

Turbidity Study - 2003



City of Tucson
Water Quality Management Division
Technical Support and Development Services

Charles A. Carroll
March 2004

Turbidity Study - 2003

Objective

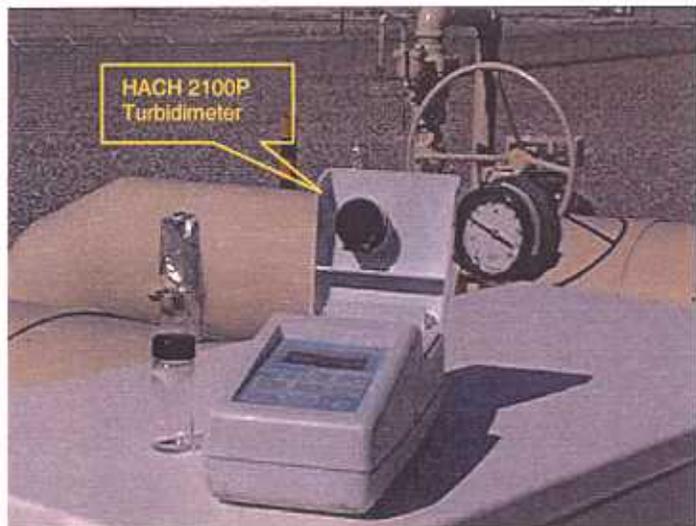
Analyze the 2003 Turbidity data to look for potential contamination existing in or entering the distribution system, and then determine the sources/reasons for the high turbidities. Investigate correlations between Turbidity and other parameters such as temperature, pH, electrical conductivity, bacteriological positives, and seasonal conditions. Compare the water quality in 2003 to that of 2002 with respect to Turbidity.

Introduction

Turbidity is a measure of the “cloudiness”, or opacity of water. All natural waters are turbid to some degree, surface waters generally more so than groundwater. It can be caused by the presence of solid particles made up from various items including clay, silt, plant and animal debris, corrosion products, and limescale.

Turbidity is measured in Nephelometric Turbidity Units (NTU), which is a measure of water’s ability to scatter light. The higher the NTU, the higher the water’s ability to scatter light, indicating higher amounts of suspended particles existing in the water.

Tucson Water operates 11 separate drinking water distribution systems throughout Metropolitan Tucson. The



main system (10-112) provides water to more than 98% of Tucson Water customers. The remaining 2% are served by ten small isolated systems located in the outlying areas of metropolitan Tucson. In May of 2003, Tucson Water began operation of System 10-270, which serves the Sierrita Foothills area, increasing the number of isolated systems from nine in 2002 to ten in 2003.

The Water Quality Management Division of Tucson Water conducts extensive monitoring at 260 dedicated sampling stations, located at various points within the Tucson vicinity, which are representative of the water customers receive. Turbidity measurements, along with other

City of Tucson
Water Quality Management Division
Technical Support and Development Services



field parameters, are conducted monthly at each dedicated sampling station. Monitoring at the dedicated sample stations demonstrates the quality and safety of water throughout the distribution system.

There are no regulations for Turbidity of ground water systems, but it is generally accepted that drinking water supplies have Turbidities of 1 NTU or less (World Health

Organization). Measurement of Turbidity at the dedicated sampling stations has been ongoing since 2002, furnishing two complete years of data for study. Turbidity has become an additional tool to better monitor our system, and to discover potential problems early.

Analysis/Results

For 2003 there were 3,114 Turbidity analyses at the dedicated sampling stations. General statistics for the entire data set are shown in Table 1.

Table 1: General Statistics

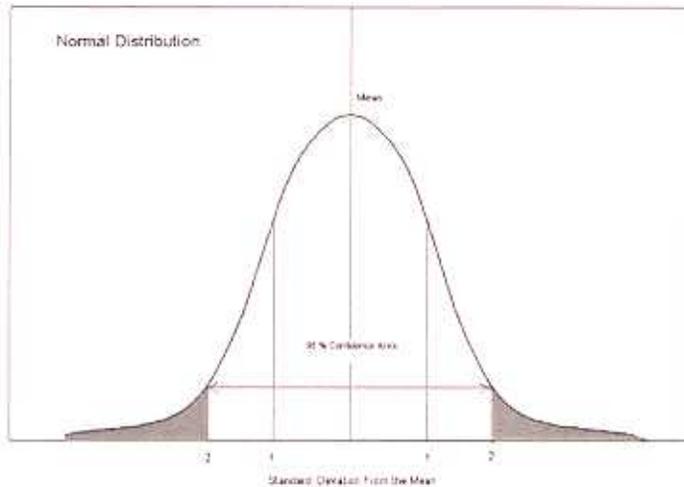
2003	Turbidity	Temperature	pH	Conductivity
Average	0.21	26.9	7.69	441
Maximum	2.79	37.4	8.42	958
Minimum	0.04	8.9	6.56	224
Standard Deviation	0.14	4.2	0.29	113

2002	Turbidity
Average	0.17
Maximum	2.63
Minimum	0.01
Standard Deviation	0.13

City of Tucson
Water Quality Management Division
Technical Support and Development Services

Statistical Discussion

Comparing the 2003 data to 2002 shows that the average Turbidity increased by 0.04 to 0.21 NTU, but the standard deviation only increased from 0.13 to 0.14. This indicates that the number of occurrences of very high readings in the 2003 data set did not change much from the 2002 data, but that the magnitude of those readings was higher.

