Localized Differences in Geodetic Datums

MALSCE

May 12, 2011

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Datums

- Tidal
  - Unique to location, based on local sea levels
  - Based on 19-year observation to ensure recording of the 18.6 year tidal epoch.
  - Most local sea levels are determined by relative heights from a major tidal station.
- Geodetic
  - NAVD, North American Vertical Datum of 1988
  - NGVD, National Geodetic Vertical Datum of 1929
  - There were others, but not as notable.

NGVD v. NAVD

- Based on the Mean Sea Level elevation from 26 tidal stations, 21 in the USA, 5 in Canada.
- Formerly known as the Sea Level Datum of 1929 but was changed in 1973 due to confusion with local tidal datums.
- Current FEMA FIRMs are based on NGVD so it is the commonly used datum.

Based on the Mean Sea Level elevation at Father's Point, Rimouski, Quebec, Canada.

An average of many MSL elevations across all of North America was calculated. The elevation at Father's Point was used for two compelling reasons:

- It was within the error of the average and measurements.
- It has also been held for the Great Lakes Datum, although GLD heights are dynamic not orthometric.

The preliminary FEMA dFIRMS are based on NAVD and will be used when they are officially adopted (perhaps early Summer of 2012).

VERTCON, CORPSCON

VERTCON returns the orthometric height difference between NAVD 88 and NGVD 29 at the geodetic position specified by the user. **VERTCON interpolates the datum transformation at a point, based on a computed model.**

CORPSCON contains the VERTCON model and will return the same results in a windows environment. (VERTCON is still in DOS.)

Many surveyors have noted differences between NGVD and NAVD based on ground surveys that are not consistent with the results of VERTCON conversions.

VERTCON

- It is not the intent of the notice to declare when to use a datum transformation or by what method but only to declare that **when a mathematical transformation is appropriate, VERTCON is recommended. …** Note that VERTCON is not appropriate to transform between NGVD 29 and NAVD 88 for first-, second-, or third-order heights. [**Federal Register** / Vol. 72, No. 132 / Wednesday, July 11, 2007]
- The VERTCON 2.0 model **was computed on May 5, 1994 using 381,833 datum difference values**. A key part of the computation procedure was the development of the predictable, physical components of the differences between the NAVD 88 and NGVD 29 datums. This included models of refraction effects on geodetic leveling, and gravity and elevation influences on the new NAVD 88 datum. Tests of the predictive capability of the physical model show a **2.0 cm RMS agreement at our 381,833 data points.** For this reason, the **VERTCON 2.0 model can be considered accurate at the 2 cm (one sigma) level**. Since 381,833 data values were used to develop the corrections to the physical model, VERTCON 2.0 will display even better overall accuracy than that displayed by the uncorrected physical model. This higher accuracy will be particularly noticable in the eastern United States. **… Problem Lines in VERTCON: In rare cases, local distortions of 20 cm (0.66') or more were found in the NGVD 29 network.** The existence of these distortions can be determined by performing transformations around the project area. If dramatically different transformations are obtained over a small area, the presence of a problem NGVD 29 line is indicated. **Users encountering these problem lines should contact NGS for further assistance**. [Professional Surveyor: *NGS Toolkit, Part 9:* The National Geodetic Survey VERTCON Tool, Donald M. Mulcare]
- The VERTCON 2.0 model expresses datum differences between NAVD 88 and NGVD 29 due to removal of distortions in the level data, as well as due to the physical differences in the height systems. In some rare cases, these local NGVD 29 distortions could be 20 cm or more. **If both ends of your old vertical survey were tied to one of these "problem" lines, then the datum difference of the problem line is appropriate to use to transform the survey data**. If both ends of a vertical survey are tied to "undistorted lines", then it is appropriate to use a slightly distant point to compute the transformation, no matter how close your survey data may approach a given problem line. The possible presence of a problem NGVD 29 line in the vicinity of your survey will become evident if dramatically different datum transformation values are computed within a small area. [National Geodetic Survey (NGS) Height Conversion Methodology, Dennis G. Milbert, Ph.D.]

Vertical Sources

NGS only publishes elevations on one datum. When an NAVD elevation is established on a benchmark, the NGVD elevation is removed from the public record. Some benchmarks are published on NAVD through the NGS and NGVD through other sources.

