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# Allocated Impact Zones For Areas Of Non-Compliance

# ALLOCATED IMPACT ZONES FOR AREAS OF NON-COMPLIANCE

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## EXECUTIVE SUMMARY


The present means of regulating water quality standards and establishing permit limitations for point source discharges are limited by the absence of any rationale placing mixing zone limits on the area where adverse environmental impacts may occur. Mixing zones have been defined by plume location, need for dilution volume, or a uniform linear distance for all discharges or classes of discharges. Mixing zone boundaries derived by this engineering approach ignore the multiple or additive discharge conditions that characterize receiving waters and have had little to do with the goal of protecting our environment.

Current state water quality standards programs provide mixing zone guidance incorporating a fraction of the cross-sectional or surface area of streams and lakes or a uniform linear distance limitation. This guidance fails to consider multiple source impacts, sensitivity of aquatic resources, and socioeconomic factors.

To address the limitations of current practice, an impact allocation procedure is presented and discussed in this report. This procedure addresses many of the socioeconomic and ecological factors that need to be considered in waste management:

- All present and projected future discharges are to be considered together.
- Ecological and toxicological data are needed to whatever level of detail they exist or can be determined.
- Waterbody uses are prioritized and assigned numerical relative values based upon socioeconomic considerations. Similar

considerations are necessary to select an appropriate level of protection. These decisions are part of the risk management process, and are separate from the risk assessment parts conducted by scientists and engineers.

- Each discharger is assigned a fraction of the available environmental value of a waterbody based upon an allocation model and expressed by area.

- If the assigned area is too limiting, alternatives such as discharge relocation or redesign, toxicity reduction, termination of limiting process, etc., are to be considered. Purchase of unneeded allocation from another discharger is appropriate.

The data requirements and socioeconomic decisions required to satisfy all levels of this allocated impact zone procedure are extensive and, in most present instances, not practically achievable. However, several of the initial steps are not unreasonable and the use of the entire procedure utilizing effluent volume and toxicity may be considered to be the eventual goal. A goal that could be achievable during the third round of effluent permit review and revision around 1991. During this period of time many more effluent toxicity data will be available as a result of the second round of permits and the socioeconomic decisions could be made.

This procedure is intended for the use of both state and USEPA water quality standards coordinators and permit writers who should work in concert with each other.

# INTRODUCTION

This report describes a procedure to determine the environmentally acceptable size of mixing zones, called allocated impact zones (AIZ) herein, around point source discharges into freshwater and saltwater ecosystems. This term has been used previously in USEPA (1984, 1985, 1985), Neely (1982) and Bergman <u>et al</u> (1986) in their workshop summary. The more commonly used term, mixing zones, will not be used because of historical confusion about which of two definitions apply. Engineering oriented professionals consider a mixing zone as that area or volume of dilution water necessary to reduce contaminant concentrations to some acceptable level or to a totally mixed condition (Villemonte <u>et al</u>., 1973 and Lillesand <u>et al</u>., 1975). Plume shape, size and depth are additional similar engineering concepts of mixing zones (Neely, 1982). Another historical definition for a mixing zone is the area contiguous to a discharge where receiving water quality is not required to meet water quality criteria nor other requirements applicable to the receiving water (USEPA, 1976). This concept is supported by environmental scientists and water quality managers. The two definitions are rarely compatible as demonstrated by the conflicts of applicability when the two groups (e.g., plant engineers and state and EPA permit writers) address the issue.

The concept of allocated impact zones has been chosen for several reasons:

- It avoids the historical confusion concerning definition of mixing zones.

- The concept defines that the AIZ boundary as the point where water quality characteristics permit long-term exposure without interfering with any activity of aquatic organisms or causing ill effects to any life history stage (Fetterolf, 1973).

- The word "allocated" was chosen since this approach demands consideration of all point sources within a defined waterbody rather than on a discharge by discharge basis as is done when mixing zone is the common concept. As with wasteload allocation, acceptable areas of non-compliance with water quality standards should be considered holistically to avoid excessive potential damage.

- The word "impact" is realistic, as well as descriptive, since there is the potential for adverse impact on aquatic life when water quality standards are allowed to be exceeded, as is the case in the AIZ.

- Mixing zone concepts focused on farfield requirements. The recent incorporation of effluent toxicity testing in discharge permits is emphasizing also the concern about nearfield impacts. The new term, AIZ, incorporates both.

A detailed discussion of the historical development of mixing zone guidance is presented in Appendix A. This guidance has resulted in defining mixing zone boundaries that are based on cross-sectional area or volume and uniform linear limits.

## ALLOCATED IMPACT ZONE PROCEDURE

In the absence of any holistic approach to the allocation of potential impact areas, many ecosystems have been degraded or are in the process of degradation, due to case-by-case decisions for point source discharges from industrial and municipal outfalls and dredging or construction activities. The allocated impact zone procedure organizes and manages discharges by including all point source discharges in the decisionmaking process!

There are several opportunities that regularly occur when the AIZ procedure could be initiated:

- Anticipated revisions in water quality standards.
- Impending permit review/revision period.
- New ecosystem uses are being considered.
- Expansion of industrial or municipal discharge is anticipated.
- New pollution control organization is being developed.

Figure I is the chronological sequence of the steps in the allocated impact zone procedure and will form the outline for the balance of this report.

### Determine Need for Allocation

In addition to the above mentioned opportunities to initiate this plan, there are other reasons for organizing impact allocation in an holistic manner. In each state there are examples of excessive damage to aquatic ecosystems as a result of present management.

Determine Need for Allocation

↓

Establish Waterbody Boundaries

↓

Analyze Current and Future Discharge Data

↓

Analyze Ecosystem Data

↓

Develop Environmental Mapping

↓

Assign Relative Values

↓

Determine Level of Protection

↓

Select Allocation Procedure

↓

Allocate AIZ

↓

Specify Quality Within AIZ

Figure 1 Chronology of Allocated Impact Zone (AIZ) Designation Activities.

procedures. Since a case-by-case approach led to these problems, a similar approach for rehabilitation will not be successful or, if so, not cost effective. Current federal and state budget limitations necessitate using the most cost-effective procedures in environmental management. Instead of attempting to eliminate the impact of one stress at a time, the whole of a particular waterbody must be considered so that only the necessary prioritized problems are scheduled for improvement.

Waterbody Boundaries

Care must be taken in establishing the boundaries for the rivers, lakes, and estuaries of concern. Since this approach is an attempt to assess cumulative impacts, the boundaries should not be so limited that the present case-by-case approach is maintained. If too large, the area would not be manageable.

Common sense can frequently be of use in this part of the exercise. If a part of the aquatic environment is physically, chemically, or ecologically distinct, that part may be considered to be a candidate for analysis. A river pool between dams is an example as would be a lake. A side arm of an estuary that has a uniquely low flushing rate could be another example. The presence of a space-limited biological population or community could define the limits of an area. A water quality limited area could also be a separate consideration.

## Discharge Data

All point source discharges, including combined sewer overflows, should be identified for the waterbody of concern. Available characterization information, such as discharge flow rates, toxic components, general water quality, toxicity, diurnal and seasonal variability, etc., should be obtained. Anticipated changes in operations, such as expansion, process changes, level of treatment, etc., should be documented. Similar information, if available, should be obtained for planned future discharges.

