Section 8 Management Alternatives

8.0 INTRODUCTION

Performing the 208 areawide study for Long Island involved a variety of investigations that were necessary for the development of sufficient data upon which future planning will be based. These fact finding studies were undertaken by a number of government personnel and private consultants specializing in various aspects of environmental management.

One of the key objectives of the study is the development of a planning process that will lead to the implementation of controls and abatements from nonpoint and point sources of pollution. This interim report covers in general terms the structural and non-structural options that can be employed on Long Island for these purposes. The principal sources of information reported are past studies and those included in the present 208 undertaking. An attempt has been made to incorporate only that material which is most useful to the development of the final plan. As such, the interim report provides an overview for planning purposes. This report is not meant to be inclusive, but rather to identify the major classes of techniques and technology for the interested reader. The actual selection of specific equipment and facilities is beyond the scale of the 208 program. No preferences are stated or implied. Normative judgements are made in the *Plan Summary*. This section is presented in two parts.

The first section addresses nonpoint pollution sources and predominately stresses non-structural solutions applicable under three major headings, *i.e.,* stormwater runoff control, conservation and watershed management, and land use controls. Legal, administrative and design criteria are not mentioned. They are covered in the *Plan Summary* and in Section Six.

The second section addresses point source pollution control and here the emphasis is on structural solutions. Conventional treatment technology is generally covered, and includes primary, secondary and tertiary treatment. A limited discussion of advanced removal techniques for phosphorus, nitrogen and dissolved inorganics is included. The balance of the section mentions alternatives to conventional technology, ranging from sprinkler irrigation and meadow/marsh/pond systems to onsite facilities, such as waterless composting toilets, aerobic biological units and subsurface denitrification septic systems.

8.1 NONSTRUCTURAL APPROACHES

8.1.1 Introduction

Nonpoint source pollutants cause many of the most common and familiar pollution problems, including polluted well water; polluted and clogged rivers and streams; an overgrowth of weeds and algae, bacterial contamination of shellfish, plus sediment in lakes and ponds; and loss of wildlife. A description of these problems will demonstrate why attention must be given to a control program that limits discharges from nonpoint sources.

8.1.1.1 Pollution of Ground and Surface Waters. When the groundwater that supplies municipal and private wells becomes polluted, the water can no longer be used for drinking without costly treatment — treatment that may be impractical in the case of private wells. Groundwater becomes polluted when bacteria, chemicals or salts find their way into aquifers, the water-bearing underground rock formations.

A primary source of pollution of groundwater can be from cesspools

and septic tanks. They were often placed where the soil cannot do its proper filtering job because it is either too impervious (like clay) or too wet. Similarly, leaks that develop in sewer pipes – and they often do – will contribute to groundwater pollution.

Improperly located, designed and managed landfills, chemical or petroleum storage facilities and mining operations also may contribute to both chemical ground and surface water pollution. The concentration of pollutants works its way through soil and reaches the aquifer. And especially in coastal areas, freshwater wells may turn brackish as the water that is removed is replaced by the ocean's salt water.

Pollution of streams and the accumulation of silt or other sediment is a problem in some areas. When organic matter is washed into streams, there is an increased demand for oxygen (biochemical oxygen demand or BOD), which reduces the oxygen available for fish and other aquatic life, sometimes to a point where the water can no longer support life. It also may make the water unfit for swimming or other recreational uses. A stream that is filled with sediment can no longer support aquatic life, supply reliable amounts of water or offer boating and other recreational opportunities.

While much stream and groundwater pollution comes from inadequately treated point source waste discharges, a substantial amount comes from the following nonpoint sources: urban storm runoff, agricultural runoff, construction sites, hydrographic modification and solid waste sites.

Urban storm runoff carries with it debris; concentrations of chemicals and fertilizers that have accumulated on the earth's surface during dry weather; leaves, twigs and other organic matter; grease and spilled petroleum products from roads, parking lots and gas stations; animal droppings; and during winter thaws, salt used to melt ice on streets and sidewalks. The extent of pollution from urban runoff is partly due to the large areas of impervious surface which increase runoff water and do not allow contaminants to be absorbed into the soil where they can be filtered.

Agricultural runoff from croplands and pastures carries sediment, fertilizer, pesticides, herbicides and animal waste into the water.

Construction sites, where the land has been stripped of soil-holding vegetation, unless developed according to an approved erosion control plan will erode and contribute locally heavy sediment.

Hydrographic modification, *i.e.,* changing the character of the stream itself by such measures as channelizing, may lead to increased flooding in unprotected downstream areas or modifying of fish and wildlife habitats.

Solid waste sites, including landfills and dumps, petroleum storage areas or mining operations, if poorly designed and operated, may contaminate both surface and underground water supplies with toxic chemicals and/or bacteria.

8.1.1.2 Pollution of Marine Waters. Weeds and algae have a number of unpleasant effects. Besides disrupting the ecological balance of the water body and reducing fish production, excessive weed and algae growth interferes with swimming and boating, and is generally unpleasant to look at. Algae smells as it decays. Excessive sediment can significantly reduce the depth of lakes and streams, eventually filling them in. Adding too many organic nutrients to the water accelerates the eutrophication or aging process; the growth and decay of weeds and algae is speeded up, using up the oxygen supply and killing off fish and other water life.

The nonpoint sources that contribute to this problem are similar to those contributing to stream and groundwater pollution: urban and agricultural runoff which include fertilizer and animal wastes, semi-wild duck populations on inland ponds and individual cesspools and septic systems.

Added to this problem has been the loss of some of the Island's wetlands. Wetlands are like nature's treatment plants. They act as retention basins and filtering systems, removing and storing many of the nutrients in agricultural and urban runoff before they reach open waters. By interfering with the efficient natural system, we have had to create new, expensive and often less successful systems to replace what nature provided free. Fortunately, the remaining wetlands in Nassau and Suffolk Counties are now protected by the provisions of the Tidal and Freshwater Wetlands Acts of 1973 and 1975.

One of the major concerns that must be addressed satisfactorily in waste treatment planning is that of nonpoint source pollution. In drafting the 1972 Amendments to the Water Pollution Act, Congress recognized that structural controls over sources of nonpoint pollution are often undesirable and inappropriate. Structural controls are limited in coping with sediment, pesticide, micro-organisms and nutrient runoffs.

Proponents of land use planning and control strategies claim that the structural approach has been inadequate on four counts. First, control technologies have not been able, at the current level of funding, to keep pace with the growth in waste loads. Second, control technologies are not available for all sources. For instance, sediments, nitrates and phosphates resulting from land runoff are not practically susceptible to treatment at this time. Third, even the most effective technologies seldom achieve 100 percent removal, which may be necessary for sustaining environmentally sound growth in some urban/industrial centers. (At this time, even 90 percent removal effectiveness is still an outstanding achievement.) Fourth, the exponentially increasing costs associated with higher removal rates may impose economic burdens upon governments and private firms which are beyond their current financial capacity.

The most practical and economic approach to such pollution is preventive rather than remedial, *i.e.,* preventing erosion and runoff by improvements in land use management and agricultural practices.

In general, nonpoint source pollution control relies on "best management practices" (BMP). For example, good agricultural conservation practices can reduce sediment yields from 50 to 90 percent.[1] Preventive measures can

[1] Mark Pisano, "Nonpoint pollution! an EPA view of areawide water quality management," *Journal of Soil and Water Conservation,* May, June 1976, p. 98.

include limits, prohibition, substitution and changes in the method of use of various contaminants to achieve control over the magnitude of specific sources. Figure 8–1 depicts the relationships between source and type of water pollution.

TYPE \ SOURCE	Domestic Waste	Industrial Waste	Agricultural Drainage	Construction Runoff	Urban Storm Water Runoff	Mine Drainage
Organic Waste	●	□	●	□	●	
Nutrients	●	□	●		□	
Sediment			□	●		□
Thermal Waste		□				
Toxicants		□	□		□	□
Other Types*		□				

● Major or primary factor
□ Possible major factor – varies with conditions
* Includes bacteria, oils, scums, etc.

FIGURE 8–1 *Relations Between Source and Type of Water Pollution.*

8.1.1.3 Land Use Practices. Most of these problems are caused by relatively few practices, most of which have to do with the way we use the land. The choice is to use land wisely by either limiting the production of pollutants or to keep pollutants from entering the waters and affecting its quality. Or land can be used poorly, and lead to serious and expensive consequences.

A list of poor land use practices, those that lead to lowered ground and surface water quality, includes the following:

Using unnecessarily large areas of pavement which increases urban runoff.

Cleaning streets infrequently, with the possible result that the "first flush" after a storm in an urban area carries large quantities of chemcals, debris and organic materials.

Overusing lawn fertilizer or road salt, or piling leaves in the gutters of urban streets.

Overusing agricultural fertilizers, allowing animals direct access to streams, and other agricultural practices.

Failing to take measures to reduce soil erosion during construction, or during agricultural and forestry operations.

Failure to take measures to reduce or prevent sand mine leachates and petroleum and chemical spills from reaching ground and surface waters.

Locating housing with septic systems on unsuitable soils.

Filling and using wetlands for urban development.

Locating and designing waste disposal sites so that they leach (filter down) into water sources.

Location of industrial facilities in prime recharge areas.

Dog curbing laws, sales of ducks as Easter pets, and encouraging semi-wild duck populations on inland ponds by artificial feeding.

Efforts to clean up and prevent water pollution from nonpoint sources are aimed at halting or remedying these kinds of practices. The solutions involve regulation, monitoring, improved maintenance practices, voluntary citizen compliance, structural improvement, improved construction practices and improved land use planning implementation. By and large, nonpoint sources that can best be controlled by regulatory and administrative means and by public education, *e.g.*, industrial and animal wastes, landfills, agricultural chemicals, etc., are not stressed in this report. These issues are covered in Section Six, the Plan Summary and Section J of the Areawide Waste Treatment Management Plan. The balance of the non-point portion of this report discusses three broad approaches to nonpoint control – stormwater runoff, water conservation and watershed management, and land use strategies.

8.1.2 Stormwater Runoff

Every parcel of land is part of a larger watershed. Ideally, a stormwater runoff management solution for any development project should be based on, and support, a plan for its entire drainage basin. This is not a revolutionary idea, but only recently have data collection and data handling technology made this economically possible in a meaningful way. Even in the absence of such basin-wide plans, new approaches to residential land planning, which have been evolving since about 1955, have made it possible to apply more creative approaches to stormwater management within a project. With their application, the new effects of incremental urbanization can avoid most

negative impacts and may produce benefits, enhancing opportunities for future implementation of an overall basin-wide drainage plan. See Figures 8–2 and 8–3.

The major residential boom in the post 1945 era relied on the total subdivision of land into individual lots, often with the complete stripping of natural site features and their replacement by an "efficient" design. However, some proposed residential developments clustered dwellings and created common open space, seeking to preserve and enhance natural site attributes. These various innovative concepts of land planning, which have now become grouped under the common title Planned Unit Development, present opportunities for stormwater management consistent with the emerging new philosophy advocated by this report. Traditional subdivision design practices will also benefit from the new stormwater management approaches, but not always to the same degree.

8.1.2.1 The Basic Concepts. The water falling on a given site should, in an ideal design solution, be absorbed or retained onsite such that development

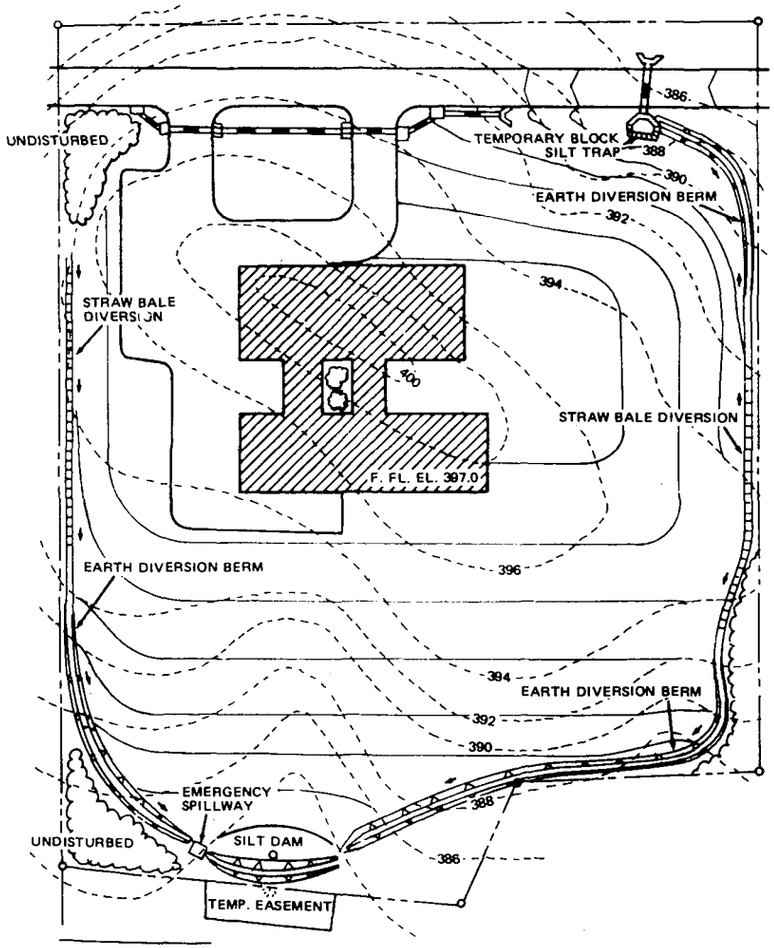
Mechanical Measures

1. **Land Grading:** Grade only those areas necessary for immediate construction. Minimize cut and fill; avoid heavy grading.
2. **Bench Terraces:** Constructed across the slope of the land to break long slopes and slow the flow of runoff.
3. **Subsurface Drains:** Sometimes required at base of fill slopes to remove excess ground water.
4. **Diversions:** Ridges and channels used to divert runoff away from erodable slopes; particularly useful along highway embankments.
5. **Dikes:** Useful around large parking lots to collect runoff for gradual release through grassed outlets or subsurface drains.
6. **Sediment Basins:** A permanent or temporary dam to detain runoff and trap sediment.
7. **Filter Berms:** Gravel or straw bale dikes used to filter stormwater runoff prior to discharge.
8. **Vertical Drainage:** Techniques to infiltrate excess runoff water to rapidly permeable subsoil to reduce excess runoff water.

Vegetative Measures

1. **Vegetative Protection:** Conserve maximum amount of ground cover particularly along stream corridors.
2. **Temporary and Permanent Seeding:** Seeding will add stability to soils which are not needed either permanently or temporarily for construction. Grasses, legumes, trees, shrubs, vines and ground covers can be used.
3. **Mulch:** Straw mulch can be used to protect constructed slopes and other areas regraded at an unfavorable time for seeding.
4. **Stream Channel Stabilization:** Eroding or erosion-prone channels and stream banks can be stabilized by use of vegetation, rip-rap and mechanical measures.

