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Water Use at Palmetto Point and Middle Island, Saba, Dutch Caribbean: A Modeled Approach for Settlement Viability

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Abstract The neighboring abandoned villages of Palmetto Point and Middle Island, on the northwest of Saba, Dutch Caribbean, relied upon rainwater caught in cisterns as their primary source of potable water. The island of Saba is located in the northern Lesser Antilles, and thus is subject to a rainy and dry season in the course of a year. Using measurements of the village cisterns and their respective catchments combined with variations in monthly rainfall data over the course of a year, a study of water replenishment versus water consumption is possible for Palmetto Point and Middle Island. As a result, fluctuations in population in villages with measurable, finite supplies of potable water allow a researcher to determine the viability of the villages at particular points in time, and the resultant effects on internal economies and social dynamics during these periods.

Keywords Household archaeology · Water consumption · Internal exchange systems · Subsistence strategies · Colonial caribbean archaeology

Introduction

Across the Caribbean, small islands are often lacking in naturally occurring sources of fresh water. While some archaeological studies among pre-Colombian populations in the Americas have highlighted water access as the primary factor influencing the short and long term viability of any settlement (Drewett 2007; Johnson 2009; Scarborough 1998), it has been largely overlooked in colonial-era archaeological research; the procurement and consumption of water plays a central role in the daily activity cycle on individual and community levels. A settlement's viability is then inherently delimited by its ability to procure sufficient amounts of potable water. Insufficient supplies of potable over extended periods of time can serve as the mitigating cause for abandoning even well-developed settlement areas. Among those settlement areas in the Caribbean

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where insufficient water is available from rivers, springs, or wells, cisterns were often constructed to collect rainfall to serve as a source of water during the colonial era, and this practice continues into the present. Cisterns store a finite, measurable amount of water with only one or two means of replenishment, and preserve well in the archaeological record. The potential for cisterns as an avenue of research in archaeology will be demonstrated through an analysis of water availability versus water consumption at two neighboring abandoned colonial-era villages, Palmetto Point (presently known as Mary's Point among residents) and Middle Island, located in Saba, Dutch Caribbean. Using measurements of the village cisterns and their respective catchments (Haviser 1985), combined with variations in monthly rainfall data over the course of a year, a study of water replenishment versus water consumption is possible for Palmetto Point and Middle Island. As a result, fluctuations in population in villages with measurable, finite supplies of potable water allow a researcher to determine the viability of the villages at particular points in time, and the resultant effects on internal economies and social dynamics during these periods.

Saba

Saba is the northernmost stratovolcanic island in the active arc of the Caribbean Lesser Antilles, situated at approximately 17.38° N, and 63.14° W, measuring approximately 13^2 km, and approximately 900 m at its highest elevation (Fig. 1). Saba is a rhomb-shaped single volcano rising to a central dome-capped peak (Roobol and Smith 2004, p. 31) (Fig. 2). It has a population of about 1,500 people (in 2011), residing across four main settlements; The Bottom, which is the administrative center of the island and situated in the southwest, the village of St. John's on the south side of the island, the village of Windwardside in the southeast, and the village of Hell's Gate (Zion's Hill) in the northeast. The island receives an average of 1,041 mm of rain per year, (Nielsen 2007, p. 21) however the actual amounts vary considerably across the island.

The first documented attempt by Europeans to settle on Saba was undertaken by the Dutch in 1640 (Brugman 1995; Goslinga 1985; Hartog 1975); however, it is likely that the island was already occupied by a small potpourri of English, Scottish, Irish, and French refugees from St. Christopher following the Spanish siege of 1628 (Espersen 2009; Johnson 1994). The seventeenth century Saban economy was first centered on fishing, sugar, tobacco, cotton, and indigo production, as well as some cattle-raising (Adams 1795; Anonymous 1778; Coombe and Anderson 1778; Smart et al. 1815, p. 415; Thompson 1814; Wentworth 1834). The rich fishing grounds of the Saba bank are accessible only 10 km southwest of Saba, and its proximity would have served as a motivation for the Dutch to settle the island. Sugar cultivation was an important early industry on Saba, the earliest evidence of which is derived from a Dutch West Indies Company (WIC) document dated 1686, detailing pounds of sugar due by particular individuals on the island (Johnson 1994). Saba was briefly captured by the English in 1665 and from 1672 to 79, and also by the French in 1666. Saba was captured again by the English in 1781, as part of the Admiral George Rodney's sack of St. Eustatius. Following a brief occupation by the French and a subsequent re-occupation by the English, Saba was returned to the Dutch in 1815.

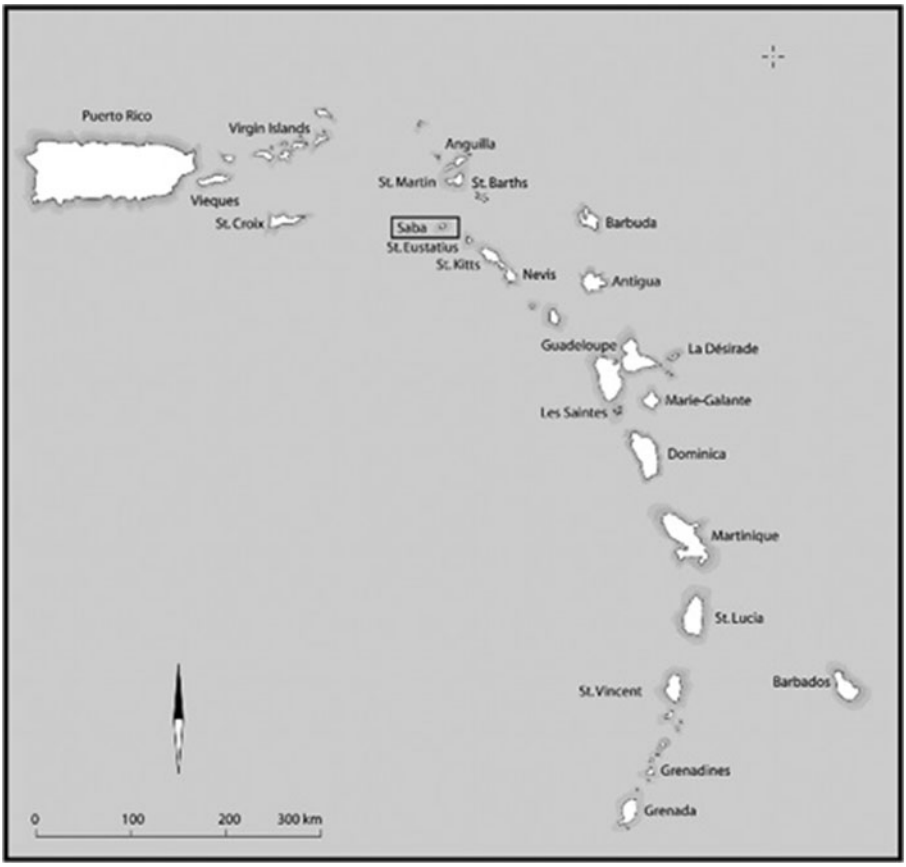

Fig. 1 The location of Saba

The eighteenth century in Saba saw political stability and steady economic growth in the agricultural sector along with a population boom. Between 1705 and 1780, the population of both enslaved Africans and those of European-descent Sabans rose from 577 to 1,301 (Johnson 1994, p. 134) (Fig. 3). This coincided with the period of economic growth on Saba spurred by a regional export economy centered on salted fish, coffee, cotton, indigo, sugar, sweet potatoes, and other vegetables. With flat, arable land already at a premium on the island, as more land came under the plough, an increasing shortage of land would have resulted which would have pushed the burgeoning population to settle along the undeveloped north slopes of Saba. The northwest slope of Mary Point Mountain, leading down to Torrens Point, was one of the few areas on the north face of Saba that could be effectively terraced to permit settlement and agriculture. The settlement area at Palmetto Point is situated neatly over a tract of soil noted by Veenenbos (1955) as "suitable for cultivation with major limitations," which is of better quality than the majority of soils on the island (Fig. 4).

