The Quality Assurance/Quality Control Aspects of Using a Submersible Area/Velocity Probe When Metering Flows in an Intermittently Wet/Dry Environment Such as Combined Sewer Overflows

Thorough quality assurance/quality control (QA/QC) of a combined sewer overflow (CSO) flow monitoring program is not only dependent upon proper equipment selection and site characteristics, but also on the ability of the monitoring person or persons to observe and recognize characteristics of collected data which would qualify that data as being true and representative of that site or arbitrarily random with no sense of order or reliability.

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The art/science of open channel flow metering (measurement of flow) has evolved to the point where today temporary flow metering is considered Astate of the art@ if you can install a secondary flow monitoring device that will measure depth and velocity at regular intervals and obtain representative data in a defined flow conduit. Sounds simple. Let=s consider the variables. <u>Depth</u> <u>measurement.</u> Hopefully if you are asked by a Municipal Official, Engineer, or Regulator to measure a specific flow you will have input in deciding if that site=s hydraulic characteristics can provide depth and velocity measurements with some reasonable assurance that those measurements are true. For instance, if a site=s particular flow pattern is such that the surface turbulence is very irregular, how can you expect, with any degree of certainty, that the periodic depth measurements taken will be representative of the site=s normal depth for a given time period. Remember, most temporary flow studies utilize portable flow metering devices for the purpose of measuring varying head and velocity levels at defined intervals and calculating flows based on the averaging of those individual samples. Most of these meters turn on at defined intervals, take a reading, and turn off again until the next reading. This Aon time@ may be as short as three seconds. If metering intervals are once every 15 minutes, then the data collected in four, three second readings (or 12 seconds in one hour) is determining average hourly flow rates at that site. Not very reassuring. Depth measurement can be checked easily enough by direct measurement with a tape measure or carpenters rule. I say this with tongue in cheek. Have you ever tried, while straddling a flow channel in the bottom of a manhole, wearing full safety gear, holding a light in one hand and a rule in the other measure wastewater flowing at 3 feet per second (fps), with all the accompanying solids typically found in the municipal wastewater, while also remembering to keep your mouth shut. Well this is no easy task and remember that meter manufacturers ∀ 0.276 inches accuracy. Well if your reading is ∀ 0.25 inches we would consider you an experienced field technician.

Since we have determined that depth measurement is easily evaluated by using a hand held rule, what about velocity? Most manufacturers and literature references will tell you the best method for evaluating a submersible electronic velocity sensing device is with another portable submersible electronic sensing device. As you can see you will have to put your faith in the unknown at some point. We have also mentioned sampling intervals. Many regulatory protocols are requiring a minimum of 15 minute intervals between readings. As previously stated this can translate into as little as 12 seconds total reading time in the course of one hour. In and of itself, I do not find this very reassuring.

Obtaining representative data (accuracy). Accuracy as defined in the AFlow Measurement Engineering Handbook@ [1] is Athe closeness of agreement between measurement and the value of the measurand@. An interesting statement. It goes on to state that accuracy Ais both a function of a flow meter=s precision and the ability of the measurer to recognize, avoid, and correct for bias errors.@ What does this all mean and how do we do it? Well, one method that assists us in avoiding and recognizing bias errors is our evaluation of a meter=s ability to provide repeatable data. This quality we refer to as Arepeatability@ has become one of the standards when reviewing and considering the quality of open channel flow metering data. But does this guarantee accuracy? Sorry it does not. Repeatability only recognizes a sensor=s ability to predict that changing head/velocity (H/V) relationship that exists in an open channel free flow environment, it does not guarantee that 2" of head at 3 fps is really 2" and 3 fps. This can only be guaranteed by physically measuring the level and velocity at the metering point in question, which we have previously discussed. So how is repeatability evaluated? Let=s consider scattergraphs. Scattergraphs are those graphs generated by plotting individual H/V readings taken at a particular site on an X Y graph. This graph not only reveals some particular characteristics of a site, but it can also reveal that particular meter=s ability to repeat itself within that specific hydraulic environment. What? If we believe that a particular flow (hydraulic) environment is stable in the sense that pipe material, slope and wastewater viscosity are unchanging, then specific depth readings will always be associated with specific velocity readings in a free flow environment. To state it even simpler, if, at a depth of 2" the flow velocity is 3 fps, then whenever the depth is 2" we should be able to measure the velocity as 3 fps (i.e., repeatability). Therefore, we say our flow meter has the characteristic of repeatability if, whenever it records a depth of 2" it is also recording a velocity of 3 fps. This should and will be evident on a scattergraph of all data collected.

All of this leads me to what I originally wanted to discuss, and that is the QA/QC techniques for using a submersible A/V probe when metering flows in an intermittently wet/dry environment such as CSO=s. Unlike open channel flow monitoring in sanitary sewers (SS), CSO monitoring present far greater challenges. What makes a CSO different from a CSS environment? First, CSO=s only convey wastewater when the upstream CSS has exceeded its design capacity. This occurs most often following storm and/or snow melt events. Secondly, prior to passing through the CSO, wastewater usually has to overflow a dam (weir) or pass through an orifice or some other control device which almost always will alter the normal hydraulic flow characteristics of the upstream CSS system. Third, in many instances, CSO structures are located on main lines or interceptors in low lying areas, and thus require a tide gate or some other means of downstream control to prevent the entrance of receiving waters into the combined sewer system. All of these differences create additional problems and concerns for anyone trying to monitor and measure CSO flows.