MassDOT Survey Division publishes some benchmarks on both datums. MassDOT Survey Division publishes the information from the Massachusetts Geodetic Survey. Some benchmarks can be found on the NGS list.

There are other sources of varying quality:

FEMA

Municipality benchmarks

Benchmarks published on plans.

Presumed Quality Benchmarks

Barnstable County

(or thereabouts)

- From Provincetown to Plymouth, there are 113 benchmarks with published NGVD and NAVD elevations.
- The data was obtained from NGS and MassDOT only, 1st, 2nd & 3rd order only. Most of the benchmarks are 2nd order.

Condition	1st Order, Class II	2nd Order, Class I	2nd Order, Class II	3rd Order
Length D miles, Error = $T*D^{1/2}$ ft	T = +/- 0.017 ft	T = +/- 0.025 ft	T = +/- 0.033 ft	T = +/- 0.050 ft

The lengths of the individual level runs used to establish the published benchmarks are not known, so an error estimate at each monument cannot be calculated. Nevertheless the following are error estimates for 2nd Order, Class II levels for given distances:

D = 100 miles, Total Error < 0.330' (distance from Provincetown to Plymouth, the long way)

D = 50 miles, Total Error < 0.233'

D = 25 miles, Total Error < 0.165'

D = 12.5 miles, Total Error < 0.117

D = 6.25 miles, Total Error < 0.083'

D = 3.125 miles, Total Error < 0.058'

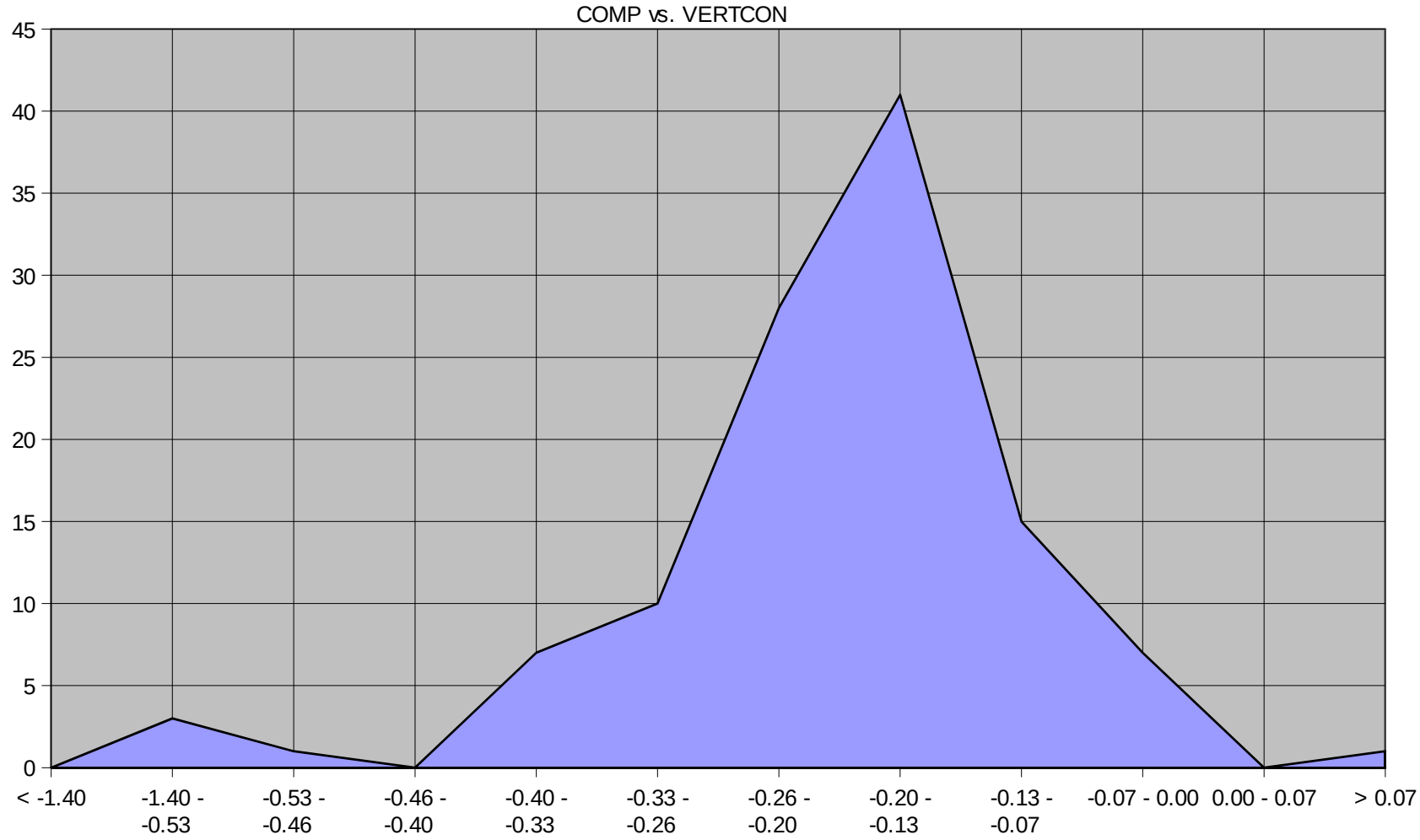
D = 1 mile, Total Error < 0.033'