## Ecosystem Data

No attempt will be made here to list all of the appropriate data desirable to conduct an allocated impact zone analysis. Rather, categories will be identified with examples and highlights that may not be readily apparent. The analysis should initially be conducted with available data, regardless of source. If data gaps become apparent, or if additional data are desirable to establish status and trends, a decision must be made as to whether the time and cost are justified on the criterion that a better allocation could be made or that such efforts would not aid substantively in the allocation process.

- Identify all public and private water supply intakes.

- Water quality and sediment and pollutant transport models available for the waterbody of concern should be evaluated as to their utility in the allocation process. Annual and seasonal flow data will be used to determine appropriate models.

- Ambient water quality data, including toxic chemicals, will be needed. Data for existing water quality limited areas will be especially critical.

Useful guidance and additional suggestions are available in the Water Quality Standards Handbook (USEPA, 1984) and the Technical Support Document for Water Quality-based Toxics Control (USEPA, 1985).

As with the abiotic data needs, the states should use their expertise to determine their specific or unique needs for biological data. The following is general guidance as to the most important data needs. Once the available data have been gathered, synthesized, and evaluated for completeness, site specific characteristics and the cost effectiveness of additional data production will determine the extent of additional data needs.

- Primary producers - Data for autotrophic organisms such as phytoplankton, periphyton, macrophytes, and macroalgae are needed. Habitat-forming groups are especially important.

- Macroinvertebrates - The major categories of importance are crustaceans, shellfish, polychaetes and others that are important in aquatic and human food chains or indicators of water quality. Data on human pathogens in commercial species are also necessary.

- Fish - Data from creel censuses, surveys, etc., will be most useful. All major groups need to be analyzed as to spawning and nursery areas, residue data when available and migratory pathways. Historical data will assist in the determination of what indigenous species were important, before recent major anthropogenic changes.

- Threatened or endangered species - Such a species is any aquatic plant or animal that has been determined by the Secretary of Commerce or the Secretary of the Interior to be a threatened or endangered species pursuant to the Endangered Species Act of 1973, as amended. The present or past occurrence of any such species should be considered.

- Recreational and Other Uses - These should be identified due to their role in determining relative values. Examples are body contact activities, recreational fishing and shellfishing, irrigation, and boating.

The ecosystem data should be organized, where possible, into environmental maps. This format will be quite useful in determing the potential impact of existing point source discharges. These maps will also be useful if there is a need to locate, relocate, or modify an existing or proposed discharge.

## Environmental Mapping

The following mapping examples each had a different goal and therefore is not as broad an application as desired to develop allocated impact zones. Diener (1975) described seven Texas estuarine areas in terms of dimensions; major vegetation types; geology and geological history; drainage basins and stream discharge records; hydrological, biological and benthic properties; populations and economic development; pollution; and navigation projects. Hunt (1975) described a study to improve the presentation of coastal zone data. Various methods were discussed for the presentation of data on shellfish growing areas, salinity, groundwater level, flood tide currents and current velocities, distribution of zooplankton, sediment type versus benthic organisms, and a variety of water quality characteristics. Thurlow and Associates (1975) completed a report on Ecological Sensitivity Mapping of the Lower Great Lakes Watershed as a planning tool to handle spills of hazardous materials. Their mapping was concerned with various types of recreational areas and water supply intakes as well as biological populations, both land-based and aquatic, and locations of toxic chemicals and oil storage. The International Joint Commission sponsored a Workshop on Environmental Mapping of the Great Lakes (1976) in which papers were presented on such subjects as uses of environmental maps in determining areas of noncompliance, industrial and power plant siting needs, dredge and fill, navigation, municipal intakes and discharges.

An atlas for Narragansett Bay, Rhode Island (Olsen et al., 1980) displays similar presentations but also includes sections on recreation, shipping, pollution, dredging, and particle movement.

An atlas of the natural resources of Chesapeake Bay (Lippson, 1973) graphically presents depths, tides, currents, salinity, sediments, marshes, and aquatic plants. A variety of invertebrate and fish species are represented as to seasonal distribution and spawning and nursery areas. The locations for concentrations of ducks, geese, and swans were also represented.

The USEPA (1980) conducted a remote sensing demonstration project using the Boston Harbor marine discharge 301(h) application data. The project report included a variety of maps and overlays to show the relationship of metal contaminated sediments to outfalls, location of discharges and monitoring stations, and one excellent map showing existing and proposed beaches and boating facilities, diving and fishing areas, parks, camping, historical sites, etc. Another map showed areas of commercial finfish and shellfish resources, lobster buoy counts, and areas of closed or restricted shellfishing.

In the process of developing environmental maps, it is usually not sufficient to consider only present conditions which include the results of anthropogenic activities that have already negatively affected the fisheries populations, physical habitat, and water quality. Consequently, historical perspectives, when available, should be considered in order to know what the unaffected conditions were before man's activities.

Environmental maps have many uses other than for the definition of allocated impact zones. State and federal regulatory agencies can use them in a variety of ways (Fetterolf, 1977):

- Identifying concurrent or conflicting water uses.
- Selecting management objectives.
- Preparing environmental impact statements leading to impact minimization.

- Designing research and monitoring programs.
- Understanding status and trends through time.
- Identifying habitat that must be protected, preserved, or restored.
- Future planning

Displays of environmental maps have great potential in raising the environmental consciousness of the public. Maps can be a solution to the problem of explaining environmental concepts and issues to lay people and scientists alike. In addition, environmental maps can facilitate the transmission of factual information, communicate the interrelationships of uses and other factors in the ecosystem, and link environmental science to the personal interests and concerns of the public.

## Relative Environmental Value

A comparative numerical rating will be established for the numerous environmental uses of aquatic ecosystems from spawning habits of endangered species to anoxic hypolimnetic waters to municipal water supplies and bathing beaches. The past unwillingness to accept this responsibility is one of the major reasons for the case-by-case impact assessment that has ignored any approach that considers the cumulative impact of multiple stresses. The assignment of numerical relative values is manageable if we consider it as an acceptable part of environmental management and a prioritization process. Using this more comfortable approach at the beginning allows the value part to be considered after the prioritization has occurred.

Each state agency has the best knowledge of the various environmental, social, industrial, municipal, and recreational uses of the waters under their jurisdiction. Detail is provided in the environmental use area (Appendix B) to ensure adequate guidance in the prioritization and assignment of relative value.

## Level of Protection

The concept of level of protection has been used and misused for many years. It is controversial, but, like the AIZ concept itself, is an essential step in the protection of aquatic resources. It is acknowledged that any estimate of the amount of area assigned to AIZ must be based on "expert opinion". However, there are varying degrees of protection desired or required for different waterbodies; therefore, the acceptable risk differs between waterbody segments. Consequently, several degrees of protection are recommended: maximum level of protection for fragile environments; low level of protection for the less valuable environment or an environment most capable of withstanding insults; and a moderate level of protection intermediate between the two. The percent of environmental value to be consigned to impact zones could be, for example, 1 percent of the total environmental value (see Example 1) for maximum protection to 10 percent for a low level of protection, with values from 1-10 percent being selected for intermediate protection. One could allot more than 10 percent where economics or other considerations warrant, or restrict the risk to less than 1 percent for waterbody segments with unique biological environments. Additional guidance is included in Appendix C.

