State of New Jersey
Department of Environmental Protection

2024 NEW JERSEY STATEWIDE WATER SUPPLY PLAN

APPENDIX G

SEASONAL PCWS DEMAND ANALYSIS: STATEWIDE AND COASTAL

Appendix G:

Seasonal PCWS Demand Analysis: Statewide and Coastal

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SEASONAL PCWS DEMAND ANALYSIS: STATEWIDE AND COASTAL

An analysis of the extent to which public community water systems (PCWS) in non-coastal, coastal, and barrier island coastal communities vary regarding the differences between summer and non-summer demands, expressed as the ratio between summer (June through September) and non-summer months. Coastal PCWS have much higher average ratios (2.37) than non-coastal PCWS. However, barrier island PCWS drive much of that difference. The relationship between the average ratio and the percentage of residential land use was strongest for barrier island PCWS and weakest for non-coastal PCWS.

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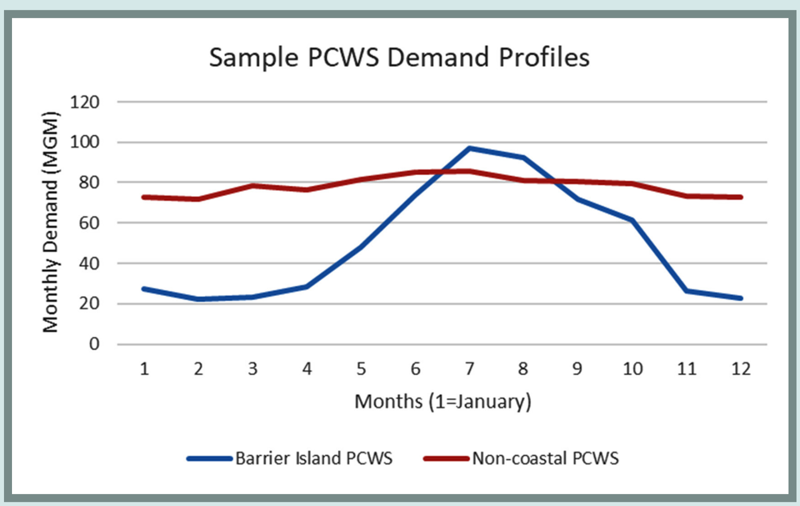
OVERVIEW OF ANALYSIS

Prior water demand analyses (Van Abs et al., 2018) showed that public community water systems (PCWS) with a significant exposure to the summer tourism economy had very different monthly demand patterns. While most PCWS have summer demands that exceed winter demands, this pattern was magnified for coastal PCWS along the Atlantic coast. For the 2024 NJSWSP, the analysis was further developed and with more detailed statistical tests, as reported in this appendix.

The first purpose of this analysis is to assess 5-year annual average demands and ratios of summer to non-summer demands for all PCWS that have available data, for use in the 2050 PCWS demands model. Monthly demand data for 464 PCWS were provided by DEP from the New Jersey Water Tracking database for this analysis. Summer months were selected as June through September, based on an analysis of aggregate monthly demands as a percentage of aggregate annual demands across all PCWS in the database.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
% of Annual Demands	7.7	7.0	7.5	7.4	8.3	9.4	10.5	10.0	9.3	8.5	7.2	7.4

The second purpose is to identify PCWS with ratios of summer to non-summer demands that are greatly higher than other PCWS, potentially reflecting a major coastal tourism demand, so that their demand projections should be assessed in a different manner than non-coastal PCWS. The distinction between PCWS demand profiles can be shown in the following chart for two PCWS; one is a barrier island PCWS and the other is a non-coastal PCWS in northern New Jersey. Summer demands slightly exceed non-summer demands for the non-coastal PCWS. However, summer demands are nearly five times the non-summer demands for the barrier island PCWS.



Analyses compared these ratios in several ways:

- statewide;
- by general geological area (Bedrock and Coastal Plain geology);
- by location on barrier islands and other near-coastal areas;
- by the percentage of the developed service area in Residential land uses; and
- by comparing the largest PCWS (comprising either 80% or 90% of total demands) to smaller PCWS.

SUMMARY OF RESULTS

The aggregate demands of all PCWS in the database represent nearly 1 billion gallons per day (997 mgd) in annual average demand for the years of 2016-2020. The ratio of summer to non-summer demands is 1.29, or roughly a 30% higher summer demand than the non-summer demand. The median value of individual PCWS results was 1.23, with a fairly wide distribution of values. The largest PCWS (80% of statewide demands, from 66 PCWS) have a ratio of 1.25 and a tighter distribution. Based on these results, a ratio higher than 2.0 was selected as representing an unusually high ratio.

The geological analysis provides a different perspective. PCWS serving areas with bedrock geology (which generally are not in major tourism areas) have an even lower ratio, of 1.19. Coastal plain PCWS, on the other hand, have a ratio of 1.49 and a wider distribution of values. The coastal plain PCWS can be further subdivided into those on Atlantic Coast barrier islands (primarily Ocean, Atlantic and Cape May counties), those with at least half of their service area within one mile of Atlantic Coast waters (either the shore or tidal bays), and those in the second set that are not on barrier islands. The results clearly indicate that barrier island PCWS have by far the highest median ratios. Interestingly, the non-barrier island coastal PCWS have a median that is not greatly different from the non-coastal systems.

	All Coastal PCWS (n=57)	Barrier Island PCWS (n=33)	Non-Barrier Island Coastal PCWS (n=24)	Non-Coastal PCWS (n=407)
Median Ratio of Summer to Non-Summer Demands	2.11	**3.17**	1.55	1.20

Statistical t-tests were conducted along with Mann-Whitney U tests (to address samples that may not have a normal distribution). These tests confirmed that coastal and non-coastal PCWS were significantly different, as were barrier island and non-barrier island coastal PCWS. Further, coastal PCWS in Monmouth County are statistically different from other coastal PCWS and from coastal PCWS.

The percentage of residential land use within the service area showed a lower correlation to the ratio of summer and non-summer demands for all sizes of PCWS, though coastal PCWS showed a somewhat stronger relationship than either barrier island or non-coastal PCWS. However, when PCWS size is added as a factor for either the ratios or % residential area by location (barrier island, coastal, non-coastal), some tests (barrier island PCWS and non-coastal PCWS for the ratio; % residential area for all locations) were found between the largest systems and all other systems in those locations. However, only two barrier island PCWS are within the top 80% PCWS, and seven with the top 90% PCWS.

The results show that barrier island PCWS have monthly demand profiles that are very different from profiles of non-coastal and even other coastal PCWS. Therefore, the projection of demands to the year 2050 will need to address these distinctions, as population changes will not have the same effects on annual demands as with other systems, due to the outsized tourism-based summer demands.

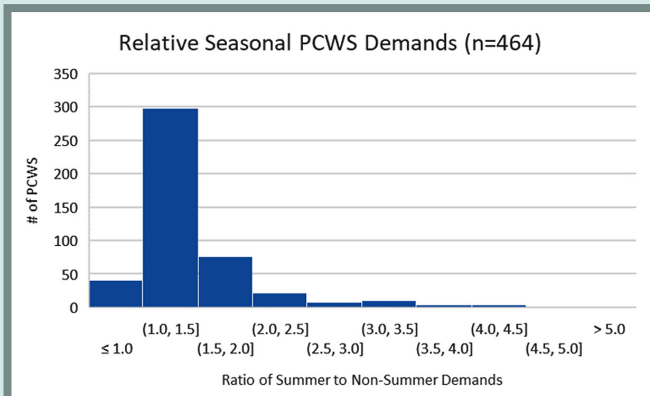
STATEWIDE ANALYSIS

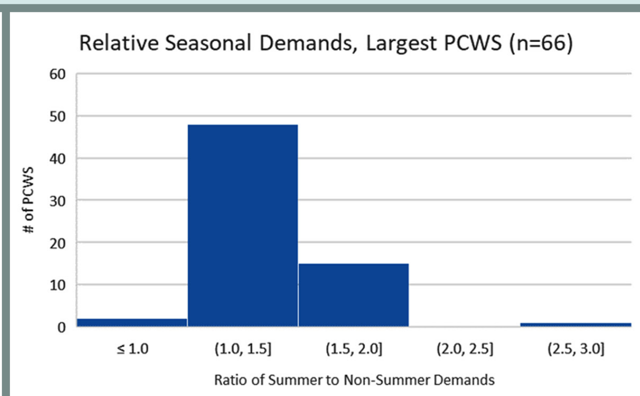
The primary focus of the statewide analysis is to understand the summer and non-summer withdrawals and the ratio between them. These values are important for two purposes. First, they are entered into the 2050 PCWS Demand Model directly for all PCWS for which data are available. Second, the results can be generalized for use in assessing summer and non-summer demands for PCWS that do not have available data.