Definitions

COMP - shall refer to the comparison or difference between a published NGVD elevation and a published NAVD elevation on the same benchmark.

VERTCON – shall refer to the difference between NGVD and NAVD based on a VERTCON result.

Benchmark Comparison

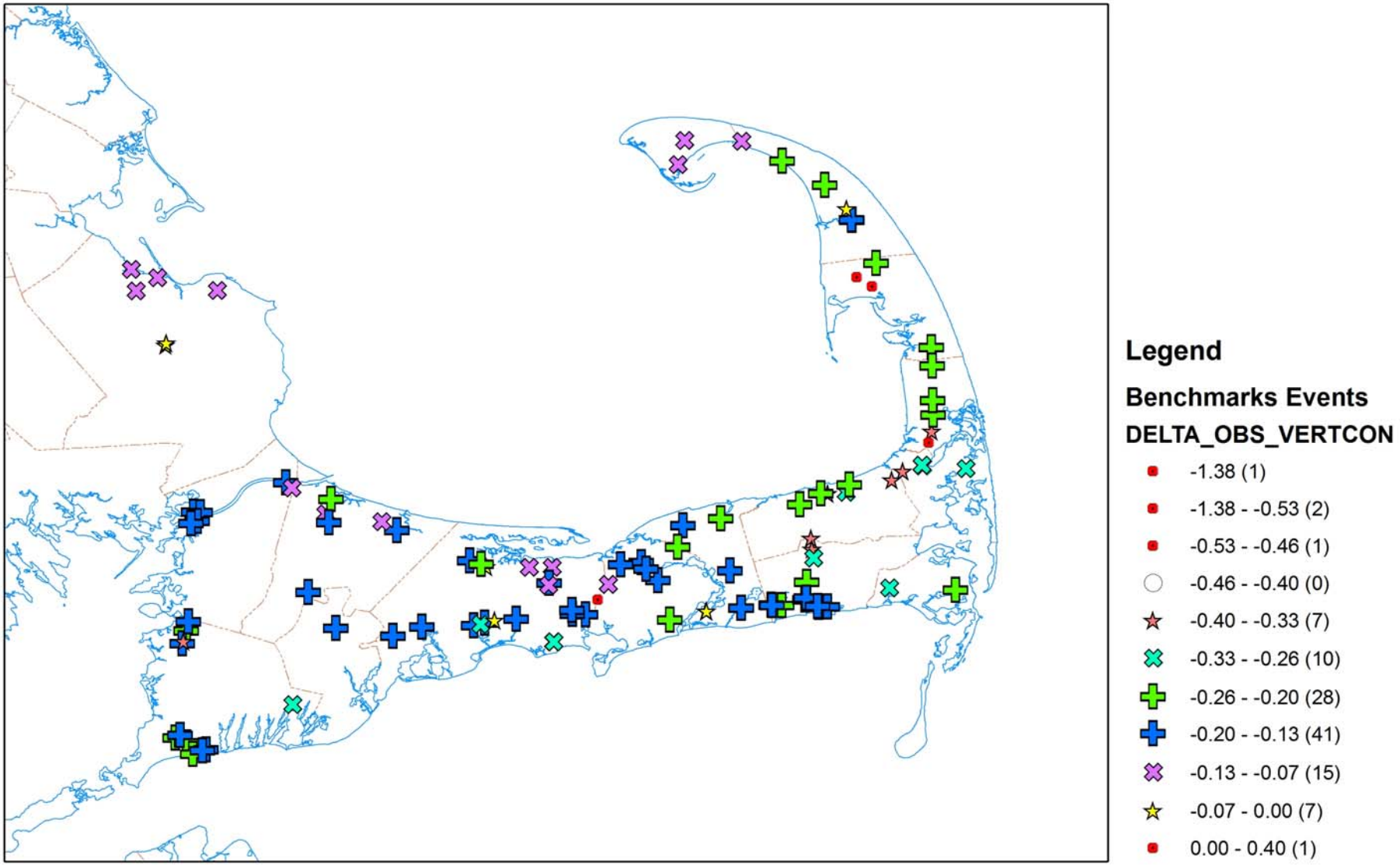


Distribution of the difference between COMP (the comparison of the published benchmark elevations) with the difference determined by VERTCON at the location of the benchmark.

Basic Statistics

- The average VERTCON conversion of the sample set is 0.865.
- 7 marks (6.2%) are within 2 cm of VERTCON.
- 5 marks (4.4%) are clearly too far outside of range to be incorporated in a solution.
- The average of the other 108 marks (95.6%) is 1.058'.
- 69 marks (61.0%) are within 2 cm of VERTCON - 0.198 (1.063, plus or minus 0.066')

Where do these variations occur?



Origins

- It is extremely important to note that certain benchmarks may be based on benchmarks that are not relative to those used for a datum conversion.
- Example: It is commonly known that the FEMA RM's typically do not agree with the NGS and MassDOT benchmarks.
- Example: Seven benchmarks across Cape Cod match the VERTCON model. The other 106 benchmarks are different by more than 2 cms.
- Example: 145 AE in Wellfleet is off by more than a foot (COMP = –2.24). We could assume that there was a typo in the data sheet and change one of the elevations by a foot to result in an observed difference of –1.24. This would be the same compared difference as benchmark M4 which is in Wellfleet, but would not address any elevations based on 145 AE.
- **A datum conversion must be appropriately applied. If you do not know if a datum conversion then you should go find out.**

