modelled:

- SCENARIO 1:** Mean annual rainfall
- SCENARIO 2:** Meteorological drought (<80% of mean annual rainfall) ; data from year 2000 used
- SCENARIO 3:** Climate change scenario; assuming reduction in mean annual rainfall by 30% (see box to right)

Quote: "Although little detailed work has been carried out on the effects of the most recent climate change scenarios on the water resources of individual islands and Caribbean states, a few general inferences may be made on the basis of on-going climate modelling of the Caribbean Basin. The modelling, indicates that irrespective of scenario a likely significant decrease in overall rainfall especially during the important rainy season of up to 30% over the period 1990s to 2070s, region wide."

Source: **Exploring the Water Management Implications of Potential Climate Change (2007)**, Dr. Adrian Cashman, Dr. John Charlery, Dr. Leonard Nurse, University of the West Indies



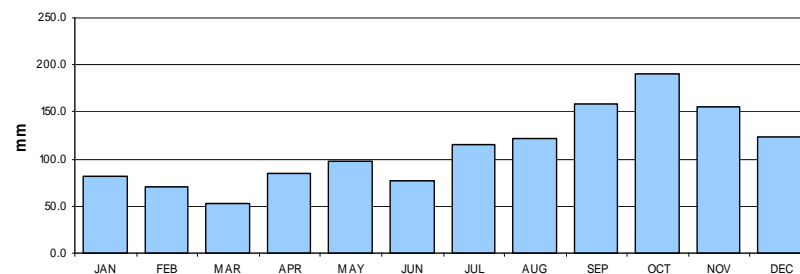
Precipitation Map of Annual Rainfall, Antigua (Inches)

Source: Cooper, B. and V. Brown, Integrating Management of Watersheds and Coastal Areas in Small Island Developing States of the Caribbean, St. John's, Antigua - Ministry of Tourism and Environment, 2001, p. 6

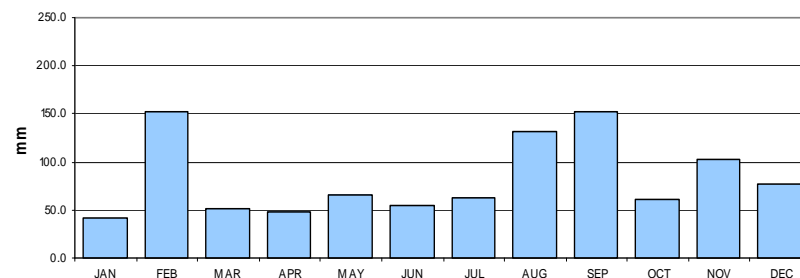
Green Castle station: Mean annual rainfall
 Source: Antigua and Barbuda Meteorological Services)

| JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | TOTAL | % of mean |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|-----------|
| 94.2 | 57.7 | 58.7 | 65.0 | 26.7 | 38.6 | 68.3 | 85.6 | 325.6 | 88.1 | 83.6 | 33.0 | 1025.1 | 76.7% |
| 51.1 | 22.4 | 41.9 | 114.3 | 74.9 | 88.4 | 46.5 | 103.9 | 96.8 | 269.5 | 82.3 | 127.8 | 1119.6 | 83.8% |
| 101.6 | 70.6 | 38.1 | 30.5 | 67.8 | 65.3 | 152.4 | 83.8 | 184.2 | 89.7 | 164.3 | 67.8 | 1116.1 | 83.6% |
| 85.3 | 97.3 | 260.9 | 223.3 | 180.8 | 126.2 | 126.0 | 174.5 | 218.4 | 233.7 | 232.7 | 243.8 | 2202.9 | 164.9% |
| 77.2 | 49.3 | 29.7 | 50.5 | 355.6 | 138.4 | 173.0 | 52.1 | 93.0 | 96.5 | 101.9 | 80.0 | 1297.2 | 97.1% |
| 98.0 | 65.5 | 49.5 | 136.7 | 88.4 | 67.3 | 57.7 | 97.8 | 284.0 | 101.6 | 140.0 | 68.6 | 1255.0 | 94.0% |
| 36.8 | 91.2 | 100.1 | 23.9 | 45.2 | 25.4 | 77.5 | 308.6 | 335.8 | 179.6 | 76.2 | 100.3 | 1400.6 | 104.8% |
| 66.8 | 67.6 | 20.1 | 89.7 | 72.4 | 113.3 | 189.2 | 108.0 | 80.0 | 147.3 | 128.0 | 313.7 | 1396.0 | 104.5% |
| 52.1 | 162.6 | 10.2 | 78.7 | 76.2 | 66.0 | 149.9 | 228.6 | 211.1 | 168.4 | 52.6 | 41.1 | 1297.4 | 97.1% |
| 27.4 | 67.8 | 43.7 | 115.6 | 44.5 | 79.8 | 75.4 | 148.8 | 191.0 | 150.1 | 309.9 | 208.3 | 1462.3 | 109.5% |
| 58.9 | 34.8 | 93.5 | 119.6 | 72.9 | 55.9 | 190.8 | 54.9 | 91.9 | 151.4 | 474.0 | 78.0 | 1476.5 | 110.5% |
| 42.4 | 152.1 | 51.3 | 47.5 | 65.0 | 54.1 | 62.0 | 130.8 | 152.4 | 61.5 | 102.4 | 76.5 | 998.0 | 74.7% |
| 41.7 | 18.0 | 16.5 | 46.5 | 5.1 | 9.1 | 168.7 | 59.7 | 88.1 | 181.1 | 98.6 | 292.1 | 1025.1 | 76.7% |
| 34.3 | 20.3 | 42.4 | 252.2 | 31.8 | 52.8 | 120.9 | 73.4 | 93.7 | 170.2 | 81.0 | 71.4 | 1044.4 | 78.2% |
| 51.6 | 47.2 | 21.3 | 34.0 | 46.5 | 96.5 | 66.3 | 96.8 | 43.9 | 205.7 | 237.2 | 116.3 | 1063.5 | 79.6% |
| 64.5 | 158.8 | 74.9 | 74.4 | 365.8 | 113.0 | 146.6 | 63.2 | 66.3 | 254.5 | 223.3 | 195.8 | 1801.1 | 134.8% |
| 117.6 | 82.8 | 7.4 | 34.8 | 97.5 | 148.3 | 142.7 | 186.7 | 64.8 | 378.7 | 163.8 | 47.8 | 1472.9 | 110.3% |
| 303.8 | 47.5 | 15.2 | 27.9 | 135.4 | 90.4 | 98.3 | 158.5 | 224.5 | 226.3 | 61.5 | 90.9 | 1480.3 | 110.8% |