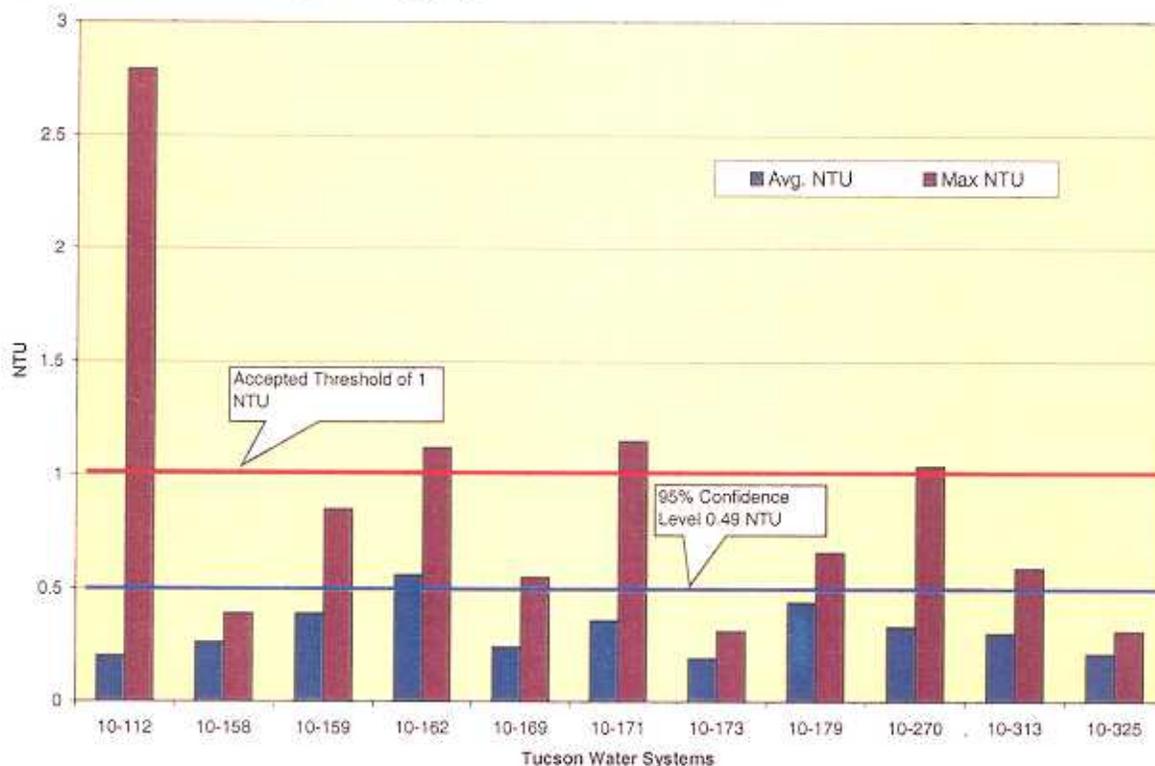


The 95% confidence level of a normal distribution of numbers is two standard deviations above or below the mean or average of that data. It is the point above or below the average at which one can be 95% certain that the cause for the number was an influence other than the random scatter within the data. In the case of Turbidity readings, differing sampling

techniques, the use of different meters, entrained air within the water samples, and variability in the different waters sampled can cause scatter. By focusing on Turbidity readings greater than 2 standard deviations above the mean, we can be 95% certain that we are looking at readings caused by influences other than these routine variations introduced in the process of taking the readings. The 2003 Turbidity data, having a mean of 0.21 NTU and a standard deviation of 0.14 NTU, calculates that readings above $[0.21 + (2 * 0.14)] = 0.49$ NTU result in 95% confidence that they were caused by influences other than the random scatter inherent in the data. This is a bit higher than the 95% confidence level for 2002, which was 0.43 NTU, reflecting the larger amount of variance within the 2003 data. Looking at this threshold of Turbidities higher than 0.49 NTU resulted in 67 analyses above that limit, 46 of which came from the main distribution system and 21 which came from the other isolated systems. For analytical purposes in this report, there are then two targets for comparison, the generally accepted threshold for drinking water of 1 NTU and the 95% confidence level of the 2003 data of 0.49 NTU.