FIGURE 8–2 *Partial List of Erosion and Sediment Control Measures for Construction Sites.*



Source: *Erosion-Siltation Control Handbook* (Draft), Fairfax County, Virginia.

FIGURE 8–3 *Sample Erosion and Sedimentation Control Plan.*

would not significantly alter the quantity and peak rate of runoff leaving the site from that produced from undeveloped sites.

Just as the importance of water quality is being increasingly recognized, a major new emphasis needs to be placed on the identification and application of "natural" engineering techniques to preserve and enhance the natural features of a site, and to maximize economic-environmental benefit. "Natural" engineering techniques are those which capitalize on, and are consistent with, natural resources and processes. Engineering design can be used to improve the effectiveness of natural systems, rather than negate, replace or ignore them.

Among the new trends in basic philosophy that should be pursued are:

(a) Concurrent recognition of the convenience drainage and overflow or flood conveyance elements of existing and proposed drainage systems, the use of on-site detention storage to reduce downstream peak flows, the use of land treatment systems to manage stormwater, and a recognition that temporary ponding at various points in the system, including on the individual lot, is a potential design solution rather than a problem in many situations.

(b) A continuing recognition that there is a balance of responsibilities and obligations for collection, storage and treatment of stormwater to be shared by individual property owners and the community as a whole.

(c) A new recognition that stormwater is a component of the total water resources of an area which should not be casually discarded but rather should be used to replenish that resource. Stormwater problems signal either misuse of a resource or unwise land occupancy.

(d) A growing emphasis on the recognition that every site or situation presents a unique array of physical resources, occupancy requirements, land use conditions and environmental values. Variations of such factors within a community generally will require variations in design standards for the optimal achievement of runoff management objectives.

The above key concerns, while not all-inclusive, embody a basic philosophy that should receive consideration. Although this portion focuses primarily on residential design practices, these concepts should be considered and applied to entire drainage basins in which any development may proceed. The responsible solution for individual developments will be more difficult to achieve in the absence of basin-wide plans, particularly where current practices are based on traditional drainage concepts. For example, if current practices allow an upstream development to use traditional drainage approaches that increase runoff, a development relying on new concepts might be unable to accomodate the amount of excess runoff thereby generated without additional significant costs. The approaches suggested herein should allow development to proceed on individual projects in the absence of a basin-wide plan, since the strategy for the retention and attenuation of peak runoff and total runoff to values not significantly different from predevelopment levels would normally be compatible with any future plan that might evolve for a watershed.

8.1.2.2 A Definition of "Stormwater Runoff System." The term "stormwater runoff system" used herein is, first of all, composed of both natural and man-made elements. In the past, designers have often failed to capitalize upon natural elements and have at times ignored them when a constructed element was installed. These components include not only those which contain and convey stormwater, but also those which absorb, store and otherwise use stormwater rather than dispose of it.

Within a single system, there are components that are designed primarily to obtain convenience at the smallest scale of the system, *e.g.*, the individual site of intersection, during minor or frequent storms. During an infrequent or major storm, the capacities of many of the convenience-oriented components will be exceeded and flow capacity must be provided by other components designed to provide safety and minimize damage throughout the system, from the individual site to the discharge point of the drainage basin to downstream areas. It must be recognized and emphasized that a total stormwater runoff system cannot be expected to prevent inconvenience and minor property damage during a major storm event. A design that would eliminate all such stress would be fundamentally unreasonable and economically infeasible. Expected damages from a major runoff event would include minor erosion and scour, damage to lawns and vegetation, and damage to unwisely located structures, but flooding or undermining of buildings or essential facilities should not occur.

Thus a stormwater runoff system should be considered as a single system having three purposes: (1) the control of stormwater runoff to minimize damage to property and prevent physical injury and loss of life which may result from major storm events having a frequency of occurrence of less than once in 50 years; (2) the control of stormwater runoff to minimize inconvenience and disruption of activity from more frequent storm events (greater probability of occurrence than once in 50 years); and (3) maximizing the infiltration of stormwater.

There are a wide range of analysis techniques available for guiding the design of stormwater runoff systems. The choice of technique must be suited to the size and complexity of the area, the degree of safety and convenience sought and the cost factors involved. Regardless of the techniques selected to guide the design, the following factors must be considered:

1. Rainfall
   a. historic
   b. predictable future
   c. bases for design
2. Drainage Area Characteristics
   a. at the site
   b. downstream,
   c. upstream
   d. basin-wide
3. Land Use Characteristics
   a. present

b. future-short term
c. full development

4. Design Options
   a. on site detention/storage
   b. overland flow
   c. channel capacity; volume/storage
   d. storage, detention, routing
   e. natural drainage system
5. Risk Analysis
   a. to life
   b. to property
      i. on the site
      ii. downstream
      iii. upstream
6. Costs
   a. initial
   b. amortization
   c. operation
   d. maintenance
   e. replacement
   f. inconvenience
   g. flood damage

8.1.2.3 Storage Considerations and Criteria. One of the primary factors to consider in stormwater runoff management is storage. The availability or absence of facilities for temporary or permanent runoff storage is an important element in design. Storage should not, however, be considered a cure-all for stormwater runoff management. In many instances, the storage capacity required to assure both maximum safety and convenience will not be economically feasible, but may still be desirable.

Providing stormwater storage can reduce peak runoff rates; aids the recharge to groundwater; provides attenuation mechanism if stormwater is to be treated; and reduces potential of downstream flooding, stream erosion and sedimentation.

Storage occurs naturally to some degree in most Long Island watersheds. Natural storage is provided by surface depressions and interception by vegetation. Greater storage is possible where the depressions and swales in the drainage area have highly pervious recharge areas. Much natural storage is usually lost through development. This volume can be replaced using swales, recharge techniques, vegetal practices, and by utilizing special inlets that meter the outflow from planned ponding areas. Where detention storage is used, overland conveyance must be designed with sufficient capacity to assure no downstream damage from major storm events. Large scale temporary retention storage should be used to replace storage loss due to the increase of impervious surfaces associated with development.

Rooftop and parking lot ponding are two methods of stormwater retention. In addition, recharge facilities and dry ponds may be utilized to control large amounts of stormwater runoff.

8.1.2.4 Degrees of Storage. Different degrees of storage should be considered in residential design. The lowest degree is the natural storage provided by surface depressions and by foliage and ground cover interception of rainfall. To take advantage of this storage, natural ground cover should be maintained. Small volumes of temporary storage can be provided for in the design of swales, pipes and channels. Outlets from temporary storage can be designed to attenuate peak outflow, and safely discharge stormwater runoff thus assuring protection of adjacent and downstream properties from flooding, erosion or sedimentation damage. Temporary storage facilities include rooftop and parking lot ponding, recharge sedimentation basins and normally dry ponds.

The comparative amounts of storage that may be achieved using different combinations of facilities will vary. The designer of storage should determine that the cost of storage provisions will not exceed benefits accrued and that the designs will be economical to maintain. The residential storage system should be coordinated with watershed and regional storage plans for flood control, water supply and recreation.

8.1.2.5 Other Storage Considerations. In creating ponds or lakes, the following considerations are worthy of mention.

1. Access to shorelines may be effectively limited to desired locations by planting thorny decorative shrubs.
2. Lake bottoms within ten feet of the shore should be so graded that water depth normally will not exceed eighteen inches, to simplify immediate rescue of small children.
3. Extensive areas of shallow water, especially in upper reaches of the lake, should be avoided to prevent undesirable weed growth.
4. Dense plantings of shrubs that will act as barriers to automobiles are appropriate where vehicles might otherwise run into the lake, especially at night.
5. Paved walkways roughly paralleling the shoreline, low-level night lighting, fixed benches, floored rain shelters and sensitive landscaping can add considerably to the charm of a lake or pond setting, and to the desirability of the surrounding neighborhood. Massive plantings of seasonally colorful shrubs, such as azaleas, redbud, dogwood or Japanese maple, can help publicize an area and create particular pride of ownership throughout the neighborhood.

8.1.2.6 Streets and Curbs. The primary purpose of residential streets is to provide vehicular access to homes and community facilities. Vehicles using the streets will vary from routine automobile traffic to larger delivery and service trucks and emergency police and fire vehicles. Streets also have several secondary functions. One is to provide routes for pedestrian and bicycle traffic; another, more relevant, is to collect and convey stormwater runoff.

Planning a drainage system should be done simultaneously with street layout and gradient planning, and careful consideration should be given to the following:

1. The functions of streets as parts of the stormwater management system.

2. Street slopes in relation to stormwater capacity and flow velocity in gutters and/or street swales.

3. The location and sizing of street culverts. Culverts may be sized to create temporary upstream storage if there is proper consideration of earth bank stability and potential overflow effects during major flood conditions.

4. Location of streets in relation to natural streams, storage ponds and open channel components of the system.

5. Location and capacity of inlet points to pipes in relation to gutter slopes, the spread of water across streets and the flow of water across intersections.

6. Coordination of street grades with lot drainage. Positive slope away from all sides of the house must be accomplished. Lot drainage becomes difficult when there is less than one and one-half to two percent (usually fourteen to 24 inches) fall from the earth grade at the center rear of the house to the street curb at the lowest front corner of the lot.

7. Use gutters, downspouts and dry wells on all newly constructed houses to reduce volume of runoff water in roads.

8.1.3 Water Conservation Practices

Water conservation is a means for reducing the necessary capacity of facilities needed to collect, convey and treat both domestic and industrial waste; for reducing per capita usage of water; and for the proper return of water to the aquifer.

The domestic use of various devices available to curtail water use include faucet aerators, flow control shower heads, automatic flush valve toilets, shallow trap water closets and the English dual cycle water closet. Figure 8–4 lists water saving devices ranked by cost-effectiveness.

Industrial, commercial and agricultural reuse of water is another option. For instance, in-plant recirculation of water would reduce total water requirements and also decrease waste discharges.

Planners of wastewater systems should be cognizant of possibilities for reuse of effluent, generally after some type of treatment, and alert both local governments and water users to such possibilities. Treated sewage effluent, for instance, can be utilized for irrigation purposes. However, special attention should be paid to land use impacts by such reuse practices (*i.e.*, heavy metal residues in food, reduction in soil permeability, etc.).

Water conservation practices could be encouraged by incorporating them within building codes, state and local regulations, and the initiation of pricing policies that encourage less wastage of potable waters – particularly when used for non-drinking purposes.

Hardware Device	Water Savings GPCD (1)	Estimated Installation Costs Matl. $	Labor $	Total $	Water-Savings Cost-Effectiveness Total $ / GPCD (1)
1. Aerator for Lavatory and Kitchen Sink	0.5	2	0	2	4
2. Dual Cycle Water Closet	17.5	100	30	130	7.4
3. Limiting Flow Valves for Shower	6	35	15	50	8.3
4. Batch-type Flush Valves (2) for Water Closet	15.5	120	38	158	10.2
5. Vacuum Flush Toilet (for 100 homes)	22.5	–	–	295	13.1
6. Recycle Toilets	24.7	300	25	325	13.2
7. Batch-type Flush Valve (1) for Water Closet	7.5	75	30	105	14
8. Shallow Trap Water Closet	7.5	80	30	110	14.7
9. Urinal with Batch-type Flush Valve	7	150	25	175	25
10. Washing Machine with Lever Control	1.2	35	0	35	29.2
11. Vacuum Flush Toilet (for Single Homes)	22.5	–	–	1520	67
12. Limiting Flow Valves for Lavatory	0.5	45	23	68	136

(1) GPCD, gallons per capita per day * *Source: Wenk (1976)*

FIGURE 8–4 *Water Conservation – Plumbing Devices Ranked by Water Saving Cost Effectiveness.*

8.1.4 Watershed Management

A properly implemented watershed management program is essentially a preventive and conservation approach primarily meant to prevent deterioration of groundwater supplies in undeveloped areas. It is a useful adjunct to other waste management options in the following ways:

1. It makes possible a broader range of community development patterns in non-watershed areas.

2. It helps minimize erosion and associated runoff problems.

3. It assures the availability of potable waters.

4. It can provide the locations for eventual recharge.

5. It is an important land use alternative in the attainment of Suffolk County's long standing open space protection program.

6. It may provide a significant cost-effective benefit over sewering approaches.

8.1.5 Land Use Practices

Land use strategies loom as a promising complement to treatment technology. The way the use of land is managed is pivotal to the entire pollution problem. Without environmentally sensitive land use planning and control, investments in wastewater treatment facilities can easily be squandered. Well conceived and administered land use controls will allow reasonable levels of growth with minimal resource degradation and with a more favorable cost-effectiveness rate.

8.1.5.1 The Land Use Planning Process. Land use planning is a decision process as to how land should best be allocated and used based on current conditions and anticipated future events, *i.e.,* as expansion, abandonment and renewal proceed through time. In simpler terms, it is an effort to anticipate future events and desires so that better decisions can be made today. The planning process has traditionally been oriented toward improving the man-made physical environment (*i.e.,* the location, character and quality of housing, commercial and industrial activities, transportation, utilities and community factilities).

The interrelationships of land use and water quality are numerous and quite complex. Figure 8–5 is a schematic diagram of these relationship. Summarily stated, population and economic growth, private market forces, land use regulations, public services and facilities, and the natural features result in a particular land use pattern and land consumption rate. This pattern, with its underlying determinants, can cause water quality problems:

Damaging, and perhaps poorly distributed, point source waste discharges (*i.e.,* domestic, industrial and power plant discharges).

Damaging non-point loads generated by urban and rural land uses as well as construction activities.

8.1.5.2 Overview of Land Use Strategies and Techniques. In developing land use strategies for water quality management programs, there are several goals toward which such efforts should be aimed (See Figure 8–6):

Reduce and balance point discharges with the water quality standards and established wasteload allocations for receiving waters. The planner should seek to distribute waste-generating development in a manner which does not overburden the receiving water body at points of waste discharge.

Reduce and balance harmful non-point discharges. The planner should set forth plans and programs which minimize both the production of non-point pollution and the entry of such wastes into water bodies.

