Efficiency vs Equity in Water Resource Allocation With Interruptile Permitted

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Executive Summary

The general principles of equity and efficiency are used to suggest a normative framework within which permitted withdrawals will be allocated. The interruptible permitted withdrawals are distinguished from non-interruptible permitted withdrawals within this framework. Important concerns in the allocation of limited resources between interruptible and non-interruptible permittees are identified and discussed.

When all permittees have equitably invested in the reliability of the raw water supply system, risk and reliability will be equitably allocated to all users. Interruptible users provide no incremental increase in system yield. Their operations must assure that no marginal costs are imposed on permittees who have invested in structural and operational improvements to ensure reliable raw water supply. The single mechanism to provide this assurance is curtailment of Potomac withdrawals during periods of low flow.

Equity and Efficiency in Allocating Potomac River Water With Interruptible Consumptive Use Permits

To ensure the equitable, reliable and efficient development of the water resources of the Potomac River, the Water Resources Administration of the Maryland Department of Natural Resources promulgated Regulation COMAR 08.05.09. The regulation requires that permitted consumptive users of the Potomac River in excess of 1 MGD must either provide reservoir storage (to compensate for consumptive withdrawals during low flow conditions), operate in an interruptible fashion (curtailing all withdrawals from the Potomac River during low flow periods), or reduce consumptive withdrawals below 1 MGD during periods of low flow. This report presents an analysis of the development and implementation of interruptible consumptive withdrawal permits on the Potomac River.

Summary

The general principles of equity and efficiency are used to suggest a normative framework within which permitted withdrawals will be allocated. The interruptible permitted withdrawals are distinguished from non-interruptible permitted withdrawals in this framework. Important concerns in the allocation of limited resources between interruptible and non-interruptible permittees are discussed, including:

1. Allocation of Water Quality Releases
2. Changing Operating Rules
3. The Form of the Interruptible Rule
4. Allocation among Multiple Interruptible Permittees
5. Marginal Costs of Interruptible Operation
6. Overall System Reliability
7. Allocating Gains and Losses From Future Operating Changes

When all permittees have equitably invested in the reliability of the raw water supply system, risk and reliability will be equitably allocated to all users. Interruptible users provide no incremental increase in system yield. Their operations must assure that no marginal cost is imposed on permittees who have invested in structural and operational improvements to ensure reliable raw water supply. The single mechanism to provide this assurance is curtailment of Potomac withdrawals during periods of low flow.

Equity vs. Efficiency: The Basis for Allocating Risk

The overall goal in developing interruptible withdrawal permits is to achieve a technically efficient water supply system in which economic efficiency can be brought to the distribution of system costs while achieving an equitable allocation of the available resource. A technically efficient system consists of the least costly combination of storage, treatment, and

distribution facilities, combined with coordinated system operating rules that allow all permitted demands to be reliably satisfied. Economic efficiency requires that the price of joining the technically efficient system must be based on the marginal cost of serving each user. Equity requires that permittees bearing equivalent shares of the costs and risks of the system receive equally reliable allocations of the available resource.

The cooperative development and operation of the raw water supply system for the Washington Metropolitan Area (WMA) created a natural, equal partnership among the three water supply utilities serving the WMA. The three utilities shared both a common desire to jointly utilize Potomac River basin water resources, and a similar desire for reliable system operation. This resulted in a joint cooperative agreement by all three water supply utilities to construct reservoir storage to assure their raw water supply. In addition the utilities continue to jointly fund the activities of the ICPRB's section on Cooperative Water Supply Operations (CO-OP), to continue to improve forecast tools and operating procedures for the WMA water supply system.

The incremental cost of serving each of these utilities is identical. Cost allocation for reservoir construction and continuing operational improvement studies, is proportional to each utility's demand. This allocation equates the marginal

price each utility pays to participate in the system with the marginal cost imposed by each utility's demand. The three utilities each have substantial investments in the augmented raw water supply system and all available flow is committed at times of low flow. The three utilities share an equal risk in joint operation of their water resource systems and are treated as equal partners in allocating the available supply of raw water.