Allocation Options

Once the judgements have been made regarding environmental value and level of protection, the administrative process of allocating impact zones begins.

First, one must decide how much of the acceptable loss in environmental value can be assigned to present discharges and how much can be allocated to future applicants. There are several considerations that should be given attention when making this decision. Available projections on future municipal-industrial growth can be evaluated to estimate the potential need for future zones. Planned plant closures due to obsolescence, etc., should be considered. Also, some classes of industry are utilizing production or waste treatment technology based on more efficient use of water (e.g., closed-cycle cooling, water reclamation and re-use. If non-point source pollution is a significant factor, as it frequently is, it may be desirable to allocate a portion of potential impact to that source.

As was stated briefly in the Executive Summary, this AIZ procedure using all aspects presented and the allocation option based on toxicity mass is unlikely at present to be achievable for more than a few waterbodies. Each step taken in the procedure results in a more ecologically sound allocation, even if the allocation option chosen is one of the more simple of the following suggestions.

Since many of the second round permits being developed contain requirements for effluent toxicity testing, such data will become much more common and the inevitable syntheses of these data will provide useful generalizations that will satisfy the toxicity data requirements of this procedure. Until that time an estimate of high, medium, or low toxicity could be based on a comparison of effluent chemical concentrations with water quality criteria. Increased public awareness and the need to establish priorities will result in an atmosphere conducive to making the necessary judgements on relative value and level of protection. In the interim, the AIZ procedure can evolve in practice to the final goal of complete utilization in anticipation of the third round of permit review/revision around 1991.

Next, one must select a method for allocating the size of individual impact zones. Several options are available:

1. All AIZ are allocated equal amounts of environmental value. Advantages -- simple, direct and easy to calculate. Disadvantages -- large volume discharges would require a much greater level of treatment than would small volume discharges. May allow small number of dischargers to discharge relatively large quantities of toxic or persistent pollutants.

2. Each discharger within in a general class of discharges (paper mills, metal finishing plants, municipal waste treatment plants, power plants) is allocated the same amount of environmental value, but different classes of dischargers are given different amounts of environmental value. Advantages -- simple and direct, could better allow for general

differences in volume of discharge, could take into account general persistence of toxicity of different classes of discharges.

Disadvantages -- there is a rather large variation in discharge volumes and toxicity in any given class.

3. Impact zone allocation directly proportional to the volume of the discharge (e.g., for each unit volume of the flow, the zone would be allocated a unit of environmental value).

   Advantages -- simple calculation, superficially fair to all dischargers.

   Disadvantages -- encourages dilution pumping to obtain a larger zone and does not consider toxicity or persistence.

4. Impact zone allocation proportional to some monotonic increasing function of the discharge volume, that has a finite upper bound.

   Advantages -- in contrast to Option 3, would discourage dilution pumping and would not unduly favor large volume discharges.

   Disadvantages -- assumes that all discharges have the same toxicity when available data have demonstrated a range of at least 1 to 2 orders of magnitude.

5. Impact zone apportionment based on toxicity mass that considers toxicity and volume of waste.

   This approach has as a basis the actual cause for concern -- hazard to the environment. Its chief disadvantage lies in the need for effluent toxicity data before decisions can be made. However, regulatory discharge permits are incorporating toxicity testing requirements that will provide some data with which to consider this more realistic approach to allocation. The Technical Support Document for Water Quality-based Toxics Control (USEPA, 1985) contains procedures for effluent toxicity modeling using the product of toxicity units and stream or effluent flow. DiToro, et al. (In press) used an approach similar to toxicity mass in their study of the Naugatuck River in Connecticut. Their interest was to develop a mathematical modeling approach for effluent and ambient toxicity to Ceriodaphnia sp., a freshwater cladoceran. Toxicity load was the product of toxic unit concentration and stream flow.

Quality Within Allocated Impact Zones

In addition to developing an allocated impact zone that will define the regulatory boundary where water quality standards are to apply, it is also necessary to state the conditions that are not to be exceeded within an AIZ.

The Water Quality Standards Handbook (USEPA, 1984) has stated that any zone should be free of point and nonpoint source related:

- Materials in concentrations that will cause acute toxicity (lethality) to aquatic life;
- Materials in concentrations that settle to form objectionable deposits;

- Floating debris, oil, scum and other matter in concentrations that form nuisances;
- Substances in concentrations that produce objectionable color, odor, taste, or turbidity and;
- Substances in concentrations which produce undesirable aquatic life or result in a dominance of nuisance species.

In addition to these general guidelines for AIZ quality, the Technical Support Document for Water Quality-based Toxics Control (USEPA, 1985) has provided design criteria to prevent lethality in the allocated impact zone:

- The criteria maximum concentration (CMC) for whole effluent toxicity must be met within 10% of the distance from the edge of the outfall structure to the edge of the regulatory AIZ in any direction;

- The CMC must be met within a distance of 50 times the discharge length scale in any direction. The discharge length scale is defined as the square-root of the crosssectional area of any discharge outlet; and

- The CMC must be met within a distance of 5 times the local water depth in any horizontal direction from any discharge outlet.

The outfall design must ensure that the most restrictive of the above three conditions are met (USEPA, 1985).

EXAMPLE ALLOCATIONS

The following example of a lentic ecosystem and the additional two examples in Appendices D and E are completely hypothetical and decisions as to relative value and level of protection are not meant to be recommendations or average values. Each site must be considered independently. The numerical values in these examples may be quite different from those that would be developed using actual conditions.

All calculations were carried out to four significant numbers before rounding to two significant numbers.

The allocation procedure used in these examples is the one involving effluent toxicity and volume of discharge. The inherent purpose of waste treatment based on permits and water quality standards is to protect the aquatic ecosystem from unacceptable toxic effects. Since it is impractical to expect all undiluted effluents to be chronically non-toxic, allocation of potential impact should be based when possible on the toxicity and volume (toxicity mass) of the effluent. In the absence of sufficient data and decisions on relative value and level of protection, the other allocation procedures discussed earlier may be used in the interim as long as all discharges in a waterbody are considered together.

Example 1

This example will be of a simplified lentic system such as a lake, reservoir or small estuary that is divided into m environmental zones with known areas ($A_1$, $A_2 \ldots A_m$) and assigned relative values ($RV_1$, $RV_2$, $\ldots RV_m$). There are presently n discharges with toxicity masses of $Q_1$, $Q_2, \ldots Q_n$. From this information, allocated impact zones will be determined.

Several technical and socioeconomic decisions should be made before proceeding. The level of protection (p) and the fraction of the total AIZ for the waterbody to be assigned to present dischargers (r) must be chosen. Additionally, environmental maps demonstrating areas of use need to be developed at whatever level of detail is necessary to accomplish the allocation process.

Any site-specific unique characteristics or uses, such as municipal or irrigation water supply, endangered species, etc., should be considered. In this first example, there are two municipal intakes and hypothetical local requirements preclude any discharges within 0.5 miles.