City of Tucson
Water Quality Management Division
Technical Support and Development Services

Figure 1 - Maximum and Average Turbidity by System for 2003



Maximum and Average Turbidities

Figure 1 shows the average and maximum turbidities for the 11 systems comprising the Tucson Water Distribution system. On average for 2003, as was also the case in 2002, all systems were well below the accepted threshold of 1 NTU. All but one system, 10-162, averaged below the statistical 95% confidence limit of 0.49 for the data set. This system is the Silver Bell West system, serviced by well W-001A. The storage tank at the well site was recoated in early 2003, but the Turbidity in this system did not subsequently go down. It may be that because this well is very low capacity and very deep, corrosion from the large surface area of column and casing pipe per gallon of water produced, contributes to the high Turbidities. Further investigation into the cause of this Turbidity has been requested. A new well is to be drilled and equipped for this system before 2006.

Turbidity readings exceeded the 1 NTU accepted level 21 times in 2003. This number is up from five exceedances in 2002. There were 17 in the main system 10-112, and 4 in three of

City of Tucson
Water Quality Management Division
Technical Support and Development Services

the isolated systems (10-162, 10-270, 10-171). While this number is up for 2003, it represents only 0.7% of the data. The 21 exceedances are shown in Table 2.

Main system Exceedances in 2003

The exceedances in the main system occurred at 14 sample locations. There were 4 readings above 1 NTU at SP-260 and 2 at SP-595. SP-260 is located at the Skyline Country Club Estates. It appears to be on a spur line feeding only a swimming pool. That line may be corroding.

Table 2: NTU Readings above the generally accepted level of 1 NTU

System	Point	Address	T	R	S	Date	NTU
10-112	SP-065	1731 E. Orange Grove Rd.	13	14	6	11/03/03	2.21
10-112	SP-130	2617 E. Water St.	13	14	32	02/20/03	1.40
10-112	SP-140	3700 W. Orange Grove Rd.	13	13	5	08/21/03	1.10
10-112	SP-155	4750 N. La Cholla Blvd.	13	13	22	11/10/03	2.03
10-112	SP-165	310 W. Lawton St.	13	13	13	03/03/03	1.28
10-112	SP-170	6200 N. 1 st Ave.	13	13	12	12/15/03	1.05
10-112	SP-175	4223 N. Limberlost Pl.	13	13	24	4/21/03	1.42
10-112	SP-180	625 W. La Pasadita St.	13	13	23	4/21/03	2.79
10-112	SP-260	6600 N. Swan Rd.	13	14	2	8/20/03	1.00
10-112	SP-260	6600 N. Swan Rd.	13	14	2	10/1/03	1.03
10-112	SP-260	6600 N. Swan Rd.	13	14	2	11/25/03	2.56
10-112	SP-260	6600 N. Swan Rd.	13	14	2	12/22/03	1.40
10-112	SP-410	7940 S. Kolb Rd.	15	15	19	11/12/03	1.27
10-112	SP-430	3661 N. Homestead Pl.	13	16	30	10/13/03	1.04
10-112	SP-595	8427 E. 2 nd Pl.	14	15	9	8/18/03	1.04
10-112	SP-595	8427 E. 2 nd Pl.	14	15	9	10/20/03	1.84
10-112	SP-755	3210 W. Westridge	14	13	5	3/17/03	2.17
10-162	SR-262	12402 N. Lockett Rd.	11	11	31	12/29/03	1.12
10-270	SR-270	Cherokee Ln.	16	10	24	10/27/03	1.04
10-171	SR-271	3131 W. Graham St.	11	14	4	9/23/03	1.15
10-171	SR-271	3131 W. Graham St.	11	14	4	12/29/03	1.06

SP-595 is located at about Speedway and Camino Seco. The high turbidity readings there could also have been caused by line corrosion, but the sample point is in a low spot on a cul du sac, and could also be a collection point for sand in the lines. Flushing in the area would probably help.

City of Tucson
Water Quality Management Division
Technical Support and Development Services

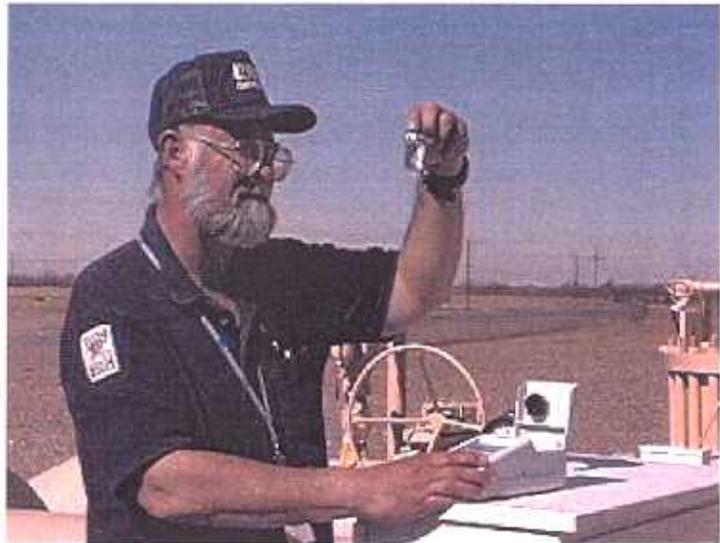
The 67 readings above the 2003 statistical 95% confidence threshold of 0.49 NTU compares favorably to the 90 readings that were above the 2002 statistical threshold of 0.43 NTU. These readings, especially those that occurred in the main distribution system, were used for further analysis to determine possible causes that may have created those high readings. The numbers of occurrences above 0.49 NTU found in the distribution systems are shown in Table 3.

