# Water Allocation Under Scarcity

***Grace M. Johns and Jay Yingling***

Florida's water management districts are required by Florida Statute to establish minimum flows and levels (MFLs) for surface water and ground water resources within their jurisdiction. The intent of the legislation is to protect the state's water resources by restricting new permitted water withdrawals from the resource once actual flows and levels reach the established minimum flows and levels. In general, the amount of water available from these sources once minimum flows and levels are attained is referred to as safe yield.

Because of water abundance, the existing water allocation system in Florida has been very efficient in allocating water supplies. As water withdrawals from freshwater sources approach or exceed safe yield estimates, it becomes essential to design and implement methods that guide the allocation and use of limited freshwater supplies and that encourage alternative water source development while minimizing the cost of water. As relatively inexpensive fresh water sources become increasingly scarce, water supply utilities in growing areas will be faced with fewer and more expensive water supply options. Allowing creative methods to reallocate freshwater supplies provides another potentially lower cost water supply option. Other water users, particularly agriculture, can also benefit from these methods.

The goal of fresh water management under scarcity is to design methods so that the regional economy and its people can enjoy the greatest possible net benefits from water use while maintaining the sustainability of water and related natural resources. To this end, alternate methods should be evaluated with respect to (1) maximizing the efficiency in allocating water to permittees, (2) improving the efficiency of water use by permittees, and (3) promoting the development of economically feasible alternative water sources.

This paper describes a water reallocation mechanism specifically applied to Florida that can meet the goals under scarcity conditions and provide benefits to water supply utilities. The mechanism, called voluntary reallocation, was first introduced in MFL rulemaking for SWFWMD's Southern Water Use Caution Area in 1993. This paper also describes the benefits of voluntary reallocation to water supply utilities and the public as specifically applied to Florida and highlights the existing legal and political issues affecting its implementation.

### Application of Voluntary Reallocation in Florida

The use of market-like mechanisms for allocating scarce freshwater has been debated in Florida for many years and the debate continues. To date, no state agency has implemented such a program. In the 1984 *Florida Water Resources Atlas*, economists Lynne, Moerlins, and Milliman discuss the potential role of water markets in Florida. In Chapter 17, "Water Economics and Finance," they state:

"From an economic perspective it appears that some mix of the public and private approaches could provide for economically efficient and equitable results. The private, market-oriented system tends to be very efficient; however, the public sector may be better equipped to identify the true social costs and thus the social and economic efficiency of certain activities and to evaluate appropriately benefits and costs in the public interest. Determining the appropriate mix of public and private involvement is an important economic policy issue that deserves further research and debate in Florida."[1]

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A 1997 report by the Florida Office of Program Policy Analysis and Government Accountability recommended that Chapter 373, (The Water Resources Act) Part II, Florida Statutes, be amended to allow voluntary reallocations of supplies within stressed areas. According to the report, "Proponents contend that voluntary reallocation allows markets to help determine what the most economically efficient uses are at any given time, while still protecting the environment and existing legal users."

The Florida Water Resources Act addresses the allocation of water under scarcity. Chapter 373.233, Florida Statutes, titled "Competing Applications," states: "(1) If two or more applications which otherwise comply with the provisions of this part are pending for a quantity of water that is inadequate for both or all, or which for any other reason are in conflict, the governing board or the department [DEP] shall have the right to approve or modify the application which best serves the public interest. (2) In the event that two or more competing applications qualify equally under the provisions of subsection (1), the governing board or the department shall give preference to a renewal application over an initial application."

Water transfer mechanisms should efficiently and equitably reallocate water from constrained freshwater sources in a manner that encourages the efficient use of water and alternative source development. The sufficiency of the competing applications provision to achieve these goals will not be tested until the water management districts begin to significantly limit additional freshwater withdrawals from specific sources. Without additional guidance, significant legal and administrative costs may result to water management districts when renewing permits as the affected parties present their cases to the governing board, mediate conflicts and reach agreements.

Renewing permittees who lose their permitted water quantities might not be compensated for their investment in equipment and land improvements associated with the water use activity. Perhaps most importantly, the competing applications provision, by itself, may not encourage the movement of water to new uses as the economy changes over time resulting in temporal water use inefficiencies and constrained economic development. Granting preference to existing legal users may reduce conflict but will not necessarily improve water use efficiencies or reduce potential negative economic impacts.

Where feasible, the competing applications provision could be augmented through the use of market-like approaches that assist in moving scarce water from lower-valued uses to higher-valued uses while promoting water conservation and alternative source development. The intent of market-like approaches is to provide suggestions regarding possible reallocation of water from one user to another. These suggestions will be based on the relative net benefits of water use to the new water user and the existing water user, and the distribution of alternative water source development costs and conservation costs among users. The governing board then has the right to approve or deny each proposed water transfer based upon other public interest considerations, including environmental protection.