At DE we realize that each CSO site is different and requires special consideration when attempting to monitor overflows. In some cases there is no sure way to guarantee accurate overflow measurement other than the ability to describe the event duration and range of depths above an installed sensor. In other cases, some, if not all, of the previously described monitoring requirements can be met. Obviously, sensor pre-installation calibration is essential prior to installation, placing the sensor in a range of depths and observing level readings along with response times will help guarantee that the sensor used will respond to changing depths rapidly, which is necessary in the ever-changing environment of CSO=s. Sensor placement is important in that all attempts should be made to place the sensor as far away (downstream) of any regulator or weir in order to avoid the turbulent conditions created near these structures. Remember, smooth laminar flows are the ideal monitoring environment. When placing the sensor, you must also consider the downstream back flow device; if your sensor is too close to the back flow regulator, back flow conditions will exist and will be evident when viewing the raw data scattergraph (Figures 1 & 2). Now that the meter has been calibrated and installed, how are you going to be sure that the data collected during and following storm events is a true measure of the real conditions of the site being monitored? Unlike monitoring SS flows, where you can physically take a field measurement and compare it to the actual meter output reading, CSO=s are for the most part dry with no flow over the sensor and when there is flow CSO=s are not safe environments to enter for field calibration measurements. There are a number of ways to get around this problem. First, following initial sensor installation, you can chalk the site with powdered carpenters chalk. This is done to confirm a bypass event between site visits. The time between visits is generally weather dependent but should not exceed 14 days. At the follow up site visit, meters are downloaded and the site is visually inspected for the presence or absence of the carpenters chalk. If the chalk is absent it is noted on the field form (Figure 3) and the site is re-chalked prior to leaving. It is important to note whether the chalk was present or absent at each visit since this is used to confirm overflow events when reviewing the collected data. The overflow readings collected (Head/Velocity/Flow) confirmed by the absence of the carpenters chalk, can then be imported to a CSO reporting program along with rainfall data collected at intervals equal to that of the CSO flow meter. This data can then be viewed in a scattergraph for free flow and site specific characteristics which may affect the H/V relationship. If a tight scattergraph is obtained, which indicates the meter is providing repeatable data (Figure 4), it can then be used when evaluating future overflow data and the sensors true measure of those events. Remember, however, that repeatable scattergraphed data in and of itself does not infer accuracy. Periodic removal and calibration of the sensor will be necessary to guarantee your CSO flow monitoring accuracy. This practice can continue for an indefinite amount of time as long as chalking, tracking scattergraphed data and periodic calibrations are performed.

The following scattergraphs (Figures 5 through 10) were generated from data collected from a case study of a CSO site located in Southwestern PA and monitored by DE for the period from October 1999 through October 2003. The flow meter used was an American Sigma 910 with a submersible Area/Velocity probe. What the evaluation of this information reveals is that when site selection has followed proper protocols and sensor placement and meter selection has been optimized, data collected at this particular overflow structure exhibited a hydraulic profile allowing it to be measured and evaluated for repeatability over the study period. This evaluation includes the use of field inspection data to verify overflow events between visits (chalking) and the use of H/V scattergraphs to verify sensor stability and drift. By applying biweekly data collected to historical scattergraphs, we are able to monitor sensor performance and identify drift and the need for sensor calibration and/or replacement. We have also combined all of the H/V overflow points on one scattergraph, which reflects the entire four year study (figure 8).

Conclusion

Monitoring of CSO=s is as much an art as a science. Science and technology have provided the tools; however, site selection, installation, meter maintenance and data review, all need to be carried out by a skilled, experienced technician. There is no substitution for visual observation; however, there are tools such as historical scatterplotting which can and should be used as part of the entire overflow monitoring program. As the data attached confirms when each monthly scatterplot is laid on top of the previous month, sensor drift or lack of can be observed and confirmed. As the four year summary scatterplot indicates, this site exhibited very little to no variations in expected hydraulic characteristics. From the data attached, along with field notes of chalking and periodic calibration, we are able to say that the flow data collected and reported at this site is as complete and as accurate as provided by the meter and site characteristics.

