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# SUMMARY AND ANALYSIS OF MEASUREMENTS OF DISCHARGE FROM BLUE SPRING, NEAR ORANGE CITY, FLORIDA 1932–2002

# Summary and analysis of measurements of discharge from Blue Spring, near Orange City, Florida, 1932 – 2002

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## Executive Summary

This report presents a summary and analysis of 536 discharge measurements at Blue Spring near Orange City, FL, during the period March 1932-March 2002, to determine if measurements of spring discharge are affected by measuring-section location. The primary purpose of this analysis is to determine if, since the early 1990's, apparent persistent changes in temporal patterns (declines) in discharge that have been noted by other workers could be an artifact of changes in measurement locations, rather than an actual decline in the amount of water discharged from the spring.

There does not seem to be a significant effect of measurement-section location on measured spring discharge. However, there is no way to prove definitely from examination of these long-term, yet still somewhat limited data, that measuring-section location does not affect determination of spring discharge to some, albeit small, degree. The actual spring discharge may change between monthly (or less frequent) measurements, and, thus, obscure any effects of measurement-section location. Multiple near-synoptic measurements along the spring run might provide sufficient data to determine if discharge varies along the spring run. In any case, the use of a single measuring-section location in future monitoring would eliminate uncertainly about effects of measurement location and would probably be advisable.

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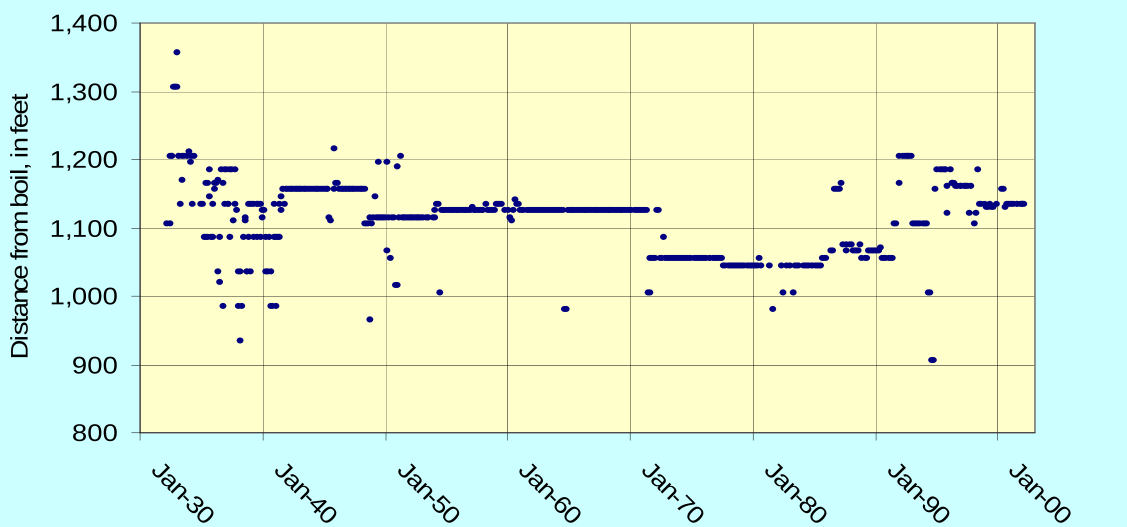
# Discussion

Over the period of record (1932 to present) there have been many changes in locations of discharge-measurement section. This report describes an analysis of the measurements to determine if measurements of spring discharge are affected by measuring-section location. Studies by Bill Osburn and others at the St. Johns River Water Management District (SJRWMD) have documented decreases in discharge over time from Blue Spring. The primary purpose of this analysis is to determine if, since the early 1990's, these apparent persistent changes in temporal patterns (declines) in discharge could be an artifact of changes in measurement locations, rather than an actual decline in the amount of water discharged from the spring.

It is believed that negligible flow in Blue Spring run is derived from surface-water inflow or from ground-water seepage from the Surficial aquifer system. Therefore, in this report, all spring flow and all diffuse upward leakage of ground water is considered to be derived from the Floridan aquifer system.

Location of the measuring section theoretically could affect measurement of discharge and, at some springs, it definitely does. The distance from the measuring section to the spring boil has varied over the period of record (Figure 1), from about 900 ft to about 1360 ft for most measurements. Two measurements in 1933 were made at a distance of about 105 ft below the spring. The measuring section locations have not been random with date; rather the locations tend to be relatively constant for periods of many years. For example, most locations in the 1940's through the 1960's were made about 1120 to 1160 ft from the spring boil. During the 1970's and 1980's, the measuring sections were generally about 1040 ft to about 1080 ft from the boil. These changes in location are relatively small, but could affect the amount of water measured if there was a significant inflow to the spring run from hidden vents or from diffuse upward leakage (seepage) along the spring run. Thus, in theory, trends in spring discharge with time could be related to trends in measuring location with time.