The State's consumptive use regulation identifies the reservoir storage required to maintain the reliability of all permitted users of the Potomac system after a new consumptive withdrawal is added. The storage requirement combined with revised system operating rules represent the technically efficient operating solution for the new system, including an additional consumptive user as an equal partner. The reservoir storage -however it is provided- represents the marginal cost of serving an additional consumptive withdrawal. Imposing this requirement on the new consumptive permittee sets the price of joining this efficient allocation system equal to the new user's marginal cost, satisfying economic efficiency. After satisfying the requirement of the consumptive use regulation, the consumptive permittee is viewed as an equal partner in the operation of the Potomac raw water supply system. The equitable allocation of water among all equal partners will equalize the risk of shortage born by all permittees.

Allocation of water to all users is equitably treated by satisfying all demands through system operation. The new permittee is viewed as an equal partner in the system due to the efficient level of extra capacity provided. Equity therefore dictates that all users who have bought into the system at efficient levels receive equal consideration and priority in satisfying their demands through operational allocation of available supply.

As an alternative, the consumptive use regulation allows consumptive permittees to opt for interruptible withdrawals, in lieu of providing the prescribed volumes of reservoir storage. In such a case, an interruptible permittee could not be considered an equal partner in the system. For an interruptible permittee, the only means available to assure that a consumptive use would impose no incremental impacts, would be to agree to fully curtail all withdrawals that would adversely impact other users.

In the following discussion, a permittee making no contribution to system reliability other than agreeing to shut off all withdrawals on request is termed a "fully interruptible" permittee. Fully interruptible permittees make no structural contribution or financial investment to maintain overall system reliability. Equity requires that fully interruptible permittees must operate in a way that imposes no marginal impact

on other users. Since fully interruptible permittees incur no capital or operating costs contributing to system reliability, they must expect water to be available to them with relatively low reliability.

Interruptible permits

With the recognition of several classes of permittees, distinguished by the price each has paid to join the system (i.e. the reliability that has been purchased), the allocation of available water must be reconsidered. Formerly all users had made an equitable contribution to overall system costs, and equity considerations required a proportional allocation of risk to all permittees. With multiple user classes, the allocation of available resources and the risk of shortage must distinguish each class of permittee - equity requires the equal treatment of equals. The basis of this allocation should be the equivalence of marginal price.

EQUITY CONSIDERATIONS

1. Water Quality Releases

Allocation of available flow must recognize that observed flow consists of natural or unregulated flow plus routed reservoir releases. Included in the observed flow are releases made by the Corps of Engineers for water quality purposes. These releases will be "technically available" in the sense that it is physically possible for permitted users to withdraw and utilize this water. The availability of this water stems from the authorization of water quality as a Federally funded purpose of Randolph Reservoir. "Water quality" releases provide benefits through the entire mainstem of the Potomac. As a matter of public policy, water quality releases should not be considered available for withdrawal by interruptible consumptive users.

2. Changes in Operations

System operating rules will determine the reliability of supply for an interruptible consumptive user, as well as the marginal impacts to current permittees of future consumptive withdrawals. The system of permitted users of the Potomac will continue to change in response to changing demands, new permittees, changes in distribution and treatment systems, changes in forecast skill for both streamflow and raw water demand, and changes in meteorologic and hydrologic conditions. Efficient operation

will continue to change the system operating rules in response to the changing needs of all users. For this reason a fully interruptible permittee can expect the operating rules used to halt withdrawals to change through time. Interruptible users can expect the frequency and duration of interrupted periods to increase with growing demands. In effect the withdrawals of a fully interruptible permittee, making no contribution to the reliability or resilience of the system, must have no marginal impact on other users.