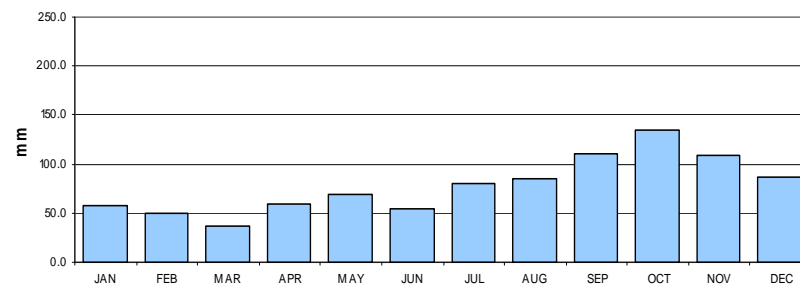
SCENARIO 1: Mean annual rainfall



SCENARIO 2: Year 2000 rainfall (meteorological drought)



SCENARIO 3: 30% reduction in mean rainfall

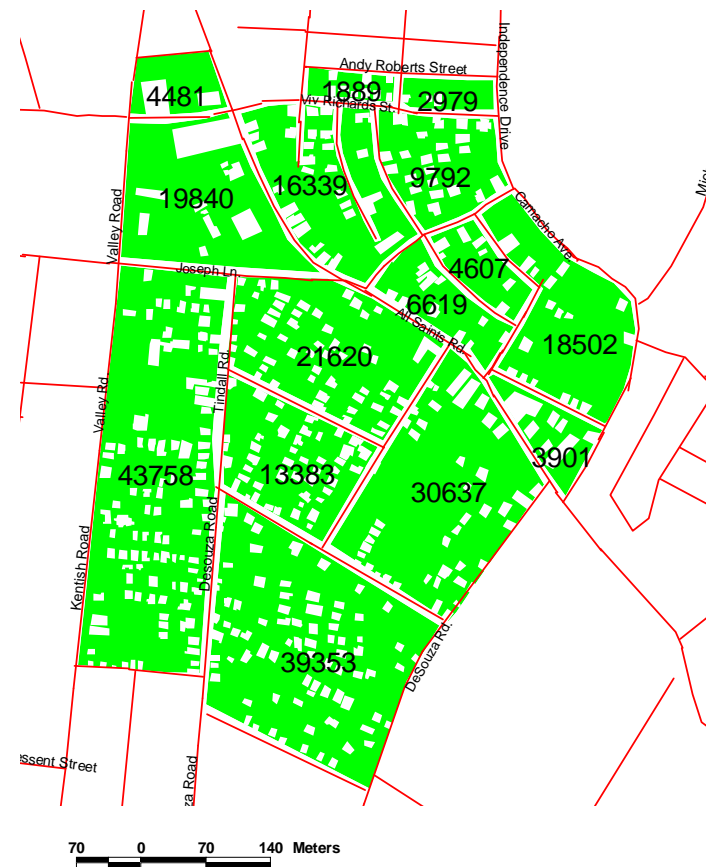
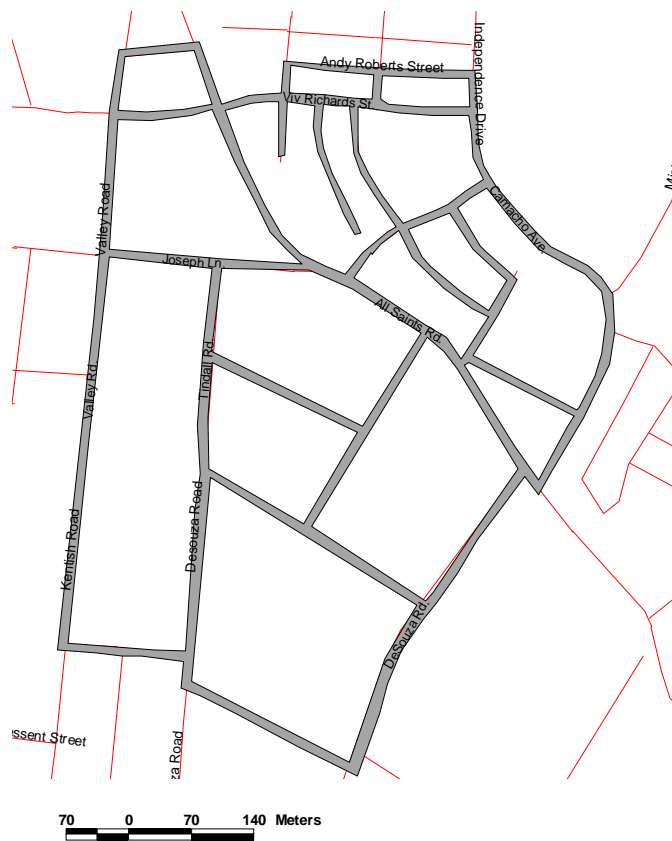