Conserve the natural features and natural systems which protect water quality and quantity. The planner should plan and control

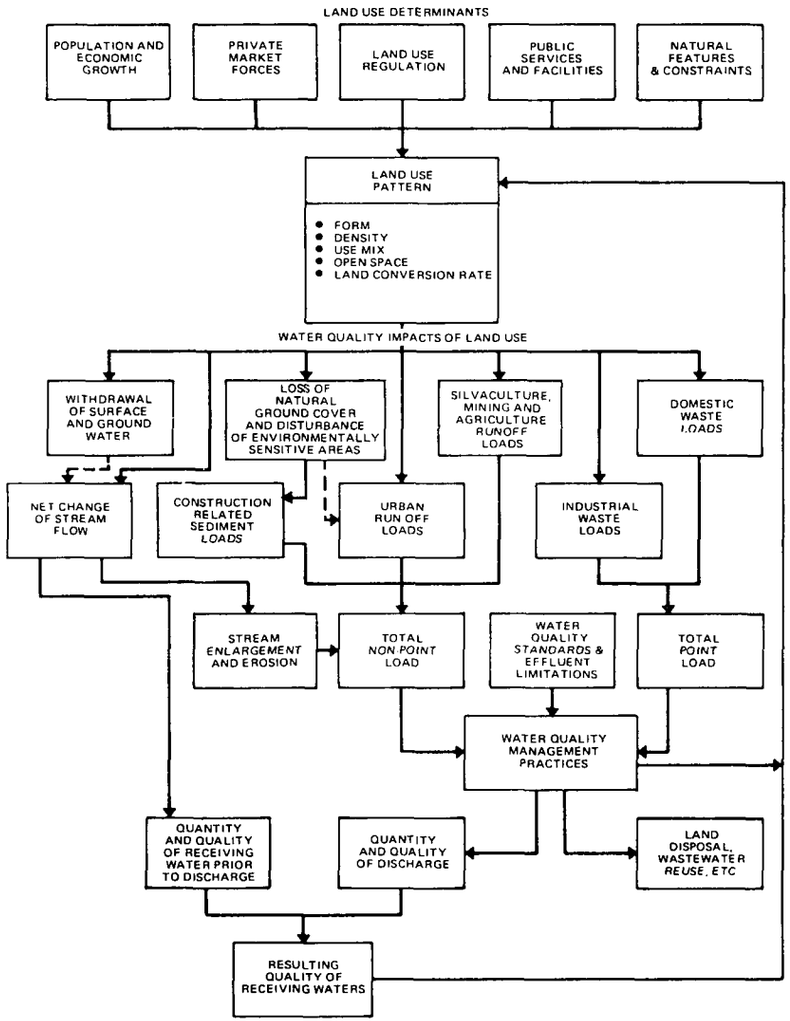


FIGURE 8–5 *Schematic Diagram of the Land Use/Water Quality Relationship.*

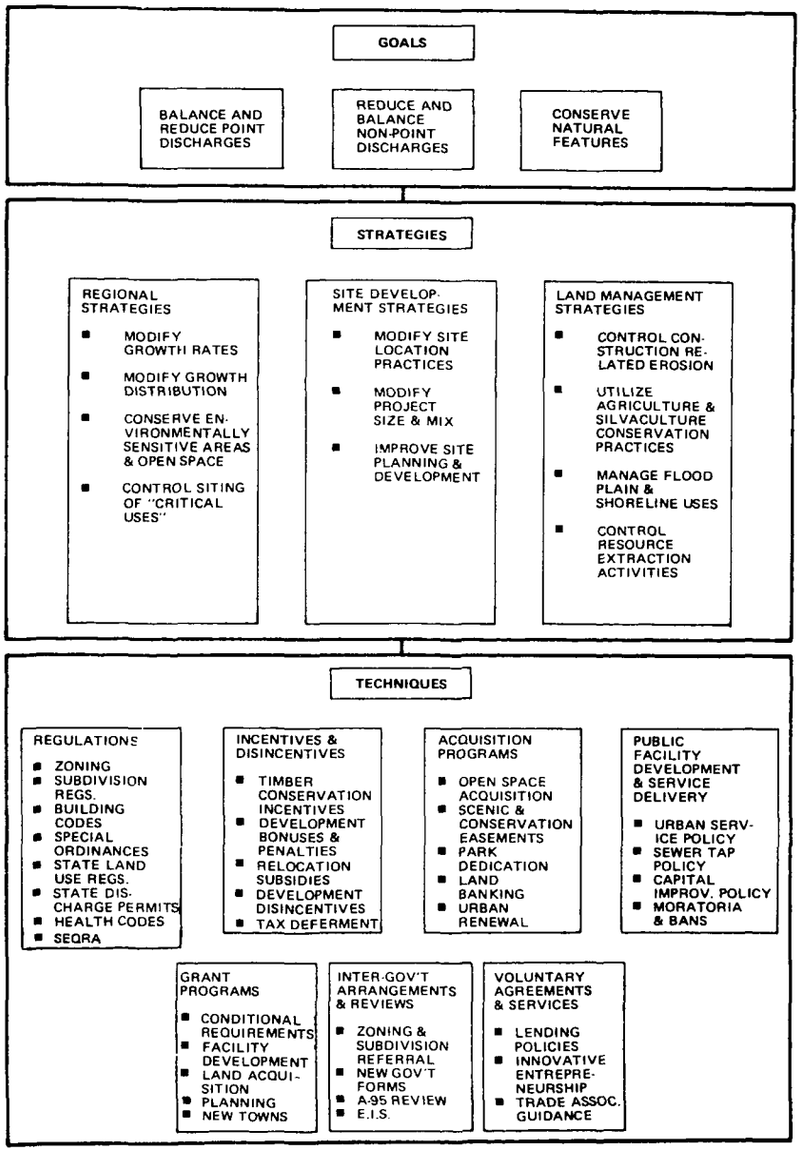


FIGURE 8–6 *The Role of Land Use Planning and Control in Water Quality Management.*

land use in ways which allow the natural terrain and ground cover to perform its runoff control, groundwater recharge and waste absorption functions.

Planning strategies oriented toward these general goals fall within three general categories which range in scope from areawide to site specific:

8.1.5.3 Regional Strategies. On the regional level, water quality management planners have responsibility for considering a wide range of options in meeting water quality standards and effluent limits. The achievement of this objective requires the sensitive consideration of growth objectives, alternative arrangements of the area's physical structures, composition of settlement areas and the location and character of open space and rural land uses. Four land use strategies which have potential for improving water quality at the regional level are:

a. Modify growth rates.
b. Modify growth distribution.
c. Conserve environmentally sensitive areas and open space.
d. Control the siting of critical uses. See Figure 8–7.

8.1.5.4 Land Management Strategies. Not all land/use water quality problems can be dealt with at the planning or planning-administration levels. Many water quality problems stem from poor land management in both rural and urban areas. The management of land is of great significance to the control of non-point pollution. The strategies which relate to land management include:

a. Control construction-related erosion.
b. Utilize agricultural best management practices to reduce storm runoff and control erosion.
c. Manage flood plain and shoreline uses.
d. Control resource extraction activities.

8.1.5.5 Site Development Strategies. Careful attention to the water quality impacts of individual projects can have important results, if not individually, at least cumulatively. At the site planning level, three strategies may prove fruitful, depending upon local conditions and institutional factors:

a. Modify site location practices.
b. Modify project size and/or mix.
c. Improve site planning and development.
d. Institute development site erosion control plan.

Techniques for implementing these strategies are diverse. In addition to traditional, well tested regulatory procedures, innovative policymakers and planners are devising an increasing array of controls in an attempt to weld environmental considerations to land planning and development endeavors. These implementation techniques include:

Regulations
Incentives and disincentives

CRITICAL USE	POTENTIAL HAZARDS TO WATER QUALITY	STRATEGY TO CONTROL IMPACT ON WATER QUALITY	PARAMOUNT LOCATIONAL CONSIDERATIONS
Sewage treatment plants	• Nutrients • Bacteria • BOD	• Separate from incompatible development • Utilize high level treatment • Separate from beneficial downstream uses	• Surrounding development • Projected need for expansion • Water quality at point of discharge • Downstream uses
Sanitary landfill	• Leaching of minerals or other pollutants into ground or surface water • Erosion	• Separate from ground and surface water • Regulate management practices	• Location of ground water table and surface water • Existing and projected development in area • Final reuse of site
Industrial plants with independent discharges	• Toxic substances • Heat • Organic wastes	• Make location compatible with waste load limitations • In-plant treatment • Permit issuance • Fines for violations	• Existing water quality and water quality standards • Projected kind and amount of effluent • Treatment plant capacity
Water processing plants	• Decrease in surface water flow	• Balance with competing uses	• Water quality at intake point • Projected development in water shed • Location of competing water uses
Power generating plants	• Heat • Residual wastes	• Prohibit in environmentally sensitive areas • Dispersion of sites • On-site cooling techniques	• Location of competing or compatible uses • Tolerance of existing biotic communities
Highways	• Sedimentation • Stream channel modification	• Avoidance of watercourse crossings, hillside locations, & channel modification • Control construction-related erosion	• Locations of water channels • Soil characteristics • Engineering design • Construction practices
Intensive cattle feedlot	• Animal waste washoff • Groundwater contamination • Sedimentation	• Stream vegetation buffers • Regulation of management practices • Sediment basins • Prohibit in environmentally sensitive areas	• Level terrain • Soil & geologic characteristics • Water quality conditions

FIGURE 8–7 *Planning Considerations for Major Critical Uses.*

Acquisition programs
Public facility development and service delivery
Grant programs
Intergovernmental arrangements and reviews
Voluntary agreements and advisory services
Public informational programs.

These goals, strategies and implementation techniques are depicted graphically in Figure 8–8.

The land use strategies outlined here are not brand new, visionary ideas. They are being considered and frequently implemented in various places throughout the country. The mechanisms to implement these strategies are even more familiar. It is more universal acceptance and adoption of these strategies that is now needed. Localities pursuing strategies to modify growth distribution, control location of critical uses, minimize erosion and sedimentation, and all the other strategies will reap benefits of improved water quality and, collaterally, preservation of other natural and human values.

In the matrix shown in Figure 8–9, the strategies for land use are evaluated as to long and short-range potential for reducing water pollution and as to ease of implementation. Each cell was rated from one to five, with the number assigned by assessment of the strategy in terms of (a) potential *effectiveness under ideal conditions, and (b) realistic feasibility for implementation*, given existing and anticipated political and economic constraints. The short-term payoffs of the strategies, it will be noted, have lower scores than the long-term payoffs. Lead time involved in implementing strategies, both legally and fiscally, generally means that full scale implementation seldom comes about in the short range. More importantly, since land use strategies seldom begin with a pure water base, impact of existing point and non-point sources will be felt for years to come, as tomorrow's treatment labors to catch up with yesterday's mistake. However, adoption of appropriate land use strategies will not only minimize water quality degradation from new development, but water quality could be expected to improve as poor land use patterns and practices are phased out.

In the short term, it is concluded that the greatest likelihood of water quality improvement would be obtained by pursuing control of critical use siting, erosion control and improved site planning and development. In the more distant future, additional benefits will be possible through more sophisticated planning for growth distribution and through protection of environmentally sensitive areas, including flood plains, shorelines and watershed conservation areas. See Figure 8–10.

The payoff index also indicates that the most effective strategies are those which can be implemented most easily. For example, modifying the growth rate has a low hypothetical payoff, not because the strategy is not valid, but because widespread public acceptance and implementation are difficult to achieve. The matrix also summarizes tools for implementing the land use strategies. The tools were also evaluated as to political and economic feasibility as well as technical efficacy. Public controls such as zoning requirements, permits and other regulations can generally be enacted with little strain on the local budget or little widespread objection. Review and advisory services are not as effective simply because compliance cannot be enforced. The matrix also illustrates that all tools cannot be used for every strategy, but that there are several means available to implement each land use strategy to improve water quality.

8.2 STRUCTURAL APPROACHES

8.2.1 Water Pollution Control

The Alternative Systems Diagram for Water Pollution Control, Figure 8–11, comprises: a network of significant wastewater sources (*e.g.,* domestic wastewater); significant waste parameters (*e.g.,* biochemical oxygen demand, or BOD); wastewater treatment alternatives (*e.g.,* activated sludge); and effluent disposal alternatives (*e.g.,* groundwater recharge). Alternatives for disposal for the concentrated wastewater solids are also included.

It should be noted that the diagram is not all-inclusive of every wastewater source, discharge parameter or treatment process. For example, there are other constituents of wastewater besides BOD, nitrogen, phosphorus and dissolved solids. However, these are considered the most significant with respect to the selection of a suitable treatment system and mode of effluent disposal.

The impact of water pollution control systems upon coastal environments may be considered to be made up of three separately identifiable aspects. First and foremost, the impact of the effluent and the residual contaminants it carries must be considered. Secondly, the construction and

FIGURE 8–8 *Regional Strategies and Techniques.*

Strategy	Implementation Techniques	Examples
Modify Growth Rate	• Policy Recommendations and Decisions by Governmental Leaders • Zoning • Public Service Policy • Building Moratoria	• State and Local Studies in Virginia, Michigan, Fairfax County, Virginia, and Florida • Population Ceiling Imposed in Lake Tahoe, Proposed in Boca Raton, Florida
Modify Growth Distribution and Density	• New Town Assistance Programs • Locational Decisions for Major Public Facilities such as Sewage Lines and Treatment Plants and Location of Major Highways • Zoning • Local Moratoria on Sewage Taps or Extensions • Regional Planning and Adoption of Policy and Controls by Member Jurisdictions • A-95 Review and Environmental Impact Statements • Tax Abatement for Open Space • PUD, Large Lot Zoning • Negotiate Densities Proposed in Impact Areas	• New Towns – Columbia, Md., Reston, Va., Jonathan, Minn. • Special New Town Incentives or Assistance: Texas, Arizona, California, Ohio • Extensive Agricultural, Low Density Zoning, State or Local Level, Hawaii; New Jersey Communities – Ramapo, N. Y. Growth Plan • Nassau-Suffolk Regional Development Plan • Plan for Year 2000, D. C. Area • Sewer Moratoria in Florida & Washington, D. C. • Prince Georges Co. Staging Policy
Preserve Environmentally Sensitive Areas and Open Space	• Aquisition Special Zones Requiring Use Permits • Zoning • Private or Public Compacts • Tax Incentives and Disincentives	• National Parks and Forests, Local or State Parks • Acquisition and Easement Programs: Boulder, Colo., New Jersey, Florida, Ohio • Maine Site Location Law • Suffolk County Farmlands Acquisition Program • San Francisco Bay Conservation & Development Commission • Shoreline or Flood Plain Zones – Wisconsin, Minnesota, College Township, Pa., Buffalo County, Wisc., Delaware • Suffolk County Greenbelts • Favorable Taxes on Undeveloped Land: Va., Cal., Fla., Conn. • Proposed Abolition of Tax Benefits That Now Encourage Development in Certain Resort Areas
Control Location of Critical Uses	• Collaborative Regional Planning & Funding • Zoning • A-95 Review; Environmental Impact Statements • Federal or State Regulation of Certain Uses	• Special Exception or Permit Required – State or Local Level. Maine Site Location Act, Local Zoning Ordinances, New York State Environmental Quality Review Act • Proposed: Power Plant Siting Act, Sediment Control Act, Toxic Waste Disposal Control Act