The areas of each environmental zone can be in any consistent unit since the normalization to fraction of total area will eliminate units of area. The area designated as living space for aquatic species will be assumed to be the total area available for AIZ consideration (this will exclude, in this example, the area around the water supply intakes) minus the sum of all other areas. The total available area for example 1 is 4,800 acres.

Given these factors the allocation procedure follows:

1. The total environmental value (TEV) for this waterbody is the sum of the environmental values (ARV) for each use

zone (Table 1). Each ARV is the product of the normalized area and its relative value.

$$TEV = A_1RV_1 + A_2RV_2 + \ldots. + A_mRV_m$$

$$TEV = 4.8$$

2. In this example, the ecosystem is characterized by a low flushing rate, significant recreational use, and a low biotic diversity with limited potential recoverability. (See Appendix C).

   Also, the current socioeconomic trend is toward increased water-oriented tourism and second home development. Consequently, a high level of protection (p) is warranted and would permit that only 2% (0.02) of the TEV could be allocated as potential impact zones. The TEV to be allocated to present and future discharges will be:

$$p(TEV) = (0.02)(4.8) = 0.096$$

3. As a result of the abovementioned socioeconomic trends, industrial development (requiring discharges to the waterbody) will be scrupulously evaluated and limited. The master plan for development of this watershed will reserve 25% (0.25) of the TEV for future discharges and that amount available for present discharges ($r = 0.75$) will be:

$$pr(TEV) = (0.02)(0.75)(4.8) = 0.072$$

Table 1 - Calculation of Total Environmental Value (TEV) for Example 1

| | Zone[a] | Area (Acres) | Normalized Area (A) | Relative Value(RV) | Environmental Value (ARV) of Each Zone |
|---|---|---|---|---|---|
| 1. | Migration | 460 | 0.096 | 3 | 0.29 |
| 2. | Spawning | 120 | 0.025 | 10 | 0.25 |
| 3. | Fishing | 1,200 | 0.250 | 5 | 1.3 |
| 4. | Nursery | 450 | 0.094 | 7 | 0.66 |
| 5. | Swimming | 100 | 0.021 | 12 | 0.23 |
| 6. | Marina | 40 | 0.0083 | 9 | 0.075 |
| 7. | Living Space[b] | 2,430 | 0.51 | 4 | 2.0 |
| | | | | | TEV = 4.8[c] |

a. Two domestic water supply intakes exist in this waterbody. Current requirements, for this example, do not permit an AIZ within 0.5 miles of these intakes. These areas have been subtracted from the total area of the waterbody.

b. Unless there is a valid reason not to do so (e.g., anoxic zone), living space will be assumed to be the total area available for allocation minus the sum of all other areas. In this example the total available area is 4,800 acres.

c. Amount of TEV to be allocated = pr(TEV) = (0.02)(0.75)(4.8) = 0.072.

4. Therefore, the environmental value available for allocation to present dischargers is 0.072 (Table 1). As stated earlier, of the allocation procedures available for consideration, the preferred procedure involves the volume and toxicity of the effluents. The amount of environmental value to be allocated to a discharger ($EVA_k$) with an effluent toxicity mass $Q_k$ is:

$$EVA_k = pr(TEV) \frac{f(Q_k)}{\sum_{k=1}^{n} f(Q_k)}$$

where the subscript k denotes a specific discharge, and toxicity mass ($Q_k$, unitless) is the product of the normalized discharge flow rate (fraction of total flow rate of all discharges) from each discharge and toxicity expressed as toxic units chronic ($TU_c$). The latter is defined in the Technical Support Document for Water Quality-based Toxics Control (USEPA, 1985) as the reciprocal of the effluent dilution that causes no unacceptable effect on the test organisms by the end of the chronic exposure period. (Detailed discussion and examples of the determination of the $TU_c$ values are in this Technical Support Document). In the calculation of $EVA_k$,

$$f(Q_k) = \frac{Q_k}{Q_k + Q} \quad \text{and} \quad Q = \frac{\sum_{k=1}^{n} Q_k}{n}$$

The results of calculations to determine the amount of total environmental value allocated to each present discharger ($EVA_k$) are shown in Table 2.

5. Once the $EVA_k$ values have been calculated, an individual AIZ can be established with regard to areal size. The area within a given environmental zone allocated to an impact zone is given by:

$$AIZ_{jk} = EVA_k \left( \frac{A_j}{ARV_j} \right)$$

where the subscript j denotes the specific environmental zone where the discharge exists and the subscript k denotes that specific discharge. The results of calculations to determine the area assigned to each discharger and the percentage of the total area in a zone assigned to AIZ are shown in Table 3.

Since the initial allocation is for a specified amount of environmental value, the more valuable or smaller the zone in which the AIZ is located, the smaller this AIZ would be. Also, the more is reserved for future discharges, the smaller is the size of each present AIZ.

Since this allocation approach is two-dimensional, the AIZ limitation is to surface area of the waterbody. A discharger, who determines that the assigned AIZ is too limiting and the discharge cannot be relocated to a different zone, may choose to relocate the discharge from the shallow, ecologically important shore area to a deeper, less important area within the same environmental zone. That would increase the dilution volume but not change the assigned surface area. The

Table 2 - Calculation of Amount of Total Environmental Value Allocated to Each Discharger ($EVA_k$)

| Discharge Number | Discharge Flow Rate ($m^3$/day)[a] | Normalized Flow Rate | Toxicity Units Chronic ($TU_c$)[b] | Toxicity Mass ($Q_k$)[c] | f(Q) | $EVA_k$ |
|---|---|---|---|---|---|---|
| 1 | 2,400,000 | 0.18 | 4.4 | 0.78 | 0.63 | 0.020 |
| 2 | 180,000 | 0.013 | 15 | 0.20 | 0.31 | 0.010 |
| 3 | 710,000 | 0.052 | 2.4 | 0.13 | 0.22 | 0.0068 |
| 4 | 50,000 | 0.0037 | 21 | 0.077 | 0.15 | 0.0046 |
| 5 | 10,000,000 | 0.74 | 1.9 | 1.4 | 0.76 | 0.024 |
| 6 | 250,000 | 0.018 | 7.0 | 0.13 | 0.23 | 0.0073 |
| | | | | | $\sum$ = | 0.072 |

a. Any consistent unit will suffice since only the relative flow rates are important as the result of normalization.

b. For the definition and use of toxicity unit chronic see the Technical Support Document (USEPA, 1985).

c. Toxicity mass ($Q_k$) is the product of the normalized flow rate and $TU_c$ (both are without units).

d. The sum of the individual $EVA_k$ values should equal or approximate pr(TEV), which is 0.072 in this example.

discharger also may benefit from more rapid mixing by the use of high velocity diffusers. If the assigned AIZ is still limiting, the discharger may have to move the facility or implement toxicity reduction procedures within the plant.

For future discharges, this process of allocating impact zones will provide significant useful guidance in site selection and choice of discharge configurations to ensure minimum adverse impact and the ability to achieve the limitations of the AIZ.

The allocation procedure, like any similar set of calculations, may at times result in what would appear to be unreasonable results. These results need to be considered and evaluated in light of available experience and common sense.