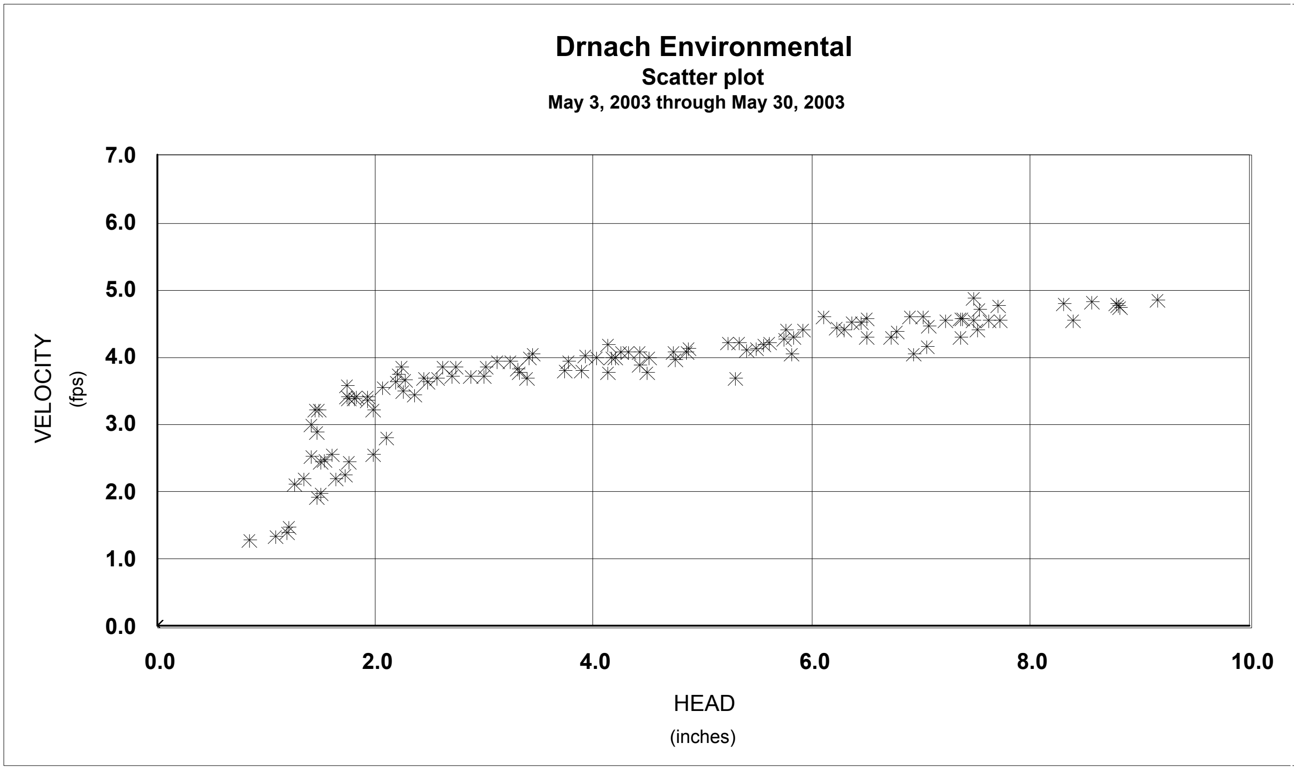

Figure1 this CSO exhibited free flow characteristics from 0.00 to 2.00 inches, the flattening out of the data above 2.00 " Of head is caused by the resulting drop in the rate of velocity increase due to the presence of a downstream 36" tide gate.

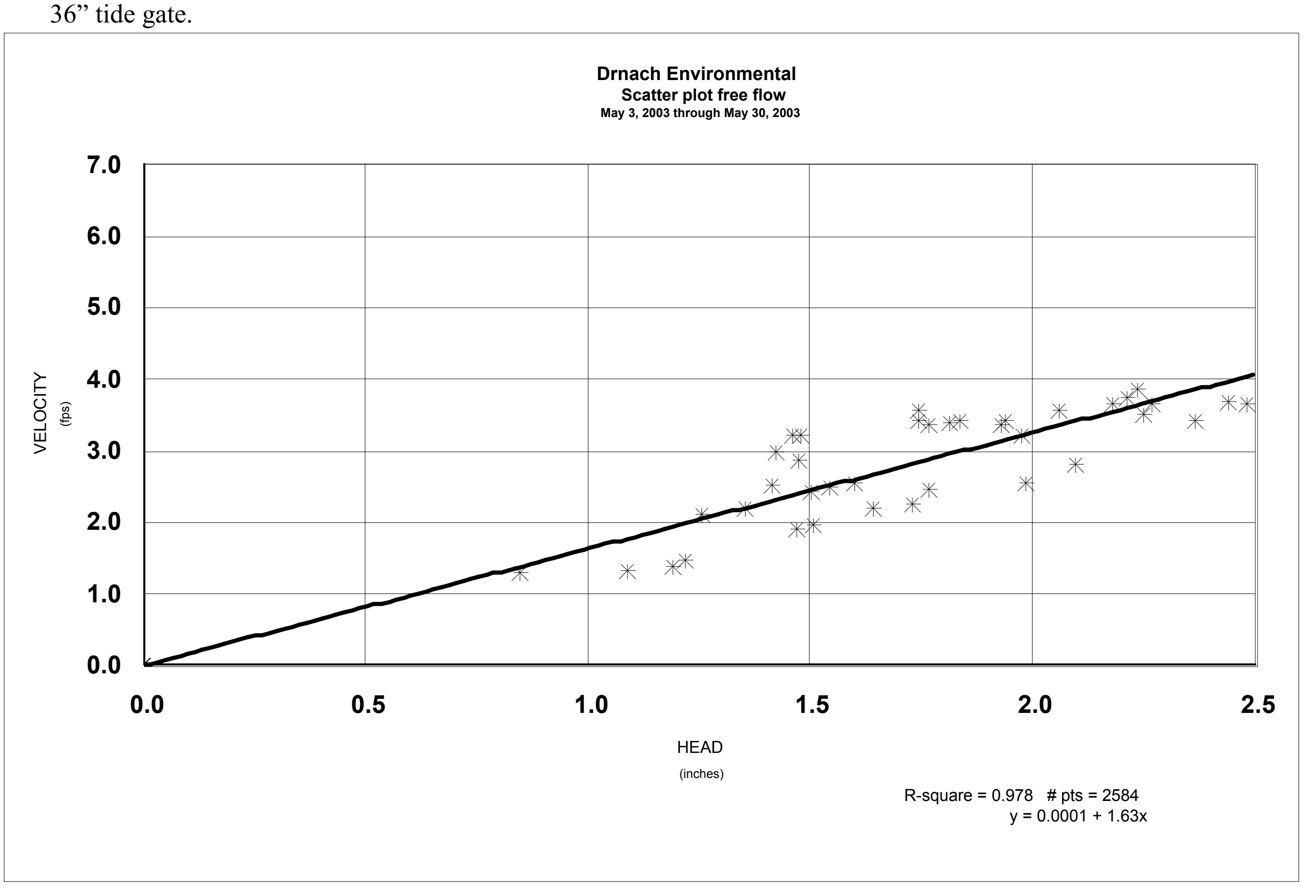

Figure 2 The data plotted represents the free flow portion of figure 1.