Palmetto Point was first settled for the purpose of agriculture to export surplus produce to the booming slave markets of St. Eustatius (Espersen 2009). Archaeological excavations at the site revealed extensive erosion likely resulting from the initiation of intensive agriculture around Palmetto Point associated with mid to late

Fig. 2 Topographic map of Saba

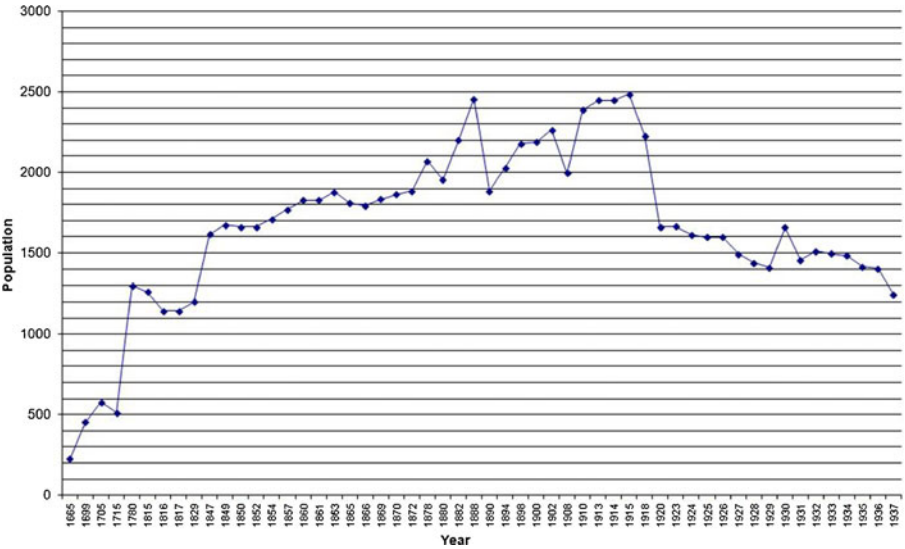

Fig. 3 Population of Saba, 1665–1937

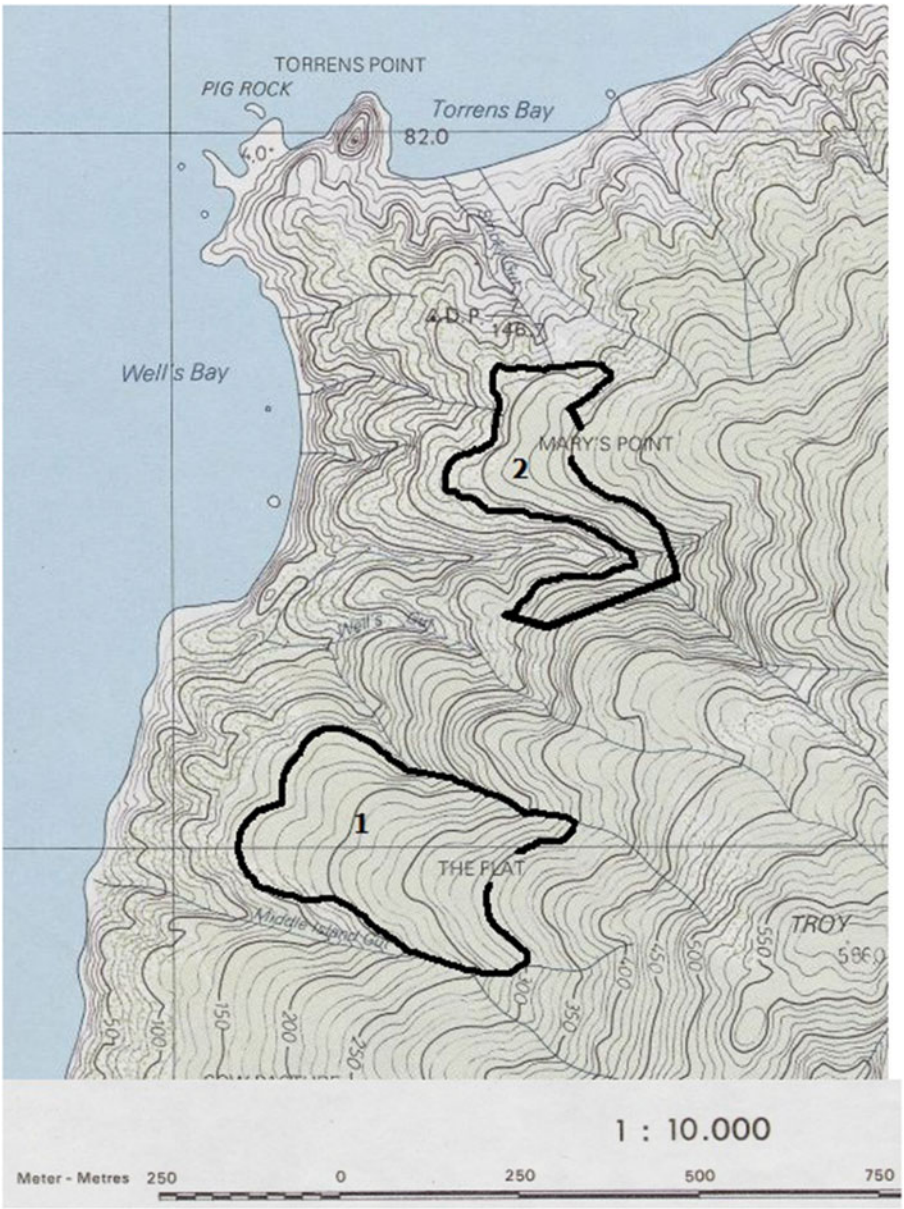

Fig. 4 Outlines of approximate settlement areas of Middle Island (1) and Palmetto Point (2)

eighteenth-century wares. This period coincides with the period of agricultural and population expansion across Saba, and also occurred during the aforementioned golden era of St. Eustatius as an international trading hub. Slave auctions formed an important element of the St. Eustatius economy during that period, and slaves in transit through the island would have required staple foods readily available from Saba, namely yams, potatoes, vegetables, and salt fish. The period of first settlement at Palmetto Point also occurs around the apex of Saba's successful regional export

economy, which ended abruptly following the hurricane of August 31, 1772. Potatoes and yams, one of the staples of the slave diet, were grown at Palmetto Point. A section of terraced land located above the immediate settlement area was known as "Yam Ground" according to the Saba Property Registers (1820–70). Saba was known for the excellent quality of its Irish potatoes and sweet potatoes, and the island continued to export barrels of "Irish" potatoes regionally until the late nineteenth century.