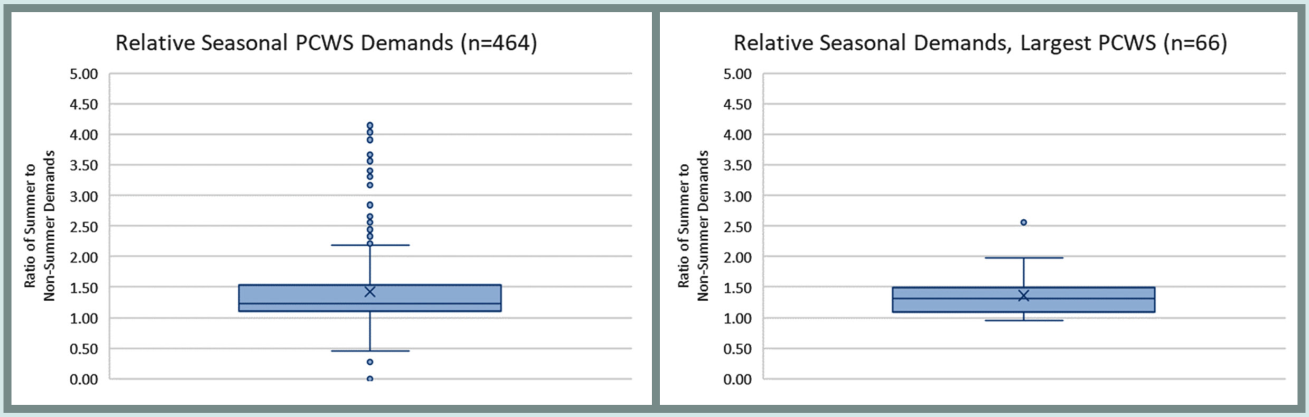
The statewide analysis involves 464 PCWS representing withdrawals as shown in the following table. Of the total annual average withdrawals, 66 PCWS represent 80% of all demands supplied to retail customers (i.e., not including regional wholesale systems such as the New Jersey Water Supply Authority and the North Jersey District Water Supply Commission, and accounting for bulk transfers among PCWS). The database includes some PCWS reporting that their ratio of summer to non-summer demands is less than one, which indicates that summer demands are less than non-summer demands, an unusual situation. These are included in the histograms and box plots below for completeness. Seven PCWS have values less than 0.8. Of these, six are very small systems or military facilities. One is a municipal system that has incomplete data. These seven PCWS are not included in the statistical tests section below.

	Statewide Annual Average (mgd)	Statewide Summer Average (mgd)	Statewide Non-Summer Average (mgd)	Ratio of Summer to Non-Summer
TOTAL (n=464)	966.62	1138.95	885.97	1.29
Top 80% (n=66)	773.11	894.71	715.28	1.25

The analysis of summer to non-summer withdrawals is of primary importance in this study. Statewide, the ratio is 1.29, meaning that the statewide summer withdrawals are 29% higher than the statewide non-summer withdrawals. However, the median among all individual PCWS is lower, at 1.23. For the PCWS comprising 80% of all annual average demands, the ratio is 1.25. The following histograms and box plots show the distributions. The box plots presenting the results with the median, 25th/75th percentiles, and outliers. The results for the largest 66 water withdrawals are markedly different, with a tighter range of ratios showing fewer results at the low and high ends.



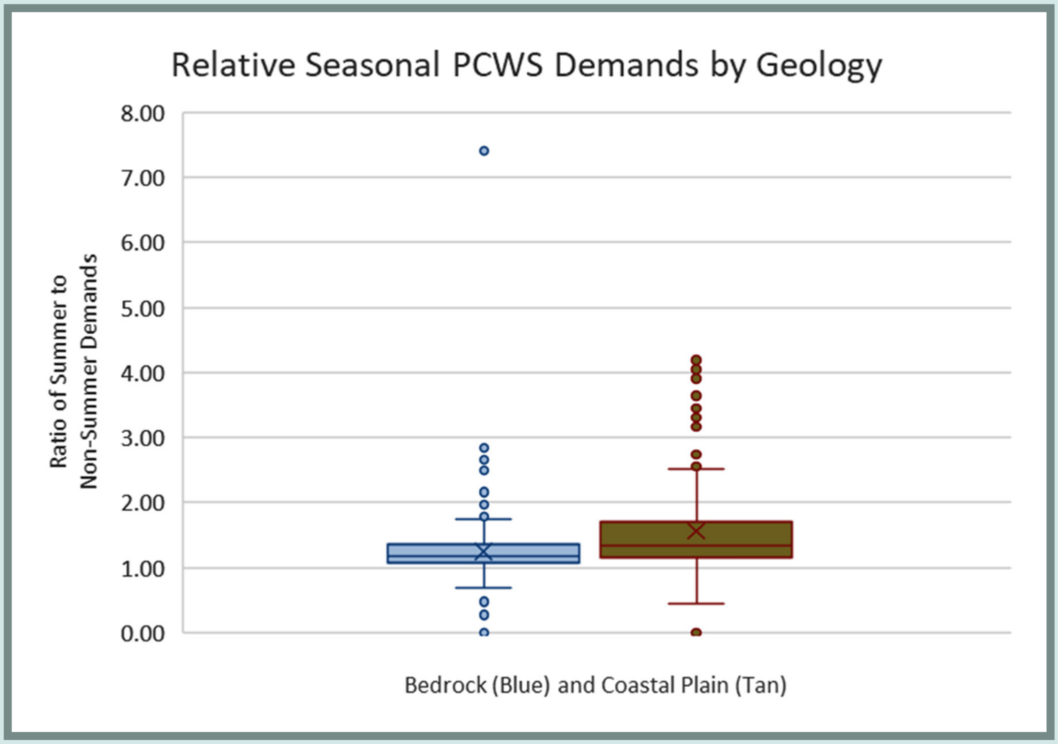




GEOLOGIC AREA ANALYSIS

One question is whether the ratios of summer to non-summer withdrawals differ significantly between PCWS located in bedrock geology and coastal plain geology. The following results indicate that the coastal plain PCWS have ratios that are markedly higher than for bedrock geology PCWS. Using total demands across all PCWS, the ratio is 1.19 for bedrock PCWS and 1.49 for coastal plain PCWS (25% higher). However, the median among all individual PCWS is lower, at 1.23 for bedrock PCWS and 1.34 for coastal plain PCWS (15% higher). As seen in the box plots, the results for bedrock systems are much tighter around the median that the results for coastal plain systems; the median coastal plain ratio (1.34) is essential the same as the 75th percentile result for bedrock PCWS (1.35).

