4. Hydrology of the Olentangy River Watershed

The Hydrologic Cycle

Water on Planet Earth is dynamic constantly being recycled from the land to the atmosphere to the ocean. Rivers and streams are just a small part of what is called the **Hydrologic Cycle** (Figure 4-1). In fact, freshwater, so critical to our discussions here, makes up less than 3% of all of the available water on Earth, with the vast bulk of the planet's water being saline and filling the ocean basins. Of the remaining 3% that is freshwater, 2.14% is tied up as ice in glaciers, 0.61 % comprises **groundwater** stored beneath the ground surface, and slightly less than 0.01 % makes up **surface waters** – rivers, streams, lakes, and ponds.

Figure 4-1 shows the **hydrologic budget** for Ohio, illustrating the relationships between atmospheric precipitation, surface water run-off, and groundwater storage and flow. As can be seen in the figure, most of the precipitation (68%) eventually returns to the atmosphere through evaporation and transpiration. The bulk of the flow of water in streams and rivers is from **surface water run-off**, augmented to varying degrees by **groundwater discharge** to these surface waters. The contribution of groundwater flow to surface water streams becomes especially critical during droughts when the contributions to stream flow from run-off drops to nearly zero.

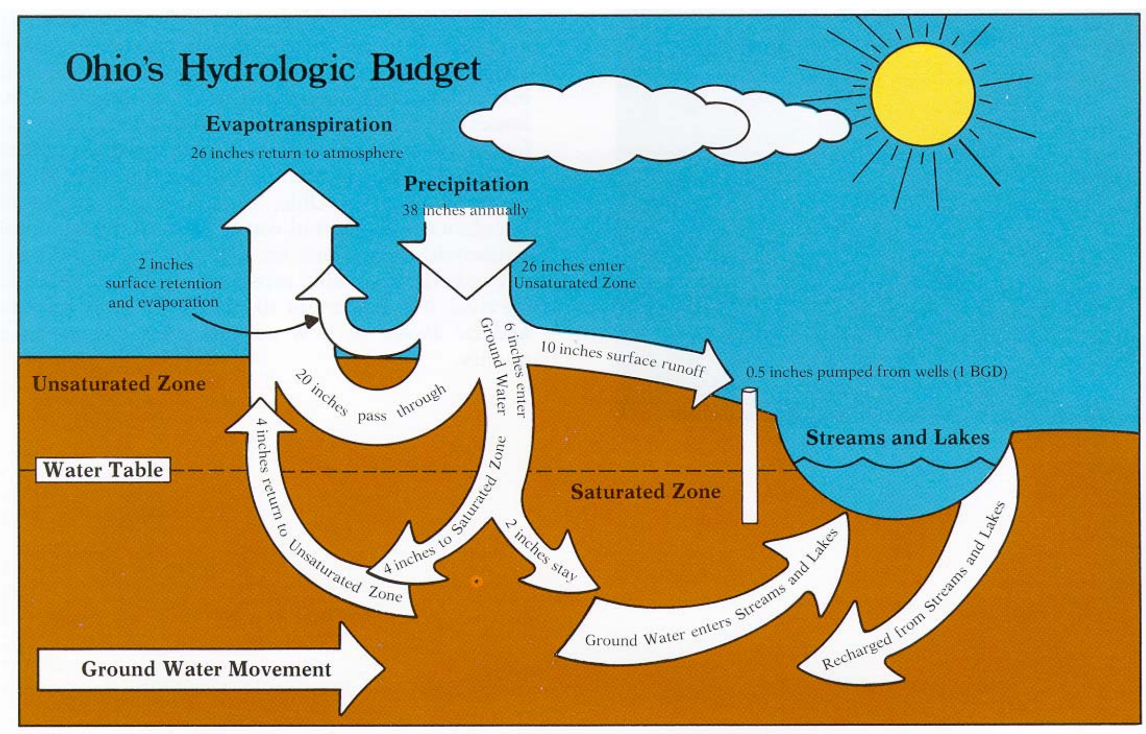

Figure 4-1: Hydrologic Budget. Source: Groundwater, Ohio EPA, July, 1987.