The input data layers were obtained from the APUA. These were the road network for Antigua and the building footprints (or roof areas)

Rooftops: A recent aerial photograph was used as backdrop for on-screen digitizing of the roof tops. A total of 446 building footprints were digitized from the aerial photograph. **NOTE:** Several building structures in the northern part of the study area are commercial buildings.

Roads: the source for this layer was a GIS line-type vector file. To estimate the rainfall capture the road surface area had to be generated as a new overlay. This was created by on-screen digitizing an approximate 10-metre corridor (following the road vector layer) that represented the roadway surface, drains, hardened sidewalk areas and verges. The total area of the road surface was computed in the GIS. **NOTE:** not all roads were captured (comparison to the Google Earth image); the total road area was therefore considered an underestimation.

Non-building areas: The overlay was generated by extracting out the building areas and road areas from the study area footprint.



Building roof surfaces
Combined area: 50,837 m²

Road surfaces
Combined area: 55,196 m²

Non-building surfaces (sub-unit area in m²)
Combined area: 237,700 m²

Rainfall capture potentials within the study area were estimated based on the following relationship:

$$\text{Harvestable rainfall (litres)} = \text{Surface area (m}^2\text{)} \times \text{rainfall (mm)} \times \text{runoff coefficient (dimensionless)}$$

About the runoff coefficient: The runoff coefficient is a factor that accounts for water losses that do not enter useful storage. In general the more impervious a surface the higher the runoff coefficient; in other words the greater the possibility of being able to divert and capture the rainfall that runs over the surface. The highest runoff coefficients are assigned to smooth metal sheet roofs, while the lowest coefficients are assigned to natural ground surfaces.

The following were the runoff coefficients assigned for the three surfaces:

Roof catchment surfaces: 0.80

Rationale: The majority of roofs in the area and across Antigua and Barbuda are constructed from sheet metal and can be expected to have a high runoff coefficient. Assignment of a 0.80 as opposed to a higher value was based on the assumption that rainwater harvesting may not be as efficient due to incomplete guttering, and leaky systems.

Road surfaces: 0.50

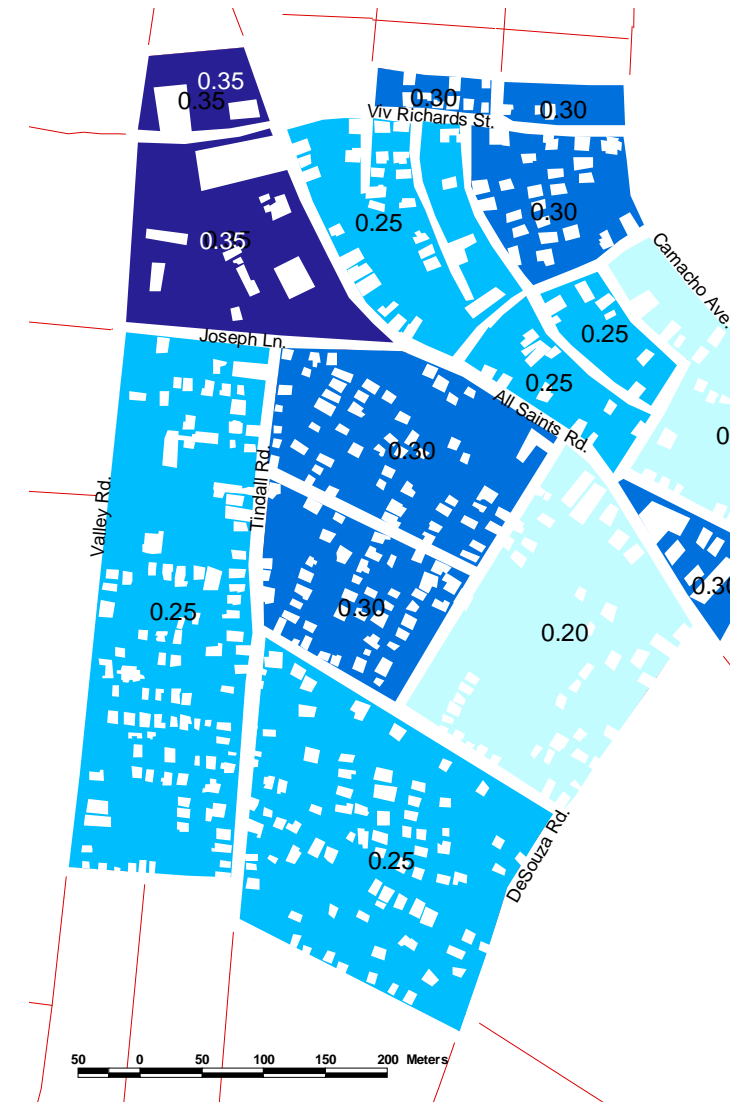
Rationale: The roads within the study area are dominated by secondary streets with hard asphalt surfaces, although in some places runoff may be impounded (on account of poor maintenance) and may permit localized infiltration. The runoff coefficient was assumed to be lower than what might be assigned to paved highways or major urban streets.