	Statewide Annual Average (mgd)	Statewide Summer Average (mgd)	Statewide Non-Summer Average (mgd)	Ratio of Summer to Non-Summer
Bedrock (n=211)	633.15	711.77	598.32	1.19
Coastal Plain (n=253)	333.47	427.18	287.66	1.49

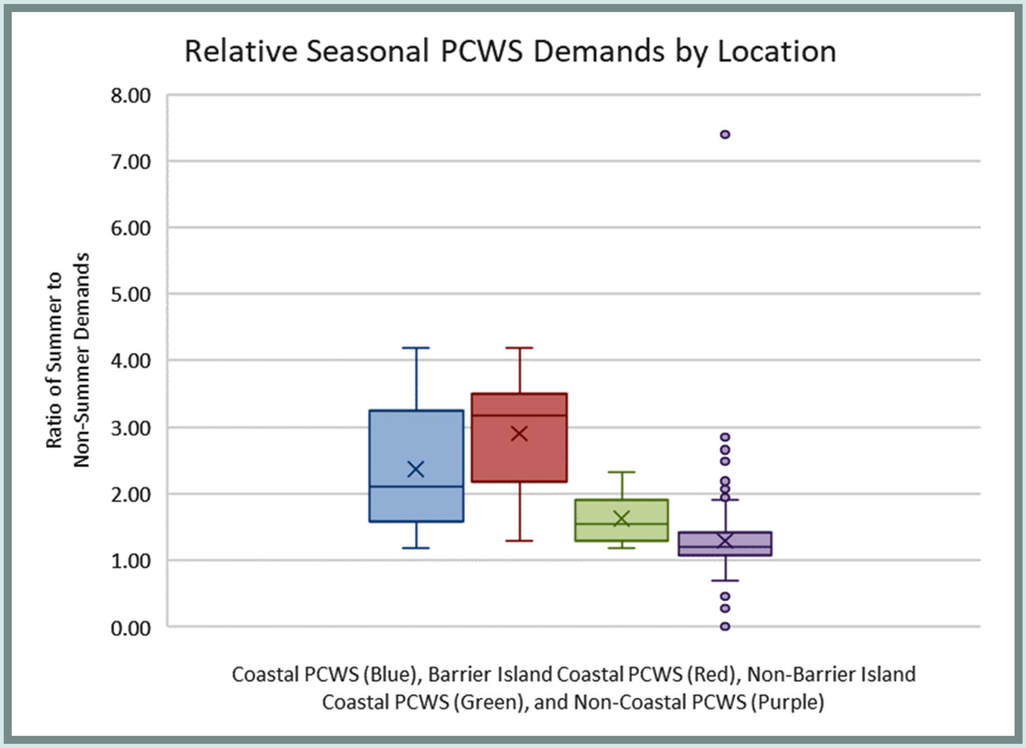


COASTAL SERVICE AREA ANALYSIS

A second question is whether the ratios of summer to non-summer demands differ significantly between PCWS that are on barrier islands or have significant service areas in close proximity to Atlantic coastal waters (i.e., the Jersey Shore or related bays. Barrier island PCWS are located on narrow areas of land that either extend from the mainland (e.g., Barnegat Peninsula) or are actually islands (e.g., Long Beach Island, Absecon Island). Coastal systems have greater than 50% of their service area within 1 mile of coastal waters, which by definition includes the Barrier Island PCWS. The results are as shown in the following table.

	Barrier Island PCWS (n=33)	All Coastal PCWS (n=57)	Non-Barrier Island Coastal PCWS (n=24)	Non-Coastal (n=407)
Median Ratio of Summer to Non-Summer Demands	**3.17**	2.11	1.55	1.20

The median ratio results indicate that Barrier Island and Coastal PCWS are very different (3.17 and 2.11, respectively). Excluding Barrier Island PCWS from the Coastal PCWS shows an even larger difference at 1.55, much closer to the non-coastal PCWW median of 1.20, indicating that the Barrier Island PCWS have much more prominent summer season peaks due to tourism than the other coastal PCWS. The box and whisker plot below shows the results in a different manner. Statistical tests bear this out, with significant differences between coastal and non-coastal PCWS and between barrier island and non-barrier island coastal PCWS.



STATISTICAL TESTS TO DETERMINE SIGNIFICANCE BETWEEN GROUPS

METHOD OVERVIEW

A series of statistical tests were conducted to detect significant differences in PCWS summer/non-summer demand ratios and % residential service areas across different PCWS characteristics. A table of findings from the t-tests and Mann-Whitney U tests is provided in the supplemental spreadsheet, while the findings of the correlation analysis are provided in-text. Several of the variables did not have a normal distribution, an assumption for t-tests that is especially important for conducting tests with small sample sizes (less than 20). For this reason, the t-tests were conducted along with Mann-Whitney U tests, a statistical test that does not assume samples have a normal distribution. For comparative purposes, the findings below provide the t-test findings along with those from the corresponding Mann-Whitney U Test. Greater confidence was placed in significant findings detected across both statistical tests. However, significant findings from only one test can warrant future analysis and may be the result of factors such as small or uneven sample size. All PCWS with summer/non-summer demand ratios less than 0.80 (n=7 and were very small PCWS) were excluded from statistical testing.

COAST AND NON-COASTAL PCWS

Regarding the Ratio of Summer to Non-Summer demands, are coastal PCWS statistically different from non-coastal PCWS? Within Coastal PCWS, is there a significant difference between Barrier Island and Non-Barrier Island Coastal PCWS?

A t-test was conducted to determine if coastal PCWS have significantly different summer/non-summer demand ratios than non-coastal PCWS. Coastal PCWS had an average ratio of 2.37, which was significantly higher ($t=8.56$; $p=0.00$) than the average ratio for non-coastal PCWS (1.30). The Mann-Whitney U Test comparing the demand ratios of these two groups supported this finding by concluding that non-coastal and coastal PCWS are distinct groups ($U=20348$; $p=0.00$).

A t-test was also conducted to determine if there is a significant difference in summer/non-summer demand ratios among barrier island coastal and other (i.e., non-barrier island) coastal PCWS. In order to conducting testing, the barrier island PCWS that are included in the coastal sample were removed to ensure the samples were independent from each other (referred to as non-barrier island coastal PCWS). Non-barrier island coastal systems had an average demand ratio of 1.63, which was found to be significantly lower (t=7.94; p=0.00) than the average ratio for barrier island PCWS (2.91). A Mann-Whitney U Test examining the demand ratios of these groups supported this finding by also concluding that there is enough statistical evidence to suggest that barrier island PCWS and non-barrier island coastal PCWS are distinct groups (U=724; p=0.00).

COASTAL PCWS SUBSETS

Are there subsets of coastal PCWS that are more like non-coastal PCWS?

There are subsets of coastal PCWS with demand ratios that are more like non-coastal PCWS. As shown in the results of the statistical testing comparing average summer/non-summer demand ratios of barrier island and non-barrier island coastal PCWS, the average ratio of non-barrier island coastal PCWS (1.63) was closer to the average ratio for non-coastal PCWS (1.30). However, statistical findings suggested that the difference in the average demand ratios of non-barrier island coastal and non-coastal PCWS was significant (t-test: t=4.37; p=0.00; Mann-Whitney: U=7614; p=0.00).