Climatic Conditions in the Watershed

Reviews of historical climate records for central Ohio indicate that within the Olentangy River Watershed, annual temperature averages 50-51 degrees Fahrenheit and average annual precipitation is 36-37 inches (Harstine, 1991). In terms of precipitation, there is significant seasonal variation with the wettest months (averaging > 3.5 inches) being January, May, June, and July, and the driest months typically being February and October (< 2.5 inches). As indicated in Figure 4-1, slightly more than 2/3 of the annual precipitation is returned to the atmosphere through evaporation and transpiration, leaving 10-12 inches as overland surface run-off. Depending on local soil conditions, up to 2 inches of this run-off can be lost as infiltration through the surface soils to the groundwater.

Stream Flow

The amount of overland surface water flow in a watershed is typically measured as **stream flow**. Overland flow occurs when the rate of precipitation in an area exceeds the rate of infiltration capacity of local surface soils. The resulting stream flow is measured in terms of volume of water moving past a reference point during a given interval of time. Usually, this is presented as **cubic feet per second** (cfs) or **millions of gallons per day** (MGD). Besides the amount of surface water run-off entering the stream, stream flow is also a function of the size of the stream channel, the roughness of the stream channel, and the slope or **gradient** of the stream channel. Generally speaking, the broader and smoother the stream's channel and the steeper the stream's gradient, the greater the flow in the stream. Stream flow increases downstream as the stream broadens and the volume of water discharging into the stream increases as the area drained by the river increases.

The amount of water that enters a stream as groundwater discharge from underlying bedrock or glacial **aquifers** is known as the stream's **baseflow**. Streams may be either **gaining streams** that receive groundwater discharge, or **losing streams** that lose water through their bed to groundwater infiltration. Whether a stream is a "gaining stream" or a "losing stream" is dependent on local climatic conditions and the porosity and permeability of the geologic strata underlying the stream. Typically, gaining streams are characteristic of humid climates and losing streams make up the bulk of the streams in arid climates. In temperate Ohio, many streams alternate back and forth, depending upon seasonal variations in rainfall.

Vegetative cover can have a major impact- slowing or diverting the flow of surface water run-off, with broad-leaf trees diverting as much as 35% of annual precipitation through leaf and twig "interception". Some of this water is absorbed by the tree through its leaves and may be returned to the air through transpiration. The rest may eventually find its way to the ground as "stem flow" where it may infiltrate into the surface soils or be released as surface water. Mixed hardwood forests in the eastern U.S. can absorb or divert an average of 20% of the precipitation falling in an area (Fetter, 1988). Forest cover can dramatically slow down the effects of a major rainfall event, spreading the flow of water out over an extended period of time as the water finds its way down from the tree to the ground and across the ground to the stream. This can greatly reduce the likelihood of erosion of surface soils and the development of flash flood events due to the sudden release of large volumes of water into the stream.

Other factors impacting stream flow within a watershed are the effects of dams and impoundments. These are often built for flood-control purposes, storing the water from major rainfall events and then slowly releasing this flow downstream, reducing the likelihood of downstream flooding. While disrupting or destroying in-stream habitat at the site of the dam and upstream the length of the impoundment, the dam often provides for a constant level of flow in the downstream portion of the stream, even during drought periods. This evens out stream flow in downstream portions of the watershed across the calendar year rather than having stream flow going from one extreme (flooding) to the other (no-flow or low-flows during droughts) with the seasons.

Other human impacts on stream flow include the effects of large-volume users, primarily municipal water systems, that divert large quantities of water (millions of gallons per day) from the stream on a regular or periodic basis to be used a drinking water source. These can comprise significant "withdrawals" from the **hydrologic budget**. On the other hand, there are also "deposits" being made to the stream by large-volume generators, primarily municipal waste water treatment plants (WWTPs) that can release millions of gallons a day of wastewater effluent back to the stream as part of their process water. If properly treated, this can be beneficial toward maintaining stream flow, especially to streams with low baseflows.

Stream Flow in the Olentangy River

General Stream Flow in the Olentangy River

The general flow characteristics for the main stem of the Olentangy River are listed in Table 2 (from D. L. Meyers, U. S. Geological Survey, 1998). The Olentangy River has a steeper gradient compared to other Central Ohio streams (MORPC, 1997) and can be described as a "variable stream." Stream flow in the Olentangy is directly influenced by rainfall events in the watershed. Stream flow hydrographs for select locations along the Olentangy River show highly irregular flow patterns marked by short, high "peaks" separated by wider, low "valleys" (see Appendix D.1). These erratic flow patterns represent typically low stream flow punctuated by short-duration, heavy rainfall events resulting in pulses of run-off entering the river and moving downstream. Reviews of historical stream flow measurements for selected U.S. Geological Survey gauging stations along the length of the river typically show strong correlations between the stream flow at any given point along the river and precipitation events that often affected the entire watershed (see Appendix D.1). This demonstrates the direct connection between rainfall events, surface water run-off, and stream flow in the river.