PLANNING STRATEGY	POTENTIAL REDUCTION OF WATER POLLUTION		EASE OF IMPLEMEN-TATION		NET IMPACT		IMPLEMENTATION TECHNIQUES												
	SHORT TERM (1)	LONG TERM (2)	SHORT TERM (3)	LONG TERM (4)	SHORT TERM (1x3)	LONG TERM (2x4)	ZONING	SUB. REGS.	BLDG. CODES	PERMIT SYSTEMS	DISCHARGE STATUTES	SPEC. ORDINANCES, USE REGS.	STATE LAND PROGRAMS	INCENTIVE PROGRAMS	DEVEL. & ACQUISITION PROGRAMS	PUB. FAC. SERVICE	GRANT PROGRAM	GOV'T REVIEWS	PRIVATE AGREEMENTS
■ Modify Growth Rates	2	5	1	2	2	10	●					□	□				●		
■ Modify Growth Distribution	3	5	2	4	6	20	●				●		●			□	●	□	
■ Preserve Environmentally Sensitive Areas and Open Space	3	4	2	4	6	16	●	□			□		●	●		●		●	●	□
■ Control Siting of Critical Uses	3	4	3	5	9	20	●				●		●	□			□		●	
■ Control Construction-Related Erosion	3	3	3	4	9	12		●		□	●	●	□							□
■ Utilize Agriculture & Silvaculture Conservation Practices	2	4	1	3	2	12						●		□						□
■ Manage Flood Plain and Shoreline Use	3	4	2	4	6	16	●	□	□		□		●	□		□				
■ Control Resource Extraction Activities	1	2	2	3	2	6	□				□	●	□							□
■ Improve Site Planning & Development	3	4	3	5	9	20	●	●		□		□	□	□					●	□

Note: 1. Values are based upon authors' judgement and experience
2. Values range from one to five indicating minimal to maximal degrees of effectiveness or feasibility
3. Implementation tools are identified as follows:
● Primary Implementation Techniques
□ Secondary Implementation Techniques

FIGURE 8–9 *Assessment of Payoffs and Implementation Requirements.*

operation of the physical plant itself will impact the environment, and must be accounted for. Last is the impact, although secondary and indirect, of the final disposition of the wastewater solids which were concentrated and removed from the wastewater stream. The Alternative Systems Diagram delineates the possible alternatives and combinations of alternatives for treating the wastewater and disposing of the effluent, as well as the residual solids.

8.2.2 Conventional Treatment Technology

The current accepted method of wastewater treatment is that illustrated in Figure 8–12. This system is referred to by a variety of titles such as: conventional treatment, biological treatment and primary plus secondary treatment. This treatment has been specifically developed to remove suspended solids, biodegradable organics and microorganisms from wastewater.

TYPE	DESCRIPTION	MAXIMUM USE DESIRABLE	MEANS OF CONTROL
Shorelines	Land bordering bodies of surface water--lakes, ocean. For planning purposes, strip extending 1000' from water edge.	Only uses inseparable from water fronts: ports, harbors, recreation, water and sewage treatment plants	• Zoning • Acquisition • Special use permits • Tax incentives • Tree protection laws • Setback and bulkhead regulation
Wetlands	Water and flood water storage areas (marshes, swamps, and bogs)	Non-disruptive agriculture; isolated urban development	• Zoning • Acquisition • Special use permits • Tax incentives
Flood plains	Land bordering watercourses. For planning purposes generally defined as land with a flooding probability of from 50 years upward, or land within 300' of a navigable stream, whichever is greater.	Natural vegetative cover; uses which will not be damaged by flooding (recreation areas, parks), or are inseparable from flood plain use	• Zoning • Acquisition • Subdivision regulations • Building codes • Special use permits • Tree protection laws • Setback and bulkhead regulation
Steep slopes	Slopes of over 12%. Depending upon circumstances, a higher percentage may be chosen	Forestry (with conservation measures to prevent erosion), recreation, low density residential.	• Zoning • Erosion control regulations • Subdivision regulations • Tree protection ordinances
Forests and woodlands	Natural vegetative cover with tree canopy	Recreation; timber production; low density development	• Zoning • Acquisition • Tax abatement
Headwater regions	Upland tributaries where stream flows are low and seasonally incapable of assimilating increased waste loads	Low density development with export of domestic discharges	• Zoning • Acquisition • Erosion control regulations
Aquifer recharge areas	Points of interchange between aquifers and surface waters.	No polluting uses; minimal impervious surface	• Zoning • Impoundment of clean streams transecting aquifers • Acquisition

FIGURE 8–10 *Environmentally Sensitive Areas.*

Suspended solids produce sludge banks in rivers, biodegradable organics lower the oxygen resources of lakes and rivers and microorganisms are the source of most water-borne disease. In the past, it was only thought necessary to substantially remove these three classes of pollutants from wastewater prior to discharge to avoid adverse environmental effects. This is no longer generally true because of the newer awareness of other serious contaminants—the danger of which was not previously realized.

Although in many locations the conventional system no longer is sufficient of itself, it is the base upon which some newer, more effective treatment systems are constructed. Therefore, a short description of this system and the degree of treatment which it can provide is given.

Wastewater is first passed through preliminary treatment of screening and grit removal. Preliminary treatment is utilized to protect pumps and pipes downstream from being harmed by large articles and abrasives which are often found in sewage. Next, primary sedimentation is provided to remove relatively large organic solids. The following step is biological oxidation in which a large quantity of microorganisms is contacted with the sewage in an aerobic environment. In this step, the microbes convert the soluble and colloidal organics producing settleable masses of microbes plus carbon dioxide and water. Two systems which are used for biological oxidation are the trickling filter and activated sludge. The microbes which are active in biological oxidation settle by gravity from the flow in the secondary sedimentation tank since they cannot be discharged with the effluent. Some are recycled to the entrance of the biological oxidation process in order to maintain an adequate population in this unit, the remainder are sent to the sludge handling section. After passage through the secondary sedimentation tank the flow is disinfected, usually by the application of chlorine, and discharged. No attempt is made to sterilize the effluent since all that is required is destruction of pathogens (disease producing bacteria). Most pathogens are more susceptible to the effects of chemical disinfectants than the non-pathogens. It is important to note that the microbes which function in the biological oxidation process are non-pathogens.

When considering the cost and effectiveness of waste treatment technology, sludge disposal is often overlooked. This is unfortunate as up to half the cost of the conventional treatment train can be charged to sludge handling and disposal. Sludge is a thick suspension of organic solids which is drawn from the bottom of the primary and secondary sedimentation tanks. Disposal usually involves two steps, the first of which is dewatering. Dewatering is generally necessary because the cost of the second step "ultimate disposal" is proportional to the volume of the sludge. Unfortuantely, sludge is usually difficult to dewater unless chemicals are added and/or it is subjected to anaerobic biological treatment. The liquid removed during the dewatering step is referred to as supernatant and is usually recycled to the initial portion of the treatment plant, *i.e.*, path from 6 to 1–2 in Figure 8–12.

Among the methods employed for ultimate disposal are landfill, land spreading, incineration, wet oxidation and processing for recovery of useful byproducts. At present, research in ultimate disposal is aimed at reduction of costs of environmentally acceptable ultimate disposal methods.

Table 8–1 illustrates the performance which can be expected of a typical well-operated conventional treatment plant. The results have been presented both as percent removal and typical effluent characteristics. This type of plant cannot provide significant removal of phosphorus, nitrogen or salts. Suspended solids, organic removal and microorganism removal are significant.

8.2.3 Biological-Physical Treatment

The inability of gravity sedimentation in the final clarifiers to remove small, light particles places a limit on the capability of conventional treatment

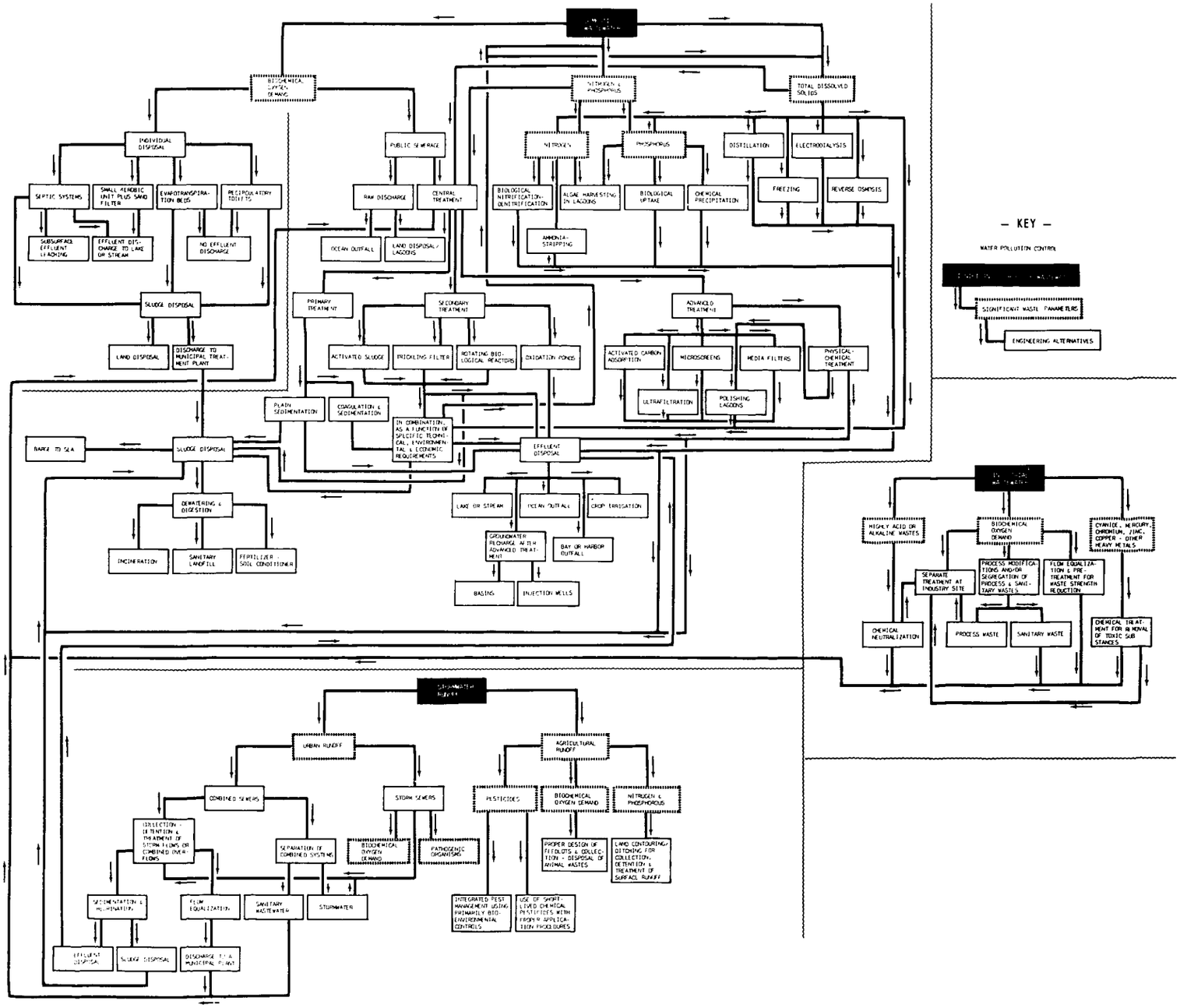


FIGURE 8–11 *Alternative Systems Diagram for Water Pollution Control.*

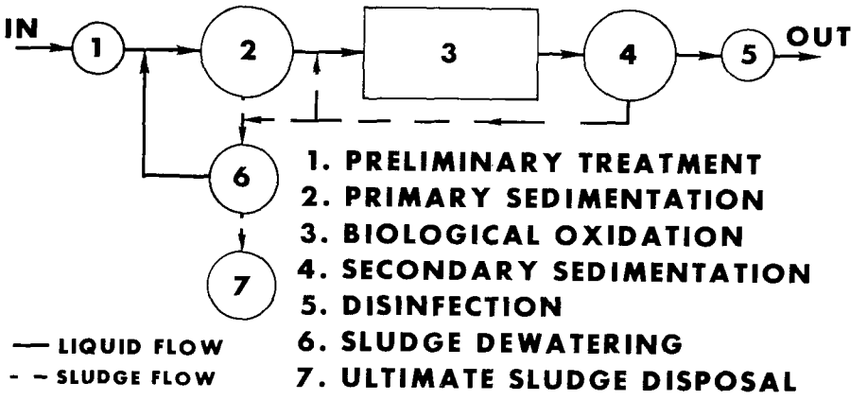


FIGURE 8–12 *Biological Treatment System—Primary and Secondary.*

to reduce suspended solids and BOD in the treatment of wastewater. The usual range of this limit is indicated by the figures presented for typical effluent characteristics in Table 8–1. Integration of a better liquid-solid separation device into the treatment scheme is thus one method of up-grading conventional treatment. Figure 8–13 illustrates the simplest type of advanced waste treatment, the biological-physical treatment system. This system is identical to the conventional treatment system with the exception of the provision of an additional solids removal step after secondary sedimentation. Three types of systems have been widely used to upgrade the performance of conventional systems; microstrainers, deep bed filtration and chemical treatment.

8.2.3.1 Microstrainers. The simplest system is the microstrainer, illustrated in Figure 8–14. Microstrainers are rotating drums on which woven filter fabrics, usually of stainless steel, are mounted. Incoming wastewater

Table 8–1

TYPICAL PERFORMANCE – CONVENTIONAL TREATMENT

Pollutant	Effluent mg/l	% Removal
Suspended Solids	20–30	80–90
BOD	15–25	80–90
COD (Chemical Oxygen Demand)	30–60	70–80
Ammonia-N	15–25	0–10
Phosphorus	6–10	0–40
Coliform	1 per ml	99.999

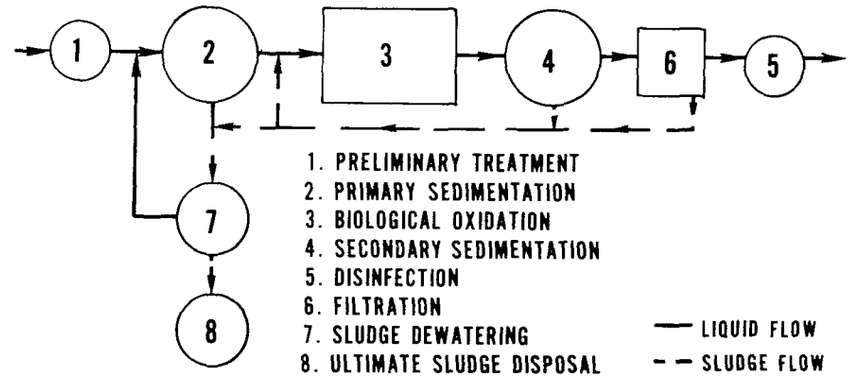


FIGURE 8–13 *Biological-Physical Treatment System.*

flows into the drums along the axis and then passes through the filter cloth which forms the drum surface. Filter rates are six to ten gallons per minute per square foot with head differential at about six inches of water. Control of headloss is obtained by washing the solids from the screen as that portion of the screen rotates to the top of the device. The backflow liquid discharges to a trough in the interior of the drum from which it is recycled to the sedimentation basin. Ultraviolet light mounted above the screen is used to prevent biological growth from blinding the screen.