Once the AIZ decision has been finalized, the assigned area must be configured (shape) by the discharger with knowledge as to seasonal plume shape and variability and adjacent biological populations and communities. The shape should be such (square, rectangular, etc.) that in-stream monitoring programs have no difficulty in establishing appropriate stations for sampling at the margins of the AIZ.

Examples of a lotic system with 4 zones and 10 discharges and a single discharge with 4 zones are included in Appendix D and Appendix E, respectively.

Table 3 - Calculation of the Areas for Allocated Impact Zones

| Discharge Number | $EVA_k$ | Zone | Area in Zone (Acres) | $ARV_j$ | $AIZ_a$ (acres) | Percent of Total Zone |
|---|---|---|---|---|---|---|
| 1 | 0.02 | Fishing(3) | 1,200 | 1.3 | 19 | 1.6 |
| 2 | 0.010 | Nursery(4) | 450 | 0.66 | 6.6 | 1.5 |
| 3 | 0.0068 | Migration(1) | 460 | 0.29 | 11 | 2.4 |
| 4 | 0.0046 | Swimming(5) | 100 | 0.23 | 2.0 | 2.0 |
| 5 | 0.024 | Living Space(7) | 2,430 | 2.0 | 28 | 1.2[b] |
| 6 | 0.0073 | Living Space(7) | 2,430 | 2.0 | 8.7 | 0.36[b] |

a. $AIZ_{jk}$ is the product of $EVA_k$ and $A_j/ARV_j$.

b. Since two discharges exist in this zone, the total area allocated is 36.7 acres or 1.54 percent of the 2,430 acres.

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Several of the basic concepts of this allocated impact zone procedure are not original with the author. They should be attributed to Dr. Donald I. Mount, Environmental Research Laboratory, Duluth, Minnesota, who in 1971, prepared the first (six pages long) of a series of mixing zone recommendations that culminated in testimony on mixing zones in Lake Michigan in 1974. While at the same laboratory during that time and later, the author had the opportunity to pursue this subject in more depth and detail with the assistance of Dr. Mount and Dr. Todd Thorslund for the initial modelling effort. Mr. Carlos Fetterolf, of the Great Lakes Fishery Commission, published several papers on this subject and, with him, the author initiated the International Joint Commission workshop on environmental mapping (see references). His continuing support and enthusiasm were critical to the development of this concept.

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# APPENDIX A

## HISTORICAL PERSPECTIVE

Most early recommendations focused on zones of passage to ensure no adverse effects of mixing zones on migration or passive drifting of aquatic species. The U.S. Department of the Interior (1968) recommended a zone of passage of 75 percent of the cross-sectional area and/or volume of flow of the stream or estuary. In these passageways, concentrations of waste materials should meet the water quality standards for the receiving water. This report also suggested that if several discharges are close together they should be on the same side so the passageway is continuous. Their recommendation that "mixing should be accomplished as quickly as possible through devices which insure that the waste is mixed with the allocated dilution water in the smallest possible area" is still a generally appropriate guide.

The National Academy of Sciences/National Academy of Engineering (1973) discussed mixing zones in a regulatory sense at great length and that discussion is therefore compatible with allocated impact zones. Since all life stages, such as spawning and larval development, are necessary functions of aquatic organisms and are not protected in AIZ, they concluded that it is essential to insure that adequate portions of every waterbody are free of these zones. "The decision as to what portion and areas must be retained at receiving water quality values is both a social and scientific decision." Information used to arrive at this decision should include current and projected types and location of intakes and discharges and percentage of shoreline necessary to provide adequate spawning, nursery and feeding areas. Other data needs were also discussed. The following quotation from this publication is presented in its entirety because it might be considered the genesis of this procedure for allocating impact zones.

> "To avoid potential biological damage or interference with other uses of the receiving system it is recommended that mixing zone characteristics be defined on a case-by-case basis after determination that the assimilative capacity of the receiving system can safely accommodate the discharge taking into consideration the physical, chemical and biological characteristics of the discharge and the receiving system, the life history and behavior or organisms in the receiving system, and desired uses of the waters."

The earliest attempt by the USEPA to regulate areas of non-compliance was technical guidance for thermal discharges. This technical guidance (USEPA, 1974) was in response to section 316(a) of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1251, 1326(a), and 40 C.F.R. Part 122) to develop effluent limitations for thermal discharges. (A more recent draft of this document in 1977 deleted the following guidance and was never officially published.) In addition to stating that a mixing zone is an area contiguous to a discharge where receiving water quality does not meet the otherwise applicable water quality standards, this guidance provides the following salient points:

- The effluent or plume may be identified at distances or in places outside the mixing zone.

- The mixing zone is a place to mix and not a place to treat effluents.

- The permissible size of the mixing zone is dependent on the acceptable amount of damage.

- The size and shape of the mixing zone should be specified so that both the discharger and the regulatory agency knows its bounds.

- A mixing zone should be determined taking into consideration unique physical and biological features of the receiving water.

- Any mixing zone must be limited to a temporal and spatial (area, volume, location, and configuration) distribution which will assure the protection and propagation of a balanced, indigenous community of shellfish, fish and wildlife in and on the receiving waterbody.

- The acceptable size for a mixing zone depends also on the number of mixing zones on a body of water. The greater the number, the smaller each must be. In this connection, future growth of industry and population must be considered.

Numerous ecological considerations were presented in these effluent guidelines for thermal discharges that must be considered before defining a mixing zone.

The extensive details presented for effluent guidelines for thermal effluents by the USEPA have not been repeated in subsequent guidance. However, the Water Quality Standards Handbook (USEPA, 1984) provided some very general recommendations and incorporated three significant progressive statements:

- A limited mixing zone, serving as a zone of initial dilution in the immediate area of a point or nonpoint source of pollution, may be allowed. Whether to establish a mixing zone policy is a matter of state discretion. Such a policy, however, must be consistent with the Act and is subject to approval of the Regional Administrator.

- The methodology used by the states should be sufficiently precise to support regulatory programs, issuance of permits and determination of best management practices for nonpoint sources.

- In the broadest sense, the zone surrounding, or downstream from a discharge location is an "allocated impact zone" where numeric water quality criteria can be exceeded as long as acutely toxic conditions are prevented.

In an earlier publication summarizing the mixing zone policies incorporated into state water quality standards (USEPA, 1980), it is clear that numerous states had some generally appropriate ecological considerations. However, the majority had quantitative limitations related to cross-sectional areas or volumes that only respond to needs for drifting and migration of aquatic species. Single linear limits (e.g., 300 meters) were incorporated into many States' standards and were based on ease in development and simplicity in enforcement. Fetterolf (1973) eloquently summarized his feelings about this approach by stating that this procedure "is a pretense, a crutch for administrative laziness, and suggests either ignorance of or disregard for intelligent, scientifically-based evaluations of a mutually desirable platform for enforcement programs".