Table 3: Occurrences of High Turbidity in the Distribution Systems

System	10-112	10-159	10-162	10-169	10-270	10-171	10-179	10-313
NTU > 0.49	46	3	6	1	2	5	3	1

Isolated Systems Turbidity Discussions

- 10-159 is a small system in the Diamond Bell Ranch area. The system averaged 0.39 NTU for 2003, but experienced three instances of high turbidity. The maximum Turbidity reading was 0.85 NTU. It is supplied by two wells, one of which is relatively new. These high turbidities could have been caused by the start up of the new pumping equipment.

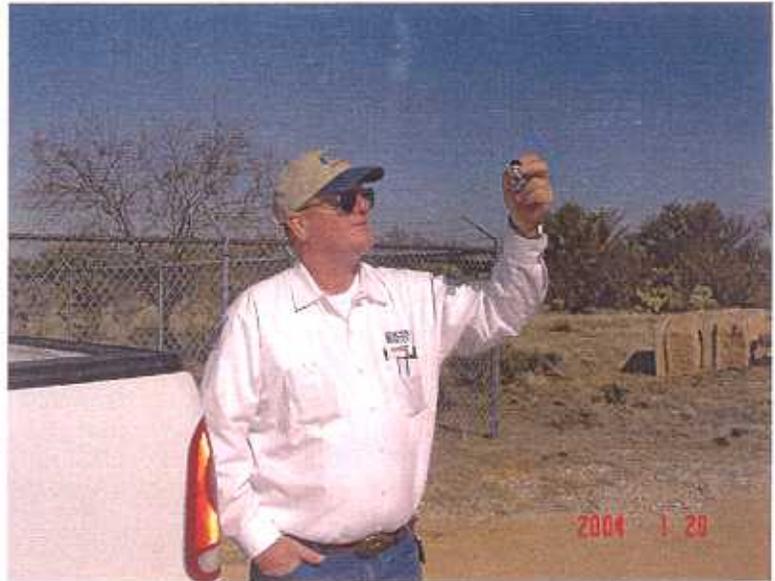


- System 10-162 is another small system, named Silverbell West that is serviced by only one well. This system also experienced high Turbidity in 2002, and as explained earlier, the inside of the storage tank at the well was recoated. For 2003, the system averaged 0.56 NTU, which is up from the 2002 average of 0.38 NTU. It experienced a total of six instances of high Turbidity, with the maximum reading being 1.12 NTU. Further investigation of the cause of this high Turbidity is warranted, because the Turbidity did not subsequently go down. As stated before, the well is scheduled to be replaced prior to 2006.

City of Tucson
Water Quality Management Division
Technical Support and Development Services

- System 10-169 serves the Corona de Tucson area, receiving water from two wells. It averaged 0.26 NTU for 2003, and only had one instance of high Turbidity at 0.55 NTU. This high reading occurred in July 2003 and may have been caused by high usage during the peak season.

- System 10-270 is a new system for Tucson Water, which came under our control May of 2003. It is serviced by one well, which underwent a lot of modernization. It averaged 0.33 NTU from May through December of 2003, with a maximum reading of 1.04 NTU. The two high Turbidity readings here were probably due to the modernization construction.



- System 10-171 serves a small area in Catalina and it too receives water from two wells. It averaged 0.50 NTU for 2003, but experienced five high readings during the year. The maximum NTU reading here in 2003 was 1.15. These high NTU instances could have been caused by the sanding nature of these two wells and possibly the continued construction in the area.
- System 10-179, named Thunderhead, serves a small area East of Old Spanish Trail adjacent to the Saguaro National Park East. It receives water from only one well. This system averaged 0.44 NTU for 2003, and had three occurrences of high Turbidity. The maximum reading for this system was 0.66 NTU. A new well has been drilled for this system, but it is not yet on line.

City of Tucson
Water Quality Management Division
Technical Support and Development Services