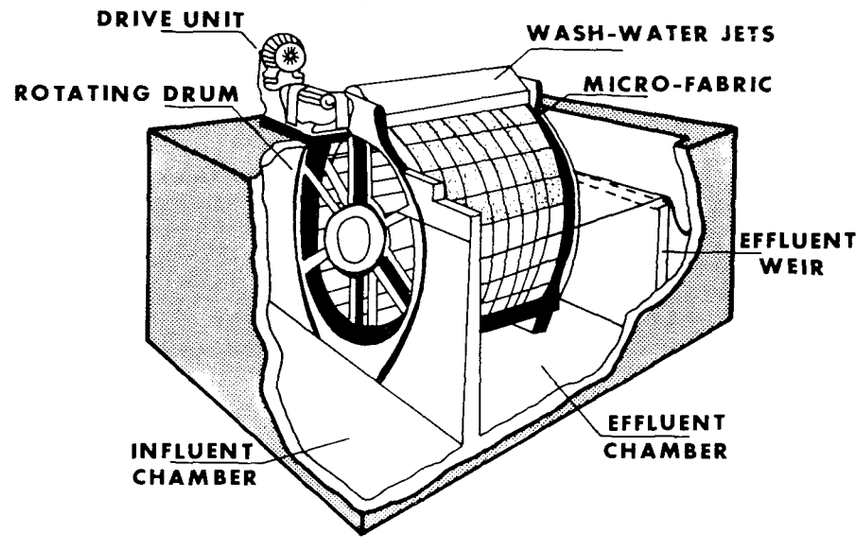


FIGURE 8–14 *Typical Microstrainer Unit.*

Microstraining is fundamentally a screening process, thus the performance is a function of screen size. Table 8–2 illustrates this effect. It can be seen that substantial improvement in effluent characteristics can be obtained by this technique. BOD removal closely parallels suspended solids removal as most of the BOD exerted by a conventional plant effluent is due to biological floc which escaped removal in the secondary tank. An extensive study of microstrainers was conducted in Chicago; based on this study a fifteen million gallons per day plant was designed and is now being installed.

Table 8–2

MICROSTRAINER PERFORMANCE ON SECONDARY EFFLUENT

Location	Screen Size Microns	Suspended Solids % Removal	BOD % Removal
Luton, Eng.	35	55	30
Bracknell, Eng.	35	66	32
Chicago, Ill.	23	71	74
Brampton, Ont.	23	57	54

8.2.3.2 Deep Bed Filtration. A somewhat more costly but more reliable upgrading technique is the use of deep bed filtration. A typical deep-bed filter installation is shown in Figure 8–15. In this technique, the wastewater is run at two to ten gallons per minute per square foot through several feet of a granular material wherein the suspended solids are deposited. Most of the removal takes place on the surfaces of the grains rather than in the bed pores. The accumulation of solids in the bed eventually produces an excessive pressure drop. At this point, the filtration run is terminated, and the bed is cleaned. Cleaning always involves an upward flow of water at a rate sufficient to expand the media, thus allowing for removal of the entrapped floc. In addition, an air scour and/or a water jet surface wash may be employed to remove solids which adhere to the grains. The nature of wastewater floc is such that it is almost mandatory for air scour or surface wash to supplement normal water backwash in order to achieve adequate cleaning.

Filter media ranges in size from ten mesh to 80 mesh and until recently only a single type of media has been employed. After backwash, however, a single medium filter is graded with the smallest size particles at the surface. This restricts filtration to the top layers of the bed. To counteract this effect, dual-media or multi-media filter beds are now coming into use. These employ granular materials of such sizes and specific gravities that after backwash the coarser material is always at the top of the filter. Typical combinations are coarse coal and fine sand or coarse coal, medium sand and fine garnet. These new combinations allow much longer filter runs at higher flow rates than single medium systems.

Typical performance of deep-bed filter systems for treatment of secondary effluent is given in Table 8–3. Removals of pollutants are only slightly better than with microstrainers, but deep-bed filters react well to shock loads.

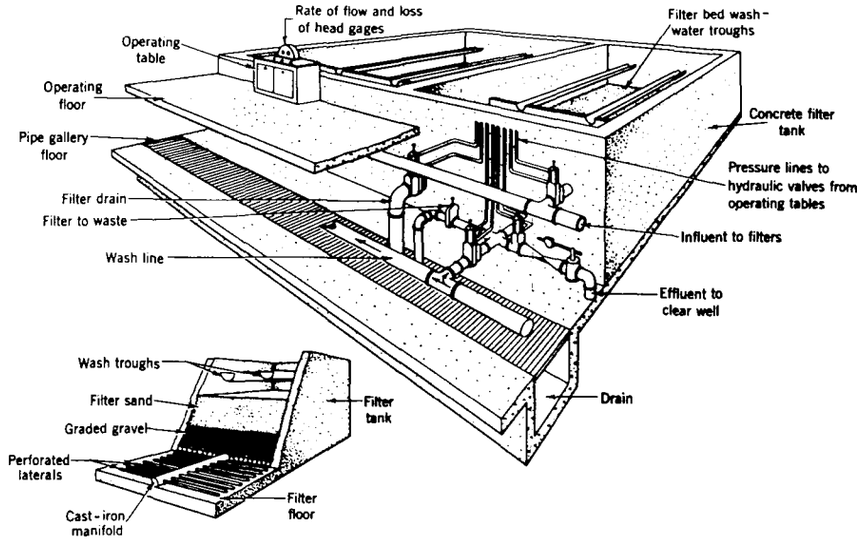


FIGURE 8–15 *Typical Rapid Sand Filter.*

Table 8–3

DEEP BED FILTRATION – SECONDARY EFFLUENT

	Flow Rate gal/min/sq. ft.	Suspended Solids % Removal	BOD % Removal
Luton, Eng.	1.5–4	72–91	52–70
Chicago, Illinois	2–6	70	80
Los Angeles, California	–	46	57
Tudor, England	–	85	–

8.2.3.3 Chemical Treatment. Suspended solids and BOD removal across a microstrainer or deep-bed filter will rarely exceed 80 percent because these processes cannot remove colloidal matter from wastewater. Chemical coagulation is the only feasible method for removal of colloids. In this process, chemicals added to the wastewater entrap the colloids into a floc which can then be removed by sedimentation or filtration. A large variety of chemical agents have been found useful as coagulants, these include salts of iron, salts of aluminum, lime and organic polymers. In addition to removing colloids, chemical treatment will coagulate the suspended solids in sewage forming large, dense flocs which are amenable to removal by sedimentation.

Chemical treatment itself only tends to entrap or coagulate colloids and suspended solids. Removal of these coagulated impurities requires liquid-

solid separation techniques. Consequently, a system which employs chemical treatment for upgrading can be quite simple or quite complex depending on the degree of removal and reliability desired.

The simplest system would have chemical addition and flocculation between the biological oxidation unit and the secondary tank. A more comprehensive system would employ the system above with a deep-bed filter following secondary sedimentation. The most complex system, which is illustrated in Figure 8–16, provides chemical addition, flocculation, sedimentation and deep-bed filtration after the secondary sedimentation step. It will be noted that a microstrainer is not included in any of these flow schemes because it does not perform well with a chemical floc.

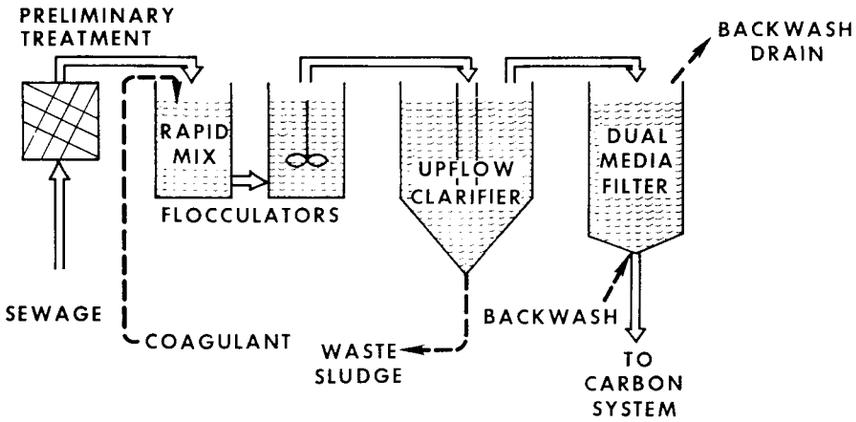


FIGURE 8–16 *Typical Flow Diagram of Clarification System.*

8.2.4 Tertiary Treatment

The term tertiary treatment causes some confusion in that it has a variety of meanings. In the general sense, it represents any stage of treatment or any treatment step applied after secondary treatment. This definition encompasses most of the unit operations and processes discussed in this chapter. In a more restricted sense, it represents a specific combination of treatment procedures applied after secondary treatment. In this restricted sense, tertiary treatment is the combination of chemical coagulation, flocculation, sedimentation, deep-bed filtration and activated carbon adsorption. Nitrogen removal procedures are optional in this treatment train. Figure 8–17 illustrates primary, secondary and tertiary treatment (restricted sense) combined together into a system which provides biological, physical and chemical treatment.

The ultimate goal of the combination of all these treatment procedures is to produce renovated wastewater, *i.e.,* wastewater which can be reused.

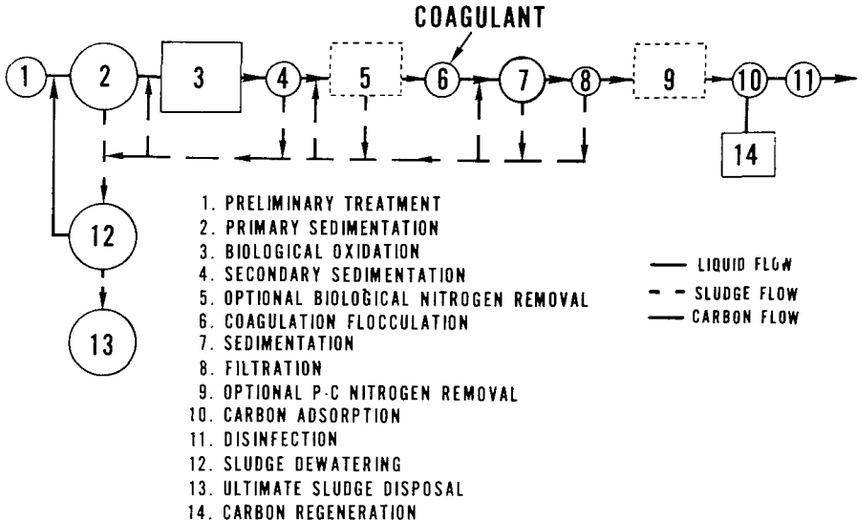


FIGURE 8–17 *Biological-Chemical-Physical Treatment System—Primary, Secondary and Tertiary.*

8.2.5 Phosphorus Removal

The key role of phosphorus in the process of eutrophication (aging of lakes and impoundments) has been known for many years. However, until recently, eutrophication of the Island's waterways was not a significant problem. Consequently, control of the phosphorus level in streams and lakes was not considered an important pollution control problem. Since the end of World War II, however, the rate of eutrophication has increased to the point where it is a major water quality problem. Although other nutrients play a role in eutrophication, recent articles have indicated that much of the recent increase in eutrophication rate is linked to significant increases in phosphorus discharges to rivers and lakes. Virtually all of the increase in phosphorus discharge is due to the activities of man and can be termed cultural eutrophication.

The major sources of phosphorus contributing to eutrophication are domestic sewage and agricultural runoff. Domestic sewage is the primary source in critical areas. Phosphorus gains entrance to sewage from human body wastes (primarily urine) and through the use of condensed inorganic phosphate compounds from detergents. Each of these sources accounts for about half of the phosphorus in domestic sewage. Treatment of domestic sewage to remove a significant portion of the phosphorus contributed by human wastes and detergents would have a significant effect on eutrophication rate.

8.2.5.1 Phosphorus Removal in Conventional Treatment. Removal of any pollutant from wastewater requires that it be converted to either an insoluble gas or an insoluble solid. Because none of the chemically stable forms of phosphorus is a gas at normal temperature and pressure, removal from wastewater is dependent on formation on an insoluble solid. Less than ten percent of the phosphorus discharged to municipal sewerage systems is insoluble and none of the conventional treatment techniques is particularly effective in insolubilizing this nutrient. Thus, phosphorus removal in conventional treatment systems is relatively poor. Primary treatment can remove only the ten percent of the phosphorus which is initially insoluble. During secondary treatment, phosphorus removal is achieved by synthesis into the biomass followed by sedimentation and sludge wasting. However, municipal sewage contains a considerable excess of phosphorus over that required for biomass synthesis during complete utilization of the organic carbon present; thus, removals are generally limited to twenty to forty percent. Studies indicate that biological systems have the capacity for much higher removals through the mechanism of "luxury uptake." However, attempts to implement this phenomenon in actual plants have not been successful.

8.2.5.2 Phosphorus Removal by Chemical Precipitation. Fortunately, phosphorus forms essentially completely insoluble precipitates with a number of substances, thus high levels of removal can be obtained when appropriate doses of the proper chemicals are applied. A large variety of chemicals can be utilized for this purpose but economic factors dictate the use of salts of iron, salts of aluminum or lime. In selecting the chemical for use at any particular site, the factors listed in Table 8–4 should be taken into account.