Palmetto Point has been experiencing significant erosion along the guts extending into the settlement area since at least the early twentieth century. Pearl Zagers, a former resident of the village, relates that she woke up one morning and her family graveyard, located in the front yard of her home, had collapsed along with a section of the cliff edge down into the gut. Since at least 2008, Cistern 2 has broken in half, and the remaining portion is now part the cliff edge.

The earliest mention of inhabitants at Palmetto Point and Middle Island in the documentary record can be found on the Captain E. H. Columbine (1816) map of Saba. It depicts four houses at Palmetto Point, while one house is drawn at the settlement area of Middle Island. It is possible that more than one house may have been present at Middle Island during this time, as thatch houses were not always regarded as "houses" on census records. This was sometimes noted as an exception on government documents, such as a 1861 census of Saba which accounts for the number of houses present at each village, "including thatch ones, in which these persons are also located." Middle Island is situated on the northernmost boundary of a former sugar plantation owned by the Dinzey family in The Bottom, and as such it may have served as a settlement area for their slaves, as well as free Sabans of African descent. The Saba Property Registers (1820–70, pp. 5, 15) document three cases of newly freed former slaves and free mulattos purchasing land and houses at Middle Island between 1830 and 1860. By the mid nineteenth century, the population of both settlements had expanded. The Captain G. H. Lawrance map (1854) depicts four houses at Middle Island, while Palmetto Point features seven houses. An island census of 1861 relates that Palmetto Point had 11 houses with a population of 58 residents and 14 slaves, while Middle Island had risen to 13 houses with a population of 49 residents and one slave (Fig. 5). Another census in 1865 details a rise in population at Palmetto Point to 75 residents in 13 houses, while Middle island expanded again to 70 residents in 19 houses. The rising populations of the two settlements throughout the nineteenth century would have consequently been met with the need to access to increasing volumes of potable and non-potable water. Indeed, ensuring a reliable supply of water at the villages would have precluded any attempt to settle in the area.

By 1934, there were at least seven cisterns in the settlement area of Palmetto Point, built as a separate structure from the house foundations. Each cistern at Palmetto Point was owned by one or several families (Carl Zagers, pers. comm.). Cisterns were considered commodities in themselves, and were not necessarily bounded to a residence or a plot of land. By 1934 there were over 250 cisterns on Saba, and ownership or shares in them were passed by will (Price 1934, p. 50). Given that there were up to seven cisterns between 11 households at Palmetto Point in 1865, some households may not have owned a cistern, but may have held a share instead. Owning shares in possessions on Saba was not limited to cisterns, and other possessions such as estates, ships, houses, slaves, and land were partitioned into shares both as part of sales and bequeathal. In the

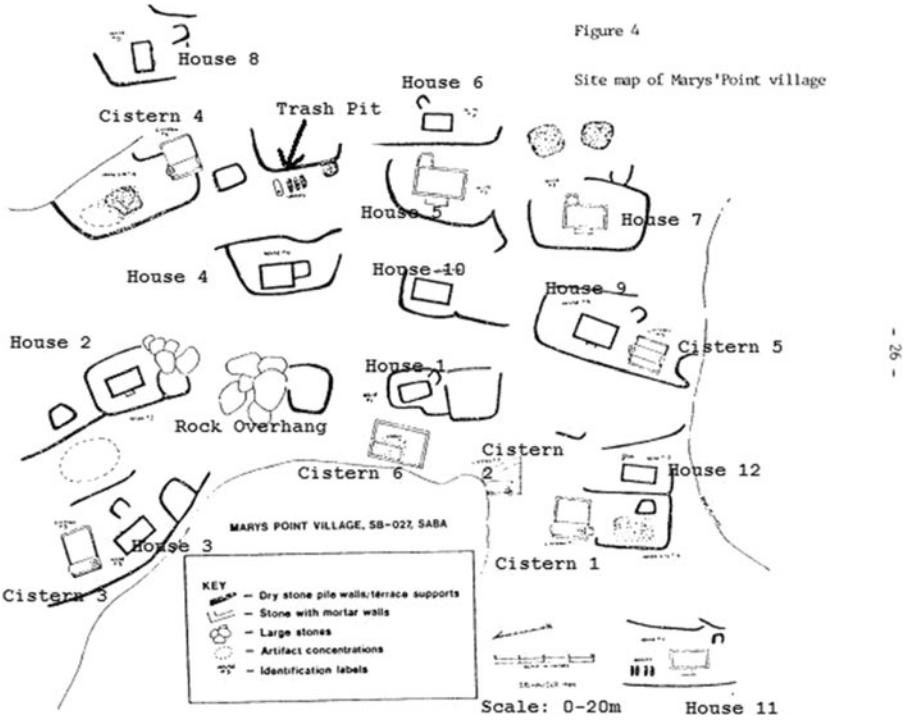

Fig. 5 Map of Palmetto Point (adapted from Haviser 1985, p. 26). Elevation rises evenly across the site from approximately 180 m at House 11 to 210 m at House 6

Saba Property Registers (1820–70), bequeathals commonly divided houses and slaves among family members, but some emancipation notices for enslaved Africans list multiple owners that were not necessarily related, indicating that shares were likely sold. In one instance, five owners of an enslaved African child are listed, all with different surnames), and in another, seven owners with four different surnames emancipated Ophelia, a 41-year old woman. Sales of shares in the aforementioned property registers extended to cisterns (one instance), ships (10 instances), land (15 instances), and houses (seven instances). In one particular transaction, a widow, Mrs. Elenor Beaks, sold the hall (living room) of her house and half of her cistern to Thomas James Kelley and Isaac Richard Kelley for 59 florins. In another, James Johnson sold to Richard Johnson Jr. nine tenths of his house at Booby Hill for 10 florins. Relative to other bills of sale, including houses, land, ships, slaves, and estates, cisterns appear the least. One bill of sale from August 1, 1867, lists "Peter Simmons and John Johnson, sold to Mr. Daniel Hassell, land with cistern in English Quarter, below the road leading to Hell's Gate, for his son Anthony Hassell, on condition that Daniel Hassell and his wife Maria, continue to hold cistern." One cistern at Palmetto Point was sold, not including land and residence, to William James Simmons in 1845 by John Zeagors for an undisclosed amount (Saba Property Registers 1820–70). This occurred in other villages across the island during this time as well.

The continual division of valuable property and the sales of shares therein reveal several important facets of the nineteenth-century socioeconomic environment of

Saba. Specie was scarce on Saba from the late eighteenth century up to the twentieth century, and as a result multiple currencies were in use of the island. Excavations at a trash pit at Palmetto Point uncovered a 2-sous coin from the French Cayenne Colony dated 1789, a 10-cent coin from the Danish West Indies dated 1862, three coins from the Netherlands date between 1880 and 89 whose denominations were unintelligible, and an 1-cent coin from the U.S.A. dated between 1850 and 59 (Espersen 2009). According to the aforementioned property registers, Spanish dollars and Netherlands florins were most commonly used in transactions. However, the use of multiple currencies was so widespread that by the late nineteenth century, the police posted daily exchange rates. The lack of specie would have encouraged the balkanization of ownership of high-value goods, such as slaves, ships, and cisterns, to provide an alternative medium for payment or exchange.