The idea of using market-like approaches to reallocate scarce water supplies was incorporated into water use permitting revisions for the Southern Water Use Caution Area (SWUCA) in SWFWMD. The revisions to Chapter 40D-2, F.A.C., "Water Use Permitting," also known as the SWUCA Rule, were passed by the SWFWMD Governing Board in November 1994.[2]

The SWUCA Rule provided a forum by which water use permittees may voluntarily transfer all or a portion of their permitted and historically used water from the Floridan aquifer to individuals seeking access to the freshwater source. The provision was called "voluntary reallocation." Under the SWUCA Rule, the commodity being transferred was not the right to own the water but a time-limited water use permit which can be amended or withdrawn given the provisions of Florida Statutes and the Florida Administrative Code. As the proposed rule was written, if the transferring permittee was compensated by the receiving permittee, the amount of the compensation would be a private matter between the two parties. The rule was silent on the subject of if and how much someone might be compensated for reallocation.

Transfers of permitted withdrawal quantities to specific highly stressed areas would be prohibited and permitted withdrawal quantities in the source permit and the new permit would be modified to reflect certain conservation standards. The issue of water metering was not considered to be an undue burden for either SWFWMD or the permittees because SWFWMD had established a water use metering program for those permittees with permitted quantities greater than 100,000 gallons per day.

The voluntary reallocation process was expected to follow a general series of steps as follows: (1) The person who wants a water use permit files an application for a reallocation permit simultaneously with the existing permittee filing a permit modification to reduce his/her permit by the amount of the reallocation; (2) SWFWMD would assess a permit processing fee, as now, which represents some portion of the administrative cost of the permit. SWFWMD's principal responsibilities would be to (a) verify that the water quantity proposed to be transferred was in fact permitted and historically used; (b) verify that the requested transfer location is consistent with the SWUCA Rule; (c) modify the permitted quantities to reflect the conservation standards described in the SWUCA Rule; and (d) determine whether the proposed use is reasonable-beneficial, will not significantly harm existing legal water users, and is in the public interest.

If conditions (a) through (d) are met, then the district would issue a reallocation permit and modify the existing permit. The exchange contract would be finalized by the buyer and seller following SWFWMD approval. If conditions (a), (b), and/or (d) are not met, then the water quantity proposed to be transferred would be reduced or denied. The two parties have the opportunity to simultaneously withdraw their requests for voluntary reallocation and the contingency part of the contract nullifies the transaction.

### Benefits to Water Supply Utilities, the Environment and the Public

Voluntary reallocation would provide benefits to water supply utilities, the environment, and the public in that it…

- Provides an efficient and equitable process for moving water among uses as the economy changes over time.
- Results in the evolution of a water price that reflects the value of freshwater.
- Provides a strong incentive for the buyer to obtain the least amount of water necessary for profitable use.
- Provides a strong incentive for water use permittees to increase water use efficiency and/or develop other sources so that the saved fresh water can be transferred.
- Relieves water management district governing boards of the burden in deciding allocations based on efficiency.
- Allows governing boards to concentrate on public interest and external costs associated with water use.

There are two major benefits of voluntary reallocation in the SWUCA. First, it would provide an efficient process for moving permitted freshwater quantities from one user to the another when it is mutually beneficial for both parties to do so, in a manner that is equitable. As a result, it would allow permitted water quantities to efficiently and equitably move from one user to another as the economy changes over time and with a minimum of conflict since transfers would be mutually agreeable.

Second, a water "price" will evolve from the individual voluntary reallocation transactions. If the value of the freshwater is relatively high, if it's reflected in the water price, and if the price is well-known to the public, the water price will provide an incentive for permittees to conserve water so that they can transfer the saved water to other water users in exchange for monetary compensation.

As a result, permittees use their permitted water allocation more efficiently while allowing other permittees and new applicants access to freshwater for beneficial use. Because the buyer is purchasing the permitted water withdrawal, the buyer is better off obtaining the least amount of water necessary for profitable use. Therefore, water conservation and alternative water sources would be considered and used if they cost less than the water price.

Markets, when well-designed, can process technical and economic information regarding the relative marginal value of water in different uses under different conditions and encourage existing and potential water users to consider water conservation and alternative source development. Alternative water sources will be developed when their costs are below the cost to obtain water through the voluntary reallocation process. Such approaches would relieve governing boards of a significant and controversial burden of deciding which competing uses should use the limited freshwater sources from an efficiency standpoint.

This type of market approach can be applied to a confined aquifer, a surface water source, a water storage facility, or an unconfined aquifer. Market-like approaches are tools for making water transfer decisions that consider the efficient use of freshwater resources. These approaches will not work in all situations and should be evaluated on a case-by-case basis.

For example, the appropriate geographic boundaries of the water source within which voluntary reallocation may take place will be based upon the impact of the water transfers on the health of the associated water and water-related resources. This, in turn, will depend on the hydrologic characteristics of the water source and the proximity and hydrology of other affected water-related resources. In some cases, the boundaries of the water source from which reallocations could occur will be too small to be practical. In other cases, the boundaries will be large enough to achieve a voluntary reallocation system that provides for the efficient allocation of water.

The aspects of voluntary reallocation that promote the equitable allocation of water from a restricted water source are described as follows:

1. All potential water users will have the same level of access to the voluntary reallocation process especially if (1) the water management district becomes an information clearinghouse for the listing of potential buyers and sellers and the posting of water prices and quantities associated with successful voluntary reallocations and (2) the district implements measures to minimize unnecessary transaction costs.
2. Voluntary reallocation allows for compensation to the per-

mittee who is giving up his/her permitted water quantity. The compensation comes from the person who will benefit from the water use — the buyer.