Table 8–4

FACTORS AFFECTING CHOICE OF CHEMICAL FOR PHOSPHORUS REMOVAL

Influent Phosphorus Level
Wastewater Suspended Solids and Alkalinity
Chemical Cost Including Transportation
Reliability of Chemical Supply
Sludge Handling Facilities
Ultimate Disposal Methods
Campatibility with Other Treatment Processes in Plant
Potential Adverse Environmental Effects

Phosphorus removal is achieved by precipitation followed by liquid solids separation. For the most part, the usual liguid-solids separation equipment in a treatment plant can be utilized for phosphorus removal. This results in a considerable savings in capital as well as integration of phosphorus removal into conventional treatment plant operation. In addition, it has been found that the use of chemical precipitants in conventional treatment can markedly upgrade performance of a treatment plant. This results from coagulation of organic suspended and colloidal solids by the chemicals added to precipitate phosphorus.

Figure 8–18 illustrates a conventional treatment plant with the three general sections in which phosphorus removal can be carried out. Chemicals can be added either just before the primary tank with removal taking place in the primary; in the secondary (biological) section of the plant with removal in the secondary sedimentation tank; or in a tertiary stage as was discussed in the section on suspended solids removal.

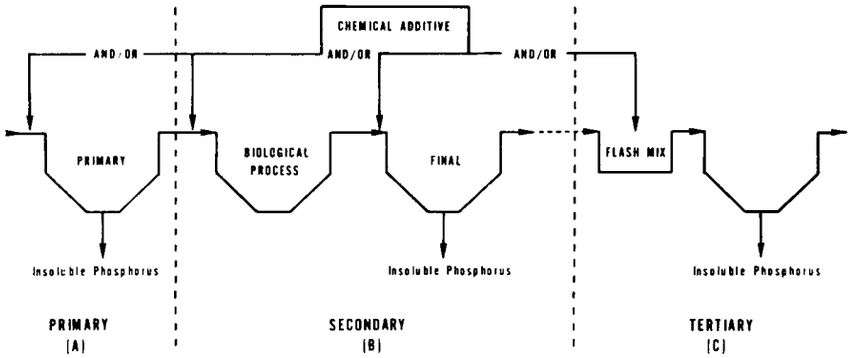


FIGURE 8–18 *Locations for Chemical Control of Phosphorus.*

Table 8–5 illustrates typical results obtained with phosphorus removal in the primary, secondary or tertiary. As can be seen, good removals are obtained in all sections; however, the lowest levels of phosphorus remaining are achieved in the tertiary addition. One reason for this is that a filter is usually included in the tertiary plant, thus better removal of fine precipitates is achieved. In addition, when the flow reaches this section of the plant all the complex phosphorus forms which are more difficult to precipitate have been hydrolyzed to orthophosphate which is the easiest to precipitate.

In plants where removal in the primary phase was practiced, a major effect to note is the significant increase in BOD and suspended solids removal achieved over the removal usually obtained in the primary tank. This may be important in helping to meet water quality standards for BOD and suspended solids if the treatment plant is overloaded.

In plants where the chemical is added in the secondary section, it has been observed that much more stable operation of the activated sludge is obtained than before chemical addition. The effect of the chemical is to weigh the sludge down, preventing its loss when a filamentous or dispersed growth predominates. Even in plants which have historically exhibited excellent performance chemical addition has improved performance by

helping maintain a higher concentration of activated sludge in the aeration tank. It has been found best to add the chemical between the biological reactor and the final sedimentation tank rather than at the head end of the secondary tank.

Table 8–5

PHOSPHORUS REMOVAL EXPERIENCE

Place	Chemical	P % Removal	P Effluent	BOD % Removal	S.S. % Removal
PRIMARY					
Grayling, Michigan	$FeCl_2$	72	4.4	78	58
Washington, D.C.	Lime	95	0.45	82	88
Mentor, Ohio	Pickle Liquor	83.5	—	59	74
SECONDARY					
Pomona, California	Alum	80–93			
Manassas, Virginia	Alum		1.0		
Richardson, Texas			0.5–0.75		
TERTIARY					
Nassau County, N.Y.	Alum		0.08		
Lake Tahoe, Calif.	Lime		0.14		
Lebanon, Ohio	Lime		0.1–0.5		

8.2.6 Nitrogen Control

Nitrogen can exist in the aquatic environment in any one of four forms: organic-N, ammonia-N, nitrite-N and nitrate-N. In sewage it is found primarily in the first two forms. In nature, biologically mediated reactions convert organic-N to ammonia-N which in turn is biologically oxidized to nitrite-N and nitrate-N.

Two major water quality objectives of nitrogen control are to prevent excessive build-up of nitrates in drinking water and depletion of the dissolved oxygen resources of streams by the biological oxidation of ammonia-N to nitrate-N. Table 8–6 shows the significance of the nitrogen oxygen demand (NOD) of a wastewater by comparison of the oxygen demand of raw wastewater to a well-treated secondary effluent. These data illustrate that 90 percent removal of organic oxygen demand (BOD) only results in a 74 percent removal of the total biological oxygen demand (TBOD). Nitrogen control is also important because ammonia-N exerts a chlorine demand which reduces disinfection efficiency, is toxic to fish and other aquatic life and stimulates corrosion of copper plumbing.

The least expensive method of preventing these adverse actions is to carry out the biological oxidation to nitrate under controlled conditions in the treatment plant. Control of ammonia-N is possible by altering the

Table 8–6

ULTIMATE OXYGEN DEMAND
IN RAW AND SECONDARY TREATED DOMESTIC SEWAGE

Component	Raw mg/l	Treated mg/l	% Removal
Organic Matter	250	25	90
Organic Oxygen Demand (BOD)	375	37	90
Ammonia-N	25	20	20
Nitrogen Oxygen Demand	112	90	21
Total BOD	487	127	74

operation of conventional activated sludge to provide for a significant degree of nitrification. The modifications involve increases in aeration rate, contact time and sludge age, and maintenance of the pH at 8.0–8.4. The latter is quite important in view of the tendency of the nitrification reaction to lower the pH. These reactions are quite temperature sensitive showing significant rate decreases as the temperature drops below 18° Centrigrade. As the temperature decreases, contact time and sludge age must be increased to compensate for the reduced reaction rates. Of all the factors listed above, sludge age is the most significant as it can be used to control the population of nitrifiers maintained in the system.

At low temperatures and when a significant diurnal flow variation exists, its has been found difficult to maintain both organic carbon oxidation and nitrification in a single reactor. In such situations, a two-stage system employing organic carbon oxidation in the first stage followed by a nitrification stage has shown significant superiority of performance. Separate sedimentation and sludge recycle is employed with each stage. This system exhibits much greater stability of performance because conditions in each stage can be established to favor the specific types of organisms desired in that stage.

Nitrification of sewage may not be sufficient for nitrogen control in some instances because an excess of nitrate in water will disqualify it from use as a potable water supply and because nitrogen in any form can serve as an algal nutrient. Phosphorus usually is the controlling nutrient in fresh waters whereas nitrogen appears to control within some estuarine environments. Areas where nitrogen is the controlling nutrient include San Francisco Bay, Lake Tahoe, the Potomac Estuary and Long Island. Removal of various forms of nitrogen from wastewater can be achieved by both biological and physical-chemical means.

8.2.6.1 Biological Denitrification. Under anaerobic conditions facultative heterotrophs will utilize nitrate ion as a hydrogen acceptor for the degradation of organic matter.

The end product of the nitrogen reduction is nitrogen gas which is essentially insoluble in water. Thus, a combination of nitrification followed by denitrification can achieve nitrogen removal from wastewater.

A three-stage biological system has been developed to provide nitrogen removal. The first stage is a high rate short aeration time (approximately two hours) biological reactor for organic carbon oxidation, and hydrolysis of organic nitrogen to ammonia. The second stage provides approximately three hours of detention and achieves essentially complete nitrification. The third stage is for denitrification of nitrate to nitrogen gas. An organic source must be added to the third stage to force the denitrification reaction to take place. A variety of substances has been evaluated for this use and methanol has been found to be far superior to all others. It is relatively inexpensive, reacts rapidly and provides only a minimum of energy for growth of new organisms. A diagram illustrating this system is given in Figure 8–19. Three alternate contactors are illustrated in the denitrification stage. Contactor I is a suspended growth contactor similar to that used in the first two stages. Solids control is somewhat difficult in this system, and it is often followed by a deep-bed filter. The other two systems supply a contact medium on which a heavy biological growth can develop. These latter systems require significantly less contact time than the three hours required in the suspended growth reactor, and they can accept higher hydraulic rates of application without fear of a washout of organisms. The coarse medium (one to two inches gravel) upflow system, requires a contact time of one to two hours and may require a supplemental filter. The fine medium downflow system utilizes particles as small as three millimeters in beds ten to twenty feet deep. Flow rate is that of a high-rate filter seven gallons per square foot with a bed contact of ten to twenty minutes. Backwash of the fine medium units is required once or twice per day to relieve clogging. In all of the denitrification systems discussed, essentially complete denitrification has been obtained in pilot-scale experiments.

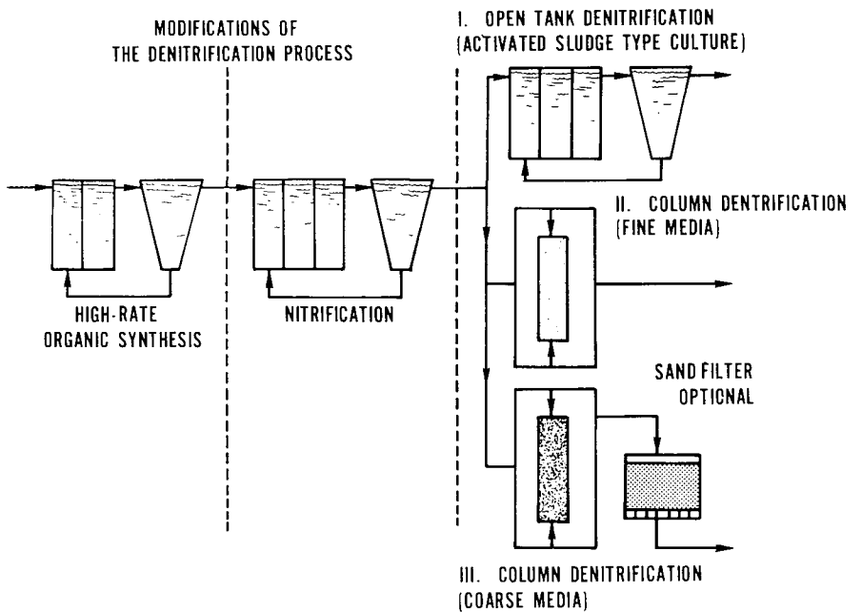


FIGURE 8–19 *Biological Denitrification—Three Stage System.*

Most experience has been with the three-sludge suspended growth system. In Suffolk County, the most used system for small treatment plants has been extended aeration and gravity sand filter. Results from a 100,000 gallons per day pilot plant in Washington, D.C. are presented in Table 8–7. This table includes data on phosphorus removal, as addition of alum to the first stage was practiced both to maintain solids control and achieve phosphorus removal.

8.2.7 Breakpoint Chlorination

Chlorine reacts with ammonia-N to yield a variety of amines and inorganic compounds by a variety of pathways. The reaction requires a theoretical dose of 7.6 grams chlorine per gram of ammonia-N. The reaction occurs in a stepwise fashion; various chloramines initially form which in turn rapidly react with additional chlorine to yield nitrogen gas.

8.2.8 Ammonia Removal by Air Stripping

Soluble ammonia can be air stripped from wastewater by converting the ammonium ion to the unionized form which is the soluble gas NH_3. This is accomplished by lime treatment to precipitate phosphorus and raise the pH of the wastewater to about eleven. Wastewater is brought to the top of a cooling tower and distributed over the column packing. Forced air is drawn through the packing media to extract the gaseous ammonia from the wastewater droplets. Problems with cold weather operation due to low air temperatures and scale formation on the tower packing media have yet to be overcome. However, ammonia stripping can be an attractive method of nitrogen removal because of its relative low cost, especially when chemical cost to raise the pH is also applied for phosphorus removal.

8.2.9 Organic Carbon Removal

Organic substances are removed by most of the processes discussed in the previous sections of this paper. However, some of the organics cannot be removed by coagulation and sedimentation, nor are they amenable to biological oxidation. These have been termed refractory organics. Activities in the advanced waste treatment program were aimed at removal of refractory organics, and two methods with economic feasibility were developed: activated carbon adsorption and ozonation.

Recent studies have illustrated that these processes are just as applicable to all types of organics present in wastewater; consequently, they will be employed in the future as general purpose procedures for removal of organics in wastewater.

Table 8–7

PERFORMANCE SUMMARY FOR THREE-STAGE BIOLOGICAL TREATMENT UTILIZING MINERAL ADDITION AND A SUSPENDED GROWTH REACTOR

Constituent	Raw Wastewater mg/l	Primary Effluent mg/l	High-Rate Effluent mg/l	Nitrified Effluent mg/l	Denitrified Effluent mg/l	Denitrified Effluent (filtered) mg/l
COD	320	218	64	43	44	38
Organic-N	10.3	5.9	0.8	0.4	0.4	0.2
Ammonia-N	11.3	13.7	7.7	0.6	0.3	0.4
Nitrite-N	–	–	1.1	0.3	0.3	0.4
Nitrate-N	–	–	4.3	11.5	0.9	0.9
Total Phosphorus	12.6	11.9	2.8	2.6	1.5	1.1
S.S.	157	90	8.8	7.1	7.1	1.7
pH (mode)	7.2	7.3	7.5	7.5	7.7	7.7

All values are averages except pH and are based on 40 determinations.

8.2.9.1 Activated Carbon Adsorption. The ability of activated carbon to remove soluble organics from wastewater is a result of the similarity of the surface chemistry of the activated carbon to that of the organic molecules. The ability of substances to adsorb organics is widespread; the characteristic of activated carbon which makes it unique is that it has a much higher adsorption capacity than other materials. The high capacity is the result of an extensive internal microporous structure formed during the activation process.

A generalized activated carbon treatment process is illustrated in Figure 8–20. The carbon and wastewater are contacted for a sufficient period of time for adsorption to take place, then they are separated. Eventually, the capacity of the activated carbon is exhausted, and it is removed from the contact vessel to a regeneration step. During regeneration some of the carbon is lost or consumed so make-up must be added.

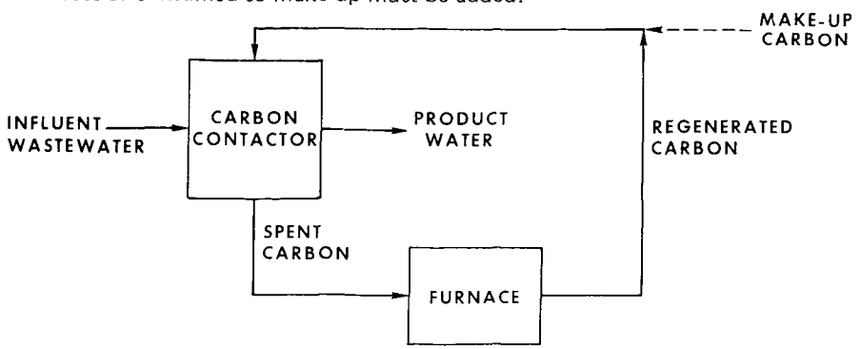


FIGURE 8–20 *Regeneration and Reuse of Activated Carbon.*

Commercial grades of activated carbon are either granular (sizes eight by 30 mesh, or twelve by 40 mesh) or powdered (greater than 300 mesh). Both forms have been found essentially equivalent in their ability to remove organics, but each type requires a different method of contacting and regeneration.