Drnach Environmental **Field Forms** **Project:**

Site ID:	Date:	Weather:	
Flow conditions:	Free Flow: Y / N	Surcharged: Y / N	
Meter current status:	[A] Head:	[A] Velocity:	Battery:
	[B] Head:	[B] Velocity:	
Field measurements:	[A] Head:	[A] Velocity:	
	[B] Head:	[B] Velocity:	

Meter Download: Y / N	Battery Change: Y / N	New Voltage:
Sensor cleaned: Y / N	Does H/V field points fit scatter: Y / N	Initial:

Notes:____

Site ID:	Date:	Weather:	
Flow conditions:	Free Flow: Y / N	Surcharged: Y / N	
Meter current status:	[A] Head:	[A] Velocity:	Battery:
	[B] Head:	[B] Velocity:	
Field measurements:	[A] Head:	[A] Velocity:	
	[B] Head:	[B] Velocity:	

Meter Download: Y / N	Battery Change: Y / N	New Voltage:
Sensor cleaned: Y / N	Does H/V field points fit scatter: Y / N	Initial:

Notes:____

Figure 3

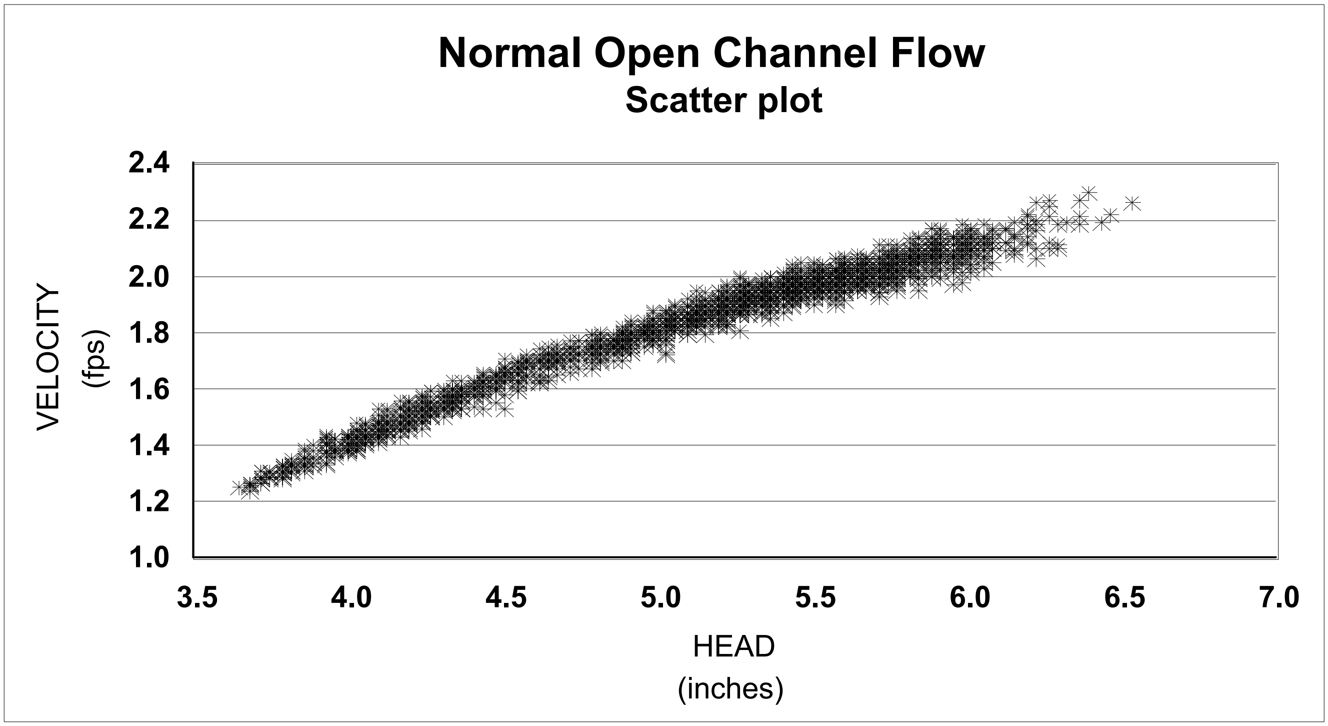

Figure 4 The data plotted represents the expected distribution of head & velocity readings in an open channel, Self cleaning, free flow environment.