Non-building areas: variable between 0.20 and 0.35

Rationale: There are varied landscapes across the study area that includes undeveloped lots with scattered to moderately dense vegetation, to semi-surfaced unimproved lots, and in some instances, hard surfaced areas, mainly in the



Runoff coefficients assigned to non-built

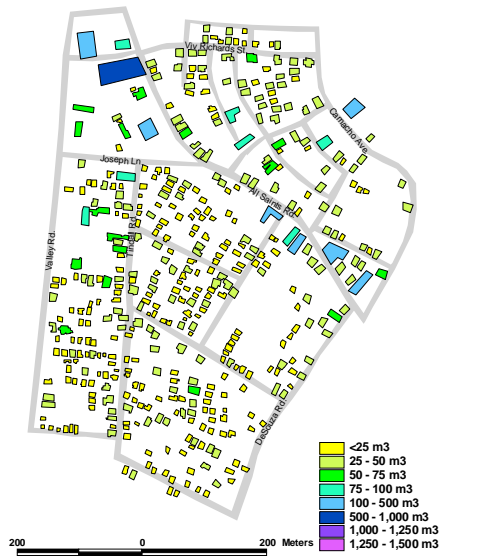
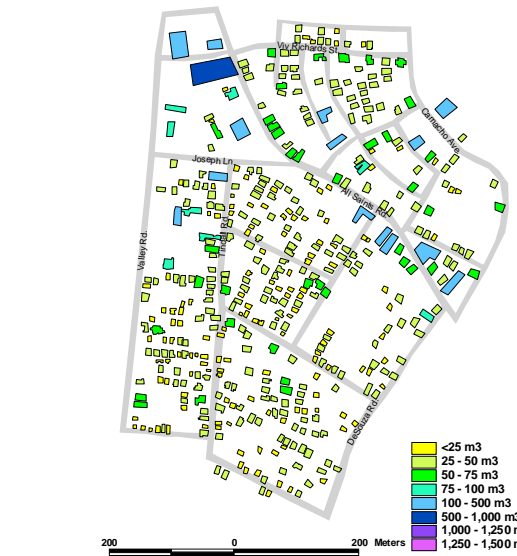
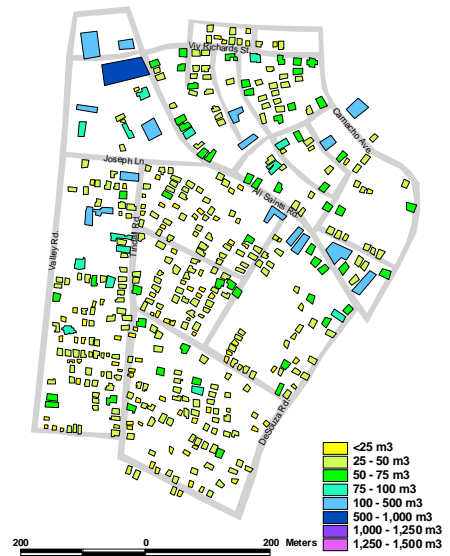


The following rainfall maps illustrate the rainfall capture potential off the roof catchment surfaces within the study area. It was assumed that all roof surfaces were of similar material, in this case, metal sheeting as is almost universal across Antigua. The assigned runoff coefficient was therefore the same for all structures; a value of 0.8 used in all three rainfall scenarios. The capture potential across the entire area is the summation of rainwater capture from all structures.