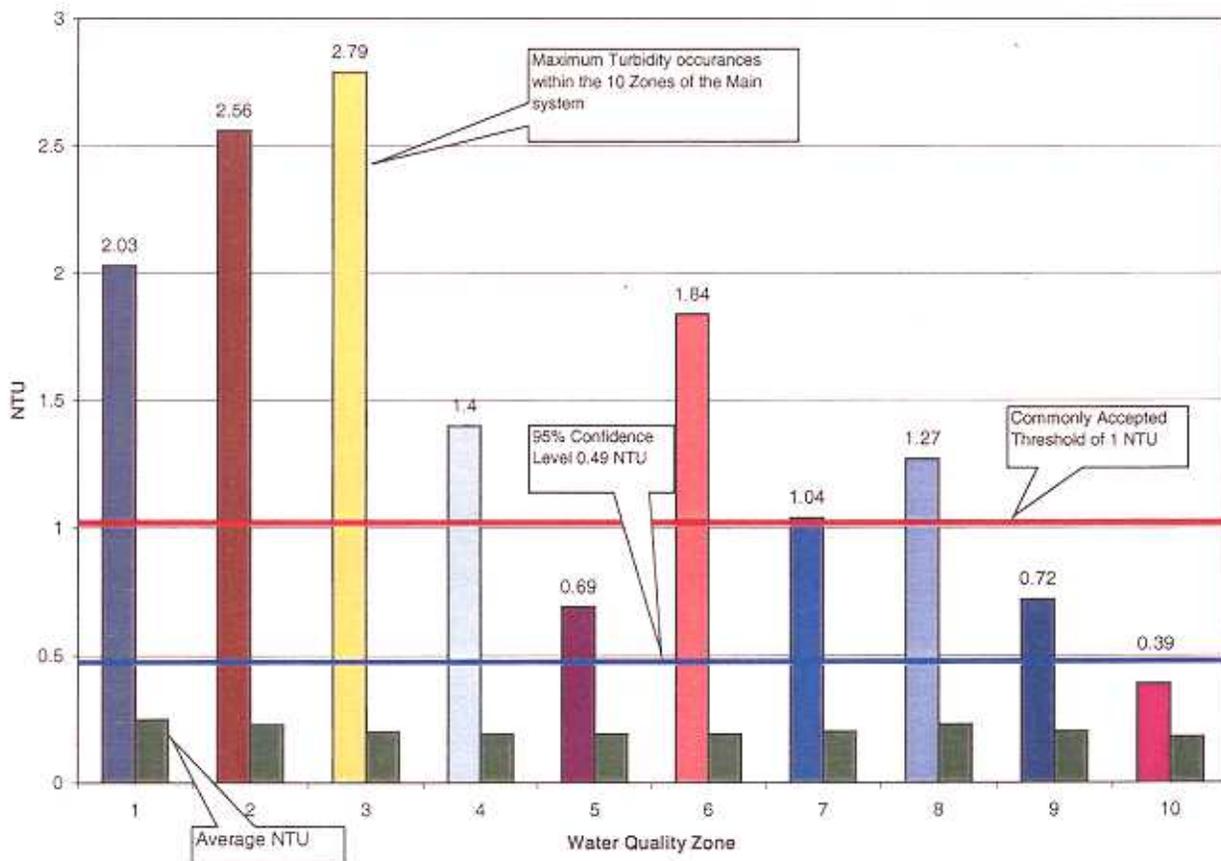
- System 10-313 is the small system serving the Fire and Police academy on South Wilmot Road. This system is also serviced by only one well, and it averaged 0.30 NTU for the year. It experienced one instance of high Turbidity at 0.59 NTU

These smaller systems are much more susceptible to higher Turbidity readings than is the main system, because maintenance, deterioration of equipment, or other possible system upsets on the one or two wells supplying their water can have a greater influence on the condition of the smaller system.

Water Quality Zones within the Main System

The main system 10-112 is divided into 10 water quality zones. This system had average and maximum turbidity readings as shown in Figure 2. The chart shows that while the

Figure 2: 2003 Maximum and Average Turbidity for the Main System Zones



City of Tucson
Water Quality Management Division
Technical Support and Development Services

average turbidity for each zone was well below the statistical high point of 0.49 NTU, all zones, except zone 10, had maximum readings above this 1 NTU threshold. Seven of the zones experienced maximum readings above the generally accepted threshold of 1 NTU. The numbers of high occurrences in the main system's zones are shown in Table 4.

Table 4: Occurrences of High Turbidity (>0.49 NTU) in the Main System's Zones

Zone	1	2	3	4	5	6	7	8	9	10
No. Above 0.43	7	15	4	3	2	3	3	5	4	0

When compared by locality within the city, zones 4 through 7, and 10 had the fewest occurrences of high readings. In 2002 zones 1,7,and 10 had the fewest occurrences. Again, as in 2002, no specific groupings of high readings were observed. Zone 2 includes eight readings above 0.49 NTU observed at SP-260 (Skyline Country Club), which causes that zone to appear higher than the others.

Relationships and Causes

Other relationships investigated such as temperature, pH, electrical conductivity did not appear to have correlations with Turbidity. Additionally, there was only 1 bacteriological positive in 2003, and it was not associated with high Turbidity measurements. The positive was at SR-239 in November 2003, and the Turbidity at the time the sample was collected was 0.16 NTU.