Granular carbon is contacted with sewage in columns through which the sewage flows. The columns may be either pressure vessels or gravity contactors; the former provide better operational flexibility, the latter are more economical. Flow may be upward through an expanded bed, upward through a packed bed, or downward through a packed bed. Packed bed operation provides filtration as well as adsorption but requires frequent backwash. Upflow systems allow for periodic removal of a portion of the carbon at the base, thereby providing countercurrent contact in a single vessel. However, good flow distribution is more difficult to achieve upflow than downflow. Columns can be connected in series as with the clinoptilolite system to achieve countercurrent contact. Alternately, a parallel flow arrangement can be used to achieve countercurrent contact. With the parallel flow arrangement, the starting time in service is staggered so that at any time one column is near exhaustion, one or more other columns are relatively fresh and all others are at some in-between stage. The flow from each column is blended to produce the final effluent.

Regardless of the contacting details, the fundamental system design parameter is contact time. The specific contact time to be used is a function of the effluent quality desired and the wastewater characteristics. In general, it has been found that as contact time increases, the rate at which organic removal takes place decreases. A point of essentially zero removal generally is located between 30 minutes and 60 minutes contact time. Contact time is always rated on an empty bed basis.

Regeneration of granular carbon is conducted in a multiple hearth furnace, a device which has had a long history of successful use for incineration of sewage sludge. Figure 8–21 illustrates a typical granular carbon regeneration scheme. Spent carbon is removed from the contactor by eduction, stored, partically dewatered, and then fed to the furnace. As the carbon moves from hearth to hearth it is dried, baked and finally reactivated. During the reactivation stage, the temperature is in the range of 1500° to 1700° Farenheit. After regeneration, the carbon is quenched and returned to a contactor. The furnace is rated at 80 pounds to 110 pounds carbon per square foot per day. Air pollution control equipment, such as an after burner and wet scrubber or cyclone, are usually required to purify the exhaust. Experience with this regeneration system at essentially full scale indicates carbon regeneration loss of five percent to ten percent per regeneration cycle. The losses are due to physical attrition in the regeneration loop and burnoff in the furnace.

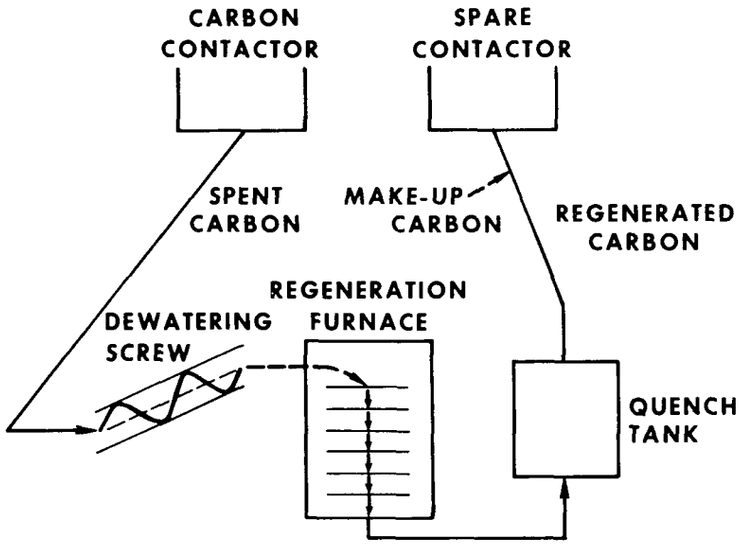


FIGURE 8–21 *Activated Carbon Regeneration System.*

In systems utilizing powdered carbon, contact is brought about by mixing of the carbon and the wastewater in a reactor-clarifier contactor. This apparatus is illustrated in Figure 8–22. The carbon and wastewater are flash mixed and flocculated in the center well of the apparatus. The mixture then flows into the outer section where gravity separation of the carbon and wastewater takes place. A pool of carbon in a thick slurry form is maintained at the bottom of this contractor.

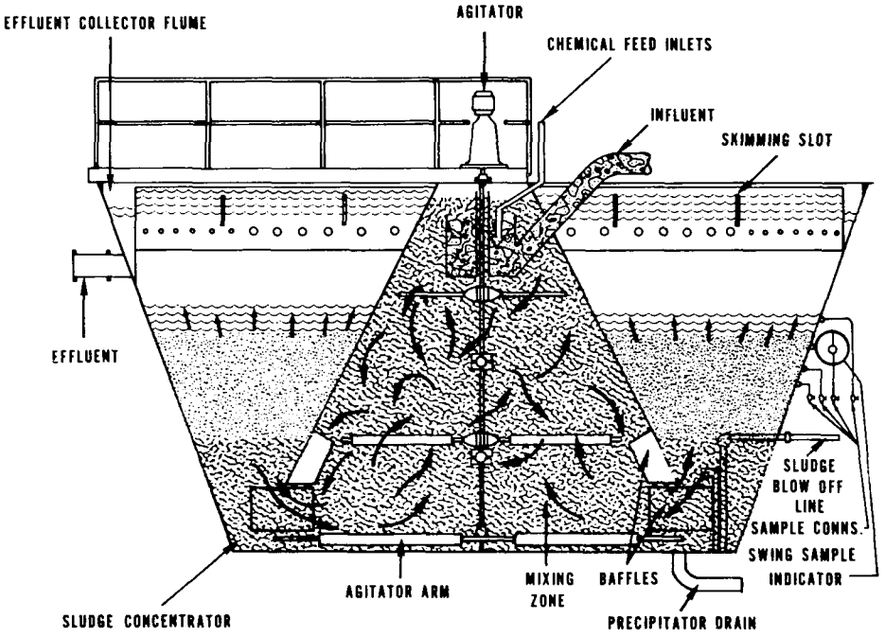


FIGURE 8–22 *Solids Contact Clarifier with Sludge Blanket Filtration.*

In this type of contactor the carbon comes to equilibrium with the organic concentration in the effluent wastewater, whereas it comes to equilibrium with the organic concentration in the incoming liquid in a granular contactor. The organic adsorption capacity of activated carbon is proportional to the concentration of organics with which it comes to equilbrium, thus it is more imperative that countercurrent contact be achieved in powdered carbon systems than in granular systems. Figure 8–23 illustrates schematically a two-stage counter flow contacting system which is utilized with powdered carbon treatment. The carbon is thickened (not shown) between stages to reduce pumping and the effluent is filtered to remove residual carbon fines. Figure 8–24 illustrates the most advanced system for powdered carbon regeneration. The slurry containing spent carbon is thickened, dewatered in a centrifuge or on a vacuum filter and injected into a fluidized bed furnace. The regenerated carbon is reslurried and pumped back into the system. In the furnace the temperature is maintained at the same level as in the multiple hearth furnace. Contact time of a carbon particle in the furnace averages several seconds. Shorter time results in only partial regeneration, long time results in particle incineration. Thus, tight control must be exercised with this regeneration scheme. To date small pilot studies have indicated the

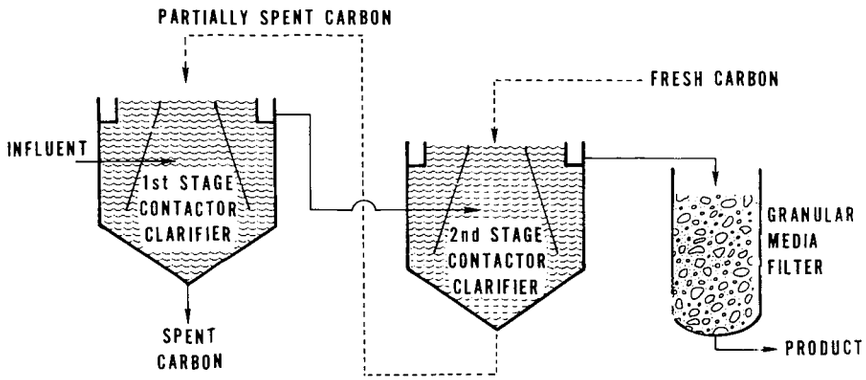


FIGURE 8–23 *Flow Diagram Two-Stage Countercurrent Powdered Activated Carbon System.*

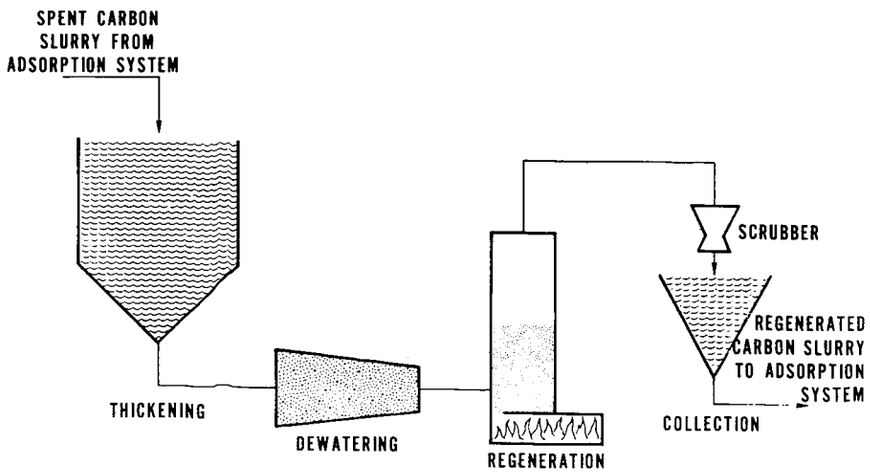


FIGURE 8–24 *Thermal Regeneration Powdered Carbon Flow Diagram.*

feasibility of this regeneration scheme with losses averaging fifteen percent. A larger version of this furnace is now being evaluated at Salt Lake City.

Both granular carbon and powdered carbon contact are excellent processes for organics removal from wastewater. Powdered carbon processes have advantages over granular carbon in that powdered carbon is cheaper than granular carbon (ten cents *vs.* 30 cents per pound); powdered carbon plants require a much smaller carbon inventory and can be dosed to meet the demand. However, granular carbon exhibits higher practical adsorption capacity, does not require complex dewatering procedures prior to regeneration and most important has been successfully regenerated at full scale. Economics demand that regeneration be incorporated into all but the smallest scale carbon adsorption plants. Thus, an engineer designing a treatment plant using carbon adsorption would most likely choose granular carbon.

Extensive processing experience has been obtained with the use of activated carbon for treatment of wastewater after biological treatment (tertiary application). Data from a number of facilities are summarized in Table 8–8. It can be seen that organic removal in the range of 70 percent to 80 percent was obtained. This is typical of the capability of activated carbon for organic removal from sewage. Data on adsorption capacity indicates a considerable spread, 0.25 to 0.87 pounds COD per pound activated carbon. This considerable spread occurs because carbon capacity is a function of desired effluent quality and influent organic concentration. Most significant, however, is that in all cases the capacity was significantly higher than that projected by an adsorption isotherm test. Biological activity on the carbon is the primary explanation of the significantly higher capacity obtained. It is theorized that partial regeneration in situ is accomplished by biological action. Naturally, this has had a favorable impact on the economics of carbon adsorption.

Table 8–8

ACTIVATED CARBON TREATMENT OF WASTEWATER TERTIARY APPLICATION

Location	Carbon	Organics, mg/l In	Organics, mg/l Out	% Removal	Organics Measurement
Pomona	Granular	43	10	77	COD
Colorado Springs	Granular	43	13	70	TOC
S. Lake Tahoe	Granular	12	3	75	TOC
Lebanon	Powdered	20	4	80	TOC
Tucson	Powdered	27	7.5	72.5	COD

The process design for carbon treatment has had to be adjusted to take account of biological action. For example, only a normal upflow backwash was provided in early granular carbon contactor design. This was found to be inadequate to insure cleaning of the carbon column so air scour and surface wash are frequently added. In addition, more frequent backwash (at least once per day) must be planned for in design. Under heavy load, carbon columns become septic and hydrogen sulfide is produced. Aeration of the feed may be required or extra-chlorination to oxidize the effluent sulfide may be needed. Under heavy load, expanded bed operation becomes superior to packed beds because clogging is less of a problem and aeration is easier to accomplish.

Powdered carbon contact design has also been affected by the realization that biological action may occur. It has recently been illustrated that when extensive biological action is encouraged, only one carbon contacting stage is required rather than two to achieve high adsorption capacity.

8.2.9.2 Physical-Chemical Treatment. Physical-chemical treatment of raw wastewater or more accurately chemical clarification—carbon adsorption was first evaluated as a treatment technique over three decades ago. It was found to produce a good quality effluent but at a cost greater than conventional processing. The recent up-grading of water quality standards has brought this treatment scheme closer to economic viability because it can produce an effluent superior to conventional processing. In addition, the developments discussed above in carbon adsorption techniques have tended to lower the cost of physical-chemical treatment. Finally, removals achieved by chemical clarification have been higher than anticipated which has also had a favorable effect on physical-chemical treatment costs.

Figure 8–25 is a general diagram of the clarification carbon treatment system. Following the standard type of preliminary treatment, the waste is dosed with chemical sufficient to achieve the desired level of suspended solids and/or organics and/or phosphorus removal required. The same chemicals are used as for phosphorus removal in the primary. Significant removals of organics, suspended solids and phosphorus are obtained by chemical clarification as illustrated in Table 8–9. Especially significant is the organic removal which is higher than would be expected from complete removal of suspended solids. This extra removal is due to coagulation and possible chemical adsorption of colloidal and soluble organics. Up to 50 percent of the "soluble" organics in sewage may be removable by chemical coagulation.