SCENARIO 1: Mean rainfall conditions

SCENARIO 2: Meteorological drought Year 2000 rainfall

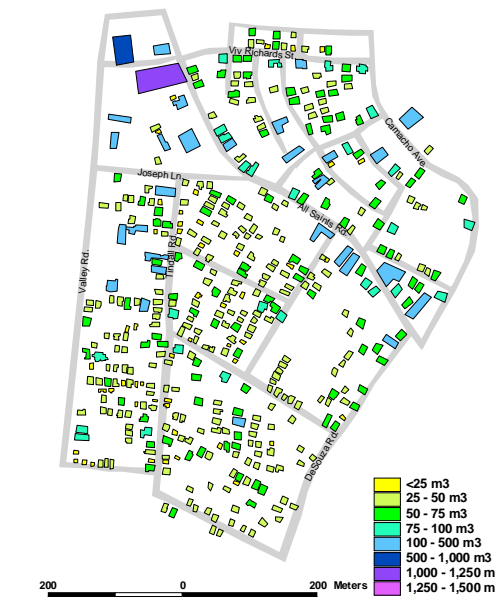
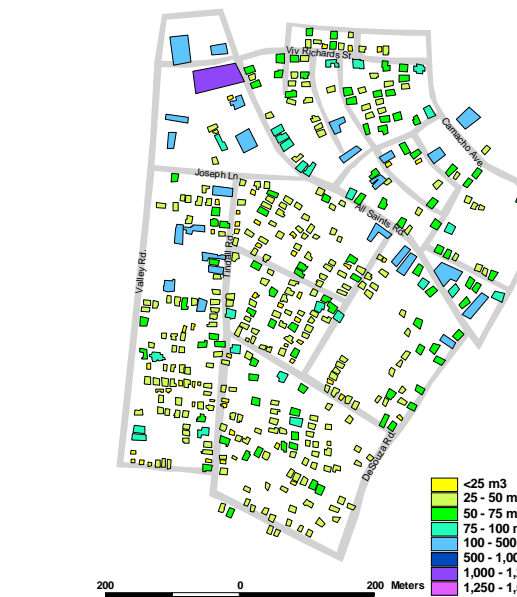
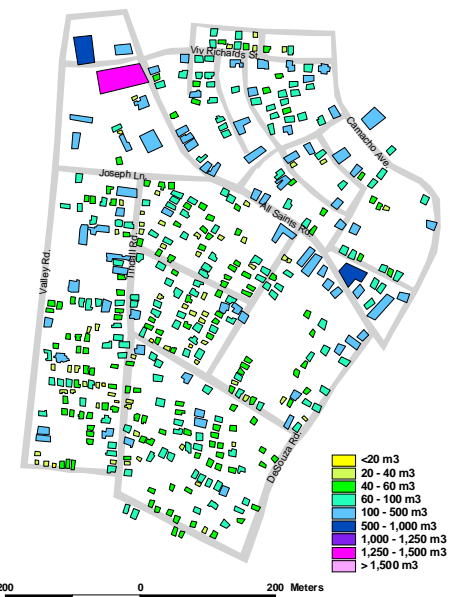
SCENARIO 3: 30% below mean rainfall



Dry season (Jan-Jun)
Capture potential: 18,920.2 m³

Dry season (Jan-Jun)
Capture potential: 16,777.2 m³

Dry season (Jan-Jun)
Capture potential: 13,241.4 m³



Wet season (Jul-Dec)
Capture potential: 35,215.4 m³

Wet season (Jul-Dec)
Capture potential: 23,810.5 m³

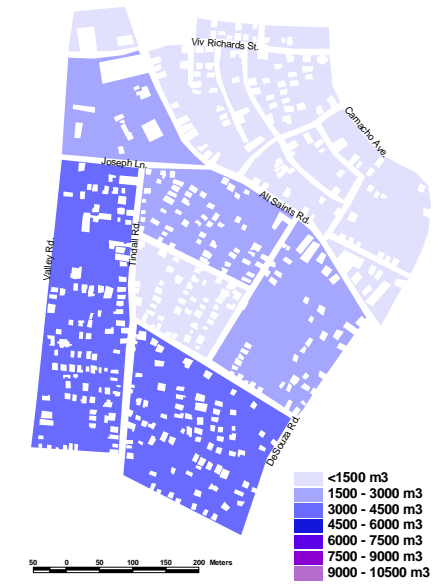
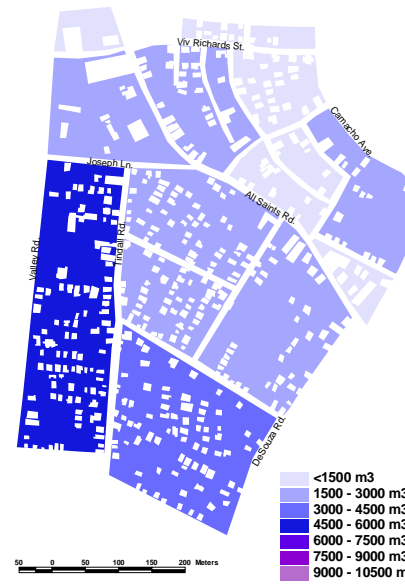
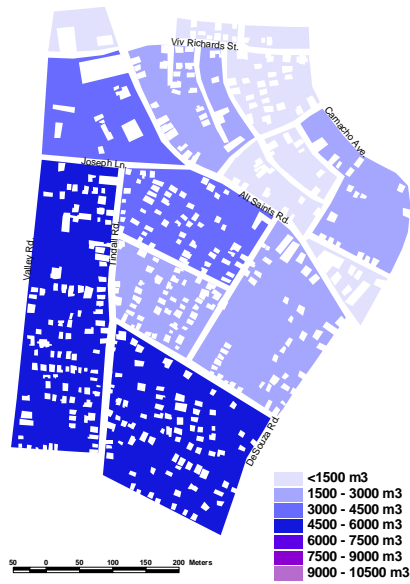
Wet season (Jul-Dec)
Capture potential: 24,648.9 m³