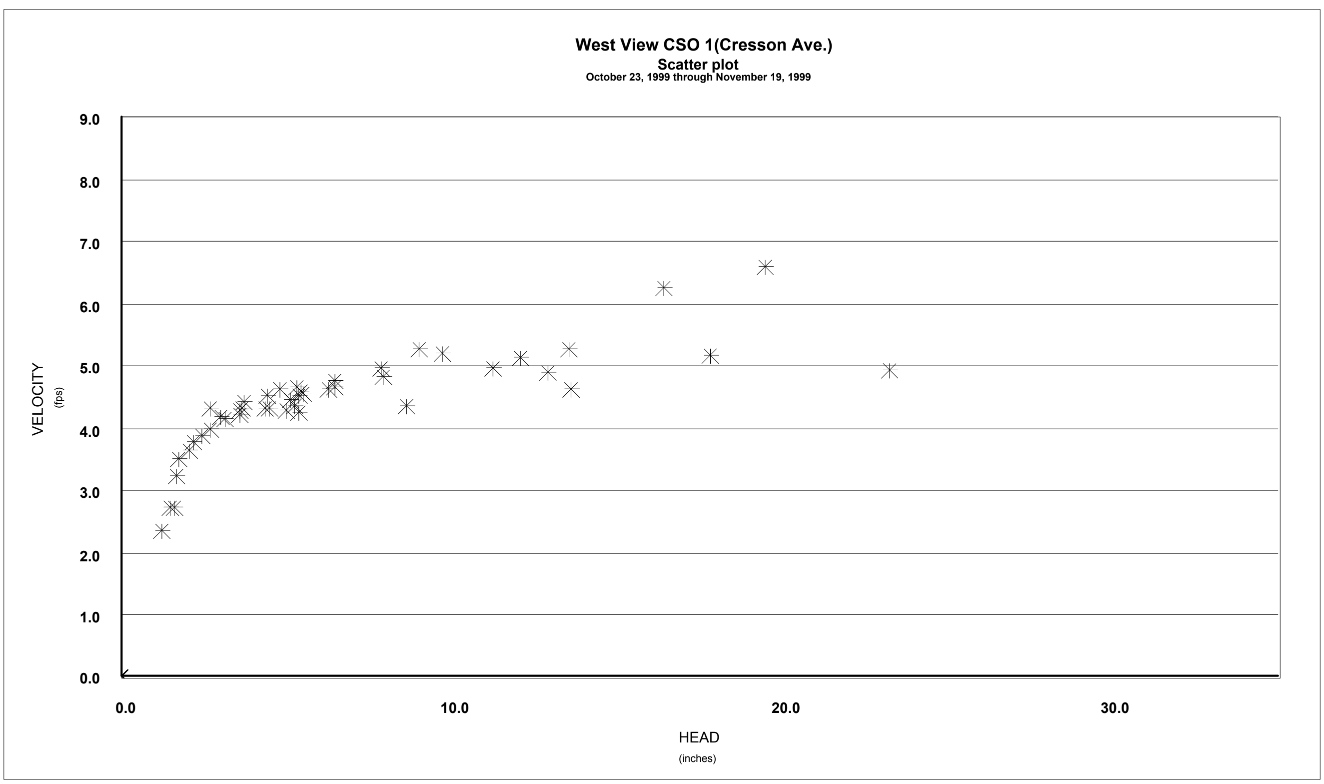

Figure 5 Monthly scatter plot of data collected October 23, 1999 through November 19, 1999.