From the early nineteenth century to the twentieth century, many Saban men left the island to seek work abroad, most commonly aboard ships as deckhands, pilots, and captains, as there was little opportunity on Saba to earn money on an island based largely upon subsistence agriculture with small-scale regional exports of produce (Crane 1971). This created an island economy based upon remittances through wage labor and a growing reliance upon imported goods. In a social environment of an expanding population within a small geographical area coupled with few opportunities to earn money on the island itself, the sale and exchange of shares in valuable assets served as a means for one to profit from his or her possessions without relinquishing total control and ownership. In a similar vein to houses, with regards to cisterns, one would only totally relinquish total ownership or all shares in such if there was an alternative means to procure water. Doing so would leave the individual without a viable, long-term means of procuring and storing large volumes of water without having to continually exchange money, favors, or labor.

Each cistern at Palmetto Point and Middle Island possessed a cement catchment for collecting rain water, and they would have served as the primary potable water source for the inhabitants. Six were noted by Haviser (1985) at Palmetto Point, but another cistern was found during an archaeological survey in 2008 buried under tree roots and eroded soil just a few meters south of Cistern 2 (Espersen 2009). The cisterns are all domed with centered-square top openings, except for Cistern 2, which had an off-centered square top opening, and Cistern 6, whose top had collapsed into the basin (Haviser 1985, p. 25). Each cistern had rectangular catchments extending upslope of the cistern, except for Cistern 5, which is located in close proximity to House 9 and may have been replenished by the house gutters. Cistern 2 was unique in having a catchment that was more triangular. All the cisterns at Palmetto Point have underground storage basins, except for Cistern 1 which has a basin halfway underground and halfway above. Most cisterns on Saba and St. Eustatius have underground basins, while those on Dutch St. Maarten are mostly above ground (Keur and Keur 1960, p. 15). Although the cisterns at Palmetto Point were constructed to collect water via cement catchments, they may have been supplemented by rainfall collected in jars or barrels from roof gutters. The rooftops of houses serve as significantly larger catchments than the cement catchments constructed alongside cisterns, which results in faster replenishment rates of water, which in turn permits higher consumption rates of water per person per day. Due to the long distances of houses relative to cisterns, rainwater collected from roof gutters could instead have been collected with a small

collection of barrels. Given their small volumes relative to cisterns, the water barrels would have been given preference over cisterns as the primary source for potable water, as the replenishment rate is higher for rainwater collected via roof gutters, and the water collected in barrels would have probably have had a higher chance of spoiling if kept stored for extended periods.

A freshwater well at Wells Bay served as a supplemental supply of water, although the quality of water is variable and dependent on the weather. James Blunt (1867, p. 539), author of *The American Coast Pilot* describes the water from this well as "not good… the inhabitants chiefly depending on rain-water, caught in tanks." Pearl Zagers, a former resident of Palmetto Point, was not fond of the well either: "They had a well, the well that I'm telling you about, they used to get water from there. When it hold a drought it's a long time, you could get spring water from there. When it would be calm it wouldn't be so bad to drink; but when it was rough, oh, it was terrible! In this place was a hard life first" (Crane 1971, p. 306). Wells were also used elsewhere on Saba. Residents of Windwardside and Hell's Gate were known to walk down treacherous mountain slopes to obtain fresh water from the well at Spring Bay and then ascend again with tubs of water carried upon their heads (Johnson 1994). Pearl Zagers (pers. comm.) also relates that at times she and others would travel to Middle Island to obtain water during periods of drought. This indicates that Middle Island may have had a more reliable supply of water than Palmetto Point between 1920 and 1934. Access to water at Middle Island would not have been a reliable option to the early inhabitants of Palmetto Point before 1816, but may have been viable leading up to 1861. Haviser's (1985) survey identified five cisterns at Middle Island, domed with center-square top openings and catchments. [Edit note: this was originally based upon Haviser's field notes… the actual publication does mention five cisterns, thus I have accounted for the change]. The catchment of the fifth cistern could not be accurately measured, thus the average area from the rest of the cistern catchments at Middle Island was employed for this cistern in the model. Residents of Middle Island were ideally situated in that they could collect fresh water from Wells Bay, and were close enough to The Bottom and Cow Pasture that they could obtain fresh water from cisterns in those locations (Haviser, pers. comm.). As such they may not have had to rely on their own cisterns as a primary source of potable water to the extent of those at Palmetto Point.

Will Johnson (1994, pers. comm.) relates that the well at Wells Bay was built by Peter "Coonks" Simmons, the husband of Mary Zagers, the woman from the late nineteenth century to whom Mary's Point owes its namesake. As the well was mentioned by Blunt in his 1867 edition of the "American Coast Pilot," it was probably constructed by Simmons between the population rise following 1850 to Blunt's observations in 1867. Pearl Zagers and Carl Zagers also noted the scarcity and poor quality of the water at the site, even that boiled water from the village's cisterns would at times turn red (Crane 1971, p. 26; Carl Zagers, pers. comm). In the absence of a well or the potential to access to water at Middle Island, the availability of water at Palmetto Point was likely sufficient prior to 1850. The scarcity of water probably resulted from a population rise between 1850 and 1865, with the expansion from five houses to eleven (Espersen 2009, p. 74). Cisterns were not being constructed with effective water catchments and/or in sufficient numbers to keep pace with the increasing demand for water resulting from the burgeoning slave and slaveholding

population, which is indicative of rising levels of poverty among residents of Palmetto Point during this period. The well constructed at Wells Bay was then an indicator of the scarcity of water available at Palmetto Point by the 1870s. Indeed, the acquisition of water was a problem that pervaded settlement strategies across Saba. Johnson (1994) relates that few people on Saba could afford to build a cistern. Stress on the water supply combined with decreasing incomes had an effect on the health of residents by extension. By the early twentieth century, allegations began reaching the Dutch government of inbreeding and poor personal hygiene (Price 1934), schizophrenia (Brugman 1995; Crane 1971; Haviser 1985; Van Kol 1904), and difficult living conditions at Palmetto Point. The scarcity and poor quality of water was described by Pearl Zagers as one of the mitigating factors resulting in the Dutch government's decision to evacuate the village in 1934. Middle Island was abandoned by the early to mid twentieth century, based upon surface collections at the site by Haviser (1985) and my ongoing excavations at the site.

While the documentary record provides a qualitative account of water availability throughout Palmetto Point's settlement period, the fluctuation of the water supply through time relative to fluctuations in population can be quantified by water consumption versus replenishment rates through monthly rainfall for each cistern. Table 1 shows the dimensions and volumes of each cistern located at each village, along with the respective dimensions of their catchments. Between 1919 and 1934, The Bottom (elevation 242 m) averaged an annual rainfall total of 1,047 mm, St. John (elevation 363 m) received an average of 1,060 mm, and Windwardwide (elevation 424 m, exposed to trade winds) averaged 1,126 mm (Price 1934, p. 11). Price did not obtain any data from other settlements, and historical monthly rainfall data from The Bottom, Palmetto Point, or Middle Island was not available. Palmetto Point, however, has an elevation of 180 m, close to the elevation of The Bottom, and both are situated on the leeward side of the trade winds. The earliest monthly rainfall data that could be obtained was from 1992. Given that Palmetto Point occupies the approximate elevation and leeward position on the island as The Bottom, the monthly rainfall data for 1992 from The Bottom (878.8 mm over the course of the year) was employed for Palmetto Point. The same monthly rainfall data increased by 140 % (1229.5 mm) was also included to illustrate water consumption rates during years of rainfall higher than the average recorded for The Bottom. Next, monthly water consumption rates of 10, 15, and 20 L per person, per day (pp/pd) at Palmetto Point and Middle Island in 1865 (population 75 and 70 respectively) was divided evenly between each cistern in the respective villages, and subtracted from the volume of water replenished in the cisterns through monthly rainfall. When the water consumed per month exceeded the quantity of water available at each cistern in the respective villages, the negative value was expressed as a deficit. This indicates the volume of water that would have to be sought elsewhere by the shareholders of the respective cistern to maintain the assumed consumption rate pp/pd, whether within the internal exchange system of the respective village, from the freshwater well at Wells Bay if potable at the time, or from other sources. These projections assume that the same number of cisterns located at each village from archaeological surveys were also present in 1865. As a result, projections of monthly water availability at Palmetto Point and Middle Island are visible for this time. The base data set is displayed in Table 1. The tables used for calculations, which are not published along with this manuscript, display the total