3. Voluntary reallocation does not preclude the use of other methods to acquire water. Permittees whose permits are approaching their expiration date and who do not want to voluntarily transfer their water, will still have to renew their permit. Thus, expanding permittees and new water users still have access to freshwater through the competing applications process as described in Chapter 373, Florida Statutes. Applicants could be precluded from the voluntary reallocation process in cases of overwhelming public interest and exempt where an applicant has already investigated alternative water sources, conservation, and voluntary reallocation and they were found to be unfeasible.
4. The public interest test becomes stronger under voluntary reallocation because the trading of permitted quantities is conducted in public view. Unless voluntary reallocation is incorporated into rulemaking, private trades will still occur but publicly available information on access to these trades will be restricted.

Water utilities would benefit from voluntary reallocation because it represents an additional source of water which otherwise would not be available. When the cost of alternative water source development and additional water conservation is greater than the cost to acquire water through voluntary reallocation, then utilities have an opportunity to lower water supply costs. Water quantities would be available from agriculture, industry, and/or other water utilities that can conserve water or use alternative water sources at a cost less than the price of water in the reallocation market. The price paid for water obtained through voluntary reallocation would only be paid on the quantities obtained through reallocation.

### Legal and Political Issues Affecting Implementation

The SWUCA Rule, including its provisions for voluntary reallocation, was subsequently challenged by various parties through the Florida Administrative Procedures Act. The hearing officer found that the voluntary reallocation provision of the Rule "exceeds the scope of the district's delegated authority under existing Chapter 373" [3].

The hearing officer's identification of which aspects were outside of the district's legislative authority can be inferred based on the following statements included in the Final Order: "The District's proposed reallocation provisions do not establish any prioritization of use for water quantities transferred nor do they provide for disclosure or impose any other requirements regarding the agreement between the transferor and the transferee. The establishment of such a program, without specific legislative authorization, exceeds the scope of the District's delegated authority under existing Chapter 373...there is no current statutory basis for allowing or authorizing the sale of permit rights."

Thus, a "voluntary reallocation program" could be within the district's legislative authority if the rule revision *specifically* stated that a reallocation is only a permit to use the water and not a right to own the water. As was intended under the rule, the use would be permitted by the district only if the proposed use passes the three-part test as specified in Chapter 373, F.S. Under this three-part test, the proposed use is consistent with state law if it: (1) is reasonable-beneficial, (2) will not interfere with any presently existing legal use of water; and (3) is consistent with the public interest, which includes environmental protection.

In the SWUCA, historically used and permitted quantities exceeded the district's estimate of safe yield from the Floridan aquifer. Therefore, water transfers, via either competing applications or voluntary reallocation, could exceed cumulative withdrawal impact criteria for saltwater intrusion and fail the public interest test. The SWUCA Rule, including the voluntary reallocation provision: (1) restricted permitting of additional Floridan withdrawals; (2) had an overall method for reducing permitted quantities toward safe yield estimates over a ten-year period; and (3) suspended the cumulative saltwater intrusion condition of issuance so that existing permits could be renewed while permitted quantities were being reduced, and so that alternative water supplies could be developed over time. The intent was to avoid disruptive, arbitrary reductions or denials of existing permits while reductions were being addressed, and to allow Floridan water use to be moved to where it was needed in the interim.

Perhaps in recognition of the need for such a transition period, subsequent statutory provisions (373.0421(2) FS) allow for a phased "recovery strategy" when aquifer levels are below adopted minimum levels. These provisions may allow transfers to occur before quantities are reduced below their "safe yield" estimates as long as the transfers are included in the overall quantity reduction and recovery strategy.

Some have criticized the use of market-like approaches to reallocate water by citing how certain water marketing arrangements in the western United States have not lived up to expectations and have resulted in significant negative third party impacts. A 1992 report by the National Research Council called "Water Transfers in the West"[4] identifies three primary reasons why this has happened:

1. The prior appropriation doctrine used in the West is a major impediment to the consideration of public interest in the reallocation of water resources. This doctrine creates vested property rights that cannot be taken without just compensation. Thus, any water market in use under these circumstances will not consider public interest in the reallocation of water.
2. Existing laws, policies and procedures concerning water market transactions and other transfers in the West often fail to ensure either that third parties are protected from negative effects or that they share the benefits of reallocation.
3. In California, the lack of clear rules and procedures pervades the water transfer process, which results in relatively high transactions costs and relatively few water transfers.

Florida water law does not have these impediments. Florida's three-part test and its water use permitting system protects the public interest, including the environment, and allows for the consideration of third party impacts prior to Governing Board approval of the transfer. The Florida Administrative Code can clearly describe the rules and procedures that will be used to evaluate potential water transfers. In fact, Florida may be one of the few states in which market approaches to allocating water may work the best. The Florida Legislature does not need to attach private property rights to water use in order to create market incentives to efficiently and equitably reallocate water from restricted water sources and to encourage water use efficiency. All water quantities would be attached to a water use permit with expiration dates consistent with current regulations.

When water quantities from a freshwater source are restricted, potential water users and those wishing to increase their permitted water quantity may have an economic incentive to pump more water than is permitted. Thus, monitoring and enforcement above historic levels, including individual metering of water pumpage and increased fines for non-compliance, will be necessary. Voluntary reallocation does not increase the level of effort needed to prevent illegal pumping of water above that which would already be needed once a freshwater source is restricted. Therefore, no additional monitoring and enforcement efforts are required under voluntary reallocation. Voluntary reallocation allows potential water users to legally obtain water from the restricted source when additional conservation and alternative source development are not technically or economically feasible.