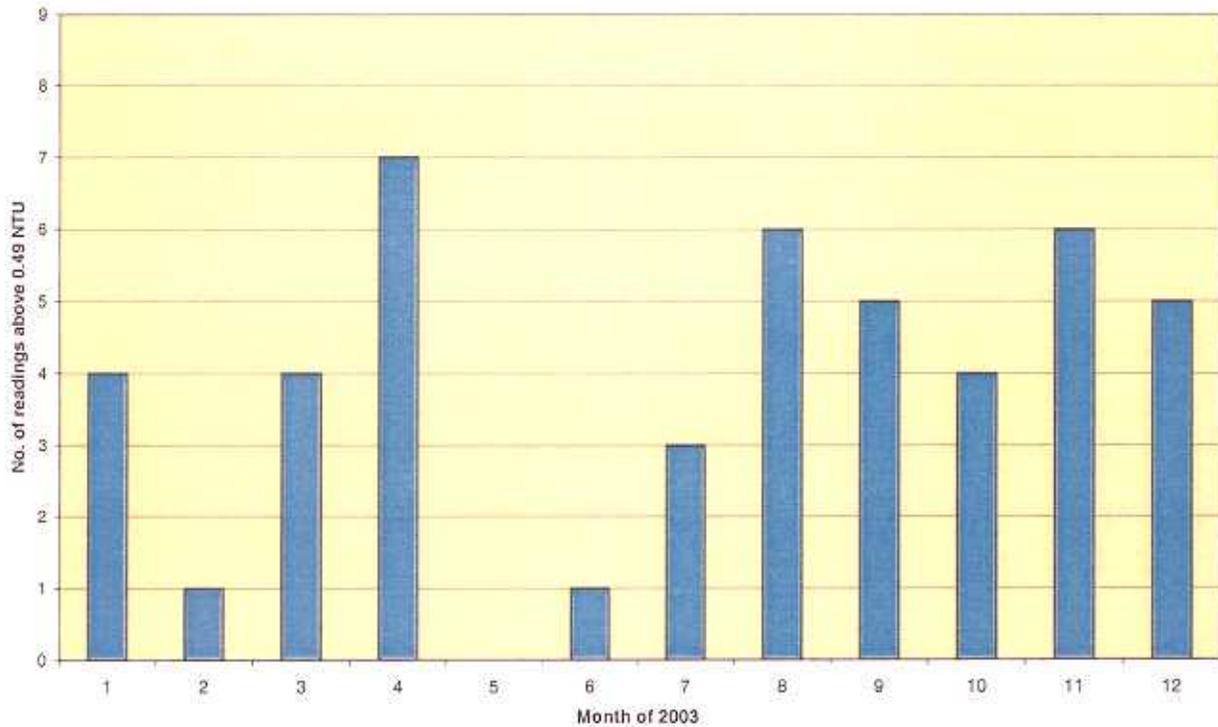


It again appears that system interruptions to the distribution systems, including hard stops and starts, can generate high turbidity readings. One potential interruption that was not considered in 2002 could be the circumstance of TSD performing routine sampling during or shortly after a flushing event. There is also evidence from SP-260, SP-595, and system 10-162 that, as the piping and equipment get older, high Turbidities can occur due to iron corrosion. It is concluded that

City of Tucson
Water Quality Management Division
Technical Support and Development Services

high Turbidity readings are generally isolated instances caused by outside influences on the system, but that iron corrosion in equipment such as well casings, column pipe, well site piping, and system valve bodies may also be contributing to high readings.

Figure 3: Main System High NTU Frequency 2003



Seasonal Impacts on Turbidity

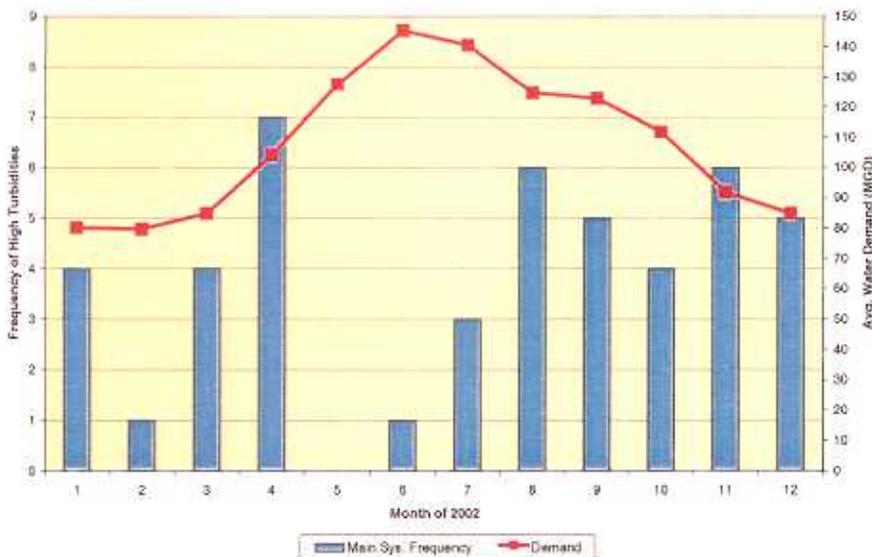
In order to look at Turbidity relationships concerning seasonal influences such as rain, and volume of water moving through the system, a frequency chart was generated to show the distribution of high readings (above 0.49 NTU) by month for 2003. This frequency distribution is shown in Figure 3. There were no Turbidity readings above 0.49 NTU in the month of May. Unlike the frequency distribution for 2002, the 2003 data does not follow a normal distribution. In 2003 there were two peak periods of high Turbidities. One is in April and the other is the period from August through December. This is quite different from 2002 when the frequency of high turbidities rose throughout the spring and summer months to a peak in August. This points out that the effects of iron corrosion on the piping systems may have had a greater effect on Turbidity in 2003 than it did in 2002.