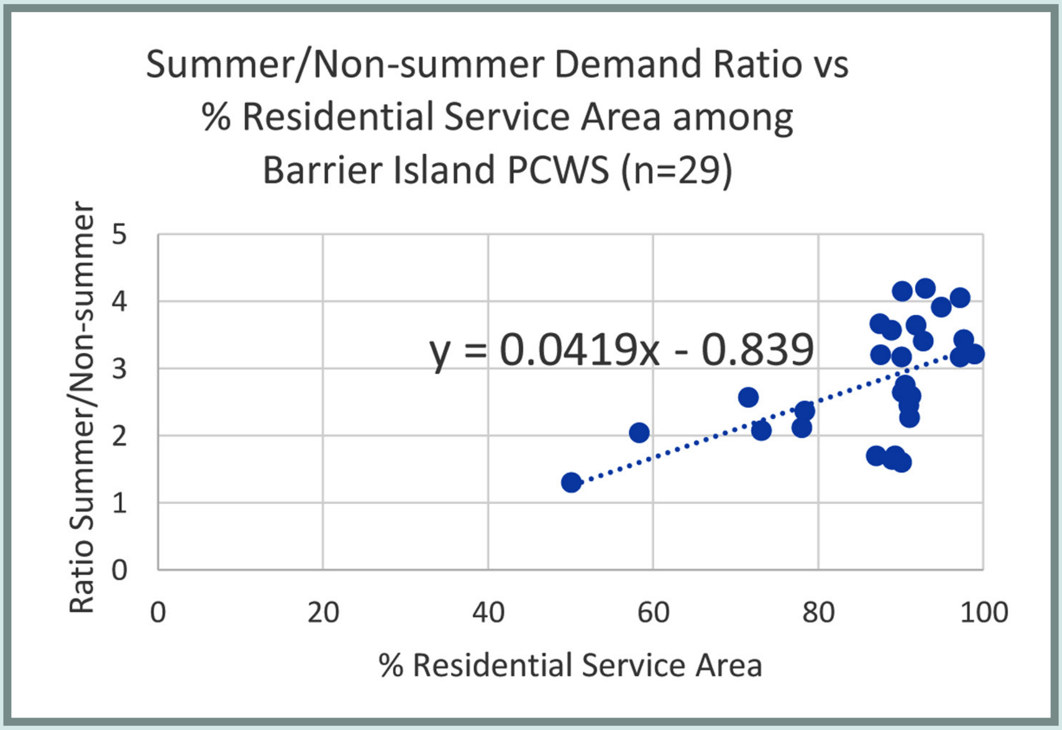
A second subset of coastal PCWS that are more like non-coastal PCWS was found in an analysis of summer/non-summer demand ratios among coastal PCWS based on county. A t-test was conducted to compare the average demand ratios of coastal PCWS in Monmouth County compared to the rest of the coastal sample. Coastal Monmouth PCWS were found to have an average demand ratio of 1.62, which was much lower than the average for the other coastal PCWS (2.57). The difference in the average ratios of coastal Monmouth and non-Monmouth PCWS was found to be statistically significant (t=-5.24; p=0.00). The Mann-Whitney U Test comparing demand ratios among coastal Monmouth PCWS and the rest of the coastal PCWS found that there was enough statistical evidence to conclude that the two groups were distinct (U=104; p=0.00). Therefore, we can conclude that coastal Monmouth PCWS appear to be a subset of coastal PCWS with demand ratios that are more similar to non-coastal PCWS. However, statistical findings suggested that the difference in demand ratio averages between coastal Monmouth and non-coastal PCWS was significant (t-test: t=2.74; p=0.02; Mann-Whitney: U=3667; p=0.00).

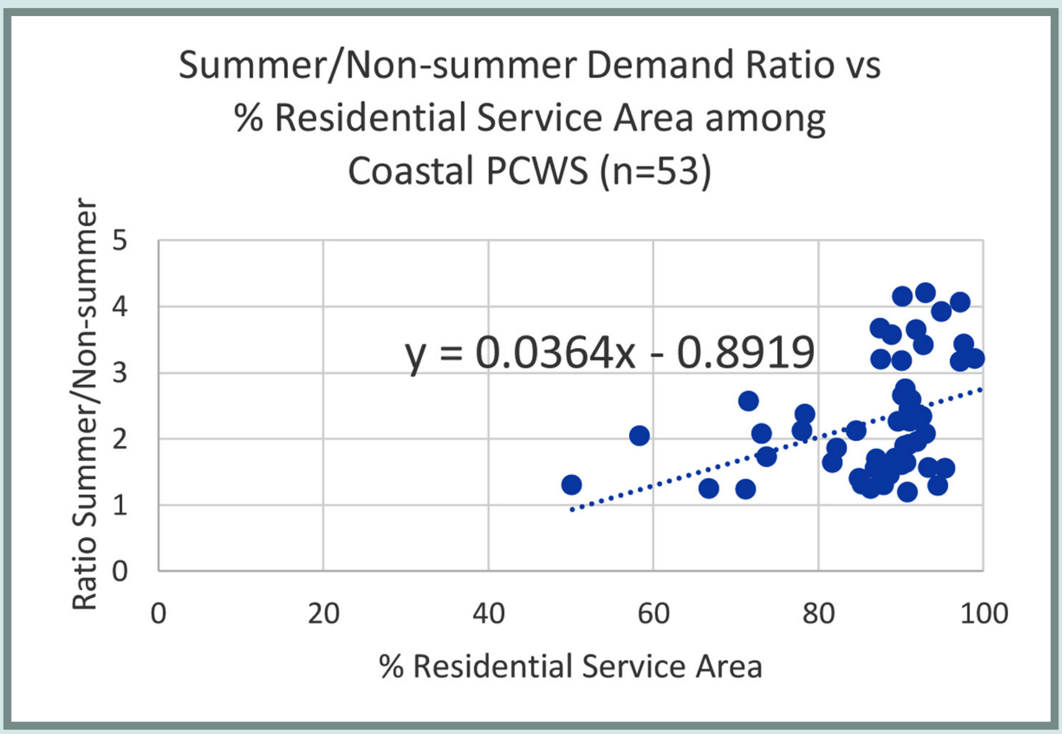
It should also be noted that all of the Monmouth PCWS are non-barrier island coastal PCWS. Although the significant findings here may only be a sub-finding of the larger sample non-barrier island PCWS findings discussed earlier in this section, further examination may determine if there are other characteristics specific to Monmouth County coastal PCWS that may result in smaller demand ratios than the other coastal PCWS.

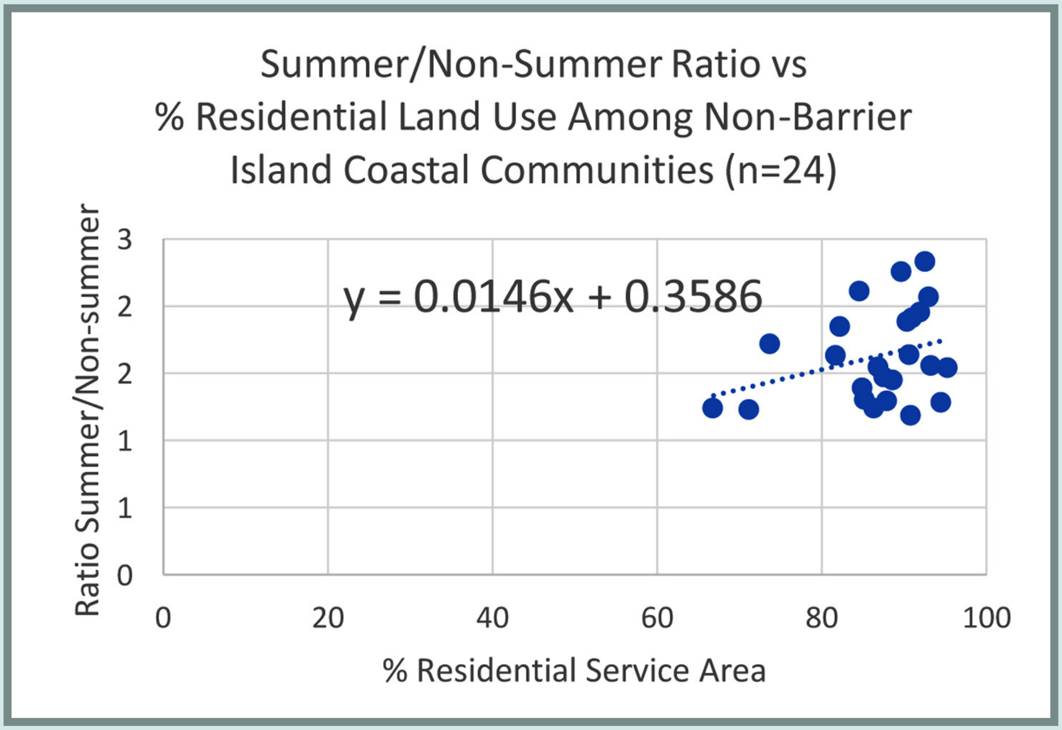
RELATIONSHIP OF DEMAND PROFILES TO RESIDENTIAL SERVICE AREAS