Another criticism of market-like reallocation approaches is that it would be unfair for certain water users to profit from water without paying for all the benefits of water supply that are paid for by the State. The fact is that water users already benefit from the water management and infrastructure improvements provided by the State of Florida. Any compensation paid to those who reallocate water from their permit would be based on the present value of those benefits that they would have received over time.

## The Future of Voluntary Reallocation Mechanisms in Florida

Market-like approaches can be a tool to assist water management districts in achieving their missions. However, there appear to be as many opponents as there are supporters of this concept. Currently efforts are underway in Florida to encourage alternative water source development by restricting fresh water supplies and subsidizing alternative water supply development through property taxes. While this approach could successfully increase water supply, it will not provide a signal to water users that Florida water resources have value beyond the cost of pumping, treatment and distribution.

As Florida's population continues to grow, water demand will likely continue to stress all forms of water resources unless the public sees a price signal associated with water use. Meanwhile, the cost of water source development is paid by the same general population regardless of whether the revenues come from property taxes or water bills. Ultimately, market-like approaches might be implemented in certain areas of Florida where other forms of reallocation and methods to conserve freshwater resources do not achieve efficiency, equity, and public interest goals.

The provision of a voluntary reallocation system in district rulemaking can be a good mix of public and private approaches to allocating freshwater from restricted sources. The commodity being reallocated is not the right to own the water but a time-limited water use permit which can be amended or withdrawn given the provisions of Florida Statutes and the Florida Administrative Code.

The water management districts consider social and environmental costs when establishing minimum flows and levels and approving individual water transfers. The private sector considers economic efficiency in the reallocation of safe yield among beneficial uses. However, these types of voluntary reallocation systems should be designed and implemented on a case-by-case basis.

## References


1. Gary D. Lynne, John E. Moerlins, and Jerome W. Milliman, "Chapter 17, Water Economics and Finance," In *Water Resources Atlas of Florida*, Institute of Science and Public Affairs, Florida State University, Tallahassee, 1984, page 245.
2. Southwest Florida Water Management District, "Notice of Proposed Rulemaking, Chapter 40D-2, Florida Administrative Code, Water Use, OGC File No. 03293" In *Florida Administrative Weekly*, December 2, 1994, Department of State, Bureau of Administrative Code, Tallahassee.
3. State of Florida, Division of Administrative Hearings, Case No. 94-5742RP, Final Order, page 517.
4. National Research Council, "Water Transfers in the West," National Academy Press, Washington, D.C., 1992, pages 191, 230 and 253.

# Automated Chlorination Control System — The Orlando Eagle Eye

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This paper presents concepts and protocol associated with the design, start-up, and operation of an automated chlorination control system based on flow, ORP, and chlorine residual. The controller is unique in design and operation in that it automatically switches, based upon a floating scale, between control by ORP and chlorine residual as setpoint for chlorine feed control.

City staff developed the Orlando Eagle Eye controller in conjunction with a local vendor. It is capable of handling process conditions that have prevented other chlorinator controllers available on the market, and tested at Water Conserv II, from functioning properly. The Water Conserv II facility, like many other plants that do not have ammonia or total nitrogen standards incorporated into effluent permits, experiences fluctuating levels of ammonia throughout the day in the final effluent. Fluctuation of ammonia in plant effluents creates difficulties regulating chlorine feed rates to maintain required chlorine residuals both in the manual mode or with traditional automatic control systems.

The city evaluated controllers available in the market and then began to develop and pilot the Orlando Eagle Eye when it was determined no off-the-shelf system met our needs. During the two-year development period, we eventually identified valuable correlations between ammonia and ORP, and the proper response to increase or decrease the chlorine feed rate to effectively control the chlorine residual of the final effluent. We documented that when ammonia levels were high, as indicated by a low ORP reading, a decrease in the chlorine feed rate was necessary to increase or maintain the combined chlorine residual. However, when ORP was high, indicating that the ammonia level is low, the chlorine feed rate must be increased in order to increase and achieve a free chlorine residual. We learned that only one setpoint signal, whether chlorine based or ORP based, could not be used for both ammonia level cases. The Orlando Eagle Eye controller determines when to use the ORP value as the control setpoint, or when to use the floating chlorine residual value as the control point, based on process conditions as identified by ORP fluctuations.

## Set the Stage

The city of Orlando's Water Conserv II Water Reclamation Facility is operated in a process control regime not intended by design. The facility expansion in 1986 increased permit capacity to 25 MGD but did not anticipate regulation of effluent nitrate limits. In 1992, an effluent nitrate limitation of 10 mg/l for a monthly average was incorporated into the facility's DEP operating permit. Since that time, the city has successfully met the nitrate permit limits without additional capital investment by altering the design mode of operation within the plug flow conventional activated sludge process. Through experimentation, city staff has modified the designer's operational protocol of the plug flow activated sludge system to allow nitrification and denitrification to take place simultaneously within the same aeration zone.