City of Tucson
Water Quality Management Division
 Technical Support and Development Services

Water Demand and Rainfall Impact on Turbidity

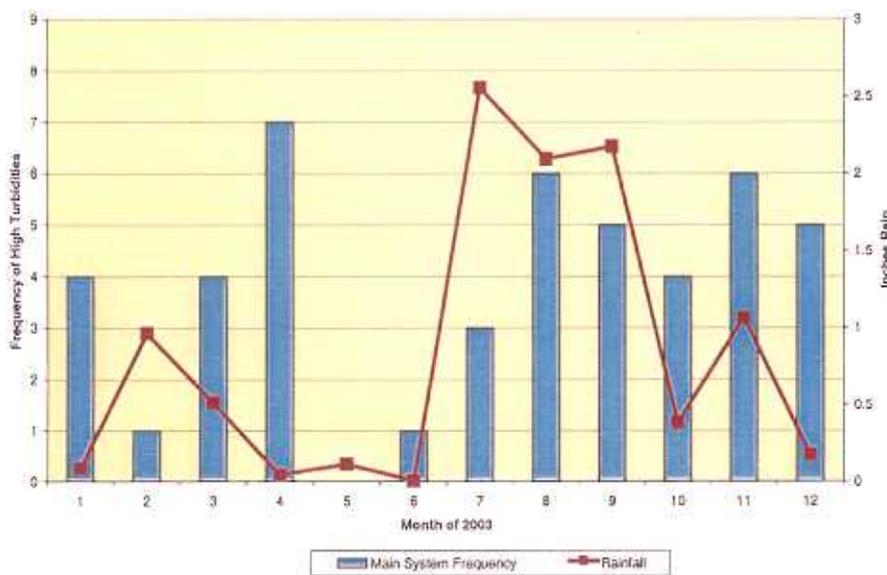
Figure 4 and Figure 5, with water demand averages and rainfall figures overlaid on the distribution show a moderate correlation between Turbidity and both water usage and rainfall.

Figure 4: Main System High Turbidities VS Avg. Water Demand 2003



that are not normally operated in order to supply the increased demand. Some of those wells, known as “sanders”, are only operated at times of high water demand. With the

Figure 5: Main System High Turbidities VS Rainfall 2003



Turbidity may be caused by the time it takes to form these cones of depression. Another

Water usage in 2003 peaked in June and rainfall peaked in July. This also happened in 2002, but in 2003 both water usage and rainfall stayed high longer into the end of summer, and the frequency of high turbidities remained up also. This may again be attributed to starting wells that are not normally operated in order to supply the increased demand. Some of those wells, known as “sanders”, are only operated at times of high water demand. With the increased flow rates, particulates that have settled in the pipelines can be picked up with the additional flow. As these wells form their cones of depression, particulate matter is potentially carried with the water. The lag between the peak demand and the peak occurrences of high

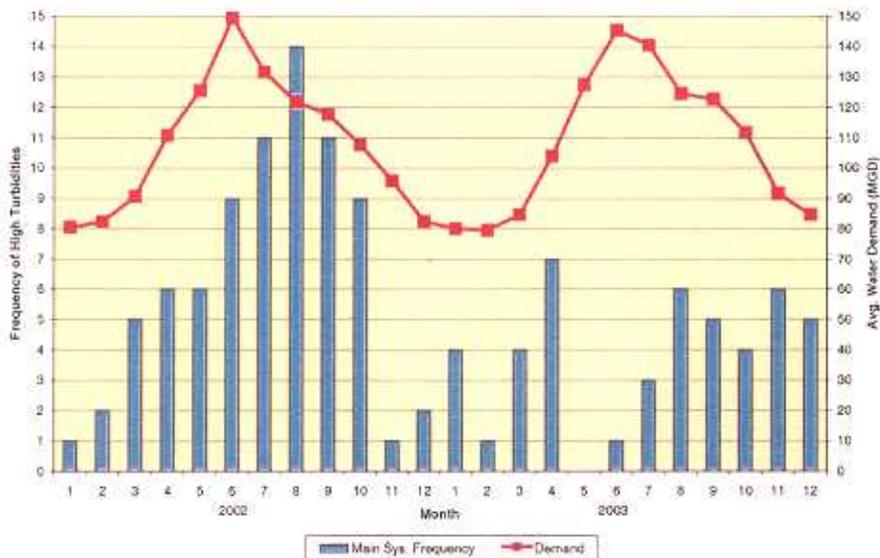
City of Tucson
Water Quality Management Division
Technical Support and Development Services

possibility for the lag could be that after the water demand hits its peak, many wells including the sanders are turned on, but then as wells are shut off due to declining demand, the sanders are left on. Potentially, therefore a higher percentage of the water is produced by high Turbidity wells, as compared to other months.