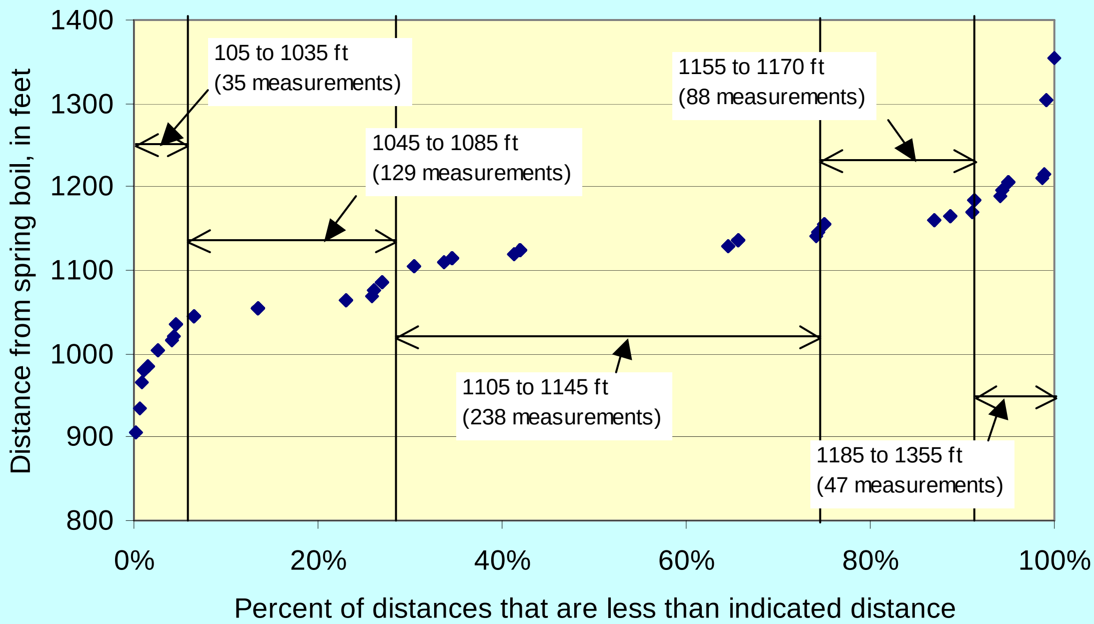
Figure 1.--Distance of measuring sections from spring boil



Floridan aquifer spring runs in many locations in Florida receive discharge not only from one (or more) major vent, but also from less conspicuous vents along the spring run and from diffuse upward leakage. No such vents in the Blue Spring run are known, but the possibility of undetected vents or seepage into the spring run cannot be eliminated. If such vents or seeps are present, then there could be gains in discharge with distance downstream from the spring.

To further investigate the possible effect of measuring section location on discharge record, all measurements were separated into groups for plotting and analysis according to distance of the measuring section from the spring boil. The location groups were defined to represent relatively small ranges in distance, as shown in figure 2, while keeping the total number of groups to a manageable number (5 groups were used).

Figure 2.--Distribution of measurement-section distance from the spring boil, and definition of the distance class intervals




Visual inspection of the groupings of discharge measurements according to downstream distance does not indicate a clear effect of measurement-section location on discharge (Figure 3). For example, during the 1930's, measurements were made both in spring-run segments closest to the spring boil (105 – 1035 ft) and in segments furthest downstream from the boil (1185 – 1355 ft). Both groups seem to indicate similar amounts of discharge, perhaps indicating no major inflow of water between the two spring-run segments.