## The Culprit

Because of the modified mode of process operations implemented at the Water Conserv II treatment facility in response to the nitrate permit limitation, it is not uncommon for the effluent ammonia-nitrogen levels to fluctuate throughout the day. When ammonia levels fluctuate, chlorine demand also fluctuates in response to the changing ammonia concentration making it extremely difficult to regulate the chlorine feed rate in a flow proportional or manual mode. At times, the chlorine demand is low, while at other times, the chlorine demand is extremely high in response to the changing nitrite or ammonia levels. As ammonia and nitrite levels rise and fall, the chlorination process moves in and out of breakpoint chlorination requiring quick and accurate adjustment to the dose rate to maintain appropriate residuals.

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Fluctuations in ammonia or nitrite entering the Chlorine Contact Chamber (CCC) create swings in the breakpoint chlorination curve. When ammonia entering the CCC is low, or if nitrite is present, it requires high chlorine feed rate to achieve free and total residual. When the ammonia entering the CCC is high, it requires less chlorine feed to achieve an increased combined residual. Prior to implementation of the automated system, the operators regulated chlorine feed manually using data from inlet and final chlorine residual analyzers and an inlet ORP probe. Even though ORP is a good indicator of the presence or absence of ammonia entering the contact chamber, it is very difficult to manually catch every event when the ORP reading drops in order to make the correct adjustment to the chlorinator and maintain the effluent total residual above 1.0 mg/l. The Conserv II staff adjusted chlorine feed rate manually for several years because the automated control systems available in the industry and evaluated through on-site pilot projects were not reliable.

## Only If You're Lucky

It should be noted that Orlando's problem is unique to facilities with effluent permit limitations that do not include strict ammonia or total nitrogen levels. Facilities that have ammonia or total nitrogen limits must increase their chlorine feed rate whenever the chlorine residual values fall below desired levels. Those facilities cannot take advantage of decreasing chlorine feed rates when the effluent ammonia values increase allowing disinfection with combined chlorine residuals; they must increase the chlorine feed rate and oxidize any ammonia entering the chlorine contact chamber and always disinfect at free chlorine residual levels.

The city has experimented with traditional chlorination control systems, those that use flow plus chlorine residual, and those that use flow plus ORP. The traditional systems evaluated were unsuccessful at our Water Conserv II facility because of their slow or improper response to fluctuations in effluent ammonia levels and the inability to switch between combined and free chlorine residuals.

## Utilizing Sliding Scale Residual Setpoints

The next generation chlorinator control system, which has been designed and developed as a joint venture between Orlando and a local vendor, is referred to as "The Orlando Eagle

Eye." Based on previous experience with traditional chlorination control systems, the City wanted to combine the use of ORP and chlorine residual measurements. The Orlando Eagle Eye system controls chlorine feed rate based on signals from the CCC inlet flow meter, the CCC inlet chlorine residual analyzer, and the CCC inlet ORP meter. When ammonia entering the CCC is low, ORP will be at its highest, and the control system references ORP readings as the controlling setpoint. Operating in this mode, as ORP drops below the ORP setpoint, the chlorinator proportionately increases its output feed rate which increases the effluent chlorine residual.

| Filter Eff $NH_3$ | CCC Inlet ORP | CCC Inlet $CL_2$ Residual | Chlorinator Feed Adjustment To Be Made |
|---|---|---|---|
| 0 | 780 (CSP1) | 5.0 | No Adjustment |
| 0.4 | 740 | 4.0 | Increase $CL_2$ Feed 150 ppd |
| 0.6 | 720 | 3.8 | Increase $CL_2$ Feed 150 ppd |
| 0.8 | 680 (TSP1) | 3.1 | Decrease $CL_2$ Feed 300 ppd |
| 0.8 | 650 | 3.0 | Decrease $CL_2$ Feed 100 ppd |
| 1.0 | 630 | 2.5 | Decrease $CL_2$ Feed 100 ppd |
| 1.2 | 600 | 2.4 | Decrease $CL_2$ Feed 100 ppd |
| 1.4 | 570 | 2.3 | Decrease $CL_2$ Feed 100 ppd |
| 1.6 | 530 | 2.0 | Decrease $CL_2$ Feed 100 ppd |
| 1.8 | 500 | 2.0 (CSP2) | Decrease $CL_2$ Feed 100 ppd |
| 2.0 | 480 | 1.8 (SP3) | Decrease $CL_2$ Feed 100 ppd |
| *Low Dose Setpoint (SP5) = Switch to Flow Proportion Control* | | | |
| 2.0 | 460 | 1.6 | No Adjustment |
| 1.8 | 500 | 2.0 | Increase $CL_2$ Feed 150 ppd |
| 1.6 | 530 | 2.2 | Increase $CL_2$ Feed 100 ppd |
| 1.4 | 570 | 2.3 | Increase $CL_2$ Feed 100 ppd |
| 1.2 | 600 | 2.5 | Increase $CL_2$ Feed 100 ppd |
| 1.0 | 630 | 2.7 | Increase $CL_2$ Feed 50 ppd |
| 0.8 | 650 | 3.0 | Increase $CL_2$ Feed 50 ppd |
| 0.6 | 710 | 3.8 | Increase $CL_2$ Feed 50 ppd |
| 0.4 | 740 | 4.0 | Increase $CL_2$ Feed 50 ppd |
| 0 | 780 | 5.0 (SP4) | No Adjustment |
| *High Dose Setpoint (SP6) = Switch to Flow Proportion Control* | | | |
| 0 | 800 | 5.2 | No Adjustment |