Table 1 Dimensions and volumes of each cistern with the respective dimensions of their catchments

	Ground catchment			Cistern			
Location	Length (cm)	Width (cm)	Area (cm^2)	Length (cm)	Width (cm)	Depth (cm)	Volume (L)
			Palmetto Point				
Cistern 1	880.0	530.0	466,400.0	580.0	220.0	260.0	33,176.0
Cistern 2	[a]	[a]	439,200.0	430.0	150.0	160.0	10,320.0
Cistern 3	980.0	600.0	588,000.0	575.0	200.0	220.0	25,300.0
Cistern 4	680.0	390.0	265,200.0	460.0	170.0	260.0	20,332.0
Cistern 5	800.0	470.0	376,000.0	530.0	230.0	300.0	36,570.0
Cistern 6	910.0	680.0	618,800.0	430.0	210.0	140.0	12,642.0
Cistern 7	[b]	[b]	449,411.0	[b]	[b]	[b]	24,747.0
Total volume							163,107.0
			Middle Island				
Cistern 1	700.0	580.0	406,000.0	390.0	190.0	290.0	21,489.0
Cistern 2	900.0	440.0	396,000.0	480.0	220.0	290.0	30,624.0
Cistern 3	[b]	[b]	449,411.0	525.0	160.0	300.0	25,200.0
Cistern 4	730.0	670.0	489,100.0	360.0	170.0	300.0	18,360.0
Cistern 5	[b]	[b]	449,411.0	280.0	180.0	220.0	11,088.0
Total volume							106,761.0

[a] Triangular catchment area=0.5 (length of triangular section x width)+length x width of rectangular section

[b] Derived from average of all other catchments for purposes of calculation

quantity of rain collected in each cistern based on 1992 monthly rainfall data (either unmodified or 140 % of the original data) from The Bottom, while the second table in each group details the volume of water left in each cistern after a month of a fixed consumption rate (10, 15, 20 L pp/pd) by residents of Palmetto Point and Middle Island in 1865.

Due to the vulnerability of the water supply at Palmetto Point and Middle Island to drought, it would be highly unlikely if rainfall was not collected from gutters lining rooftops, either in empty barrels or through long gutters feeding into cisterns. In addition, if the cisterns at Palmetto Point were indeed supplemented with rainfall from roof gutters, this indicates that the local water supply was stressed after the cisterns were constructed, as all the cisterns were constructed to be replenished via cement catchments. If the cisterns were originally intended to be replenished primarily via roof gutters, they would have been constructed in close proximity or flush to house foundations as is the practice across Saba. During their tour of Saba in 1950s, John Keur and Dorothy Keur (1960, p. 15) remarked that:

> practically all houses, from the smallest hut to the largest home, have some provision to catch rain water which falls on the roofs. The simplest installation consists of two gutters, one on each sloping side of the roof, which lead into a 50-gallon oil drum. A few houses still use the old-type large, earthenware water

> jars to catch and hold water. The larger homes have gutters which lead the water into cement and rock cisterns, some of which are 15 feet long, eight wide and six high and hold several thousand gallons.

With the exception of Cisterns 3 and 5, the cisterns at Palmetto Point were located twenty meters or more from the nearest house, also at significantly higher and lower elevations to the other. This afterthought in house and cistern construction suggests that the village water supply in the early to mid nineteenth century was adequate without the need for rooftops to supplement as cistern catchments, and that population growth did not keep pace with an increasing supply of potable water via cisterns to support it.

In order to determine the maximum sustainable consumption rate of water pp/pd for each household from water collected in rain barrels via roof catchments, based on available monthly rainfall data, a similar model was employed. It was assumed that each household would possess barrels totaling 600 L in volume for the purpose of rainwater storage from roof catchments. It was also assumed that the monthly precipitation accumulated gradually over the month, rather than a single rainfall event. If the total average weekly rainfall per month was over 600 L, the model considered that the excess water was lost to spillage. While a gradual accumulation of precipitation over the month is most likely during the dry season, torrential rainfall from tropical storms and hurricanes would have accounted for the majority of rainfall during the rainy season (May to November), resulting in lower real potential consumption rates pp/pd during this period given the spillage that would have occurred once the storage barrels had reached their capacity.

To determine the volume (in L) of rainwater each roof catchment was capable of harvesting per month, the length (in cm) and width (in cm) of the roof was multiplied by the monthly precipitation (in cm) and divided by 1,000. Given that all the houses at Palmetto Point were dismantled and rebuilt elsewhere on the island, the roof areas were calculated using the respective house dimensions (Espersen 2009, p. 70) with a 30° pitch. To determine the maximum sustainable consumption rate of water pp/pd for each household, a base consumption rate of one L pp/pd per household was found. This was obtained by dividing the population of Palmetto Point in 1865 (75 residents) by the number of houses present during the same year (11), to get an average result of 6.8 people per household. This was then multiplied by the average number of days per month in a year (365/12=30.4) in order to obtain the average volume of water consumed in month, per household, at a rate of 1 L pp/pd (Table 2).

Determining the volume of water capable of being harvested with roof catchments at Middle Island is problematic, as not all the respective foundations of the houses mentioned in the 1865 census were located. There have only been two stone and mortar house foundations, along with one stacked-stone house foundation identified at Middle Island. A fourth house featured a slab stone floor, but with no discernible foundation. To account for the remaining 15 houses as noted in the 1865 census, the majority would have been constructed without foundations upon small tracts of flat land created by terracing throughout the site. Given the small size of these 15 houses, coupled with the general poverty of free and enslaved Africans inhabiting the settlement, it is likely that most of the houses had thatched roofs, which would not be as effective as a cedar-shingled roof with regards to serving as a catchment given

Table 2 Total possible rain collection from roofs of Palmetto Point (140 % of annual rainfall average)