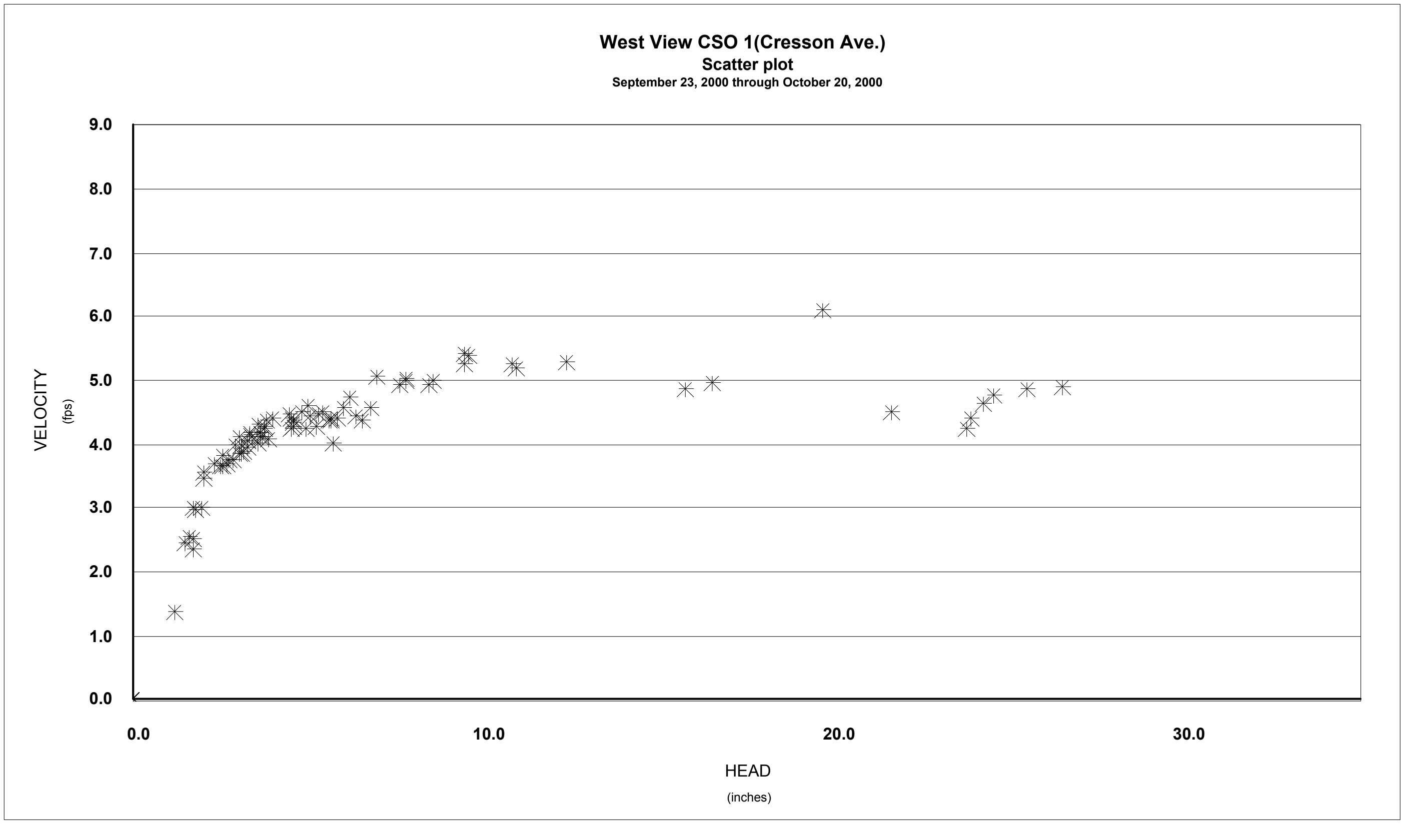

Figure 6 Monthly scatter plot of data collected September 23, 2000 through October 20, 2000.

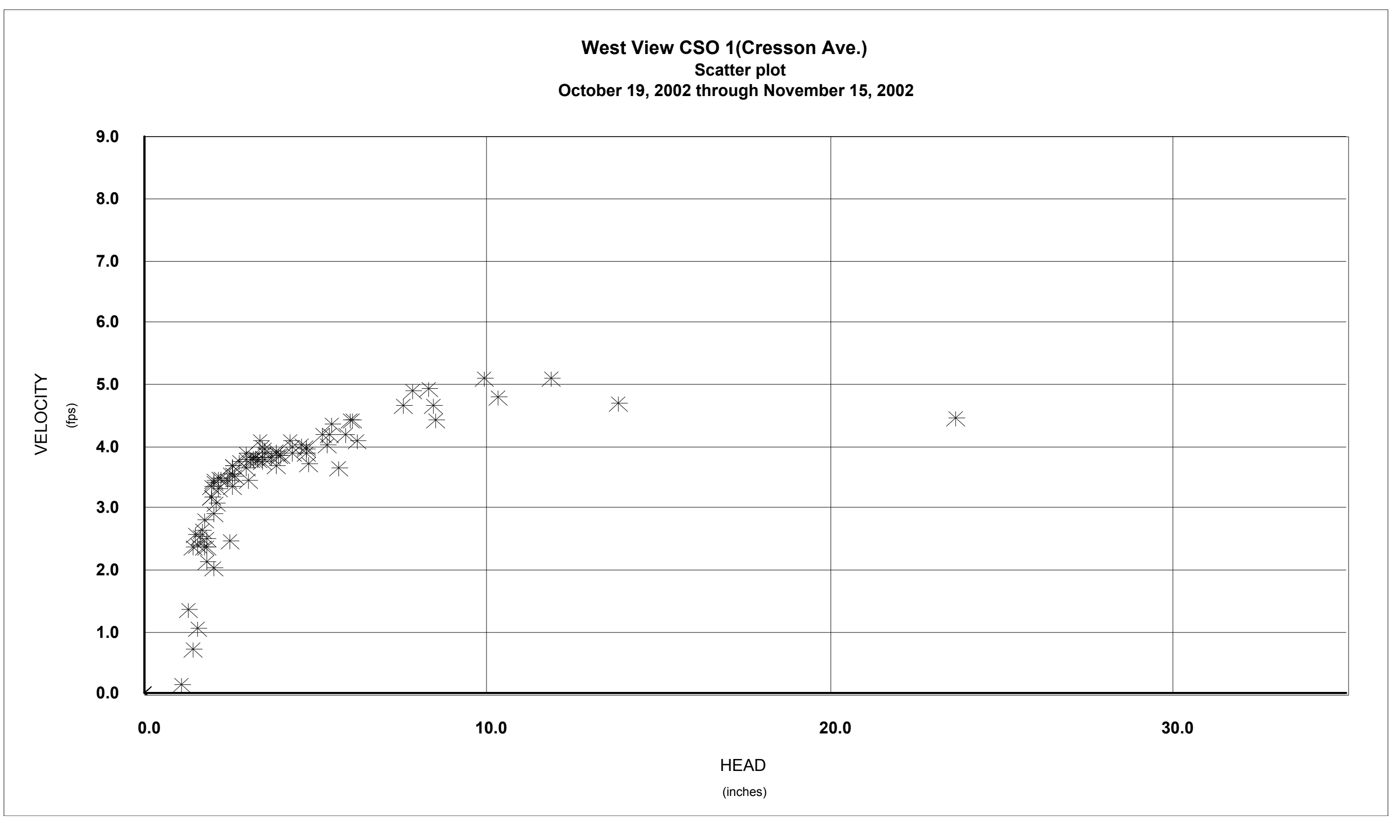

Figure 7 Monthly scatter plot of data collected October 19, 2002 through November 15, 2002.