However, when ammonia level entering the CCC increases, ORP readings will drop below an ORP trip setpoint and the control system switches to a secondary control setpoint based on total chlorine residual. As ORP readings continue to go lower in response to the presence of ammonia, the chlorine residual setpoint automatically shifts the dosage lower. The reduced chlorine feed rate favors conditions for chlorine to react with ammonia present to create chloramines, maintaining a combined chlorine residual. In the sliding scale residual setpoint mode, the lower feed rate minimizes the destruction of chloramines and prevents breakpoint chlorination from occurring, resulting in the highest chlorine residual (combined residual) with the lowest chlorine feed rate, achieving the most cost effective mode of operation.

When ammonia levels entering the CCC begin to decrease, ORP begins to rise. The rising ORP trips an early switch-back setpoint, called the "Residual to ORP" setpoint, allowing the controller's mode to revert back to the ORP based control mode.

## Cl2 Residual & ORP Sampling Location

We quickly determined through field experimentation that the locations for $Cl_2$ residual, and ORP sampling were very critical. To minimize controller lag time, the sampling location must be as close as possibly to the point where the chlorine solution is injected. However, it is equally critical that the chlorine solution and the flow stream are mixed thoroughly before sampling for $Cl_2$ residual and ORP. Incomplete mixing will result in $Cl_2$ and ORP reading being unstable, and, as a result, the operational stability of the chlorinator control system will be poor. Mixing is accomplished at Conserv II with the use of mechanical flash mixers before the flow enters the first bay of each contact chamber.

## Program Development

Initial development of the Orlando Eagle Eye program started in a classroom. A brainstorming session was conducted with key staff members of Orlando's Wastewater Bureau to document various scenarios regarding our experience with chlorine residual instability as ammonia levels rise and fall. That initial meeting produced the accompanying table, which documents our experiences at the Conserv II facility regarding ORP readings, chlorine residual readings, and chlorine dose rates at various ammonia levels, and which describes our initial design concepts of the automated chlorination controller system.

## The First Program Version

The first version of the program utilized firm setpoints to allow the chlorinator to be controlled from ORP when ammonia was absent from the flow; this condition was indicated by a high ORP reading. In this mode of operation, an ORP setpoint controlled the output of the chlorinator and adjusted chlorine feed rate to match the ORP control number. As ORP dropped, the chlorine feed rate would increase to maintain the ORP setpoint. As the ORP reading increased, the chlorine feed rate would decrease, again, to match the ORP control number. However, if the ORP value dropped to a low level, and tripped a transitional ORP setpoint, the control mode would automatically switch to a chlorine residual setpoint as the control mode.

## Another Ten Versions Followed

The more we experimented, the more we learned. Possibly the most important lesson was that firm setpoints did not work well. This method of switching modes from ORP control to $Cl_2$ residual control created high swings in the feed rate, and caused our effluent residual to go lower than 1.0 mg/l. The program modification that makes this system different than any other we have piloted involves how the control modes are switched, and then how the setpoints are determined. The program uses sliding scale setpoints instead of fixed setpoints to make the proper adjustments.

The final version program utilizes various setpoints and alarm features associated with the following signals: 1) Flow Rate, 2) $Cl_2$ Residual, 3) ORP, 4) Chlorinator Auto Valve, 5) $Cl_2$ Controller, 6) ORP Controller, and, 7) General System Setpoints.

The sliding scale setpoint program modification allows the

### Legend and Description of Initial Chlorination Control System Setpoints

| Tag | Legend | Signal | Function |
|---|---|---|---|
| CSP1 | Control Setpoint #1 | ORP | Control Setpoint #1 is adjustable and will automatically control the chlorinator, using flow and ORP, when the ammonia is low to zero. |
| TSP1 | Transition Setpoint #1 | ORP | Transition Setpoint #1 is adjustable and indicates that the chlorine feed rate will be decreasing; ORP is still falling. |
| CSP2 | Control Setpoint #2 | $Cl_2$ Res | Control Setpoint #2 is adjustable and will automatically switch the control from flow & ORP to flow & $Cl_2$ residual when this low $Cl_2$ residual setpoint is tripped. |
| SP3 | Setpoint #3 | $Cl_2$ Res | Setpoint #3 is adjustable and indicates a low chlorine residual condition. This condition will activate an alarm on the controller, and will not allow any further reductions in chlorine feed, even if the ORP or $Cl_2$ residual continue to drop. When SP3 is tripped, the control mode switches to flow proportioning, until CSP2 is reached. |
| SP4 | Setpoint #4 | $Cl_2$ Res | Setpoint #4 is adjustable and indicates a high chlorine residual condition. This condition will activate an alarm on the controller, and will not allow any further increases in chlorine feed. When SP4 is tripped, the control mode switches to flow proportioning, until CSP1 is reached. |
| SP5 | Setpoint #5 | $Cl_2$ Dose | Setpoint #5 is adjustable and indicates a minimum chlorine dose rate. This condition occurs when the chlorine residual, and the ORP, are at their lowest acceptable levels for the prevailing ammonia condition (which is at its highest concentration). This setpoint will activate an alarm condition on the controller, and will provide an automatic back-up, preventing any further decrease adjustments in the chlorine feed rate. At the tripping of SP5, the control mode switches to flow proportioning, until CSP2 is reached. |
| SP6 | Setpoint #6 | $Cl_2$ Dose | Setpoint #6 is adjustable and indicates a maximum chlorine dose rate. This condition occurs when the chlorine residual, and the ORP, are at their highest acceptable levels for the prevailing ammonia condition (which is at its lowest concentration). This setpoint will activate an alarm condition on the controller, and will provide an automatic back-up, preventing any further increase adjustments in the chlorine feed rate. At the tripping of SP6, the control mode switches to flow proportioning, until CSP1 is reached. |