Although it is generally accepted that the water table is not affected by a rainfall event, the amount of rainfall received similarly showed a slight relationship with the frequency of high Turbidities. Inches of rainfall peaked in July and remained higher during August and September than it did in 2002. The frequency of high turbidity readings hit its second peak of the year in August and remained up for the remainder of the year.

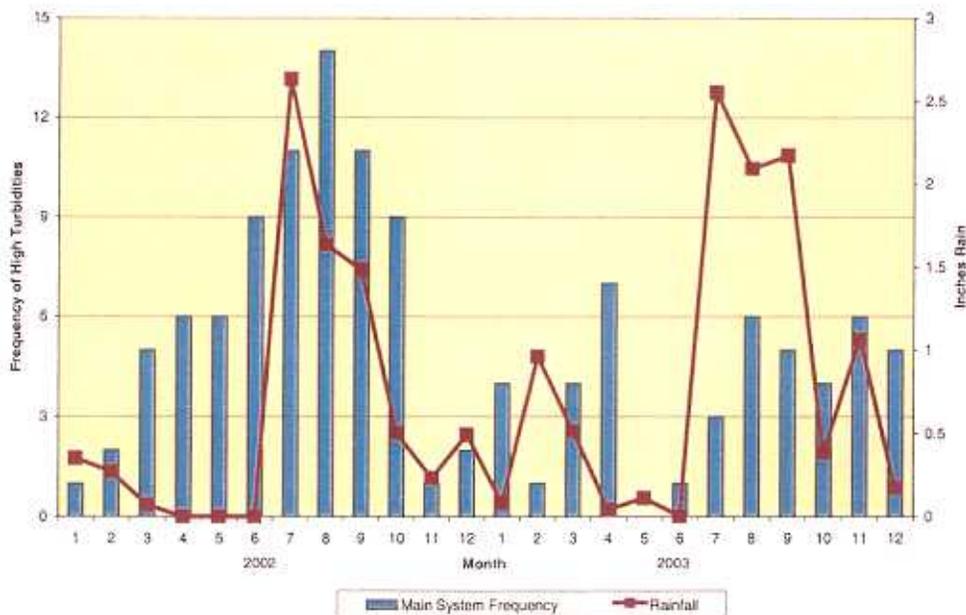
In order to better see the relationship of water usage and rainfall, figures 6 and 7 show high Turbidity frequencies plotted against water usage and rainfall for the combined years of 2002 and 2003.

Figure 6: Main System High Turbidities VS Avg. Water Demand 2003 & 2003



City of Tucson
Water Quality Management Division
Technical Support and Development Services

Figure 7: Main System High Turbidities VS Rainfall 2002 & 2003



From these two charts it is apparent that usually when the demand or rainfall increases, elevated Turbidity readings will follow.

Conclusions

The forthcoming interpolations are based on our analysis of the data.

- The entire Tucson Water System, averaging 0.21 NTU in 2003, operated at Turbidity levels well below the generally accepted threshold of 1 NTU for both 2002 and 2003. All but one small isolated system (10-162 Silver Bell West), which had a known equipment deterioration problem, operated at Turbidity levels below the statistical threshold of 0.49 NTU
- Turbidity readings above 1 NTU only occurred 21 times in 2003, out of a total of 3,114 readings (less than 1 per cent). This is a great assurance that we produce a high quality water.
- System upsets, maintenance work, and corrosion of equipment may cause high Turbidity readings, especially in the small isolated systems, as evidenced by system 10-162.

City of Tucson
Water Quality Management Division
Technical Support and Development Services

- A correlation has been determined between Turbidity, and water usage and rainfall. As water usage and rainfall increased, the occurrence of high Turbidities followed.
- No correlation has been found between Turbidity and temperature, pH, or electrical conductivity, either in 2002 or 2003.
- No correlation was evident between Turbidity and bacteriological/Coliform positives.
- Except for certain sample points known to be experiencing the effects of equipment deterioration, no specific areas of high Turbidity were found within the main system.



Insight

This investigation revealed that overall Tucson Water continues to provide drinking water of the highest quality and aesthetics. Additionally, keeping track of Turbidity assures that the high quality and aesthetics are maintained. Tracking Turbidity can quickly alert us to changes in water quality. Problems can then be recognized early on and corrected before they become disastrous.



**CITY OF TUCSON WATER DEPARTMENT
WATER QUALITY MANAGEMENT DIVISION
4401 S. Tucson Estates Parkway
Tucson, AZ 85735**

E-mail/Website: *<http://www.ci.tucson.az.us/water/>*

(520) 791-5256