More recently, EPA's Office of Water Enforcement and Permits published a Technical Support Document for Water Quality-based Toxics Control (USEPA, 1985). This document contains much detailed information on toxicity assessment of whole effluents and states that the proper design of a wasteload allocation study for a particular waterbody requires estimation of the distance from the outfall to the point where the effluent mixes completely with the receiving water. While this approach is similar to the historical engineering-oriented plume concept, guidance is given on the use of high velocity diffusers and deep water discharge techniques to reduce the area or volume of allocated impact. Numerous mixing and wasteload allocation models for rivers, lakes, and estuaries are included in this document. The important factor here is that allocated impact zone designation is not only necessary for the enforcement of water quality standards but also in the wasteload allocation procedures that are becoming much more routine for state regulatory agencies during permit renewal/revision cycles.

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# APPENDIX B

## RELATIVE ENVIRONMENTAL VALUE

Not all aquatic ecosystems will have the same critical functions or uses and the following listing is not intended to be complete but more of a guide to site specific analysis.

- ° Migratory pathways of indigenous species are rather fixed and predictable and could be adversely impacted by noxious quantities of toxic substances in allocated impact zones.
- ° Spawning grounds are extremely important especially for those bottom-spawning species dependent on very specific substrate requirements.
- ° Nursery areas for the development of larval and juvenile forms are critical not only to the protection of these forms but also the protection of the food production upon which they are dependent.
- ° Primary production in marshes and areas with rooted aquatics are important sources of food and shelter for aquatic organisms.
- ° Living space or shelter for benthic forms is critical for many species due to rather specific substrate needs and reduced mobility, especially for some shellfish species.

- Consideration of endangered species is high on any relative environmental value scale.

Once the socio-economic, ecological, and other uses have been prioritized, significant consideration must be given to the numerical relative importance of these uses. The following discussion is again primarily ecologically oriented since other uses are better understood at the local level.

Shallow water in lakes, estuaries, reservoirs, and some rivers generally has a higher environmental value and is more productive. Food production is greater in the shallow water zone because light penetration is sufficiently deep to support growth of periphyton, attached algae, and rooted vegetation; nutrients from runoff are commonly more plentiful; terrestrial food organisms are more abundant; there is a greater variety of substrates (sand, sediment, and rubble as contrasted to mostly fine sediment in deeper water) that provide diverse habitats for many kinds of food organisms; and oxygen concentrations are more favorable because wave action and diffusion processes transport oxygen to the bottom.

The density and variety of organisms is greater in shallow water, because many species spawn in shallow areas and their progeny utilize these areas as nursery grounds. In addition, prior to spawning migrations into tributary streams, numerous species concentrate in shallow waters until conditions are optimal for spawning runs; cover provides more protection from larger predators; the more diverse substrates support a greater variety of species in larger numbers than in the more uniform habitat of deep waters; and, in rivers and streams, many fish species migrate through the shallow shore zones. Protected bays and coves on large lakes, reservoirs, and estuaries are often the most biologically important, probably for the above reasons, but also because wind and wave action are less severe.

Recreational uses, such as water contact sports and sport fishing, are concentrated in the shore zone. This zone is also important to the aesthetic appeal of waterbodies. The foregoing discussion identifies certain biotic zones that are more important than others and are related to water depth. Thus, depth can be used as one convenient tool to delineate the various zones in some areas.

As discussed above, various biotic zones exist within a waterbody segment. These biotic zones are not equally important; thus, they have different environmental values. Common sense indicates that AIZ should be located in larger or less valuable areas. A value for the various biotic zones must be established in order to allocate these zones, with zones of high importance assigned high value.

This value determination cannot be strictly objective and must utilize professional, expert opinion of biologists and ecologists familiar with the local situation. Highly valued trout waters, areas inhabited by endangered species and many very productive estuaries may be assumed to be invaluable and excluded from consideration as potential allocated impact zones. Value can be based on the species diversity of the zones and the value made proportional to the ratio of species diversity in various zones. Current-swept mid-channels of large rivers or deep waters in large lakes that are devoid of dissolved oxygen, may be given low value.

Occasions will arise when there is not an adequate data base upon which to establish environmental value. In such cases, one may assume the value to be the same for all biotic zones (i.e., the value of a unit area is inversely proportional to the total area in each zone).

As is shown later, the environmental value is important because it defines upper limits on the amount of each biotic zone that may be allocated. The assignment offers dischargers a chance to select better sites and allows regulatory agencies to encourage potential dischargers into the areas least likely to be damaged. The concept of assigning environmental value is also important, because the total area within a waterbody segment allocated to all impact zones can be more easily and accurately allocated than can areas for individual zones. This is because the error, if any, is distributed proportionally and the decision considers the potential combined effects of all discharges. This must be done by competent staff but only needs to be decided once.

Some states are progressing toward such decisions. The California State Water Resources Control Board (1976) has designated areas of special biological significance for the control of wastes discharged to ocean waters. These areas will be afforded special protection for marine life to the extent that waste discharges are prohibited within the areas. These areas were designated as requiring protection of species or biological communities to the extent that alteration of natural water quality is undesirable.

The assignment of relative values to the prioritized use list may be simplified by not including point source discharges as a "use", since these are the concerns to which will be assigned an allocated impact zone. No numerical range of relative values are specifically recommended since some areas (endangered species spawning) or uses (municipal water supply intake) may be given a value (e.g., infinity) that precludes their inclusion in an AIZ. However, the mathematical process of allocation may require numerical values and, therefore, the minimum value (e.g., naturally hypoxic area) should not be given a relative value of zero, but, for example, a value of one. For practical reasons a range of values from one to 100 might be reasonable. Physical areas that have more than a single use (e.g., shellfish, water supply intake and fish migration) would have a greater value than that for any one of those single uses.

Some recent and forthcoming publications may be useful in assigning relative values. Section 301(c) of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) has led to the development of a proposed rule by the Department of the Interior for determining compensation to the public for injury to natural resources. Technical Information Documents are being prepared that will include methods for using the U.S. Fish and Wildlife Services Habitat Evaluation Procedures. These documents are being designed to estimate the effect of oil and hazardous substances on wildlife habitats but can be useful in understanding the relative value of components of aquatic ecosystems. The National Oceanic and Atmospheric Administration has published a report (Meade and Leeworthy, 1986) that describes the amount of money spent by the public on recreation in coastal counties. A series of technical support manuals were prepared to assist the states in establishing water quality standards in waterbody surveys and assessments for use attainability and analyses in rivers and streams (USEPA, 1983), estuaries (USEPA, 1984a) and lakes (USEPA, 1984b).

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# APPENDIX C

## LEVEL OF PROTECTION

The National Academy of Sciences, National Academy of Engineering (1973) briefly discussed levels of protection of fish against deleterious effects of reduced dissolved oxygen concentrations. The levels of protection were nearly maximum, high, moderate, and low and were based on productivity and quality of the fisheries. An extremely important point made in this discussion and one that is critical to the allocated impact zone concept is that the selection of a level of protection is primarily a socioeconomic decision, not a biological decision. The biological and ecological considerations and potential impacts must be evaluated and made known to those selecting a level of protection of an ecosystem.

The Guidelines for Deriving National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses (Stephan et al., 1985) states that because aquatic ecosystems can tolerate some stress and occasional adverse effects, protection of all species at all times and places is not deemed necessary. If acceptable toxicity data are available for a large number of appropriate taxa from an appropriate variety of taxonomic and functional groups, a reasonable level of protection will probably be provided if all except a small fraction of the taxa are protected, unless a commercially or recreationally important species is very sensitive. A small fraction of 0.05 (1/20) was chosen.