Site-Specific Stream Flow Data for the Olentangy River

Stream flow data for specific U.S. Geological Survey stream gauging stations along the Olentangy River and for a few of its tributary streams are presented in Tables 3 and 4. Data presented are for the time periods between 1978 and 1981 and between 1996 and 1999 as, in some cases, these time periods were the only ones for which stream flow data were available. Claridon is in eastern Marion County. The second site is just below the Delaware Dam, north of the city of Delaware, in Delaware County. Both of these gauging stations are within the Upper Olentangy River Sub-basin (Figure 2-2). The remaining two stations, just below the I-270 Bridge in Worthington and at the Henderson Road Bridge in Columbus, are in Franklin County within the Lower Olentangy River Sub-basin (Figures 2-2 and 2-3).

Very little stream flow data is available for tributary streams to the Olentangy River. Data were available for Whetstone Creek, a major tributary of the Olentangy River north of the

Delaware Dam, for the time period following 1996 (Table 4). Additional data are available for several tributary streams in northern Franklin County for the years between 1978 and 1981 (Table 3).

As indicated above and in Tables 3 and 4, stream flow in the Olentangy River exhibits wide swings in terms of peak and low-flow events, indicating the importance of major rainfall events on stream flow across the watershed. As an example, stream flow in the river at Claridon above the dam ranged from a minimum of 2.0 cfs to a maximum of 6,550 cfs. However, annual mean stream flow measurements obtained from the U.S. Geological Survey indicate a regular increase in stream flow in the Olentangy River from Claridon (179 cfs) downstream to just below the Delaware Dam (425 cfs) to Worthington (543 cfs) to the Henderson Road Bridge in Columbus (677 cfs). Some of this increase in annual mean stream flow might be attributable to the effects of controlled releases from the Delaware Dam by the Army Corps of Engineers (ACOE), boosting downstream stream flow during dry months and controlling peak flows following major rainfall events. The remainder of the increased stream flow in downstream portions of the river is due to the increased area of the watershed drained by the river with increasing distance downstream from the river's source and increased proximity to the river's confluence with the Scioto River in Columbus.

Poor Baseflow in the Olentangy River Watershed

Along with Alum Creek, the Olentangy River suffers from poor baseflow characteristics compared to other streams in central Ohio (Harstine, 1991; Tables 3 & 4). Studies of the watershed's geology and groundwater resources (Schmidt, 1960) indicate that the Upper Olentangy Sub-basin and northern portions of the Lower Olentangy Sub-basin have low baseflows due to the largely impermeable, groundwater-poor nature of the geological materials that underlie the bulk of the watershed (Figure 4-2 and Table 1). The Olentangy River flows either over clay-rich glacial tills, as it does in the Upper Sub-basin; or over shale bedrock as its does in the upper half of the Lower Sub-basin. Neither material makes for a good source of groundwater storage, and consequently groundwater recharge of the river is minimal, leading to seasonal low flow levels, especially during drought periods. Tributary streams of the Olentangy River flow over the same clay-rich tills or shale bedrock, limiting infiltration of rainwater into the ground and the availability of groundwater to recharge these streams during drought periods. While stream flow data for the tributaries of the Olentangy River are limited outside those available for Whetstone Creek, data for select tributaries in the Lower Olentangy River Sub-basin in Franklin County indicate that these streams are often ephemeral with very limited or no stream flow recorded during the drier months in the late summer and early fall (Table 3).

The possible exception to this general trend of low base flow would be the lower half of the Lower Sub-basin in Franklin County where the river is locally underlain by substantial thicknesses of groundwater-bearing permeable sand and gravel deposits (ODNR well logs). However, accumulations of clay-rich muck and alluvium flooring the channel of the river in the numerous "modified" stretches of the lower main stem and the high degree of impervious cover (up to 78%) resulting from urban land use along this portion of the river, may combine to limit the recharge capacity of the groundwater aquifer underlying the river's flood plain in Franklin County.