ORP control mode to be active when ammonia is absent; the chlorine residual mode becomes active when the ORP falls and trips a pre-selected setpoint. When this occurs, the chlorine residual setpoint becomes a sliding scale number based on the actual ORP value. In the event of increasing ammonia, as the ORP value gets lower, the chlorine residual setpoint automatically gets lower. This scenario reduces the chlorine feed rate, which is necessary to prevent the chloramines from being destroyed and to remain in the combined residual state. The result of this mode is a higher chlorine residual with a lower chlorine feed rate. As the ORP rises, indicating ammonia is decreasing, the chlorine residual setpoint automatically increases, allowing an increased chlorine feed rate. This occurs until the rising ORP value trips a pre-selected setpoint which then passes control back to the ORP mode.

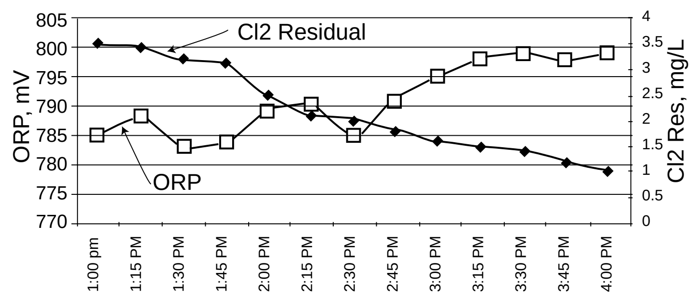


Figure 1. Event No. 1. ORP is rising while Cl2 residual is falling, which indicates that ammonia is not the cause for the falling residual and the chlorine feed should be increased to increase the chlorine residual.

### ORP and $Cl_2$ Residual Events

Event Number 1 (Figure 1) describes a condition often experienced at the Conserv II Facility. This condition depicts the controller making an increased adjustment to allow the effluent residual value to increase when the ORP is rising and the $Cl_2$ residual is falling. This condition means that something other than ammonia is the cause of the falling $Cl_2$ residual value. Because of the high ORP value, indicating there is not enough ammonia present to maintain chloramines and a combined residual, the controller has identified that an increase in chlorine feed rate is necessary to achieve an adequate chlorine residual value.

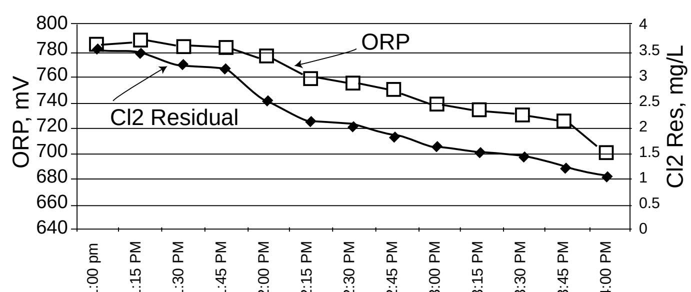


Figure 2. Event No. 2. ORP is falling while Cl2 residual is falling, which indicates that ammonia is the cause for the falling residual and the chlorine feed should be decreased to increase the chlorine residual.

Event Number 2 (Figure 2) describes a different condition. This condition shows the controller making a decreased adjustment to allow the effluent residual value to increase when ORP is falling and $Cl_2$ residual is falling. This condition means it is very likely that ammonia is the cause of the falling $Cl_2$ residual value. Because of the low ORP value, indicating there is ammonia present sufficient enough to maintain chloramines and a combined residual, the controller has identified that a decrease in chlorine feed rate will allow the chlorine residual to be maintained in the combined state, thereby, achieving an adequate chlorine residual value with a reduced chlorine dose rate.

## Additional Challenges

Along with solving a long-term problem with efficient chlorination, this project was very informative and educational. Staff learned many lessons about chlorination practices and use of associated equipment. Our largest equipment-related challenge was associated with maintenance of the ORP probe. Initially, the probe was attached to a PVC pipe and submerged about three feet at the beginning of the chlorine contact chamber. After a brief period a rust-like growth developed on the tip of the probe, causing the probe to respond too slowly. This condition created a problem with the automatic function of the control system, especially when the ORP was in a rising profile. The probe could easily be cleaned, but the acid wash procedure took about 30 to 60 minutes, and the cleaning frequency was every two to three days. This condition, other than being labor intensive, created the need to place the chlorinator back in the manual mode until the ORP probe was cleaned and calibrated. The staff deemed this unacceptable.