		Palmetto Point												
		House 1	House 2	House 3	House 4	House 5	House 6	House 7	House 8	House 9	House 10	House 11	House 12	House 13
Roof length (cm)		808	762	772	934	958	600	750	726	922	854	888	808.00	818
Roof width (cm)		370	380	420	540	530	350	380	400	470	400	380	350.00	410
Roof area (cm2)		298960	289560	324240	504360	507740	210000	285000	290400	4333	341600	337440	282800.00	335380
Rainfall (cm)		Potential Maximum Rain (liters) Collected via Roof Catchments (Palmetto Point)												
January	9.9	2986.6	2892.7	3239.1	5038.5	5072.3	2097.9	2847.1	2901.1	4329.1	3412.5	3371.0	2825.1	3350.4
February	2.7	819.1	793.3	888.4	1381.9	1391.2	575.4	780.9	795.7	1187.3	935.9	924.5	774.8	918.9
March	13.0	3886.4	3764.2	4215.1	6556.6	6600.6	2730.0	3705.0	3775.2	5633.4	4440.8	4386.7	3676.4	4359.9
April	16.5	4923.8	4769.0	5340.2	8306.8	8362.4	3458.7	4693.9	4782.8	7137.1	5626.1	5557.6	4657.7	5523.7
May	19.7	5895.4	5710.1	6394.0	9945.9	10012.6	4141.2	5620.2	5726.6	8545.4	6736.3	6654.3	5576.8	6613.6
June	3.9	1186.8	1149.5	1287.2	2002.3	2015.7	833.7	1131.4	1152.8	1720.3	1356.1	1339.6	1122.7	1331.4
July	6.8	2029.9	1966.1	2201.5	3424.6	3447.5	1425.9	1935.1	1971.8	2942.3	2319.4	2291.2	1920.2	2277.2
August	7.6	2281.0	2209.3	2473.9	3848.2	3874.1	1602.3	2174.5	2215.7	3306.3	2606.4	2574.6	2157.7	2558.9
September	4.2	1261.6	1221.9	1368.2	2128.4	2142.6	886.2	1202.7	1225.4	1828.6	1441.5	1424.0	1193.4	1415.3
October	4.2	1261.6	1221.9	1368.2	2128.4	2142.7	886.2	1202.7	1225.4	1828.6	1441.5	1424.0	1193.4	1415.3
November	26.7	8006.1	7754.4	8683.1	13506.7	13597.3	5623.8	7632.3	7776.9	11604.8	9148.0	9036.6	7573.3	8981.4
December	7.4	2218.2	2148.5	2405.8	3742.3	3767.4	1558.2	2114.7	2154.7	3215.3	2534.6	2503.8	2098.3	2488.5
Total	122.9	36757.1	35601.4	39865.3	62011.1	62426.6	25819.5	5040.7	35704.6	53279.1	41999.7	41488.2		
Average		3063.1	2966.8	3322.1	5167.6	5202.2	2151.6	2920.1	2975.4	4439.9	3499.9	3457.3		
		House 1	House 2	House 3	House 4	House 5	House 6	House 7	House 8	House 9	House 10	House 11	House 12	House 13
	Rainfall (cm)													
December		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
January	9.99	11.6	11.6	11.6	11.6	11.6	10.1	11.6	11.6	11.6	11.6	11.6	11.6	11.6
February	2.7	3.9	3.8	4.3	6.6	6.7	2.7	3.7	3.8	5.7	4.5	4.4	3.7	4.4

Table 2 (continued)

March	13.0	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
April	16.5	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
May	19.7	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
June	3.9	5.7	5.5	6.2	9.6	9.7	4.0	5.4	5.5	8.3	6.5	6.4	5.4	6.4
July	6.8	9.8	9.5	10.6	11.6	11.6	6.9	9.3	9.5	11.6	11.2	11.0	9.2	11.0
August	7.6	11.0	10.6	11.6	11.6	11.6	7.7	10.5	10.7	11.6	11.6	11.6	10.4	11.6
September	4.2	6.1	5.9	6.6	10.3	10.3	4.2	5.8	5.9	8.8	6.9	6.8	5.7	6.8
October	4.2	6.1	5.9	6.6	10.3	10.3	4.2	5.8	5.9	8.8	6.9	6.8	5.7	6.8
November	26.7	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
December	7.4	10.7	10.3	11.6	11.6	11.6	7.5	10.2	10.4	11.6	11.6	11.6	10.1	11.6
Average		9.4	9.3	9.9	11.1	11.1	7.8	9.2	9.3	10.6	10.0	10.0	9.1	10.0
Consumption rate of 1 liter pp/pd=30.4 (average days per month in a year) * 6.8 (average number of people per household at Palmetto Point in 1865) =				206.7							Average water consumption (l) pp/pd:			9.8

that a certain proportion of the water would soak into the thatching. Excavations at two trash pits at Middle Island have only turned up one machine cut nail; however, 40 wrought nails, 14 cut nails, and 1 wire nail were recovered from six 1×1 meter units within and around one of the stone and mortar foundation houses, suggesting in this case a "Saban style" house (Brugman 1995) with a cedar singled roof. By comparison, excavations across Palmetto Point by the author uncovered 368 wrought nails, 37 cut nails, and 147 wire nails, the majority found in a trash pit (Espersen 2009). The lack of nails recovered from Middle Island suggests an abundance of thatched roof houses at Middle Island. As such, only house roof dimensions for Palmetto Point were employed in the roof catchment model. Based on the projected impacts on water consumption at Palmetto Point and Middle Island upon the monthly replenishment rate of each cistern, it is evident that access to water was a pre-eminent problem facing the residents by 1865 and afterward.

A consumption rate of 20 L pp/pd at Palmetto Point was sustainable with the 1992 monthly rainfall data increased by 140 %; however, the cisterns ran dry in October. The same rate with the non-inflated 1992 monthly rainfall data resulted in empty cisterns within the first few weeks of each month from July to October, which happens to coincide with the rainy season (Table 3). This illustrates the inherent unreliability of rainfall as a primary source of water on Saba, a sentiment that is echoed by many of the present-day residents across the island. A consumption rate of 10 L pp/pd at Palmetto Point was sustainable during both annual rainfall quantities, with the exception of Cistern 4. Since the model employed an average of 10.7 people harvesting water from each cistern per day, this cistern would only be able to sustainably support about half that amount at 10 L pp/pd without going dry for several months of the year. However, periods of prolonged drought would have had a significant impact on the supply of water available from cisterns in Palmetto Point and across the island itself. In 1994, Saba received on average only 451.9 mm of rain, which would have resulted in quickly depleted cisterns at Palmetto Point in the latter half of the year at a consumption rate of just 10 L pp/pd.

Table 3 Monthly rainfall data, The Bottom, 1992

Month	Rainfall (cm)
January	9.99
February	2.74
March	13.00
April	16.47
May	19.72
June	3.97
July	6.79
August	7.63
September	4.22
October	4.22
November	26.78
December	7.42

In 1865, a consumption rate between 10 and 15 L pp/pd from cisterns at Palmetto Point guarantees a surplus of water for the following year, which would serve as insurance against future periods of decreased rainfall. Water harvested via roof catchments in the water barrel model resulted in a consumption rate pp/pd on average of 8.38 L for the unmodified rainfall data, and 9.80 L with 140 % of the original rainfall data. When combined with the consumption rates via cisterns alone at 15 L pp/pd, the consumption rate for the unmodified rainfall data increases to 23.38 L pp/pd, and 24.80 L pp/pd with 140 % of the original rainfall data. Residents of Palmetto Point and Middle Island would have supplemented their daily consumption to some degree by fresh water from the well at Wells Bay after 1850, depending on its salinity. It could have served as non-potable water when the ocean swells temporarily increased its salinity and as potable water during periods of low swells.