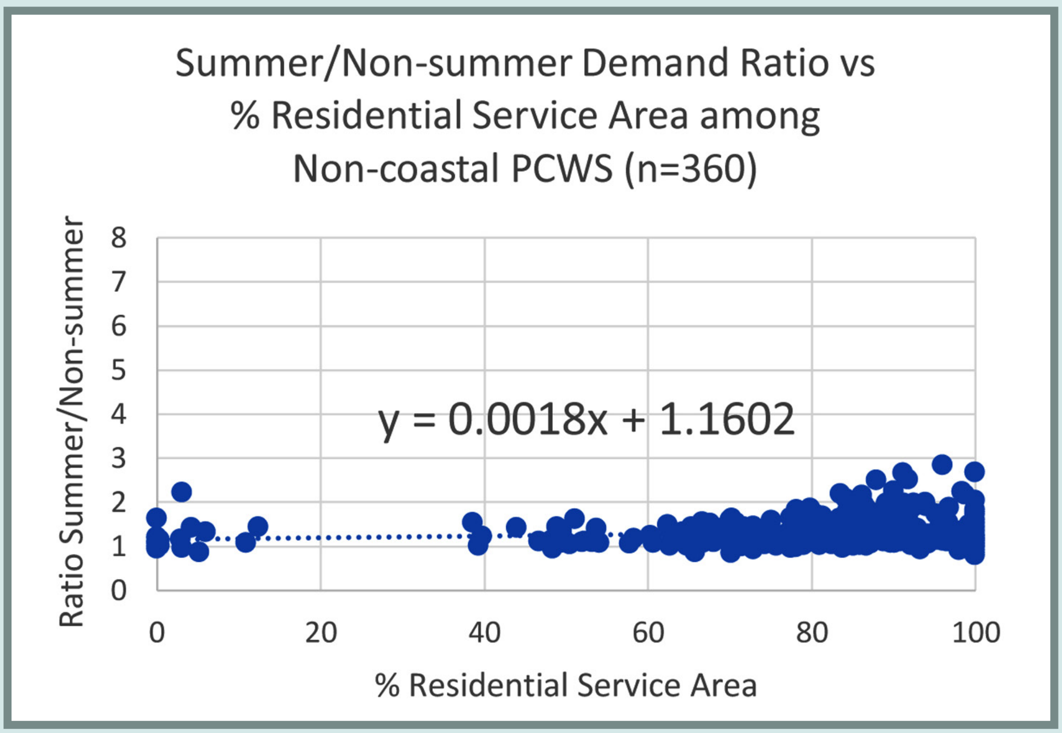
Does % Residential service area have a material effect?

To address this question, a correlation analysis was conducted alongside the t-tests and Mann-Whitney U tests. The scattergrams show summer/non-summer demand ratios and % residential service areas for PCWS in the following samples: barrier island, coastal (with and without barrier island PCWS), and non-coastal.


Summer/Non-summer Demand Ratio vs
% Residential Service Area among
Barrier Island PCWS (n=29)
y = 0.0419x - 0.839
Ratio Summer/Non-summer
% Residential Service Area
0
1
2
3
4
5
0
20
40
60
80
100


Summer/Non-summer Demand Ratio vs
% Residential Service Area among
Coastal PCWS (n=53)
y = 0.0364x - 0.8919
Ratio Summer/Non-summer
% Residential Service Area
0
1
2
3
4
5
0
20
40
60
80
100


Summer/Non-Summer Ratio vs
% Residential Land Use Among Non-Barrier
Island Coastal Communities (n=24)
y = 0.0146x + 0.3586
Ratio Summer/Non-summer
3
2
2
1
1
0
0
20
40
60
80
100
% Residential Service Area


Summer/Non-summer Demand Ratio vs
% Residential Service Area among
Non-coastal PCWS (n=360)
y = 0.0018x + 1.1602
Ratio Summer/Non-summer
8
7
6
5
4
3
2
1
0
0
20
40
60
80
100
% Residential Service Area

For the barrier island PCWS (n=29), the Pearson Correlation Coefficient was 0.57 (indicating a moderate positive relationship between demand ratio and % residential service area), which was found to be significant (p=0.00). For the coastal PCWS (n=53), the Pearson Correlation Coefficient was 0.40, indicating a moderately positive, but weaker relationship between PCWS demand ratio and % residential service area compared to the barrier island sample. However, the relationship between these two variables was also found to be statistically significant (p=0.00). In comparison, the non-barrier island coastal PCWS (n=24) had a Pearson Correlation Coefficient of only 0.31, which was not found to be statistically significant (p=0.14). For the non-coastal PCWS (n=360), the Pearson Correlation Coefficient was 0.13, indicating a weak positive relationship between demand ratio and % residential service area, which was found to be significant (p=0.01). The significance test for the Pearson Correlation analysis determines if there is enough statistical evidence to conclude that the two variables (demand ratio and % residential service area) are associated with each other; it does not indicate strength of relationship. Therefore, we can conclude that there is statistical evidence to support that non-coastal PCWS demand ratio and % residential service area are associated with each other, although the Pearson Correlation Coefficient suggests that it is a weak relationship.

To investigate further, a series of t-tests and Mann Whitney U tests were conducted to examine if PCWS % residential service area was significantly different among barrier, coastal, and non-coastal PCWS with summer/non-summer demand ratios greater and less than two. It was not possible to run statistical tests on the non-barrier island coastal sample due to small sample size.

For the barrier island PCWS, PCWS with a demand ratio greater than two had an average % residential service area of 88.45%, which was larger than for the PCWS with a demand ratio less than two (81.17%). The difference in the averages of these two groups was not found to be significant (t=0.91; p=0.41). However, the Mann-Whitney U Test comparing the average % residential service area among barrier island PCWS with demand ratios greater and less than two provided marginal evidence to suggest that these two groups are distinct (U=91; p=0.08). However, the n for PCWS with a demand ratio less than two is only 5, a small sample size.

The t-test comparing the coastal PCWS sample found that PCWS with a demand ratio greater than two had an average % residential service area of 88.68%, which was slightly higher than the average for PCWS with a demand ratio less than two (85.14%). In this case, the number of PCWS in the two groups was nearly equal (28 and 25, respectively). The difference in the averages between the two groups was not found to be significant (t=1.33; p=0.19). However, the Mann Whitney U Test comparing the average % residential service area of coastal PCWS with demand ratios greater and less than two did find enough statistical evidence to conclude that these two groups are distinct (U=463; p=0.04).

The t-test comparing the non-coastal PCWS sample revealed that PCWS with a demand ratio greater than two had an average % residential service area of 85.48%, which was larger than the average for PCWS with a demand ratio less than two (79.79%). In this case, the number of PCWS in the two groups was very different (13 and 347, respectively), emphasizing that a very small percentage of non-coastal PCWS have much higher summer demands (3.75%). The difference in the averages between the two groups was not found to be significant (t=0.79; p=0.44). The Mann-Whitney U Test comparing the average % residential service area of non-coastal PCWS with demand ratios greater and less than two found marginal statistical evidence to suggest that these two groups are distinct (U=2878; p=0.09).

Some statistical evidence was found to suggest that % residential service area has a material effect. The Correlation analysis provided evidence to conclude that PCWS % residential service area and summer/non-summer demand ratio are associated with each other in all three samples (barrier, coastal, and non-coastal). Some evidence of a material effect was also detected in the Mann-Whitney U tests, but not in the t-tests for the three PCWS samples. While Mann-Whitney U tests provide the benefit of being able to test differences among groups with small sample sizes and data with non-normal distributions, some strength of test findings is lost in tests with extremely unequal sample sizes (such as the non-coastal test). Further testing may provide further insight into if % residential service area has a material effect among all PCWS or if it has a material effect among sub-sets of the original three samples (there are some hints of this in the scattergrams, as it appeared that the demand ratio distributions get wider among the PCWS with larger % residential service areas across all three samples).

RELATIONSHIP OF DEMAND PROFILES TO PCWS SIZE

Does PCWS size have a material effect? **In other words, do larger PCWS (comprising either 80% or 90% of statewide PCWS demands) show a stronger relationship of the Ratio to barrier island, coastal or % Residential metrics, or some combination?**

EXAMINATION OF PCWS SUMMER/NON-SUMMER DEMAND RATIOS

To determine if PCWS size has a material effect, statistical testing was conducted to determine if PCWS comprising of either 80% (Top 80% Annual) or 90% (Top 90% Annual) of statewide PCWS annual average demands had significantly different summer/non-summer demand ratios for the following samples: barrier, coastal, and non-coastal. Due to sample size limitations, statistical testing for the 90% metric was conducted on all three samples, while statistical testing for the 80% metric was only conducted on the non-coastal PCWS sample. It was not possible to run any statistical tests on the non-barrier island coastal sample due to small sample sizes for Top 90% and Top 80% PCWS.