What to do… ask an expert! We consulted various experts about operations and maintenance of ORP probes. The consensus was that the flow velocity across the probe should be increased. The reasoning was that high velocity, in the range of 10 to 15 fps, would prevent the probe from developing a growth and increase the operational cycle time between cleanings. The operators, getting a little tired of frequent probe maintenance, were willing to try anything. An old pump found in the storeroom was set up to pump flow across the probe. This was no easy task. Our extremely talented staff fabricated an apparatus made of PVC pipe to house the probe and allow the water to be pumped across the probe's tip. Hand-tight couplings allowed easy probe removal for inspection and cleaning. It was a beautiful piece of work.

The new high-velocity ORP probe assembly was placed into service, having been told to expect up to three or four weeks of operation without the need for cleaning. The calculated velocity across the probe was over 15 fps, at a delivery rate of over 50 gpm. It didn't take long to see a significant change in the probe's condition; unfortunately, the change experienced was in the wrong direction. The probe was completely covered, thicker than ever, with the rust-like growth in less than eight hours. A lesson to keep in mind is that experts and consultants are not always right.

As disappointment was setting in, we began to think about reversed velocity performance. We assembled a new pumping application using a small submersible pump. Velocity was not calculated, but the delivery rate was about 1,500 ml/min; the intent was to see what the opposite extreme flow-through condition would produce. The lower flow rate provided five days of uninterrupted operation of the ORP probe without the need for cleaning. We then began to experiment with even lower flow rates across the probe by reducing the rate by 100 ml/min every cleaning cycle until we found the lowest flow rate which still allowed the probe to respond to quality changes. We found this level to be about 500 ml/min. This low flow, low velocity rate of water across the ORP probe provides about 10 days of steady operation without the need to clean the probe. The rust-like growth on the ORP probe is no longer a problem.

## Project Conclusion

We believe Orlando's Eagle Eye automated "sliding scale setpoint" chlorination control system is the only unit of its type for automatically controlling chlorination feed in a facility that does not accomplish consistent nitrification. We estimate savings over $50,000 per year at Water Conserv II facility since using this new generation of chlorination control systems. Estimated savings consist of $35,000 per year in reduced chlorine usage and approximately $17,000 per year associated with reduced staff response and chlorine adjustment time.

### Editorial Calendar

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| January | Advanced Treatment. |
| February | Water Supply. Wastewater Disposal. |
| March | Residuals Management. |
| April | Annual Conference Issue. |
| May | Treatment Technology & Operations. |
| June | FSAWWA & FWEA Awards. Misc. technical articles. |
| July | Disinfection. |
| August | Conservation/Reuse. |
| September | Industrial Wastewater. Stormwater. |
| October | Water Resources Management; FWPCOA Awards. |
| November | FSAWWA Conference; Misc. technical articles. |
| December | Collection & Distribution. |

Technical articles are usually scheduled several months in advance and are due 60 days before the issue month (for example, January 1 for the March issue).

The closing date for display ad and directory card reservations, notices, announcements, upcoming events, and everything else except classified ads, is 30 days before the issue month (for example, September 1 for the October issue). The closing date for classified ads is 5 p.m. on the tenth of the month preceding publication (for example, September 10 for the October issue).

For further information on submittal requirements, guidelines for writers, advertising rates and conditions, and ad dimensions, as well as the most recent notices, announcements, and classified advertisements, see our Web page at www.fwrj.com or call 352-374-4946.

### Glossary of Common Terms Used in this Publication

| | |
|---|---|
| AWT | advanced water treatment |
| AWWT | advanced wastewater treatment |
| AWWA | American Water Works Association |
| BOD | 5-day biochemical oxygen demand |
| $BOD_x$ | BOD test based on other than 5 days |
| CBOD | 5-day carbonaeous BOD |
| COD | chemical oxygen demand |
| CWA | Clean Water Act |
| DEP | Florida Dept. of Environmental Protection |
| EIS | Environmental Impact Statement |
| EPA | U.S. Environmental Protection Agency |
| FAC | Florida Administrative Code |
| fps | feet per second |
| FSAWWA | Florida Section of AWWA |
| FWEA | Florida Water Environment Association |
| FWPCOA | Fla. Water & Pollution Control Operators Assoc. |
| GIS | Geographic Information System |
| gpcd | gallons per capita per day |
| gpd | gallons per day |
| gpm | gallons per minute |
| hp | horsepower |
| MGD | million gallons per day |
| mg/L | milligrams per liter |
| MLSS | mixed liquer suspended solids |
| MLTSS | mixed liquer total suspended solids |
| NPDES | Nat. Pollutant Discharge Elimination System |
| NTU | nephelometric turbidity units |
| ORP | oxidation reduction potential |
| POTW | public-owned treatment works |
| ppm | parts per million |
| ppb | parts per billion |
| psi | pounds per square inch |
| PVC | polyvinyl chloride |
| RO | reverse osmosis |
| SCADA | supervisory control and data acquisition |
| SJRWMD | St. Johns River Water Mangement District |
| SFWMD | South Florida Water Management District |
| SRWMD | Suwannee River Water Management District |
| SWFWMD | Southwest Florida Water Management District |
| TDS | total dissolved solids |
| TOC | total organic carbon |
| TSS | total suspended solids |
| USGS | United States Geological Survey |
| WEF | Water Environment Federation |
| WRF | water reclamation facility |
| WTP | water treatment plant |
| WWTP | wastewater treatment plant |