The following maps illustrate the rainfall capture potential within each non-built sub-unit within the study area. The variability in capture volume is based on the runoff coefficient assigned to each sub-unit. Those areas that were more built-up with hard surfaces and structures were assigned higher runoff coefficients as compared to areas that were dominated by open fields and vegetation. The capture potential across the entire area is the summation of the sub-units.

SCENARIO 1: Mean rainfall conditions

SCENARIO 2: Meteorological drought Year 2000 rainfall

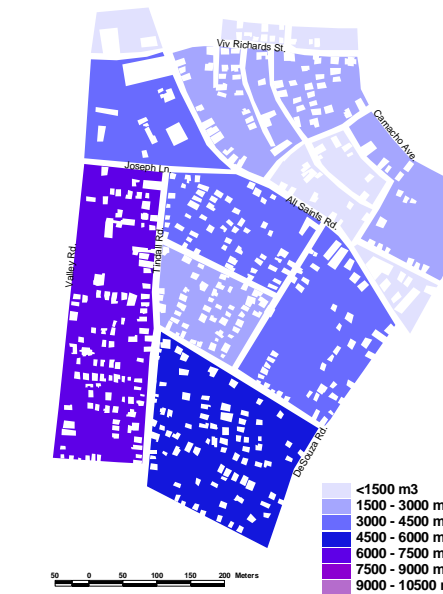
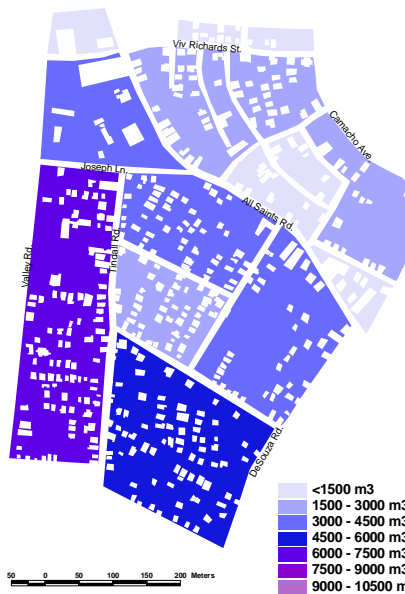
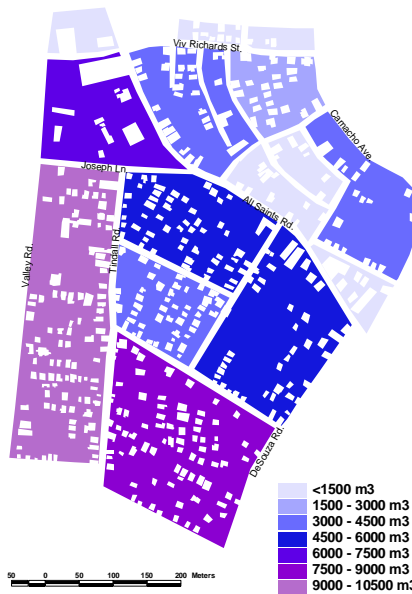
SCENARIO 3: 30% below mean rainfall