For the barrier island sample t-test, the Top 90% Annual PCWS (n=7) were found to have an average demand ratio of 2.30, which was lower than the other PCWS in the barrier island sample (3.07, n=26). The difference in the averages between these two groups was found to be statistically significant (t=-2.66; p=0.02). The Mann-Whitney Test examining average demand ratios among Top 90% and non-top 90% barrier island systems determined there was enough statistical evidence to conclude that these two groups are distinct (U=43; p=0.03).

For the coastal sample t-test, the Top 90% Annual PCWS (n=11) were found to have an average demand ratio of 1.98, which was lower than the other coastal PCWS (2.46, n=46). The difference in the averages between these two groups was found to be marginally significant (t= -1.95; p=0.07). The Mann-Whitney Test comparing the demand ratios among coastal Top 90 and non-Top 90 systems found that there was not enough statistical evidence to conclude that these two groups are distinct (U=182; p=0.16).

For the non-coastal sample t-test, the Top 90% Annual PCWS (n=109) were found to have an average demand ratio of 1.37, which was higher than the other non-coastal PCWS (1.29, n=290). The difference between the averages of these two groups was found to be not significant, but it was border-lining significance (t=1.49; p=0.14). The Mann-Whitney Test comparing the average demand ratios among non-coastal Top 90% and non-Top 90% systems found that there was enough statistical evidence to suggest that these two groups are distinct (U=18993; p=0.00).

For the second non-coastal sample t-test, the Top 80% Annual PCWS (n=63) were found to have an average demand ratio of 1.34, which was slightly larger than the average for other non-coastal PCWS (1.30, n=336). The difference in the averages between these two groups was not found to be significant (t=0.92; p=0.36). However, the Mann-Whitney U Test comparing the average demand ratios among non-coastal Top 80% and non-Top 80% systems found that there was marginal evidence to conclude that these two groups are distinct (U=12108; p=0.07).

The statistical test findings provide some evidence to suggest that PCWS size does have a material effect on PCWS demands ratio, although it appeared limited to barrier island PCWS. Although some marginal evidence was found in the coastal and non-coastal statistical tests, the barrier islands sample was the only sample to yield statistically significant findings across both tests. However, since there were also two tests in the coastal and non-coastal samples with results bordering marginal significance, further examination may help determine if a material effect also extends to these samples.

The statistical analyses do not address causation, but there is some potential that larger barrier island systems have a more diverse customer base, which could be tested by comparing percent residential demand (where a lower percentage would indicate more non-residential customers), or population density relative to residential area (where a lower value would indicate a higher concentration of rental units). Atlantic City is likely a special case, as it has a year-round tourism base (the casino industry) in addition to its summer tourism season, and therefore would have a different water demand profile. Its ratio of summer to non-summer demands is almost exactly the same as the statewide average for all PCWS.

EXAMINATION OF PCWS % RESIDENTIAL SERVICE AREA

A series of statistical tests were also conducted to examine if PCWS comprising of either Top 80% Annual or Top 90% Annual PCWS had significantly different % residential service areas for the following samples: barrier, coastal, and non-coastal. Due to sample size limitations, statistical testing for the 90% metric was conducted for all three samples, while statistical testing for the 80% metric was only conducted on the non-coastal PCWS sample. It was not possible to run any statistical tests on the non-barrier island coastal sample due to small sample sizes for Top 90% and Top 80% PCWS.

For the barrier island sample t-test, Top 90% PCWS (n=7) were found to have an average residential service area of 79.79%, which was lower than the other PCWS in the barrier island sample (89.56%, n=22). The difference in the averages of these two groups was not found to be significant (t=-1.63; p=0.14). The Mann-Whitney U Test comparing the average % residential service area among barrier island Top 90% PCWS and non-Top 90% PCWS determined there is enough statistical evidence to conclude that the two groups are distinct (U=38; p=0.05).

For the coastal sample t-test, Top 90% PCWS (n=11) were found to have an average residential service area of 81.37%, which was lower than the other PCWS in the coastal sample (88.49%, n=42). Although the difference in the averages of the two groups was bordering marginal significance, it was found to be not significant (t=-1.68; p=0.12). The Mann-Whitney U Test comparing the average % residential service area among coastal Top 90% and non-Top 90% PCWS found that there was marginal evidence to conclude that the two groups are distinct (U=150; p=0.08).

For the non-coastal sample t-test, Top 90% PCWS (n=106) were found to have an average residential service area of 75.65%, which was lower than the other PCWS in the non-coastal sample (81.81%, n=254). The difference in the averages of these two groups was found to be significant (t=-2.98; p=0.00). The Mann-Whitney U Test comparing the average % residential service area among non-coastal Top 90% and non-Top 90% PCWS supported the t-test finding. It found there was enough statistical evidence to conclude that the two groups are distinct (U=7493; p=0.00).

For the second non-coastal sample t-test, Top 80% PCWS (n=61) were found to have an average residential service area of 75.41%, which was lower than the other PCWS in the non-coastal island sample (80.93%, n=299). The difference in the averages between these two groups was found to be statistically significant (t=-2.66; p=0.01). The Mann-Whitney U Test comparing the average % residential service area of non-coastal Top 80% and non-Top 80% PCWS supported the t-test findings. It concluded that there was enough statistical evidence to conclude that the two groups are distinct (U=5462; p=0.00).

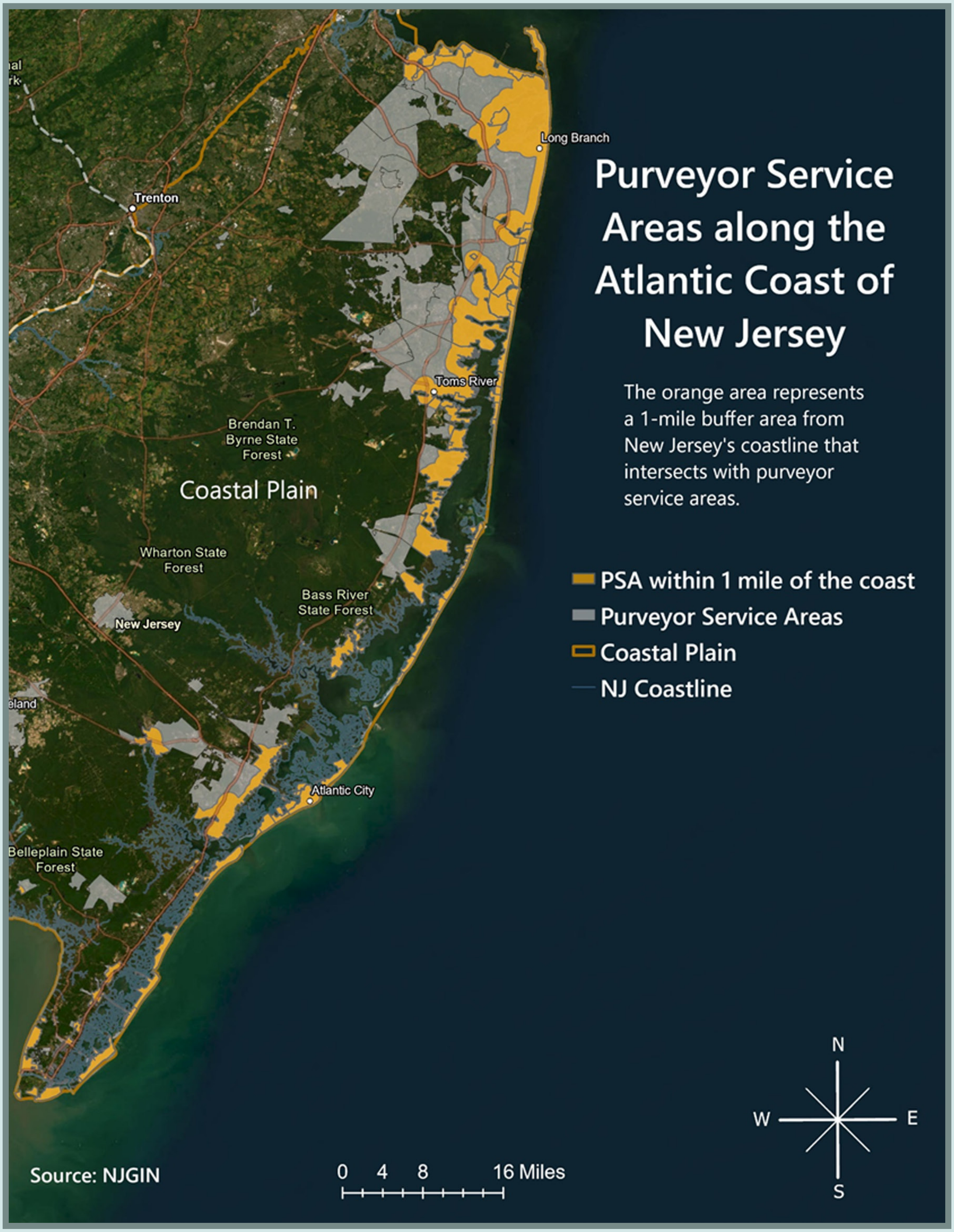
The statistical test findings provide some evidence to suggest that PCWS size does have a material effect on PCWS % residential service area. Statistically significant evidence was found in both the t-tests and Mann-Whitney U tests examining the non-coastal sample for both PCWS comprising of 80% and 90% of statewide PCWS demands. The findings for non-coastal PCWS are not surprising, given the large number of small PCWS that were created specifically for serving residential developments with little or no commercial presence and no industrial uses, such as mobile home (aka manufactured housing) parks and small, isolated subdivisions or apartment complexes. Large PCWS inevitably have a larger non-residential component. Although the t-tests for the barrier island and coastal samples were not found to be significant, they were bordering marginal significance. In addition, the Mann-Whitney U tests for these samples also suggested potential significance. Further examination with larger and possibly more even sample sizes may determine if a material effect extends to these PCWS as well.