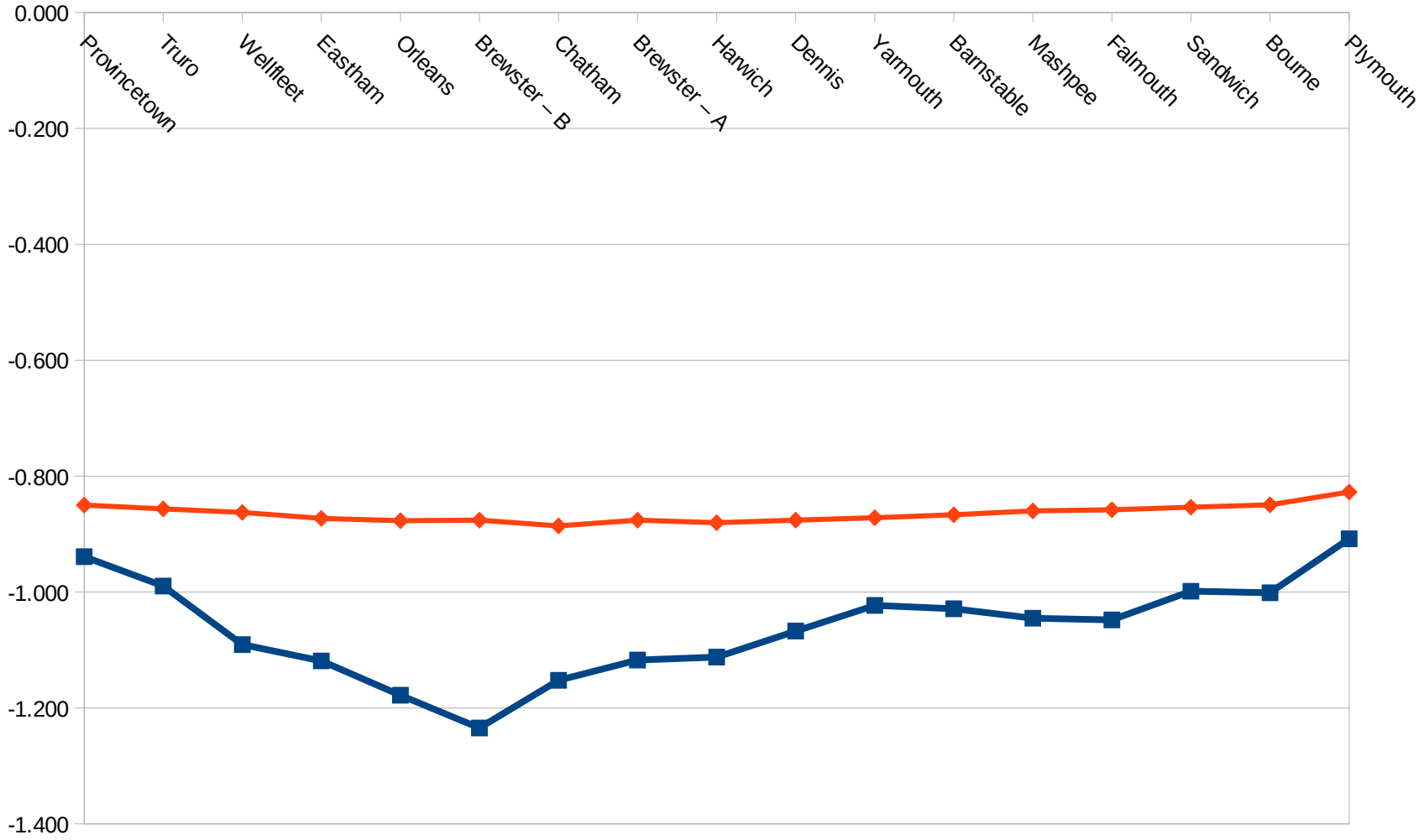
Town By Town

The VERTCON model has consistent results across small areas like towns. This allows the creation of multiple conversions based on proximal benchmarks. Benchmarks that cause the maximum difference between the average and the benchmark to exceed 0.066' have been removed from the calculation.

Town	COMP	Max	Min	Diff	VERTCON	Used	Not	% Total
Provincetown	**-0.939**	-0.922	-0.956	**0.017**	**-0.850**	2	0	100.0%
Truro	**-0.969**	-0.925	-1.005	**0.044**	**-0.858**	4	1	80.0%
Wellfleet	**-1.091**	-1.076	-1.101	**0.014**	**-0.863**	3	2	60.0%
Eastham	**-1.119**	-1.109	-1.128	**0.009**	**-0.873**	3	2	60.0%
Orleans	**-1.178**	-1.166	-1.186	**0.012**	**-0.877**	3	0	100.0%
Brewster – B	**-1.235**	-1.209	-1.253	**0.026**	**-0.876**	4	4	50.0%
Chatham	**-1.152**	-1.108	-1.196	**0.044**	**-0.886**	2	0	100.0%
Brewster – A	**-1.117**	-1.076	-1.151	**0.042**	**-0.876**	4	4	50.0%