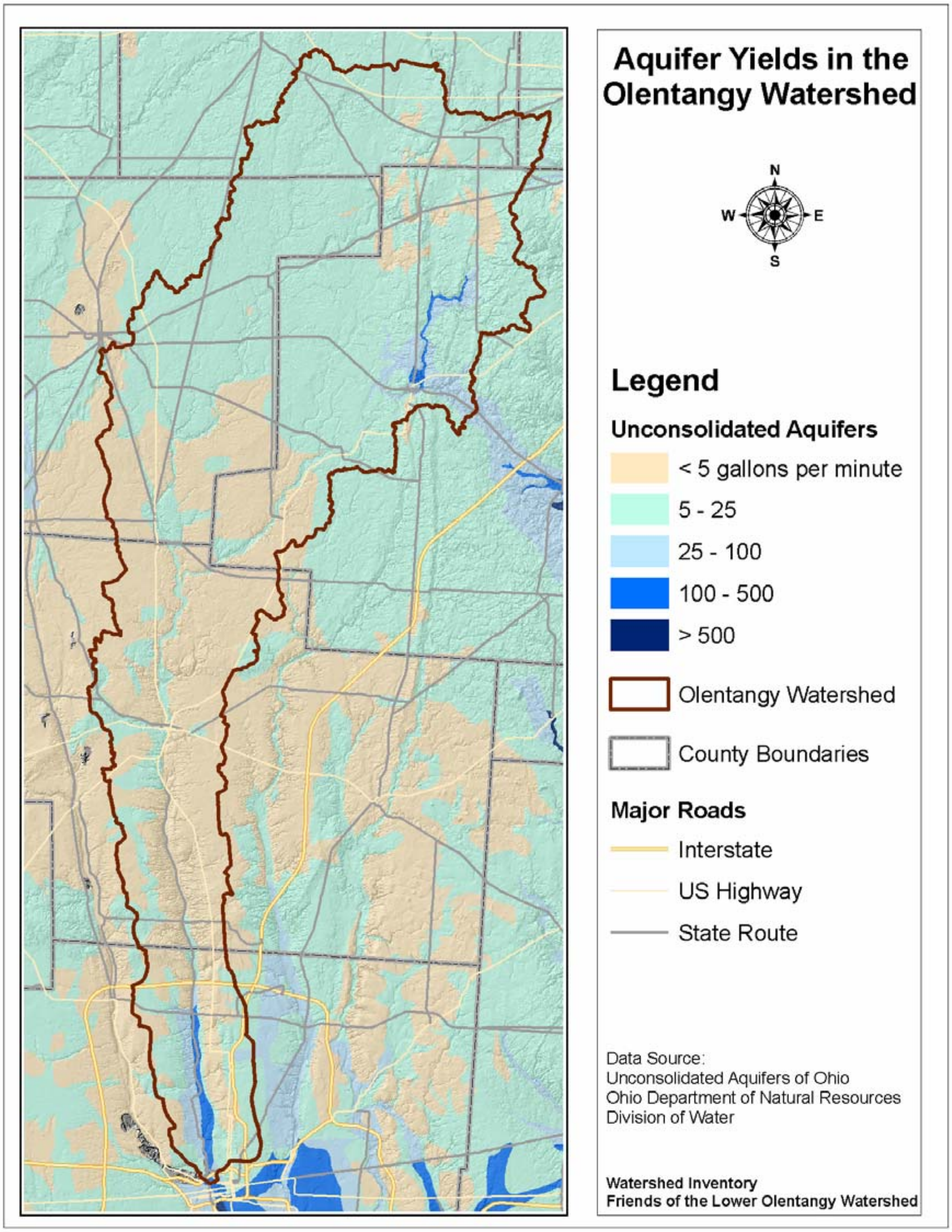

Figure 4-2: Aquifer Yields in the Lower Olentangy Watershed

Effects of Deforestation and Impermeable Surface Areas

Other factors affecting stream flow in the Olentangy River watershed include the lack of extensive forest cover across much of the watershed, due to deforestation associated with row-crop agriculture in the Upper Sub-basin and due to the increase in impermeable surface area (from 2.7 to 78%) resulting from urbanization in the Lower Sub-basin (ODNR, REALM, 2000). Deforestation reduces the retention time of rainfall falling on the land surface and contributes further to the erratic nature of stream flow in the Olentangy River and the rapidity in which rainfall events can affect flow across the watershed. As indicated above, extensive mixed hardwood forest cover can slow or divert as much as 20% of the annual precipitation in the watershed, mitigating the effects of major rainfall events, spreading the flow of water out over an extended period of time, reducing the likelihood of soil erosion and the occurrence of flood events due to the sudden release of water to the stream.