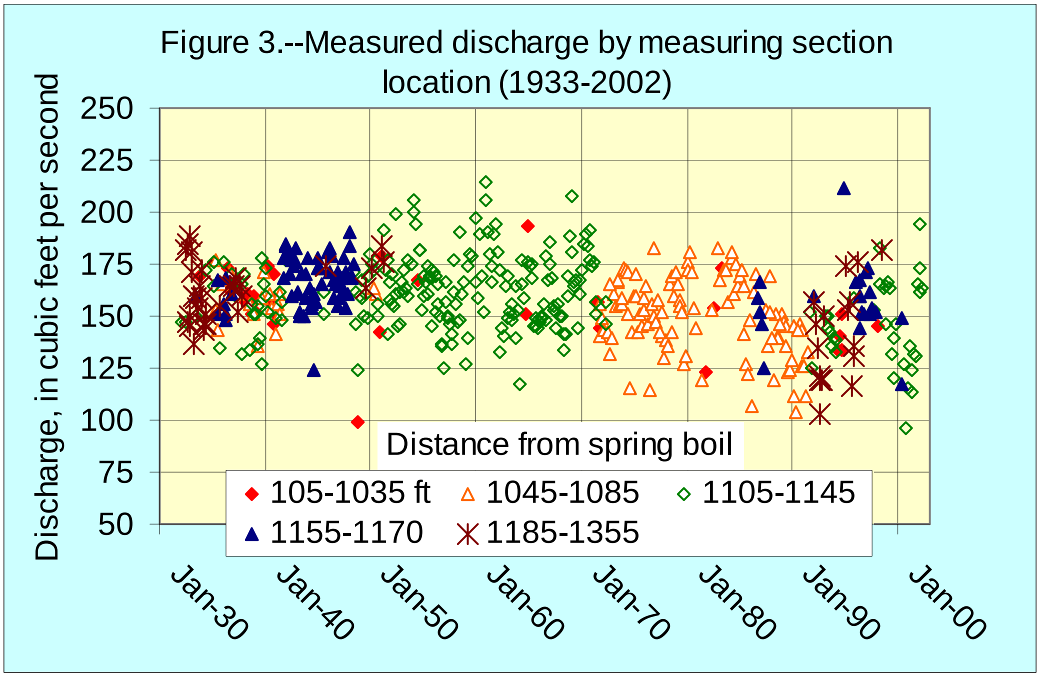
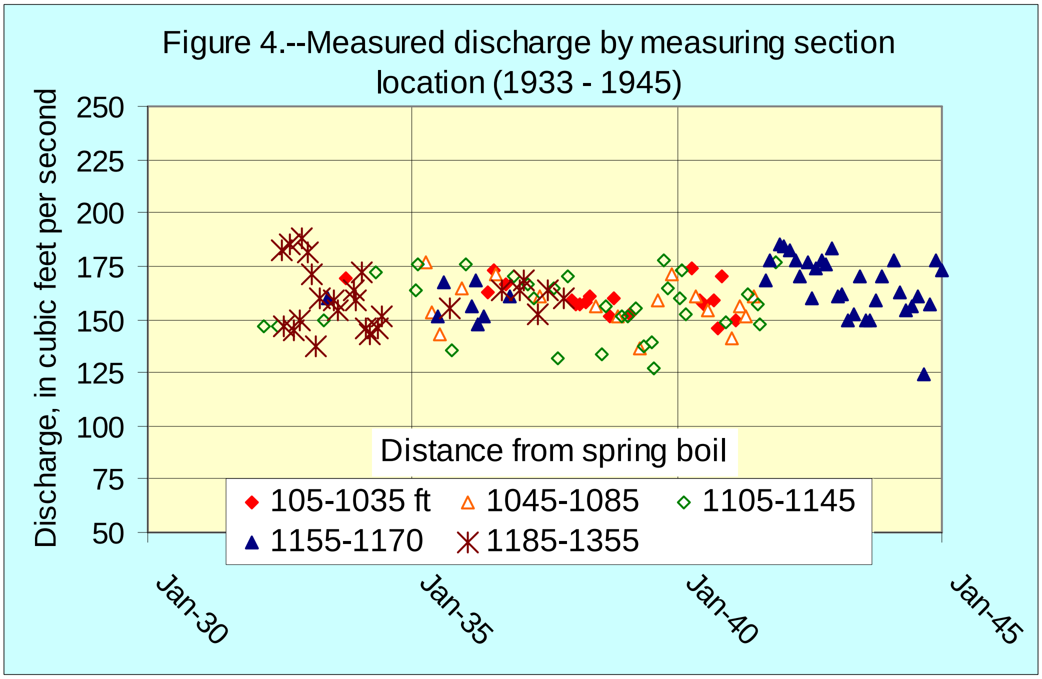
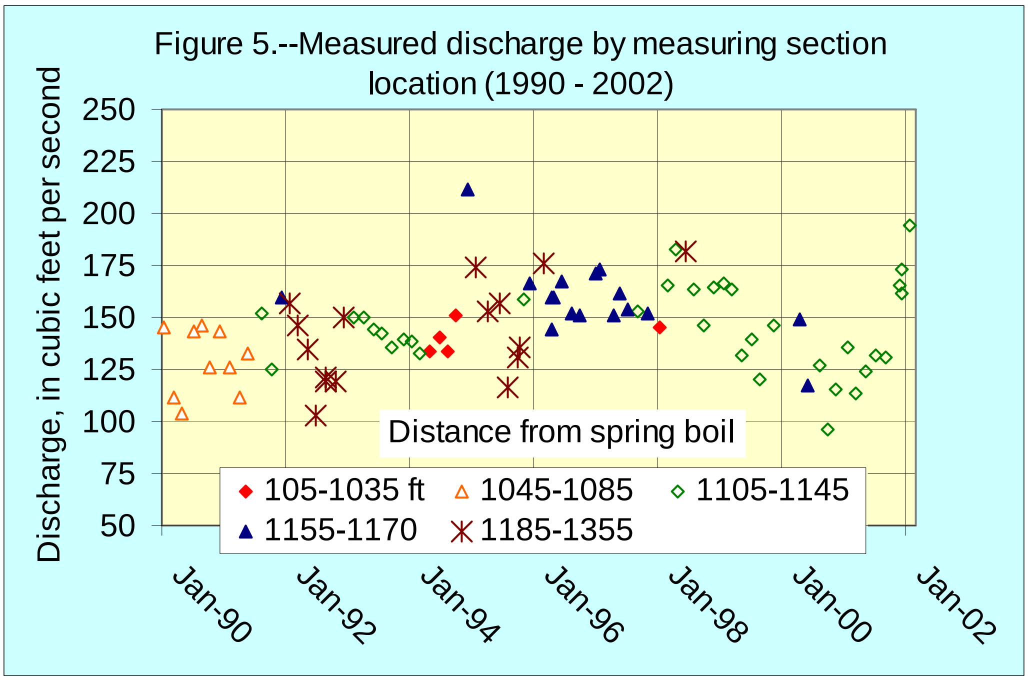