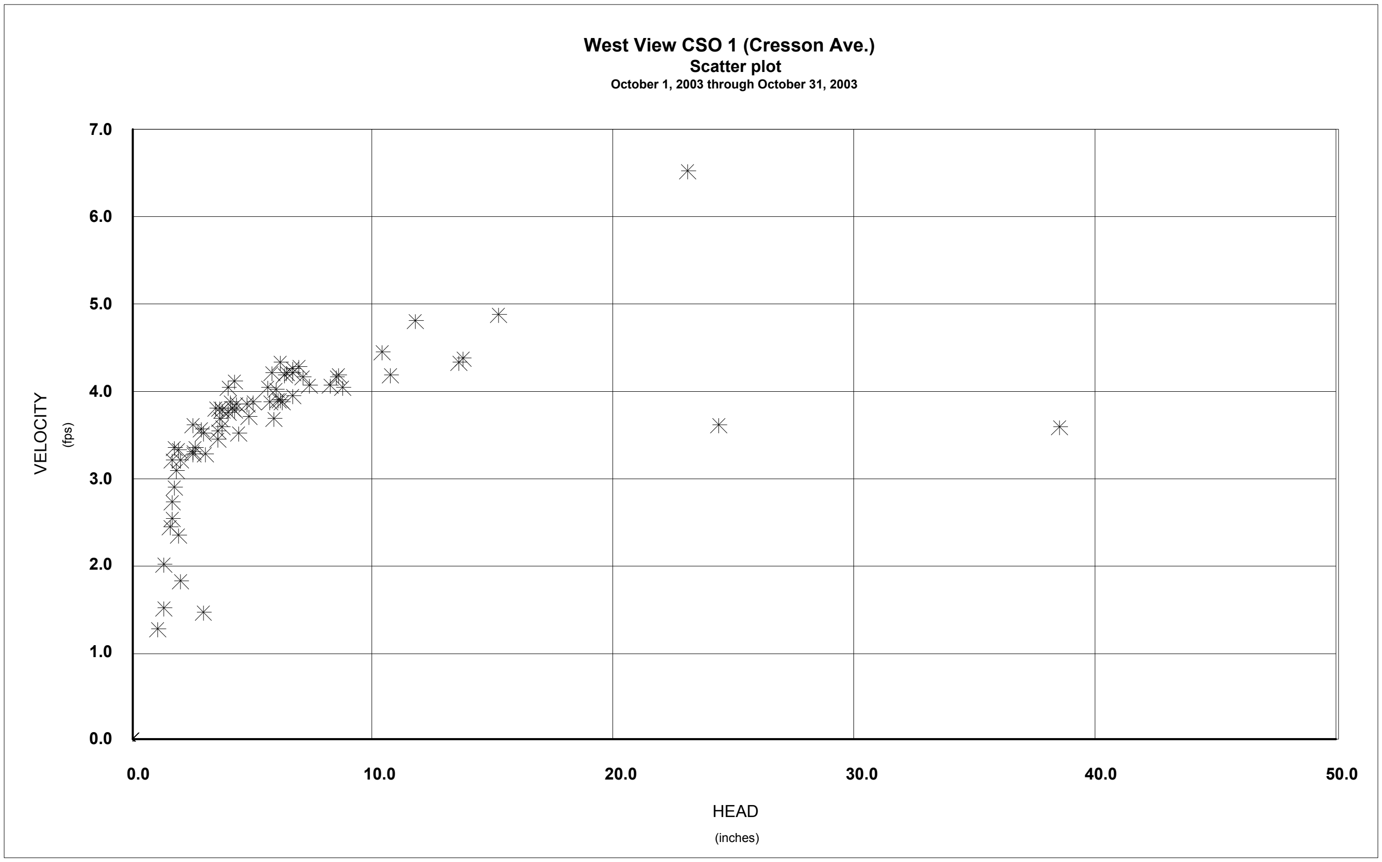

Figure 8 Monthly scatter plot of data collected October 1 , 2003 through October 31, 2003.