The use of levels of protection in dissolved oxygen criteria continues in the most recent guidance from the USEPA (Chapman, 1985). He listed four levels of risk (=levels of protection):

- No production impairment - representing nearly maximal protection of fishery resources.
- Slight production impairment - representing a high level of protection of important fishery resources, risking only slight impairment of production in most cases.
- Moderate production impairment - protecting the persistence of existing fish populations but causing considerable loss of production.
- Severe production impairment - for low level of protection of fisheries of some value but whose protection in comparison with other water uses cannot be a major objective of pollution control.

Chapman then developed numerical criteria for each of these levels (as well as an acute mortality limit) for early and other life stages for salmonid and non-salmonid waters.

These biological criteria options were developed before the socio-economic considerations were applied that subsequently would determine which level of protection (risk) would apply for a particular waterbody.

What percent of total environmental value then, could be used for allocated impact zones? Conditions necessary for all life history processes may not be provided in these zones. When an excessively large percent of a waterbody segment is made up of impact zones, the population of some species will decline and an unpredictable chain of events may ensue. Furthermore, estimates of an acceptable percent of an aquatic environment that can be allocated to impact zones must be conservative, since predictive capabilities are uncertain.

Determination of the amount of a segment's environmental value to be allocated is based on a variety of criteria, including type of waterbody, water velocity, depth, the number and type of habitats, migration patterns, and the nature of the local food chain. Level of productivity, water temperature, ability of tributary waters to provide recruitment, value to humans (aesthetic, commercial and sport fishing, recreational), endangered species, and other criteria must all be considered.

The ability of an aquatic ecosystem to assimilate wastes is an important consideration in selecting a level of protection since if overloading should occur, the system is disrupted and the ability of the ecosystem to transform those wastes is reduced. If this were to occur, the capability of that ecosystem to recover from this assault will vary. Cairns and Dickson (1977) discussed four characteristics of the ecosystems that relate to the recovery process:

- Vulnerability to irreversible damage is more likely with rivers and estuaries.

- The elasticity of an ecosystem to recover is determined by the availability of recruitment pools of organisms from tributary waters, transportability of various life stages, condition of the habitat after stress (e.g., pH change vs. residual toxicants), and degree of disequilibrium of the chemical-physical environmental quality.

- Inertia, or ability to resist displacement of structure and function, is determined by the degree to which the indigenous organisms are accustomed to highly variable environmental conditions and the degree of high structural and functional redundancy. Flow and flushing characteristics are also important.

- Resiliency of an ecosystem describes its ability to withstand a series of slight impacts without lasting effect.

An aquatic ecosystem with limited nutrients and diversity, low flushing flow, and few sources for recruitment of aquatic organisms would have a very low rate of recovery from excessive inputs of persistent chemicals and would probably require a maximum level of protection to ensure that the allocated impact zones do not collectively have a potential serious effect on the ecosystem.

Determination of the level of protection for a waterbody comprises one of the most difficult decisions in the AIZ process. The process demands high priority and the attention of natural, physical and social scientists, planners, economists, industrialists, lawyers, administrators, and the lay public. Scientists can define the choices, but society at large will have a strong hand in making the final decision (Ferrerolf, 1973).

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# APPENDIX D

## Example 2

This example will be of an industrialized lotic system, such as an impounded river channel, with limited environmental use due to developmental impacts and dredging. As before, this waterbody is divided into m environmental zones with known areas ($A_1$, $A_2 \ldots A_m$) and assigned relative environmental values ($RV_1$, $RV_2 \ldots RV_m$). There are presently n discharges with toxicity masses of $Q_1$, $Q_2 \ldots Q_n$.

Since the principal environmental uses of this waterbody are impacted by industrial and channelization operations, there are limited benthic or benthic-dependent aquatic populations. The example's level of protection (p=0.15) would allocate 15 percent of the total environmental value (TEV) as potential impact zones. Due to industrial saturation, no allocation will be held for future discharges (r=1.0).

The assumptions, analyses, and calculations for Example 2 are the same as for Example 1. The results of these calculations are shown in Tables 4, 5, and 6. The total available area of the waterbody is 1,300 acres. This example will be used to present some potential problem/solution scenarios that can develop during the use of this allocation procedure:

°Discharge #6 is a relatively low volume, high toxicity example that received an AIZ of 8.4 acres in the most

Table 4 - Calculation of Total Environmental Value (TEV) for Example 2

| | Zone | Area (Acres) | Normalized Area (A) | Relative Value (RV) | Environmental Value (ARV) of Each Zone |
|---|---|---|---|---|---|
| 1. | Migration | 150 | 0.12 | 10 | 1.2 |
| 2. | Fishing | 300 | 0.23 | 6 | 1.4 |
| 3. | Overwater Shipping | 230 | 0.18 | 1 | 0.18 |
| 4. | Living Space[a] | 620 | 0.48 | 4 | 1.9 |
| | | | | TEV = | 4.6[b] |

a. Total area (1,300 acres) minus the first three uses defines the living space (620 acres).

b. Amount of TEV to be allocated = pr(TEV) = (0.15)(1.0)(4.6) = 0.69.

Table 5 - Calculation of Amount of Total Environmental Value Allocated to Each Discharger ($EVA_k$)

| Discharge Number | Discharge Flow Rate ($m^3$/day) | Normalized Flow Rate | Toxicity Units Chronic ($TU_c$) | Toxicity Mass ($Q_k$) | $f(Q_k)$ | $EVA_k$ |
|---|---|---|---|---|---|---|
| 1 | 10,000 | 0.0067 | 0.8 | 0.0053 | 0.017 | 0.0045 |
| 2 | 800,000 | 0.53 | 3.9 | 2.1 | 0.87 | 0.23 |
| 3 | 2,000 | 0.0013 | 4.1 | 0.0055 | 0.018 | 0.0046 |
| 4 | 51,000 | 0.034 | 2.3 | 0.078 | 0.21 | 0.053 |
| 5 | 17,000 | 0.011 | 1.2 | 0.014 | 0.043 | 0.011 |
| 6 | 15,000 | 0.010 | 10.1 | 0.10 | 0.25 | 0.065 |
| 7 | 3,000 | 0.0020 | 6.2 | 0.012 | 0.040 | 0.010 |
| 8 | 150,000 | 0.10 | 3.6 | 0.36 | 0.54 | 0.14 |
| 9 | 45,000 | 0.030 | 1.9 | 0.057 | 0.16 | 0.041 |
| 10 | 410,000 | 0.27 | 1.2 | 0.33 | 0.52 | 0.14 |
| | | | | | | $\sum$ = 0.69[a] |

a. The sum of the individual $EVA_k$ values should equal or approximate pr(TEV), which is 0.69 in this example.