The lack of extensive forest cover across the entire watershed and the high percentage of impermeable surface area in the Lower Olentangy River Sub-basin allow rainfall events to generate short pulses of high surface water flow that can scour the adjacent land surfaces and transport turbid, sediment and nutrient-laden water directly into the stream, adversely impacting water quality and aquatic biotas in downstream portions of the stream. Many tributaries, especially in southern Delaware County, are short and relatively straight and flow on impervious shale bedrock so that they function like culverts shunting runoff directly down into the river. Sediment load data for the Olentangy River watershed are, however, limited. Sediment load and stream flow data for two gauging stations in the Lower Sub-basin in Franklin County were available for the years between 1978 and 1981 (U.S. Geological Survey). These data indicate rare maximum sediment loads of up to 27,400 tons per day with these higher sediment loads being typically associated with high stream flow events (Table 5). Low stream flow in the river (< 30 cfs) in the months of September and October of these years resulted in the smallest sediment loads recorded for these sections of the river (< 1.0 ton per day).

Effects of the Delaware Dam on Stream Flow in the River

The impacts of the lack of forest cover in the Upper Olentangy River Sub-basin with regard to increased sedimentation and run-off into the river are mitigated downstream to a great extent by the effects of the Delaware Dam and its upstream impoundment (Delaware Lake). Suspended sediments and bed load carried by peak flows incurred in upstream portions of the river are deposited when stream flow in the river comes into contact with the standing water in the impoundment. As a result, the lake serves a sediment sink with the upstream river-transported sediments being deposited in the lake, accumulating seasonally behind the dam. Delaware Lake has lost roughly 15% of its storage capacity to sedimentation since the dam was built in 1949 (see Appendix D.2). However, the Delaware Dam is a bottom release dam, therefore sediments that have settled to the bottom of the Lake are released downstream.

As indicated above, the Delaware Dam also controls downstream flow in the Olentangy River, mitigating the impacts of flood events generated by heavy rainfall events in the Upper Sub-basin and maintaining a minimum rate of stream flow in the Lower Sub-basin during droughts. U.S. Geological Survey stream flow measurements from immediately below the dam ranged from 2.0 to 21 cfs (1.3 to 13.65 MGD) between 1978 and 1981 and from 5.5 to 19 cfs (3.6 to 12.35 MGD) for the same gauging station between 1996 and 1999 (Tables 3 and 4). These minimum flows are maintained by the Army Corps of Engineers under an agreement with the downstream municipalities that obtain their drinking water supplies from the Olentangy River (City of Delaware and Delaware County).

A Generalized Daily Hydrologic Budget for the Lower Olentangy River

The significant “deposits” and “withdrawals” affecting the volume of water in the Lower Olentangy River mainstem under low flow conditions are presented in Table 6. The minimum stream flow rate in the Lower Olentangy River is largely governed by releases from the Delaware Dam. Outflows from the dam are highly variable depending on the season and the occurrence of major rainfall events in the watershed. Typically, daily minimum flow rates do not fall below 5.0 cfs (3.25 MGD) from November to July or below 27.5 cfs (18 MGD) during the drier months between July and October when downstream water demand increases. Table 6 is based on data collected from April 6, 1999, when minimal flow rates below the Delaware Dam were down to 7.6 cfs (4.9 MGD). Daily “deposits” to downstream portions of the river based on this minimum flow level below the dam in 1999 [releases from the dam + effluent from the Delaware City Wastewater Treatment Plant + effluent from the Olentangy Environmental Control Center] added up to 14 MGD. Downstream “withdrawals” in 1999 [withdrawals by the City of Delaware Water Plant + Delco Water Co.] had a daily average of 6 MGD. This leaves a net increase in daily flow in the downstream portions of the river of 8 MGD under the lowest flow levels measured in 1999.