Dry season (Jan-Jun)
Capture potential: 28,879.6 m³

Dry season (Jan-Jun)
Capture potential: 25,607.2 m³

Dry season (Jan-Jun)
Capture potential: 20,215.7m³



Wet season (Jul-Dec)
Capture potential: 53,751.9 m³

Wet season (Jul-Dec)
Capture potential: 36,345.1 m³

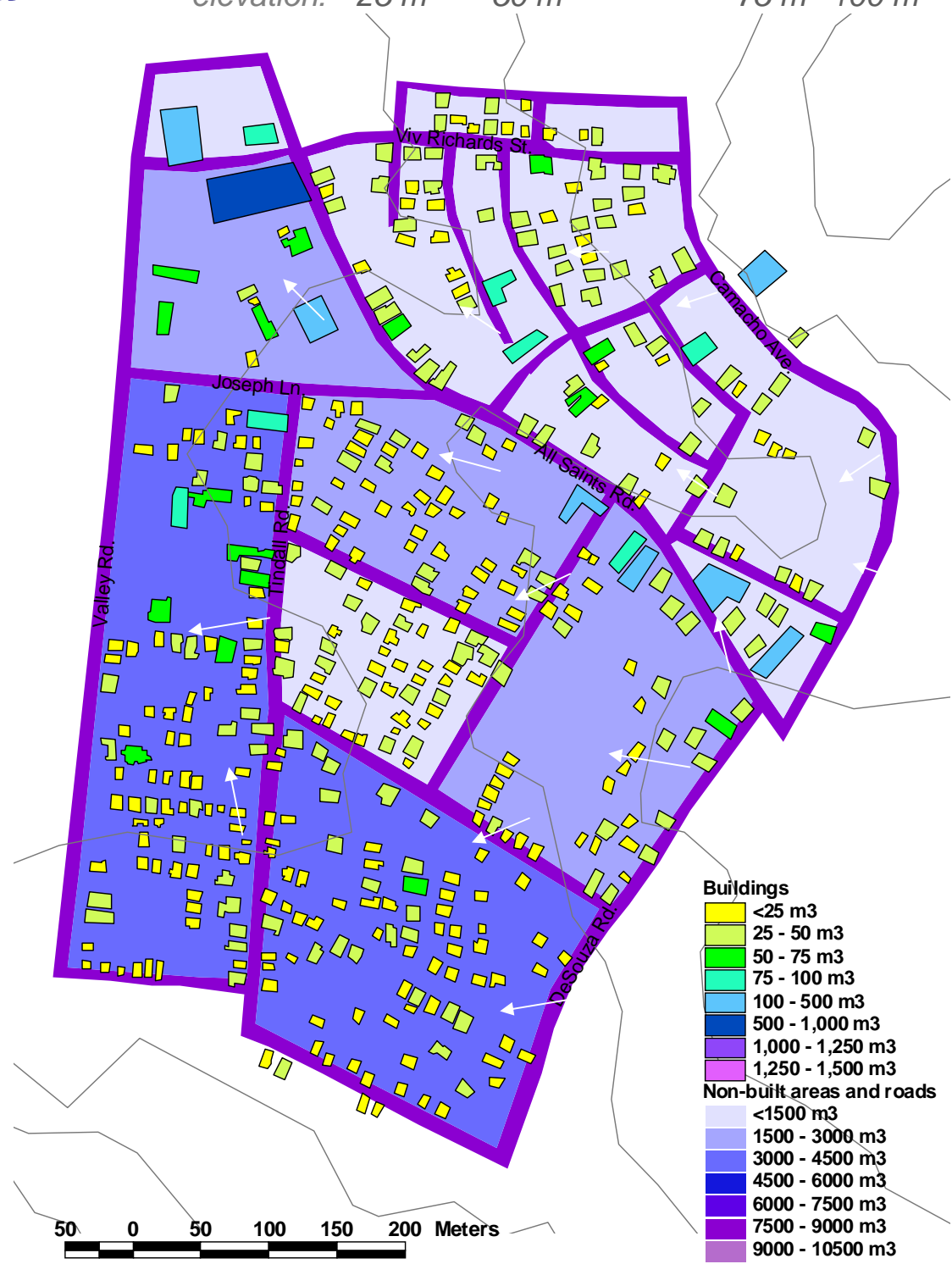
Wet season (Jul-Dec)
Capture potential: 37,626.3 m³

In this application the rainwater harvest potential under the influence of climate change is of interest. A 30% decline in mean rainfall will translate to a reduction in the capture potential that can be diverted to domestic RWH systems, and that which can be diverted to recharge aquifers (ground water) and reservoirs. This is an extremely important consideration in water supply maintenance.

The map illustrates the rainwater capture potential for each surface under a scenario with rainfall at 30% below the mean during the dry season (Jan to Jun).

Estimated rainwater capture volume (by area):

- **Buildings:** 13,241.4 m³
- **Non-built areas:** 20,215.7 m³
- **Roads:** 8,997.2 m³
- **Combined:** 42,454.3 m³



White arrows are approximate flow direction

example of a simple analysis to estimate household water supply deficits based on variability in municipal water supply reliability under the 30% reduction in rainfall (climate change) scenario is presented. The example considers the dry season rainfall regime. Two daily household demand rates (per person) are evaluated with two potable water reliability scenarios. This analysis is intended to simulate conditions/challenges that may be faced in water service provision during extreme drought conditions with a view to identifying individual households that may be most vulnerable. With actual household data such an evaluation can provide useful emergency response guidance in water service delivery.

Water Supply Deficit

Interest is supply deficit during the dry season where it is assumed that the municipal supply will be most challenged in terms of reliability. The supply deficit for each household is the difference between the harvestable rainfall and the augmentation target (the water that is required to meet household needs). This implies that the roof catchment surface is not of sufficient area to harvest the rainfall to meet the supply shortfall.