3. Form of the Interruptible Rule

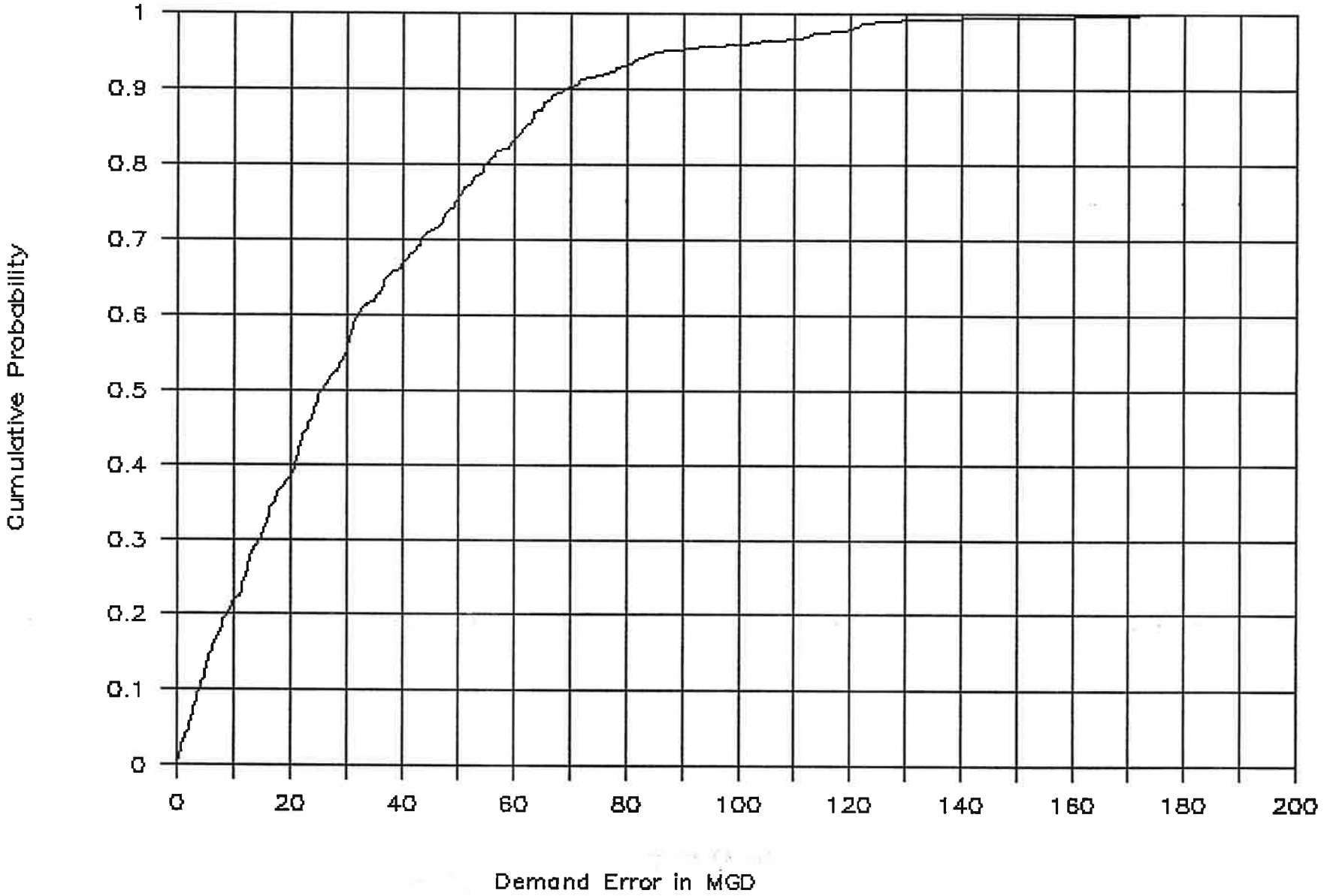
The general form of an interruptible rule proposed by PEPCO will curtail Potomac withdrawals when the observed flow at Point of Rocks less the two-day-ahead forecast of WMA demand is less than a safety factor to be determined. In general this is a reasonable form of operating rule. The cost and reliability of such an operating rule will be determined by the choice of "safety factor". The safety factor suggested by PEPCO's consultant does not seem adequate. The suggested value of 60 MG is based on a single summer of demand forecasting. The summer in question was a relatively mild summer with respect to drought conditions, so that demands (and forecast errors) were not extreme. In determining an operational safety factor the change in forecast error with both changing hydrometeorological conditions, as well as long-term changes in demand must be considered.

Figure 1 shows the cumulative density function of errors in WMA forecasted demand. These errors were simulated by preserving the correlation structure of demand between the three WMA utilities and simulating a season of daily demand forecasting during the drought of record. The mean demand for the WMA is taken at projected 2030 levels. From Figure 1 a safety factor of 60 MGD could be expected to lead to a shortfall between demand and supply approximately 17% of the time. If the safety factor in an operating rule is to be based on the frequency of forecasting errors, a higher level of reliability must be maintained. Safety factors corresponding to the 95th and 99th percentile of forecast error would require safety factors of approximately 90 MGD and 170 MGD respectively. Despite the high frequency with which interruptible permittees would be asked to curtail withdrawals, this level of operation would still represent a degradation of the reliability of the water supply system.