Under the maximum daily flow rate observed just below the dam in 1999 (=2,717 MGD) and assuming typical daily withdrawals and deposits for downstream portions of the dam, net downstream flow rates would have been significantly higher (=2,711 MGD). The low flow conditions, however, determine the baseline in terms of available water for downstream water users, canoeists and kayakers, fishermen, and aquatic biotas, as it is during these times that stream flow levels become the most critical factor to these users.

This generalized daily flow budget does not take into account stream flow from tributary streams below the Delaware Dam nor the effects of run-off from local rainfall events on downstream flow in the mainstem of the Olentangy River. These inputs increase the net stream flow in the river. For the few tributary streams in the Lower Olentangy River Sub-basin for which there are stream flow data (Table 3), the data indicate that these tributaries cease to flow during the drier months so that their impact on stream flow in the mainstem of the river would be negligible during these times of the year. No stream flow data for these tributary streams were available for the year 1999.

Future Impacts on Olentangy River Stream Flow

Discussions with Ohio EPA regulatory staff from the Division of Drinking and Groundwater and plant managers of these respective utilities brought out some important points with regard to gross stream flow in the Lower Olentangy River Sub-basin in the future. Reviewing data presented in Table 3, stream flow levels as low as 1.3 MGD have been recorded from just below the Delaware Dam in 1980. Flow rates this low in 1999 would not have been enough to meet the downstream water demands from the City of Delaware Water Plant (3.6 MGD). Increases in withdrawals from both the City of Delaware Water Plant and the Delco Water Plant in Liberty Township are likely as the population continues its explosive growth across southern Delaware County.

The City of Delaware Water Plant currently has no plans to increase its withdrawals from the Olentangy River. The city Water Plant is, however, planning on expanding its well field (from three to six wells) in the flood plain of the river north of the city of Delaware. The wells are used to augment the surface water diverted from the river and to dilute levels of nitrates and atrazine in these surface waters. Currently the well field provides 30% of the city's water supply (Ohio EPA, DDAGW, pers. comm., 2001).

The Delco Water Company currently has two operating water plants in the southern portion of the county. The Liberty Township facility, south of the city of Delaware, is taking water from the Olentangy River mainstem at a current rate of 2.32 MGD. The plant was designed, however, to take up to 7.2 MGD from the river. Four upground reservoirs currently store 700 MG on site. Delco Water also has a plant just below the Alum Creek Dam and the Lewis Center Road bridge which can take up to 4 MGD from Alum Creek. A third water supply consists of a well field in adjacent portions of Knox County.

Any potential increases in withdrawals of surface water from the Olentangy River by these two utilities will be countered by planned increases in the release of treated effluent from the City of Delaware WWTP off Cherry Street in the city of Delaware and from the Olentangy Environmental Control Center (OECC) off State Rt. 315 in Liberty Township. The city WWTP will be increasing its effluent flow to the river from a current level of 4.5 MGD to 7.7 MGD by the year 2010 (plant manager, pers. comm., 2001). The OECC has already applied to Ohio EPA to increase its discharges to the river from 4.5 MGD to 6.6 MGD effective in 2005. As can be seen from Table 6, currently about 2/3 of the downstream flow in the river at the county line consists of treated wastewater. It is likely that wastewater effluent will make up an increasingly larger percentage of stream flow in downstream portions of the Olentangy River over the next five to ten years. This makes it even more critical that regulators and plant operators insure that this wastewater effluent is effectively treated so that it does not adversely impact downstream water quality in the mainstem of the river.

Table 2: Flow Characteristics Of The Olentangy River Main Stem (from D. MEYERS, U.S. Geological Survey, 1998)

Feature	Value
Total Length:	88.5 miles
Total Drainage Area in Watershed:	543 square miles
Average Gradient:	5.5 feet/mile
Average Stream Flow:	360 cubic feet/sec or 23.25 MGD
Low Flow *	19 cubic feet/sec or 12.3 MGD
High Flow**	1,000 cubic feet/sec or 646 MGD
Flood of Record [March 21, 1927]	14,000 cubic feet/sec or 15 BGD
Most Recent Significant Flood [1959]	5,940 cubic feet/sec or 6.3 BGD
Record Drought [September 14-29, 1934]	0.1 cubic feet/sec or 0.646 MGD
Most Recent Significant Drought [April 15-18, 1986]	3.5 cubic feet /sec or 2.26 MGD
MGD = Million Gallons per Day, BGD = Billion Gallons per Day; * = exceeded 90% of the time; ** = exceeded 10% of the time	