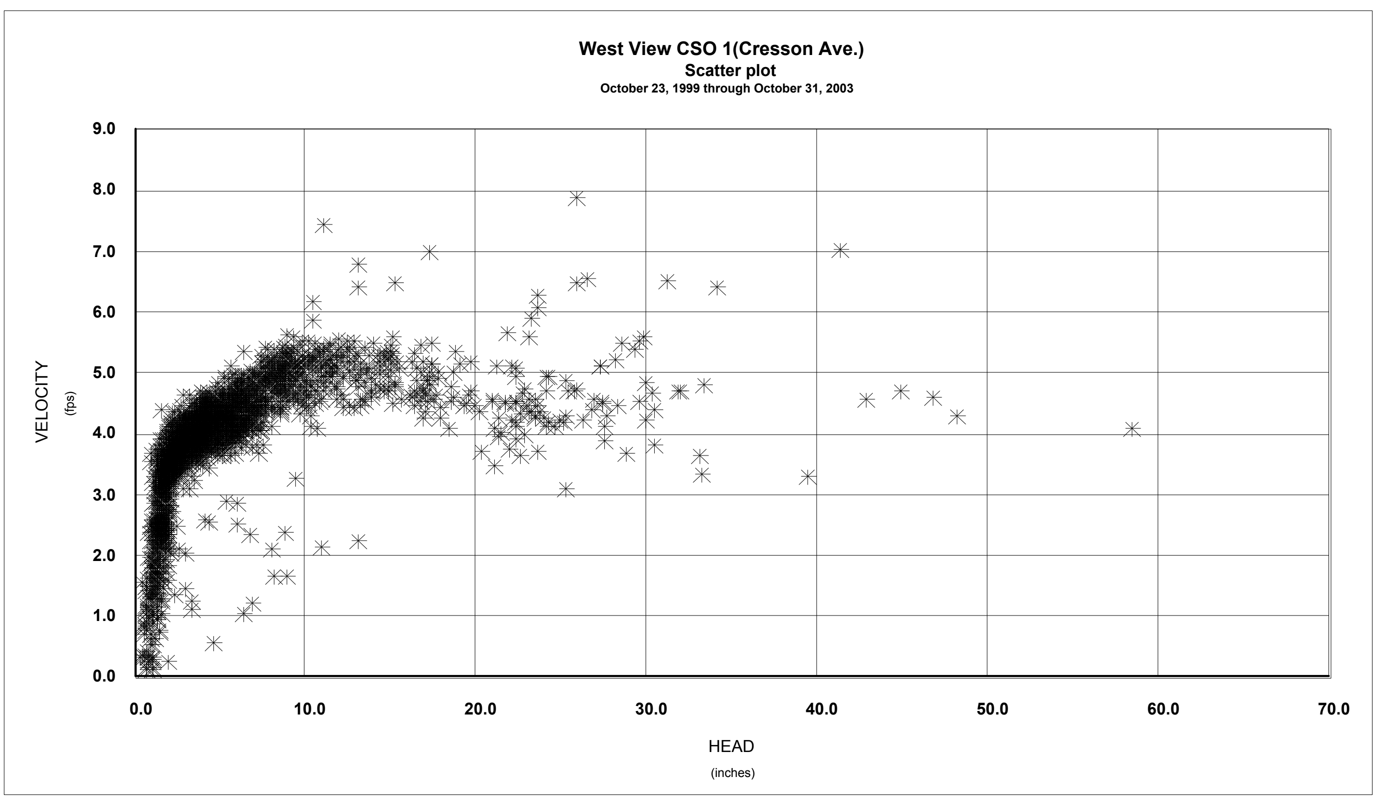

Figure 9 All collected data from October 23, 1999 through October 31, 2003.

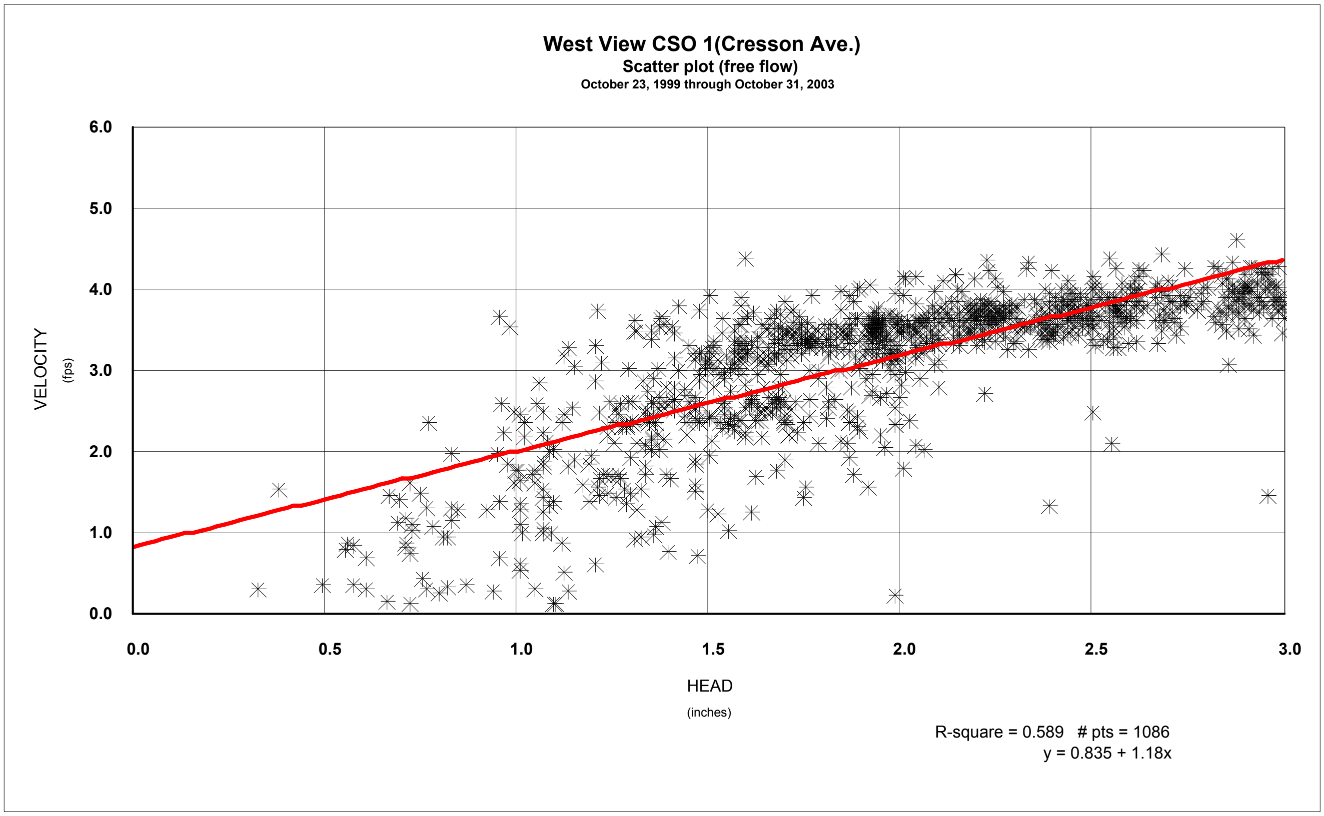

Figure 10 All free flow data collected from October 23, 1999 through October 31, 2003.

REFERENCES

Miller, R.W.: AFlow Measurement Engineering Handbook@ 3rd Ed., pp. 4.1, 1996.