Assumptions:

Household demand

by

SCENARIO 1: 100 litres/person (22 gallons/person)

SCENARIO 2: 200 litres/person (44 gallons/person)

month

SCENARIO 1: 91.5 m³

SCENARIO 2: 183.0 m³

Municipal supply reliability (in this application defined as the % of demand met by the municipal water supply)

SCENARIO 1 at 60% supply reliability: 54.9 m³ supplied; household augmentation target: 36.6 m³

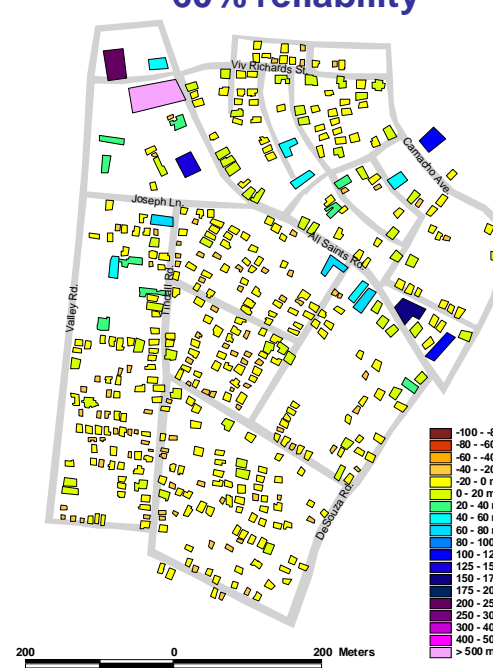
SCENARIO 1 at 80% supply reliability: 73.3 m³ supplied; household augmentation target: 18.3 m³

SCENARIO 2 at 60% supply reliability: 109.8 m³ supplied; household augmentation target: 73.2 m³

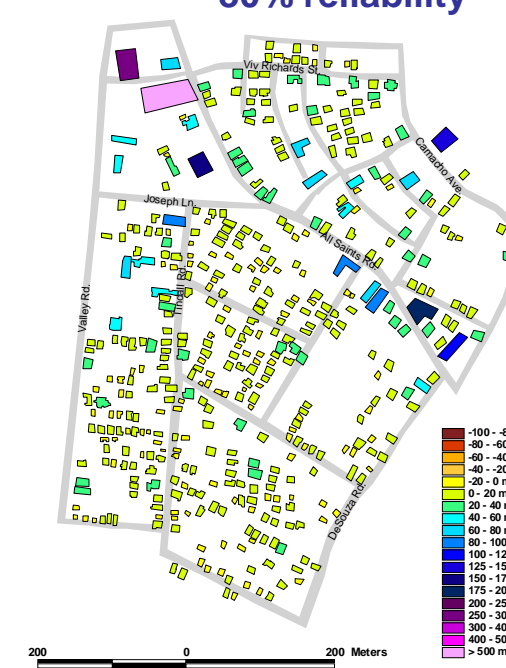
SCENARIO 2 at 80% supply reliability: 146.4 m³ supplied; household augmentation target: 36.6 m³

Persons per household: 5

NOTE: Rainfall will be harvested during the wet season and be retained as



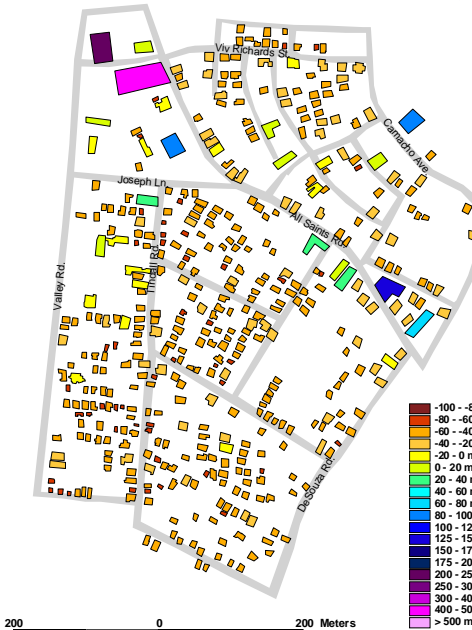
Cumulative deficit: 5535.3 m³



Cumulative deficit: 542.6 m³

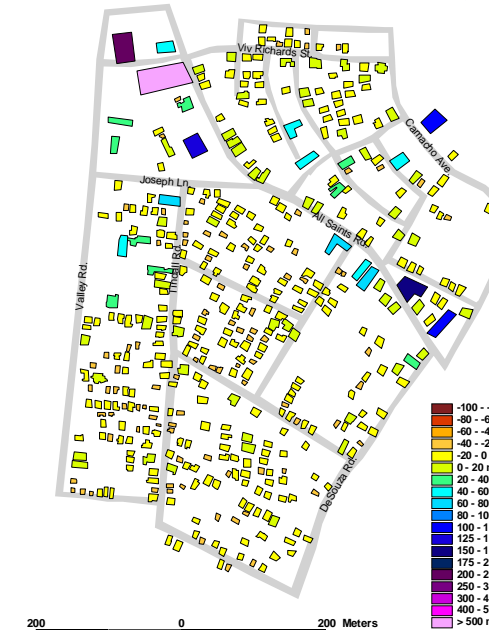
SCENARIO 2: Demand at 200 litres/person/day

60% reliability



Cumulative deficit: 20,653.9 m³

80% reliability



Cumulative deficit: 5535.3 m³