Table 3: Stream Flow Measurements (1978-1981) From Select U.S Geological Survey Gauging Stations in the Olentangy River Watershed and Elsewhere in Central Ohio (Cubic Feet/Second)			
Location	**Minimum Stream Flow Recorded**	**Maximum Stream Flow Recorded**	**Mean Annual Stream Flow**
Olentangy River at Claridon, Marion County	2.0	6,550	179
Olentangy River just below the Delaware Dam, Delaware County	2.0	4,550	425
Olentangy River at I-270 bridge, near Worthington, Franklin County	18	5,400	543
Olentangy River at Henderson Road bridge, in Columbus, Franklin County	20	6,400	677
Rush Run in Worthington, Franklin County	0.01	107	3.3
Linworth Road Creek in Columbus, Franklin County	0.0	37	2.2
Bethel Road Creek in Columbus, Franklin County	0.0	39	0.59
Unnamed tributary stream at State Rt. 315, Columbus, Franklin County	0.0	188	NA
Big Darby Creek at Darbyville, Pickaway County	26	11,500	612
Scioto River just below Prospect, at Delaware County line	12	7,460	490
Alum Creek in Columbus, just south of Bexley, Franklin County	9.6	6,840	312
Big Walnut Creek at Rees, Hamilton Township, Franklin	53	14,000	601

Table 4: Stream Flow Measurements (1996-1999) from Select U.S. Geological Survey Gaging Stations in the Olentangy River Watershed and Elsewhere in Central Ohio (Cubic Feet/ Second)			
Location	**Minimum Stream Flow Recorded**	**Maximum Stream Flow Recorded**	**Mean Annual Stream Flow**
Olentangy River at Claridon, Marion County	0.98	4,360	196
Olentangy River just below the Delaware Dam, Delaware County	5.5	4,220	418
Olentangy River at I-270 bridge, near Worthington, Franklin County	8.7	4,300	406
Whetstone Creek at Mount Gilead, Morrow County	0.1	2,060	39.8
Little Darby Creek at West Jefferson, Madison County	0.0	4,910	188
Big Darby Creek at Darbyville, Pickaway County	3.9	19,500	634
Scioto River just below Prospect at Delaware County line	9.5	6,340	568
Alum Creek in Columbus just South of Bexley, Franklin County	8.4	3,520	235
Big Walnut Creek at Rees, Hamilton Township Franklin County	39	7,840	548

Table 5 : Stream Flow and Maximum Sediment Load Data Recorded for Two U.S. Geological Survey Gauging Stations in the Lower Olentangy River Sub-Basin in Franklin County (USGS, 1979-81)					
Olentangy River Near Worthington			**Olentangy River at Henderson Road Bridge, Columbus**		
Date	**Stream Flow (cfs)**	**Sediment Load (tons/day)**	**Date**	**Stream Flow (cfs)**	**Sediment Load (tons/day)**
9/14/79	5,200	5,900	9/14/79	6,810	15,800
3/11/80	4,260	6,290	3/11/80	4,670	4,820
6/2/80	3,150	12,100	6/2/80	3,470	11,900
4/12/80	2,460	3,990	4/12/80	3,310	20,000
6/12/81	3,400	6,330	6/12/81	3,350	27,400
cfs = cubic feet/second					

Table 6: General Hydrologic Budget for the Lower Olentangy River Under Minimum Flow Conditions In 1999	
Significant Water Deposits (MGD)	**Significant Water Withdrawals (MGD)**
Stream Flow in the Olentangy River just below the Delaware Dam in April, 1999 = + 4.94	
	City of Delaware Water Plant off of US. Rt. 23, north of Delaware [Average withdrawal from the river in 1999] = -3.6
City of Delaware Pollution Control Center, Cherry Street , Delaware [Average daily effluent discharge] = +4.5	
	DelCo Water Company Liberty Township Plant [Average daily withdrawal from the river] = -2.32
Olentangy Environmental Control Center in Liberty Township [Average daily effluent discharge] = +4.5	
Total Flow in the Olentangy River downstream of the Delaware Dam in Delaware County= +13.94 MGD	Total withdrawals from the Olentangy River downstream of the Delaware Dam in Delaware County = -5.92 MGD
Net Flow under minimum flow conditions in the Olentangy River at the Delaware-Franklin county line, April, 1999 = +8.02 MGD. MGD = million gallons/day	