Figure 4 shows an expanded view of the measured spring discharge for the period 1933 – 1945. Shifts in spring discharge that might relate to change in measurement-section location are not apparent in this plot.



An expanded view of spring discharge for the period 1990 – 2002 (Figure 5) also does not seem to indicate shifts in spring discharge that relate to change in measurement-section location. This graphical inspection of measured discharge may indicate that any effects of measuring-section location are relatively small in comparison with month-to-month variation in spring discharge. However, differences in discharge related to measuring-section location could still exist but be obscured by limitations of measurement accuracy and by variation in spring discharge between measurement dates.




Statistical analysis techniques were used to further examine the possibility of a measurement-location effect on measured discharge. The Kruskal-Wallis test was used to determine if there is statistical evidence that discharge from the 5 spring-run segments are different. Table 1 is a summary of the results of the Kruskal-Wallis testing for a distance effect among the location groups over the entire period of record.

**Table 1.--Kruskal-Wallis Test for difference in discharge among location groups, 1932 - 2002**

| Segment | Distance from boil (ft) | Number of measurements | Mean discharge, ($ft^3/s$) | Mean rank score |
|---|---|---|---|---|
| 1 | 105 - 1035 | 35 | 155 | 246.14 |
| 2 | 1045 – 1085 | 128 | 151 | 215.23 |
| 3 | 1105 – 1145 | 238 | 159 | 279.28 |
| 4 | 1155 – 1170 | 88 | 164 | 330.96 |
| 5 | 1185 – 1355 | 47 | 156 | 258.70 |
| Chi-square statistic: 31.54<br>Probability of no difference in discharge among the segments: <0.0001 | | | | |

This test indicates that there is a significant difference in discharge among the 5 segments, with a small probability (<0.0001) that the discharges observed in all segments are from the same population. The test does not indicate which segments have discharges that are statistically significant from specific other segments.

Although the Kruskal-Wallis test indicates that differences among the spring-run segments do exist over the period of record, the possible reasons for these differences are not obvious. These differences may not relate entirely to spring-run segment location. Rather, some of the differences may be artifacts of the non-uniformity of measurement location in time. For example, most measurements in segment 2 were made during 1972 through 1992, most measurements in segment 3 were made during 1948 through 1972, and most measurements in segment 4 were made before 1949 (Figure 3). Thus, for example, the relatively high mean discharge in segment 4 (Table 1) may be because most of these measurements were made during a time period (before 1949) when measurements from all spring-run segments seem to indicate relatively high rates of spring discharge.

A sub-set of the discharge measurements, for the period 1932-1941, was used for another Kruskal-Wallis comparison of the discharge in the 5 spring-run segments (Table 2). During this period, the measurement locations are distributed more uniformly (but not completely uniformly) in time (Figure 4). Also, all measurements seem to indicate lack of a temporal trend in discharge during the period. Therefore the outcome of the test may be less affected by timing of measurements among the 5 distance groups. This test indicates that there is not a significant difference in discharge among the 5 segments for the time-period tested, with a probability of 70 percent that the discharges observed in all distance groups are from the same population.