Table 6 - Calculation of the Areas for Allocated Impact Zones

| Discharge Number | $EVA_k$ | Zone | Area in Zone (acres) | $ARV_j$ | AIZ (acres) | Percent of Total Zone |
|---|---|---|---|---|---|---|
| 1 | 0.0045 | Shipping (3) | 230 | 0.18 | 5.8 | 2.6 |
| 2 | 0.23 | Fishing (2) | 300 | 1.4 | 49 | 16 |
| 3 | 0.0046 | Shipping (3) | 230 | 0.18 | 6.0 | 2.6 |
| 4 | 0.053 | Living Space (4) | 620 | 1.9 | 17 | 2.8[a] |
| 5 | 0.011 | Living Space (4) | 620 | 1.9 | 3.6 | 0.58[a] |
| 6 | 0.065 | Migration (1) | 150 | 1.2 | 8.4 | 5.6 |
| 7 | 0.010 | Fishing (2) | 300 | 1.4 | 2.2 | 0.73 |
| 8 | 0.14 | Shipping (3) | 230 | 0.18 | 180 | 80 |
| 9 | 0.041 | Migration (1) | 150 | 1.2 | 5.3 | 3.6 |
| 10 | 0.14 | Living Space (4) | 620 | 1.9 | 44 | 7.1[a] |

a. Several discharges are located in the same zones. For example, discharges 4, 5, and 10 are in zone 4 (living space) and the total area assigned to AIZs in that zone would be 64.6 acres for 10.4 percent of the total area of this zone. For the three discharges into zone 3 (shipping) the total area assigned to AIZs would be 191.8 acres for 83.4 percent of the total area of this zone of very low relative value.

valuable zone (migration). Dye and plume studies demonstrated that the assigned AIZ area, and, therefore, dilution volume, would result in permit violations of effluent toxicity limits or water quality standards. Several options would need to be evaluated and cost compared: plant relocation, toxicity reduction, elimination of process causing the problem, and relocation or redesign of the discharge. There may be other options. In this hypothetical example, the discharge was extended from the shoreline migration zone (ARV=1.2) to the more valuable but larger (ARV=1.9) living space zone. That choice increased the total percent area of that zone allocated but that option was agreeable to the local regulators. In addition to gaining a larger AIZ (21 acres) in the larger but more valuable living space zone, the discharge was moved to deeper water that provided even more dilution in the two-dimensional AIZ.

°Discharge #8 has the largest assigned AIZ and percent of total zone (80 percent) and a plant expansion is being planned that would double the discharge flow and result in violation of the AIZ limits. Since no allocation for future discharges was reserved, costs to relocate the plant or discharge are prohibitive, and discharge redesign cannot solve the problem, toxicity reduction of the existing or planned processes will be necessary.

° Most of these discharges will result in violations of effluent toxicity limits or water quality standards due to the AIZ's assigned. In such an instance, it would be likely that the waterbody was already not meeting societal goals in that existing environmental damage is unacceptable. This water quality limited waterbody would have to be seriously considered for a proper, toxicity-based wasteload allocation with the goal of at least partial restoration of environmental uses.

# APPENDIX E

## Example 3

This simple example of a medium to small freshwater riverine ecosystem with one discharge may typify a majority of waterbodies outside of metropolitan areas. The example can apply to any waterbody with a single point source.

This ecosystem is a warmwater/coolwater environment of unsedimented rocky riffles and sedimented pools with some small man-made impoundments. Sportfishing occurs on shore as limited by access and is otherwise pursued in canoes and small boats. Campgrounds and swimming areas occur and in a few areas agricultural runoff has caused some adverse benthic impacts due to sedimentation. Several small villages exist on this river, but none has a point source discharge. One town has a permitted POTW (publically-owned treatment works) which is the only point source on this 15-mile long waterbody. Its mean width of 200 feet provides an area of about 355 acres. Environmental mapping needs are limited due to the small size of the waterbody but will be needed in greater detail around the existing discharge point. A waterbody of this type will have less physical and ecosystem diversity than a lentic system. For example, fishing, migration, spawning and nursery areas are not distinct but tend to occur together. In this example, the zones will be swimming, bank to bank shallow waters, pools or impoundments, and a one-mile long headwater area for put-and-take trout fishing.

The level of protection will be high (p=0.01) and land and water use projections suggest some limited but small industrial development that allows the present discharge to have 35 percent of the total allocation ($r=0.35$). The results of the allocation calculations are shown in Tables 7, 8 and 9. Note that when there is a single discharge, the calculations to obtain $EVA_k$ are not necessary since the sum of $EVA_k$ values equals pr(TEV). It is interesting to note that if this one discharge had been in either zone 1 (swimming, 10 acres) or zone 4 (trout fishing, 24 acres) the assigned AIZ's would have been 0.88 and 0.53 acres, respectively, as compared to 1.5 acres in zone 3 (pools). This AIZ size reduction (an hypothesis in an hypothetical example) may not have been achievable by the discharger or may have been environmentally or socially unacceptable due to the location or size since in both the alternative zones a much higher percentage of that zone would be allocated.

If this example typifies many situations in any state and resources available for environmental mapping and appropriate ecological data generation are limited to the point where this allocation procedure cannot be used in its entirety, a justifiable simplification may be warranted due to the generally homogenous nature of ecosystem variability in ecosystems comparable to this example. A single zone with a single environmental value could be used. That value could be an average of the values expected if detailed knowledge of the waterbody were attainable as is assumed in this example. The only data necessary would be the discharge flow rate, effluent toxicity, and waterbody area. If effluent toxicity data are unavailable, toxicity data for the same process at another site could

Table 7 - Calculation of Total Environmental Value (TEV) for Example 3

| Zone | Area (Acres) | Normalized Area (A) | Relative Value (RV) | Environmental Value (ARV) of Each Zone |
|---|---|---|---|---|
| 1. Swimming | 10 | 0.028 | 12 | 0.34 |
| 2. Shallow waters | 85 | 0.24 | 9 | 2.2 |
| 3. Pools | 236 | 0.66 | 7 | 4.7 |
| 4. Trout fishing | 24 | 0.068 | 20 | 1.4 |
| | | | | TEV = 8.5[a] |

a. Amount of TEV to be allocated = pr(TEV)=(0.01)(0.35)(8.5) = 0.030.

Table 8 - Calculation of Amount of Total Environmental Value Allocated to Discharger ($EVA_k$)

| Discharge Number | Discharge Flow Rate ($m^3$/day) | Normalized Flow Rate | Toxicity Units Chronic ($TU_c$) | Toxicity Mass ($Q_k$) | f(Q) | $EVA_k$ |
|---|---|---|---|---|---|---|
| 1 | 45,000 | 1.0 | 3.9 | 3.9 | 0.5 | 0.030[a] |

a. As discussed in the text, the $EVA_k$ calculation is not necessary when there is a single discharge in a waterbody since the sum of the $EVA_k$ values equals pr(TEV).

Table 9 - Calculation of the Area for the Allocated Impact Zone

| Discharge Number | $EVA_k$ | Zone | Area in Zone (acres) | $ARV_j$ | AIZ (acres) | Percent of Total Zone |
|---|---|---|---|---|---|---|
| 1 | 0.030 | Pools (3) | 236 | 4.7 | 1.5 | 0.64 |

be used with a safety factor to be applied to this extrapolation. The most important point to remember is that an allocation is necessary and achievable as a way to direct certain permit limitations and select monitoring stations based on an AIZ with definite spatial limitations derived from an ecological awareness of the waterbody and site.