Harwich	**-1.112**	-1.080	-1.138	**0.032**	**-0.880**	9	4	69.2%
Dennis	**-1.067**	-1.058	-1.081	**0.014**	**-0.876**	5	1	83.3%
Yarmouth	**-1.023**	-0.995	-1.050	**0.029**	**-0.872**	7	2	77.8%
Barnstable	**-1.029**	-0.980	-1.086	**0.057**	**-0.867**	15	6	71.4%
Mashpee	**-1.045**	-1.045	-1.045	**0.000**	**-0.860**	1	0	100.0%
Falmouth	**-1.048**	-0.999	-1.110	**0.062**	**-0.858**	11	3	78.6%
Sandwich	**-0.999**	-0.966	-1.041	**0.043**	**-0.854**	5	1	83.3%
Bourne	**-1.001**	-0.969	-1.064	**0.062**	**-0.850**	7	0	100.0%
Plymouth	**-0.908**	-0.848	-0.938	**0.060**	**-0.827**	5	1	83.3%

Differences between COMP and VERTCON

COMP – the comparison of record benchmarks (Blue)
VERTCON – the output result of the VERTCON program (Red)



Conclusion...

Creating a separate conversion for each town uses 86 of the 113 benchmarks or 76.1% which is greater then the 60.1% used for the overall average.

This gives us a group of solutions that are consistent with the published data.