**Table 2. -Kruskal-Wallis Test for difference in discharge among location groups, 1932 - 1941**

| Segment | Distance from boil (ft) | Number of measurements | Mean discharge, ($ft^3/s$) | Mean rank score |
|---|---|---|---|---|
| 1 | 105 - 1035 | 19 | 160 | 56.210 |
| 2 | 1045 – 1085 | 17 | 157 | 49.000 |
| 3 | 1105 – 1145 | 32 | 156 | 48.906 |
| 4 | 1155 – 1170 | 11 | 163 | 62.318 |
| 5 | 1185 – 1355 | 26 | 160 | 54.365 |
| Chi-square statistic: 2.168<br>Probability of no difference in discharge among the segments: 0.70 | | | | |

Kendall Tau trend tests were used to determine if trends in spring discharge are indicated within the spring-run segments. A lack of trends within the segments would indicate that an overall trend defined by all data could be an artifact of measuring location. The Kendall's Tau test is used by computing the Kendall Tau statistic from measurement dates and discharge magnitudes. The sign of the Kendall's Tau statistic indicates the direction of the trend. A positive value indicates increasing discharge with time, and a negative value indicates the opposite. A significant Kendall Tau is indicated by a low probability value. The probability value refers to the likelihood of finding a trend in completely trend-less data due to chance alone. A probability value of 0.05 or less is taken as evidence of a relation between discharge and date (Table 3). Results of the trend testing indicate a significant trend using measurements from all segments, and also significant trends within each segment except for segment 5. Therefore, the overall downward trend in discharge indicated by all measurements does not seem to be an artifact of measurement-section location, because trends were also detected within most of the defined spring-run segments.

**Table 3.—Kendall Tau test for temporal trends in discharge with each measurement location group**

| Segment | Distance from boil (ft) | Number of measurements | Kendall Tau | Probability level |
|---|---|---|---|---|
| Entire string run | 105 - 1355 | 536 | -0.18 | <0.001 |
| 1 | 105 – 1035 | 35 | -0.34 | 0.004 |
| 2 | 1045 – 1185 | 128 | -0.20 | 0.001 |
| 3 | 1105 – 1145 | 238 | -0.09 | 0.046 |
| 4 | 1155 – 1170 | 88 | -0.14 | 0.049 |
| 5 | 1185 - 1355 | 47 | -0.15 | 0.135 |

## Summary and conclusions

The major conclusions from this examination of the Blue Spring discharge measurements for the period 1932-2002 are:

1. Visual inspection of plots of discharge measurements does not indicate a clear effect of measurement-section location on discharge. For example, during the 1930's, measurements made in the spring-run segment closest to the spring boil and measurements made in the segment furthest from the boil seem to indicate a similar amount of discharge.

2. There are significant differences in magnitude of spring discharge for the period 1932-2002 among selected spring-run segments. However, the differences may not relate entirely to spring-run segment location. Rather, some of the differences may be artifacts of the non-uniformity of measurement location in time. For example, if a spring-run segment were measured more frequently during periods of relatively high spring discharge than during periods of lower discharge, that segment might appear to have a higher discharge than other spring run segments that were measured more frequently during periods of relatively low discharge.

3. There are no significant differences in magnitude of spring discharge among selected spring-run segments during the period 1932-1941. During this period measurement locations were more uniformly distributed in time and temporal trends in spring discharge appear to be absent. The lack of significant differences indicates there is probably little or no effect of measurement section location on measured spring discharge, at least during that period.

4. Temporal trends in discharge are significant within most selected spring run segments, as well as for combined measurements for the entire spring run. The existence of the temporal trends at most spring-run segments is an indication that the temporal trends indicated by the more extensive set of data for the entire spring run are not just an artifact of changes in measuring-section location over the years.

There does not seem to be a significant effect of measurement-section location on measured spring discharge. However, there is no way to prove definitely from examination of these long-term, yet still somewhat limited data, that measuring-section location does not affect determination of spring discharge to some, albeit small, degree. The actual spring discharge may change between monthly (or less frequent) measurements, and, thus, obscure any effects of measurement-section location. Multiple near-synoptic measurements along the spring run might provide sufficient data to determine if discharge varies along the spring run. In any case, the use of a single measuring-section location in future monitoring would eliminate uncertainly about effects of measurement location and would probably be advisable.