However, in context with global water consumption rates pp/pd, residents of Palmetto Point would have been living in a perpetual state of ration. A water consumption rate of 10–15 L of water pp/pd is close to the lowest present-day global averages. In 2006, the average consumption rate pp/pd in rural Uganda was 12–14 L, with the lowest contemporary rate being among arid areas of western India and East Africa during their dry seasons at 5 L pp/pd or less (UN Human Development Report 2006, p. 34). Even with the comparatively higher consumption rates in modern-day rural Uganda, basic sanitation is still uncommon due to poverty, low standards of hygiene, and a lack of sanitation practices (UNESCO World Water Assessment Programme 2006, p. 512). Given the similar levels of water collection and consumption between the aforementioned areas and Palmetto Point, some comparisons can be drawn in regard to hygiene. Low levels of water consumption coupled with unsanitary water sources leads to increased incidences of waterborne diseases and diarrhea. Water quality tests conducted during the mid twentieth century in Saba, St. Maarten, and St. Eustatius revealed that water in wells and cisterns was polluted to some degree; between 1939 and 1953 there were 255 cases of dysentery and 31 cases of typhoid fever between Saba, St. Eustatius, and St. Maarten (Keur and Keur 1960, p. 149). It is unknown whether latrines were present at Palmetto Point during the nineteenth century, though by the twentieth century waste from chamber pots was simply thrown "into the bushes" or over the eroding cliff that demarked the southern limits of the village (Pearl Zagers, pers. comm.). Animal pens, intended for goats, pigs, or a cow, were present in the village, though the extent to which some animals may have ranged outside of the pens is unknown. Nonetheless, their waste would have washed downhill during periods of precipitation. The slope of the village site ranges from 0 to 30°, and this would have allowed for waste from upper elevations to be washed downhill onto catchments and into cisterns. Six of the seven cisterns at Palmetto Point had upslope cement catchments, which would be problematic in this regard. The use of upslope cement catchments in the midst of poor sanitation practices across the village site predisposed residents of Palmetto Point to greater chances of contracting water-borne illnesses. This would have been a contributing factor towards the village's abandonment and eventual evacuation by 1934 due to unsanitary conditions and the difficulty in obtaining medical attention (Keur and Keur 1960, p. 29; Pearl Zagers pers. comm.; Carl Zagers pers. comm.).

The availability of water at Middle Island, based upon the assumed water consumption rates pp/pd, was markedly less than was available from Palmetto Point with the same variables. During each scenario, the cisterns at Middle Island were empty

after only 1 or 2 weeks of consumption during each month. The number of cisterns present at Middle Island would have had to be doubled in order to maintain a comparable supply of water relative to Palmetto Point with the same rates of water consumption pp/pd. Effectively, with only five cisterns, Middle Island residents would have had to suffice with only 5 L of water pp/pd in 1865 to maintain sustainable water quantities. This consumption level appears low, as the daily water requirement for a healthy human adult is approximately 2 L per day (Rosegrant et al. 2002); extended periods of physical exertion will increase the daily requirement. Evidently, additional water was probably collected through other sources in a similar fashion to those described for Palmetto Point, and could have been imported in times of need from Cow Pasture and The Bottom. Given the low quantity of water available via cisterns relative to the population, it is possible that there is a well within the vicinity of Middle Island that has yet to be discovered, or that has since been destroyed. The stress created upon water supplies at Middle Island by population in 1865 would have put pressure on residents to emigrate from the village. The fact that by the early twentieth century residents at Palmetto Point were able to obtain water at Middle Island during periods of drought suggests that its population dropped significantly by this time.

The stress upon the water supplies at both Palmetto Point and Middle Island would have served as a source of pressure to emigrate from these villages. During nineteenth century, the island economy relied increasingly remittances from wage labor abroad. It was commonplace that the men of Saba took to sea as whalers, captains, deckhands, and later to Bermuda to seek labor for extended periods, often years, as the local economy had collapsed by the close of the eighteenth century. Palmetto Point and Middle Island were no exception. The 1861 census notes 17 men and women, respectively, as inhabitants at Palmetto Point, while a census in 1865 accounts for 17 men and 24 women, with a total population of 75. At Middle Island, the 1861 census records 16 men and women respectively, while in 1865 this increased to 22 men and 28 women, with a total population of 70. The absence of men at the villages is accounted for in 1865; however, prolonged stress on the water supplies at Palmetto Point and Middle Island would have served as additional pressure on adult male residents to seek work abroad.

The consumption rates of water and its availability would have had an impact upon foodways and social dynamics at Palmetto Point. Aside from an average of about 2 L of potable water pp/pd required for survival, there was a range of activities and other elements that would have increased daily water consumption. Cooking, cleaning, and bathing would have required additional quantities of non-potable water. Livestock present at the site, such as cows and goats, would have increased consumption rates, although non-potable water could also have sufficed for their requirement. The process of "corning" fish as described by Pearl Zagers would have increased the daily average water consumption as well. Although specific quantities are not known, washing the fish required "three or four waters" after they were dried and salted (Crane 1971, p. 306). If salt fish constituted the primary protein resource for residents of Palmetto Point, this process would have had a significant impact upon water consumption. The daily water requirement of approximately two L pp/pd would also have been supplemented from the consumption of locally available water-bearing produce such potatoes, mangoes, oranges, and soursop.

The unreliable water supply at Palmetto Point and Middle Island would by extension have affected the social environment of the village. Water would have been consumed at the village with an awareness of the present requirements while being mindful of the supply in the future. These conditions at between the two villages would have been conducive to the formation of water as a tool for leveraging within their internal exchange systems during periods of drought. The structure and social dynamics of the internal exchange systems at Palmetto Point and Middle Island are likely similar to those described by Keur and Keur (1960) across Saba and St. Maarten in the 1950s. From the nineteenth century to the foundation the 1970s, Saba experienced very little immigration and tourism (Saba Catholic Marriage; Crane 1971; Will Johnson, pers. comm.), and the economy was reliant on remittances through wage labor abroad. As a result, the island's social environment was conducive to strong cultural continuity throughout this time. Keur and Keur (1960, pp. 125–126) observed that:

> Almost all shops bear the imprint of their owners' personalities, and have at least a small clientele of regular customers who exhibit a feeling of "belonging" and to whom credit is extended… There seems to be no logic to price-setting, beyond individual whim. Prices often seem fairly independent of actual cost. If a shop-keeper thinks a hat "pretty," she may charge accordingly, regardless of what she paid for it. The same merchandise may be differently priced in different shops. Usually the variation is slight, but in one case, the same brand of soap sold for twelve Antillean cents in one shop and eight in another… the attitude of living for the present day, and taking no thought for the morrow, is prevalent and a strong contributing factor to this type of buying…Customers generally do no comparison shopping, but patronize mostly the store where they "belong," making occasional purchases at one or two others nearby… Any attempt to stimulate the practical application of this would go unheeded today among those of low economic status, since cash on hand is often very little, and there is no suitable or available storage place to keep any food, much less perishables.

A lack of long-term planning among low-income Sabans regarding purchases is prevalent in the description by Keur and Keur. This mentality, though did not extend to the acquisition of water. As there are no naturally occurring sources of water on Saba that can be exploited on an island-wide subsistence level, obtaining water necessitates long term planning. This is embodied in the use of cisterns to capture and store rainwater as the primary potable water source on the island.