APPENDIX A: GIS ANALYSIS

A GIS analysis based on DEP's Purveyor Service Areas of New Jersey was used to calculate the potential exposure of PCWS to seasonal shifts in demand from coastal tourism. The analysis identified the extent to which PCWS have a major component of their service area within 1 mile of a coastal shoreline (e.g., ocean, estuary or bay) along the Atlantic Coast (Monmouth, Ocean, Atlantic and Cape May Counties). The following approach was used:

- added the GIS layer of DEP Purveyor Service Areas;
- added the New Jersey GIN 2012 coastline layer;
- created a 1-mile buffer of the Atlantic coastal and back bay shorelines in Monmouth, Ocean, Atlantic and Cape May counties only;
- intersected Purveyor Service areas with the 1-mile buffer of coastal shoreline;
- created a table, with a column that calculated the area within the 1 mile buffer; and
- created a column for Coastal Service Area (%), which equals portion of the purveyor service area within the coastal shoreline 1 mile buffer divided by the total purveyor service area, by PWSID.

The following figure shows the relationship of service areas to the Atlantic Coast.


Purveyor Service Areas along the Atlantic Coast of New Jersey
The orange area represents a 1-mile buffer area from New Jersey's coastline that intersects with purveyor service areas.
PSA within 1 mile of the coast
Purveyor Service Areas
Coastal Plain
NJ Coastline
Long Branch
Trenton
Toms River
Brendan T. Byrne State Forest
Coastal Plain
Wharton State Forest
Bass River State Forest
New Jersey
Atlantic City
Belleplain State Forest
Source: NJGIN
0 4 8 16 Miles
N
W
E
S

APPENDIX B: SPREADSHEET DEVELOPMENT

This analysis uses data from the spreadsheet “NJWaTr_PWSID_Demands_2011-2020v3”, which was loaded into a new spreadsheet, “NJWaTr_PWSID_Demands_2011-2020v3 Analysis”. Information on the worksheets is provided below.

1. Notation: text documentation of the spreadsheet
2. Annual All PCWS: original data from DEP showing annual withdrawals, 2011-2020, in millions of gallons per year (mgy) by PCWS
    - Column P was added to provide an annual average for the years 2016-2020, in millions of gallons per day (mgd).
3. Seasonal All PCWS: This worksheet includes original data from DEP showing monthly average demands (mgm) for the years 2016-2020 by PCWS. The columns are included below.

    A. SiteName: DEP designation of Drinking Water Use Area #

    B. PermitNumber: Public Water Supply ID (PWSID) from DEP

    C. CountyName: primary county location of the PCWS, from DEP

    D. OwnerName: PCWS owner, from DEP

    E. Through P: average monthly water demands for each month for 2016-2020, in mgm

    Q. 2016-2020 Annual Avg (mgd): from Column P of Annual All PCWS table

    R. 2016-2020 Summer Avg (mgd): average of values from Columns J through M (June through September)

    S. 2016-2020 Non-Summer Avg (mgd): average of values from Columns E through I and N through P (all non-summer months)

    T. Ratio Summer: Non-Summer: Column R divided by Column S

    U. Ratio >2: indicates “Y” where Column T value is greater than the number 2, or “N” otherwise

    V. Ratio <0.8: indicates “Y” where Column T value is less than the number 0.8, or “N” otherwise

    W. IsBarrierDWSA: indicates “Y” where primary service area of PCWS is on a barrier island, or “N” otherwise
    - provided by DEP, with additions of three systems in the Long Beach Township system, Loveladies Harbor North and South and High Bar Harbor

    X. CSA % (1=100%): indicates the fraction of a PCWS service area that is within 1 mile of coastal waters (Atlantic Ocean or related bays) in Monmouth, Ocean, Atlantic and Cape May counties (From Rutgers GIS analysis)

    Y. Coastal Sort: indicates “Y” where either Column W is “Y” or Column X is greater than 0.5 (i.e., 50% coastal)

    Z. RES% Served: fraction of the PCWS developed service area (i.e., excluding undeveloped areas such as wetlands, open space, barren lands) that is residential land use, from GIS analysis using the 2015 DEP Land Use/Land Cover data (From Van Abs et al. (2018) analysis)

    AA. Geology (Coastal or Bedrock): indicates whether the primary portion of the PCWS service area is in Coastal (C) or Bedrock (BR) geology

    AB. Top 90% Annual: indicates “Y” where a PCWS is among the largest annual demands that in aggregate comprise 90% of the statewide total demands provided by DEP

    AC. Top 80% Annual: indicates “Y” where a PCWS is among the largest annual demands that in aggregate comprise 80% of the statewide total demands provided by DEP
    - This is a subset of the PCWS in Column AB.

    AD. Comments: provides information on data issue (e.g., months with no results) or the nature of a PCWS service area that may affect results (e.g., military facilities)

4. Barrier Island Sort: reorders the data from Worksheet 3 to identify those PCWS listed as Barrier Island PCWS, and then to segregate by the Ratio of summer to non-summer demands above and below 2; sorted in the following manner:
   - IsBarrierDWSA (Column W);
   - Ratio>2 (Column U); and
   - PermitNumber (Column B).
5. Atlantic Coast Sort: reorders the data from Worksheet 3 to identify those PCWS listed as Coastal, and then to segregate by the Ratio of summer to non-summer demands above and below 2; sorted in the following manner:
   - Coastal Sort (Column Y);
   - Ratio>2 (Column U); and
   - PermitNumber (Column B).
6. Atlantic Coast Sort RES%: reorders the data from Worksheet 3 to identify those PCWS listed as Coastal, allowing a comparison of the Ratio of summer to non-summer demands to the percentage of PCWS service area that is residential; sorted in the following manner:
   - Coastal Sort (Column Y); and
   - PermitNumber (Column B).
7. Geology Sort: reorders the data from Worksheet 3 to identify those PCWS in Coastal Plain (C) or Bedrock (BR) geology, allowing a comparison of the Ratio of summer to non-summer demands to geology of the PCWS service area; sorted in the following manner:
   - Geology (Coastal or Bedrock) (Column AA);
   - Top 90% Annual (Column AB);
   - Ratio>2 (Column U); and
   - PermitNumber (Column B).