During extreme drought conditions (unusually high temperature, unusually low flow, extended periods without significant precipitation) both the level of demand and the variability in demand is greatly increased. The increased variance of extreme demands leads to increased prediction errors which must be incorporated in the safety factor for an interruptible permit. The safety factor proposed by PEPCO's consultant suggests that the absolute magnitude of prediction error will be constant.

Figure 1

Forecast Error CDF



This is clearly not the case during extreme low flow conditions. More importantly this will not be the case as the mean seasonal demand increases. As the total demand of the WMA grows, the magnitude of the forecast error will also grow. For this reason an arbitrary quantile of forecast error from an average condition year is an inadequate safety factor for the interruptible operating rule proposed by PEPCO. While the use of a safety factor in the operating rule is in general reasonable, the proposed value of the key parameter in the operating rule, the safety factor, is inadequate.

4. Multiple Interruptible Permits

The form of interruptible rule proposed by PEPCO links the curtailment of withdrawals to the available supply of Potomac River Water -one user will be prohibited from withdrawing water so that it will be available for another user. In the event that several interruptible users are permitted, the situation may arise in which insufficient flow is available to satisfy the consumptive withdrawals of all interruptible users, but some interruptible consumptive uses could still be supported. In this event the WRA must develop a separate appropriation system for interruptible users. One alternative would be a strict priority system in which "seniority" is effectively assigned to interruptible consumptive withdrawals. Under such a system withdrawals by interruptible permittees would be halted based on

seniority until all other "higher" uses could be satisfied, or until all interruptible permittees were offline, which ever came first. Alternatively, all interruptible permittees could be viewed as having equal priority leading to a proportional reduction of all interruptible withdrawals.

5. Marginal Costs From Interruptible Operation

Equity in interruptible operations links reliable allocation to system contribution. Since a fully interruptible user has paid no price to join the system, interruptible operation must ensure that other permittees experience no marginal cost resulting from the interruptible user's operations. Due to the uncertainty in forecasting demand and supply, there will be incremental impacts from interruptible operation, such as increased pumping costs or incremental drawdown in water supply storage. These incremental changes represent a cost imposed on the water supply utilities by the interruptible permittee. Equity requires compensation of these costs by the interruptible permittee.

6. Overall System Reliability

In addition to uncertainty in predicting the WMA demand, all operations must account for uncertainty in the Potomac allocation of WMA demand. Should unexpected circumstances such as equipment failure cause an increase in the demand for Potomac River water (as opposed to water from the Patuxent or the

Occoquan) the interruptible permittee's consumptive withdrawal would again impose an uncompensated cost on the utilities. A proportion of the Potomac discharges in excess of water supply and water quality needs currently represents a safety factor providing incremental reliability for the water supply system. Consumption of this safety factor would adversely impact the reliability of the WMA raw water supply system. A fully interruptible permittee should therefore be required to curtail withdrawals if this allocation is required to offset a failure in another part of the system.

7. Allocating Gains and Losses From Future Operating Changes

In general, changes in forecast skill will change system reliability. Significant improvements in forecast skill and operating rules are equivalent to additional water that can be provided by the system. If additional water can be produced through non-structural means, who is entitled to the water? For example, if PEPCO develops a demand forecaster, or a new operating rule that could support an additional 30 MGD withdrawal, does that automatically entitle PEPCO to 30 MGD of consumptive withdrawal? Conversely, if rapid growth in the WMA leads to a deterioration in forecast skill (equivalent to a reduced system yield), how will this loss in yield be allocated?

The WMA water supply utilities are committed to continued research and development of improved operating tools. The regular activities of the CO-OP section of the ICPRB represents an ongoing commitment on the part of the water supply utilities to continue to upgrade and improve operations and operational forecasting tools. Anticipated operational improvements will produce marginal increases in system yield. The allocation of this additional supply "created" through improved resource management is a policy decision that the Water Resources Administration must face in the future.