In my interview with Pearl Zagers and her sister Gladys Hassell in 2008, they mentioned that they ate no canned food, and instead relied entirely upon subsistence agriculture. Every family owned goats and chickens in stone-circle pens. Produce from Mary's Point included "grey" corn, "irish" (white) potatoes, and yams, supplemented with butter and cream made from goat's milk, meat when livestock are available for butchering, fresh and salted fish from Well's Bay, oranges, mangoes, bananas, "tannias" (taro root), tamarinds, and unspecified vegetables. Any small surpluses were sold in The Bottom, about a two hour walk from Mary's Point, on Sundays following Church service. It is a common practice around Saba for residents to cultivate crops on somebody else's land (Crane 1971, 1987; Johnson 1994; Keur and Keur 1960). In this case, the standard agreement was that the owner of the land received 1/4 of the harvest, but in some

cases with potatoes this was decreased to 1/5, given their value on the island (Crane 1987). Reciprocal help, called "change work," was used during planting and harvesting seasons, as paid labor was expensive and difficult to find (Keur and Keur 1960, p. 75). The sense of "belonging" to a store as described by Keur and Keur is probably a reflection and continuity of "change work," by engaging in preferential trade in commodified items with those who are considered members of one's internal exchange network.

On Saba, including Middle Island and Palmetto Point, access to water in cisterns was granted proportionate to the amount of shares owned. Shares were purchased, but the water was not. There are no oral or documentary accounts which relate or suggest that the sale of water on Saba was normalized during the nineteenth to mid twentieth centuries. It did, however, occur during periods of severe drought. Changes within the internal exchange system would result when normally uncommmodified goods and services become commodities. Such was witnessed on nearby St. Eustatius during an extended drought on the island during the mid nineteenth century by the Methodist evangelist Daniel P. Kidder (1849, pp. 20–22):

> Those whose cisterns yet contained water, generously shared with their neighbors who were entirely out, until their own households were in danger of being destitute of this great blessing. Prayers were ordered in the public congregations on the Sabbath-day for rain. The drought continued and became alarming. Boats were dispatched to the neighboring islands with casks to obtain water. The water in wells because very low, and man and beast felt the awful effects of the drought. In the midst of this state of things, one person, desirous of turning this visitation of Divine Providence to individual account, and having large cisterns as yet scarcely touched, hoarded up this precious gift of Heaven, and would not give, or but rarely to a suffering neighbor. The object was to constrain them to buy and a price was set upon a pail of water at once exorbitant and cruel. The people were driven to nearly the last extremity, and one day more would have witnessed a strange sight among them.

While this example of social leveraging through water supply occurred in a larger population center than Palmetto Point and Middle Island, it illustrates the potential power and influence available to a group or individual owning potable water during periods of drought in this environment. By 1912, drought was so severe on Saba that island residents actually did begin to sell rainwater. "If one excludes the top of the rock (Saba), covered and moistened by passing clouds, one can say that Saba is going through hard times. Fields, gardens, cisterns, everything is dry. Rainwater can be bought only expensive" (*Amigoe di Curaçao* 1912, p. 2). It is important to note the distinction between water and "rainwater"; the latter implying that it is derived from a cistern or other storage vessel using a catchment, rather than from a naturally occurring source. By 1865 the residents of Palmetto Point and Middle Island would have been in a continual state of water ration. Throughout the water consumption versus water replenishment tables for Palmetto Point, Cistern 4 was always the first to run dry, followed by Cistern 2. As such, families who owned these cisterns would have found themselves in need of seeking potable water elsewhere, while their neighbors would still have had a supply of their own. Attempting to explain how water distribution was mediated during periods of

drought at Palmetto Point is at this time a point of speculation. Given that there was a practice of communally sharing butchered livestock across the island, it is possible that water would have similarly been shared between families during times of need, to an extent. However, this situation served to foster a social environment where those families or individuals who owned the largest and fastest-replenishing cisterns at Palmetto Point, being Cisterns 3 and 6, would have been in a recurring position to leverage within the social environment of the village during periods of drought. The owners of cisterns still containing water could have exchanged this commodity in return for favors, food, material goods, or money, as witnessed in 1912, resulting in the increasing commodification of water. With only four cisterns at Middle Island with a population of 70 in 1865, the owner of any cistern would have found themselves in such a situation as well, regardless of drought. As previously mentioned by Pearl Zagers, during the early twentieth century, when there was no water to be had in Palmetto Point, they would travel to Middle Island in order to obtain it. Middle Island was not normally a destination for trade by residents of Palmetto Point; rather, The Bottom was their destination for selling agricultural produce and purchasing goods. In this sense, drought results in the expansion of Palmetto Point's internal exchange system to include other families or villages outside of their normal sense of "belonging," as their own system is no longer able to provide for their needs. In these villages that had little in terms of liquid assets, accessing water through shareholding and trade would have been a foundational aspect of their internal exchange systems.

The quantification of water availability, supplemented by oral and documentary accounts of water use and census records together provide foundational data for studies into the viability of settlements in areas where continuous access to potable water is not guaranteed. Based upon accounts from the documentary and oral history records, as well as data garnered from site surveys at Palmetto Point and Middle Island, reliable access to water became increasingly difficult as the two villages expanded between 1850 and 1865, and continued thereafter. A consumption rate between 10 and 15 L pp/pd of water from cisterns pp/pd was sustainable during years of average rainfall in Palmetto Point. This is similar to the consumption rates of present day Uganda, among the lowest in the world. Water supplies at Palmetto Point were likely supplemented by water collected from roof gutters, which could account for an additional 8.38–9.80 L of water pp/pd during years of average and above average rainfall, based on the model which assumed an average of 600 L of storage in barrels. The unequal replenishment versus consumption rate among the cisterns at Palmetto Point would have created a social environment where families or individuals owning cisterns with higher replenishment rates, such as Cisterns 3 and 6, could have exercised social leveraging within the internal exchange system of the village, especially over those relying on cisterns with low replenishment rates, such as Cistern 4. This manifested itself on St. Eustatius in the mid nineteenth century, on Saba in 1912 during a drought, where remaining supplies of fresh water were being sold at high prices, and during periods at Palmetto Point when cisterns ran dry and residents sought water at Middle Island during the early twentieth century.

A water consumption rate of around 5 L pp/pd would be required to sustain cisterns at Middle Island by 1865 in the model, and if alternative methods of water collection were not sufficient to meet demand, then the 70 residents in Middle Island would probably have represented an approximate population apex. Given the stress of water supplies at Middle Island in 1865, the ability of Palmetto Point residents to acquire water at Middle Island during the early twentieth century suggests that the

latter village had a more stable water supply, which would require a significant drop in population to sustain. It is apparent in both the documentary record and through this water consumption model that further population increases at both villages after 1865 would further exacerbate the problem of water shortages, and as such both villages began to decline in population after this point, leading to their eventual abandonment.

The acquisition and consumption of water plays an integral part in everyday life at both the individual and community level. Consumption rates are difficult to assess in pre-industrial areas with unbounded water supplies, such as a lake or river. However, in those areas where the main source of water is from precipitation, it becomes possible to construct a model to estimate daily water consumption per person. If daily or monthly precipitation records are available to researchers of these environments, the effects of drought and the subsequent effects on the social environment can be studied at both village and household levels. This can provide insights into social dynamics and village-level internal exchange systems by viewing water as a commodity in times of drought, and can also indicate the viability of a household or entire settlement by studying the quantity of water available relative to the population. Cisterns are artifacts in their own right and can provide valuable datasets that should not be overlooked by archaeologists.

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