Table: Statistical Tests Conducted to Examine PCWS Demand Ratios and % Residential Service Area						
PCWS Variable	**Testing Populations**	**Sample Size**	**Mean**	**Variance (t-test)/ Standard Deviation (Mann-Whitney U Test)**	**t-Score (t-tests) / U Statistic (Mann-Whitney U Test)**	**P-Value**
PCWS Demand Ratios by Location (Barrier, Coastal, Non-coastal)						
Summer/Non-summer Demand Ratio (t-test)	Coastal (all)	57	2.37	0.85	8.56	0.00**
	Non-coastal	399	1.30	0.21		
(Mann-Whitney U Test)	*Coastal (all)*	*57*	*2.37*	*0.92*	*20348*	*0.00***
	Non-coastal	*399*	*1.30*	*0.46*		
Summer/Non-summer Demand Ratio (t-test)	Barrier Island	33	2.91	0.69	7.94	0.00**
	Non-barrier Island Coastal	24	1.63	0.12		
(Mann-Whitney U Test)	*Barrier Island*	*33*	*2.91*	*0.83*	*724*	*0.00***
	Non-barrier Island Coastal	*24*	*1.63*	*0.35*		
Summer/Non-summer Demand Ratio (t-test)	Non-barrier Island Coastal	24	1.63	*0.12*	*4.37*	*0.00***
	Non-coastal	399	1.30	*0.21*		
(Mann-Whitney U Test)	*Non-barrier Island Coastal*	*24*	*1.63*	*0.35*	*7614*	*0.00***
	Non-coastal	*399*	*1.30*	*0.46*		
Summer/Non-summer Demand Ratio (t-test)	Coastal Monmouth	12	1.62	0.16	-5.24	0.00**
	Coastal Other	45	2.57	0.85		
(Mann-Whitney U Test)	*Coastal Monmouth*	*12*	*1.62*	*0.40*	*104*	*0.00***
	Coastal Other	*45*	*2.57*	*0.92*		
Summer/Non-summer Demand Ratio (t-test)	Coastal Monmouth	12	1.62	0.16	2.74	0.02**
	Non-coastal	399	1.30	0.21		
(Mann-Whitney U Test)	*Coastal Monmouth*	*12*	*1.62*	*0.40*	*3667*	*0.00***
	Non-coastal	*399*	*1.30*	*0.46*		

Table: Statistical Tests Conducted to Examine PCWS Demand Ratios and % Residential Service Area						
PCWS Variable	**Testing Populations**	**Sample Size**	**Mean**	**Variance (t-test)/ Standard Deviation (Mann-Whitney U Test)**	**t-Score (t-tests) / U Statistic (Mann-Whitney U Test)**	**P-Value**
PCWS Demand Ratios by % Residential Service Area - within Location Comparison (Barrier, Coastal, Non-coastal)						
% Residential Service Area (t-test: Barrier Island PCWS)	Demand Ratio Greater than 2	24	88.45	97.69	0.91	0.41
	Demand Ratio Less than 2	5	81.17	301.57		
(Mann-Whitney U Test)	*Demand Ratio Greater than 2*	*24*	*88.45*	*9.88*	*91*	*0.08**
	Demand Ratio Less than 2	*5*	*81.17*	*17.37*		
% Residential Service Area (t-test: Coastal PCWS)	Demand Ratio Greater than 2	28	88.68	85.20	1.33	0.19
	Demand Ratio Less than 2	25	85.14	101.22		
(Mann-Whitney U Test)	*Demand Ratio Greater than 2*	*28*	*88.68*	*9.23*	*463*	*0.04***
	Demand Ratio Less than 2	*25*	*85.14*	*10.06*		
% Residential Service Area (t-test: Non-coastal PCWS)	Demand Ratio Greater than 2	13	85.48	646.82	0.79	0.44
	Demand Ratio Less than 2	347	79.79	506.70		
(Mann-Whitney U Test)	*Demand Ratio Greater than 2*	*13*	*85.48*	*25.43*	*2878*	*0.09**
	Demand Ratio Less than 2	*347*	*79.79*	*22.51*		
PCWS Demands Ratio by 80% or 90% Cumulative PCWS Flows - within Location Comparison (Barrier, Coastal, Non-Coastal)						
Summer/Non-summer Demand Ratio (t-test: Barrier Island PCWS)	Top 90% Annual	7	2.30	0.41	-2.66	0.02**
	Non-top 90% Annual	26	3.07	0.66		
(Mann-Whitney U Test)	*Top 90% Annual*	*7*	*2.30*	*0.64*	*43*	*0.03***
	Non-top 90% Annual	*26*	*3.07*	*0.81*		
Summer/Non-summer Demand Ratio (t-test: Coastal PCWS)	Top 90% Annual	11	1.98	0.45	-1.95	0.07*
	Non-top 90% Annual	46	2.46	0.91		
(Mann-Whitney U Test)	*Top 90% Annual*	*11*	*1.98*	*0.67*	*182*	*0.16*
	Non-top 90% Annual	*46*	*2.46*	*0.96*		
Summer/Non-summer Demand Ratio (t-test: Non-coastal PCWS)	Top 90% Annual	109	1.37	0.07	1.49	0.14
	Non-top 90% Annual	290	1.29	0.26		

Table: Statistical Tests Conducted to Examine PCWS Demand Ratios and % Residential Service Area						
PCWS Variable	**Testing Populations**	**Sample Size**	**Mean**	**Variance (t-test)/ Standard Deviation (Mann-Whitney U Test)**	**t-Score (t-tests) / U Statistic (Mann-Whitney U Test)**	**P-Value**
(Mann-Whitney U Test)	*Top 90% Annual*	*109*	*1.37*	*0.27*	*18993*	*0.00***
	Non-top 90% Annual	*290*	*1.29*	*0.51*		
Summer/Non-summer Demand Ratio (t-test: Non-coastal PCWS)	Top 80% Annual	63	1.34	0.07	0.92	0.36
	Non-top 80% Annual	336	1.30	0.23		
(Mann-Whitney U Test)	*Top 80% Annual*	*63*	*1.34*	*0.27*	*12108*	*0.07**
	Non-top 80% Annual	*336*	*1.30*	*0.48*		
PCWS % Residential Service Area by 80% or 90% Cumulative PCWS Flows - within Location Comparison (Barrier, Coastal, Non-coastal)						
% Residential Service Area (t-test: Barrier Island PCWS)	Top 90% Annual	7	79.79	224.04	-1.63	0.14
	Non-top 90% Annual	22	89.56	86.74		
(Mann-Whitney U Test)	*Top 90% Annual*	*7*	*79.79*	*14.97*	*38*	*0.05***
	Non-top 90% Annual	*22*	*89.56*	*9.31*		
% Residential Service Area (t-test: Coastal PCWS)	Top 90% Annual	11	81.37	181.05	-1.68	0.12
	Non-top 90% Annual	42	88.49	64.48		
(Mann-Whitney U Test)	*Top 90% Annual*	*11*	*81.37*	*13.46*	*150*	*0.08**
	Non-top 90% Annual	*42*	*88.49*	*8.03*		
% Residential Service Area (t-test: Non-coastal PCWS)	Top 90% Annual	106	75.65	186.91	-2.98	0.00**
	Non-top 90% Annual	254	81.81	636.44		
(Mann-Whitney U Test)	*Top 90% Annual*	*106*	*75.65*	*13.67*	*7493*	*0.00***
	Non-top 90% Annual	*254*	*81.81*	*25.23*		
% Residential Service Area (t-test: Non-coastal PCWS)	Top 80% Annual	61	75.41	143.63	-2.66	0.01**
	Non-top 80% Annual	299	80.93	581.62		
(Mann-Whitney U Test)	*Top 80% Annual*	*61*	*75.41*	*11.98*	*5462*	*0.00***
	Non-top 80% Annual	*299*	*80.93*	*24.12*		
*implies significance at alpha=0.10						
**implies significance at alpha=0.05						