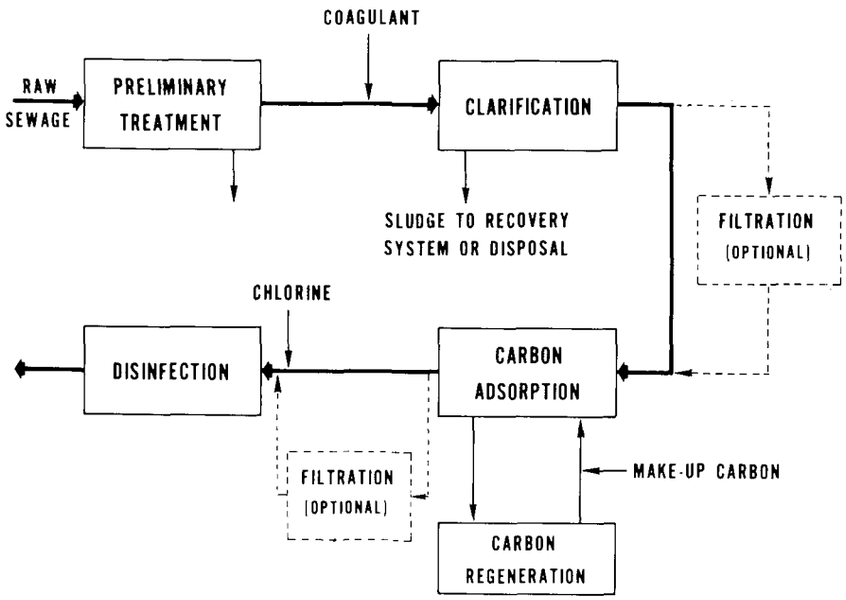


FIGURE 8–25 *Flow Diagram of a Physical-Chemical Treatment System.*

Table 8–9

ACHIEVEMENTS OF CHEMICAL CLARIFICATION

Plant	Chemical	Organic Removal %	S.S. Removal %	P Removal %
Ewing-Lawrence	170 mg/l $FeCl_3$	80	95	90
New Rochelle (ZM)	Lime pH 11.5	80	98	98
Westgate, Virginia	125 mg/l $FeCl_3$	70	–	–
Salt Lake City	80–100 mg/l $FeCl_3$	75	–	80
Blue Plains	Lime pH 11.5	80	90	95

After clarification is complete, the wastewater is passed to the carbon adsorption step for completion of the removal of soluble organics. Table 8–10 gives data from a number of plants which indicate that very good quality effluents can be obtained as well as high carbon adsorption capacity. As indicated previously, this is the result of biological action on the carbon. In physical-chemical treatment systems, the carbon is subjected to a heavier load than in tertiary plants, thus extra care in design must be taken to insure that the disadvantageous features of biological action on carbon can be mitigated.

Table 8–10

ACTIVATED CARBON PERFORMANCE IN PHYSICAL-CHEMICAL TREATMENT PLANT

Plant	Effluent Organics mg/l	Carbon lbs. TOC lb. A.C.	Capacity lbs. COD lb. A.C.
Blue Plains (G)	TOC = 6	0.15	0.41
Lebanon (G)	TOC = 6	0.22	0.50
Ewing-Lawrence (G)	TOC = 3–5	0.3	–
New Rochelle (G)	COD = 8	–	0.6
Owosso (G)	COD = 25	–	0.65
Salt Lake City (P)	COD = 22	–	0.36

(G) - Granular Carbon
(P) - Powdered Carbon

Filtration is presented as an optional step in Figure 8–25, but it would be wise to include it in the treatment scheme. Filtration acts as the safety factor in the solids removal step; therefore, its use can bring a high degree of reliability to the treatment scheme. In addition, it can be used to prevent an

overload of solids on the carbon which could foster excessive biological action. The positioning of the filter prior to or after the carbon contact is dictated by the method of carbon contact. Expanded bed and powdered carbon systems usually require filtration after the carbon step. Packed bed systems will benefit from filtration before the carbon.

Tables 8–11, 8–12 and Figure 8–26 provide information on the performance of three physical-chemical treatment pilot plants. These data illustrate removals at various stages of treatment for a variety of pollutants. The Blue Plains data include nitrogen removal by clinoptilolite.

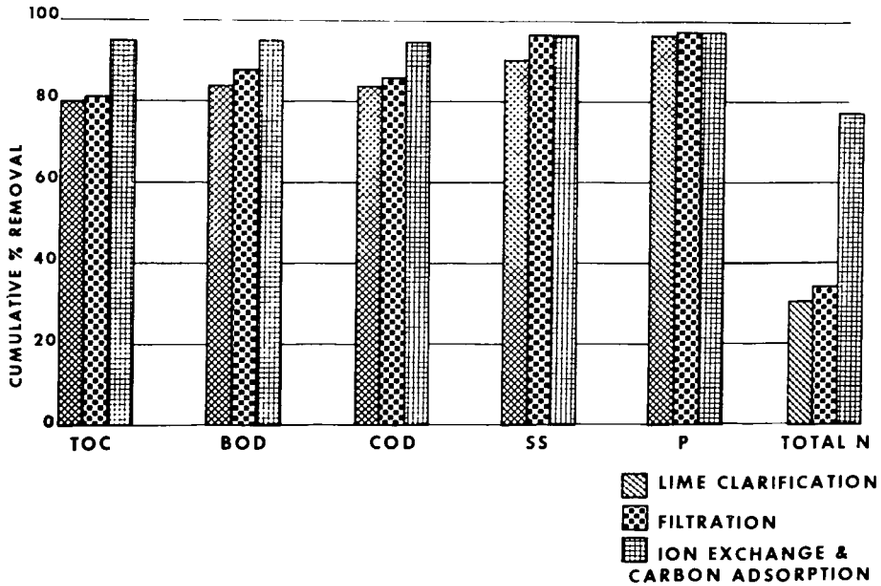


FIGURE 8–26 *Removal Efficiencies of Physical-Chemical Treatment—Blue Plains Pilot.*

Table 8–11

POWDERED CARBON PILOT PLANT OPERATING CONDITIONS

Flow Rate 50 gal/min
Chemical 425 mg/l Lime to pH 10.8
Carbon 150 mg/l + 0.4 mg/l polymer

Results

	COD	BOD	SS	P
Raw Sewage	222	144	200	7.3
Clarified Effluent	65	47	28	1.4
Final Effluent	35	13	7	0.4

Table 8–12

ROCKY RIVER WASTE TREATMENT PLANT CLARIFICATION-CARBON PROCESS

	Raw	Polymer Clarification	Carbon Contact Time, minutes			% Removed
			14	23.4	32.6	
Suspended Solids, mg/l	107	65	13	15	7	93.3
BOD, mg/l	118	57	21	11	8	93.3
COD, mg/l	235	177	67	50	44	81.3

Table 8–13 lists the features which physical-chemical treatment has with respect to conventional treatment systems. Because of these features and a favorable cost comparison a number of communities are planning physical-chemical treatment systems.

Table 8–13

ADVANTAGES OF PHYSICAL-CHEMICAL TREATMENT vs. CONVENTIONAL PRIMARY + SECONDARY

1. Less Area Requirement—½ to ¼
2. Lower Sensitivity to Diurnal Variation
3. Not Affected By Toxic Substances
4. Potential For Significant Heavy Metal Removal
5. Superior Removal of P Compounds
6. Greater Flexibility In Design And Operation
7. Superior Organic Removal

8.2.9.3 Ozone Oxidation. In addition to carbon adsorption, another physical-chemical method of organics removal, ozonation, has been evaluated and found worthy of development. However, this procedure is several years behind activated carbon in development because so much required information has not yet been obtained.

Ozone is a powerful oxidant which is generated by passing a properly conditioned air stream between electrodes, one of which produces a corona discharge. It must be generated on site and used immediately. Ozone is only poorly soluble in water so that special contacting techniques must be used to insure optimum utilization.

8.2.9.4 Pure Oxygen Activated Sludge. The last improvement in procedures for removing organics from wastewater is the application of pure oxygen in the activated sludge process. The use of pure oxygen does not permit activated sludge to go beyond its inherent capability but allows a closer approach to this limit within an acceptable economic framework.

Early work in the biological treatment field pointed out the advantages of pure oxygen over air as the source of oxygen in activated sludge. However, the cost of the pure oxygen was quite high and a feasible system to achieve high degreees of utilization was not available, so the concept lay dormant. Over the last decade, the cost of pure oxygen has decreased and a system was devised which could achieve high utilization efficiency. Figure 8–27 illustrates the UNOX system developed by Union Carbide. The key features of this system are the use of covered reactors to prevent loss of oxygen; a baffled reactor to prevent short-circuiting and recompression and recycle of gas in each chamber. In all other respects, the system is virtually identical to a conventional activated sludge.

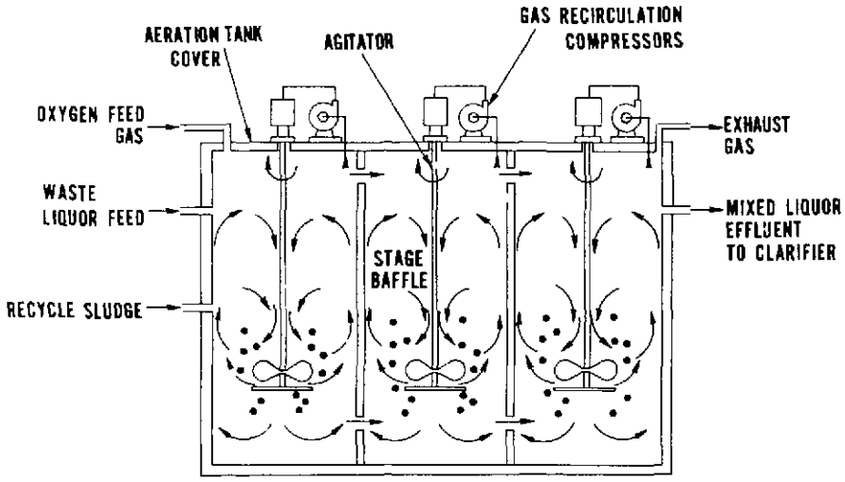


FIGURE 8–27 *Schematic Diagram of Multi-Stage Oxygenation System.*

8.2.10 Dissolved Inorganics Removal

In the process of its domestic or industrial use an increment of dissolved mineral matter is added to water. The magnitude varies from 100 milligrams per liter to 500 milligrams per liter per use depending generally on local conditions. Extensive reuse of wastewater even for industrial use will require at least partial demineralization of wastewater. Electrodialysis, ion exchange and reverse osmosis seem promising.

8.2.10.1 Electrodialysis. In sewage application, electrodialysis suffers severe limitations. The anion plates foul quite easily, drastically reducing treatment performance unless the feed has received extensive pretreatment. In addition, as the sewage is demineralized its electrical resistance increases. This limits the degree of economically feasible demineralization which can be obtained. It is difficult to reduce the TDS of water much below 300 to 400 milligrams per liter with electrodialysis. For these reasons electrodialysis is no longer considered a leading candidate process.

8.2.10.2 Ion Exchange. At present, ion exchange shows much promise f for removal of dissolved inorganics. Cost of operation is lowest, especially at the salt levels anticipated in wastewater and the technology of ion exchange at full scale is proven.

Ion exchange systems require regeneration with solutions much higher in TDS than the original feed yielding a difficult problem of brine disposal.

8.2.10.3 Reverse Osmosis. At present, reverse osmosis is the most expensive of the three processes discussed for demineralization. However, its potential is considerably superior to that of the other two. This process is indeed in its infancy as the first working membranes were developed only fifteen years ago. In addition, membranes which will desalt water will remove virtually every other pollutant from wastewater. Thus reverse osmosis may become an all purpose pollution contol system.

In this process water is forced to flow through a semi-permeable membrane (permeable to water but not to salts) by application of high pressure. Pressures of several hundred pounds per square inch are required to achieve fluxes of the order of ten gallons per square foot per day. The degree of demineralization can approach 99+ percent and increases with the pressure applied.

The heart of this process is the membrane. At present, the best membranes are cast from a mix of cellulose acetate, acetone, formamide and magnesium perchlorate. Special techniques form a membrane with a thin (one micron) skin which provides the desalting surface and a thick (100 microns) porous sublayer which supplies a structural backing. This membrane is compresssible, hydrolyzes at low and high pH and is easily damaged. Work is being conducted to develop new, tougher membrane materials.

Even if new membrane materials are found, the engineering problems of this process will remain unchanged. These problems are a structural support system to absorb the several hundred pounds per square inch pressure drop across the membrane and control of fouling on membrane surfaces. The support system must not only support the membrane but should provide high membrane area per unit volume.

Three configurations are in use, tubular, spiral-wound and hollow fine fiber. The tubular system has the membrane positioned along the inner wall of a porous one-half inch diameter tube. The spiral-wound module uses a stack of flat membranes separated by spacers and rolled into a jelly-roll form. The hollow fiber uses microscopic fibers of the membrane which are in essence thick-walled microcylinders. Here, pressure is applied outside the fiber and water permeates into the hollow core. As a rough guide, membrane area per unit volume is twenty square feet per cubic foot for tubular systems, 250 square feet per cubic foot for spiral wound systems and 2000 to 5000 square feet per cubic foot for hollow fine fibers. The systems are in reverse order on the basis of fouling resistance. In general, the tubular system is

preferred for dirty water application and the other two for clean water application.

Control of fouling can be achieved by pretreatment, establishment of turbulence at the membrane surface and chemical cleaning techniques. Application of these techniques is easiest in the tubular system. In addition, tubular systems afford the only opportunity for in-situ membrane replacement. At present none of the systems possess a marked advantage over the others.

The economics of wastewater demineralization are quite imprecise as life times of membranes and resins is not known, nor is degree of fouling and degree of demineralization required.

8.2.11 Summary

A review of many of the newest developments in wastewater treatment technology have been presented. In the interest of brevity, some areas such as microorganism removal and ultimate disposal have not been covered, and the coverage of others has been less than complete. It should be clear, however, that the wastewater treatment planner now has a whole range of treatment procedures. It is well within the realm of practicability to conceive of taking any wastewater and purifying it to any degree desired. All that is necessary is to hook together the various unit operations and processes required. A number of combinations which have already found some utility are summarized in the figures and tables below.

8.2.11.1 Biological-Physical Treatment. This system employs a filter to upgrade the performance of conventional treatment. It is illustrated in Figure 8–13 on page 299.

8.2.11.2 Biological-Chemical Treatment. In this system, illustrated in Figure 8–28, chemical coagulants can be added at various points for phosphorus removal and improved solids removal.

8.2.11.3 Physical-Chemical Treatment. In this system, illustrated in Figure 8–29, chemical clarification and activated carbon are combined to achieve wastewater purification.

8.2.11.4 Biological-Physical-Chemical Treatment. This system illustrated in Figure 8–27 combines a large number of processes to achieve a high degree of purification for a large variety of pollutants. Table 8–14 summarizes the performance to be expected from these treatment schemes.

8.2.12 Sprinkler Irrigation

Sprinkler irrigation of domestic, industrial and agricultural liquid wastes is appropriate when the disposal systems are adequately designed and conscientiously operated. The principles involved in adequately handling these liquid wastes can be discussed by use of a renovation-conservation cycle.

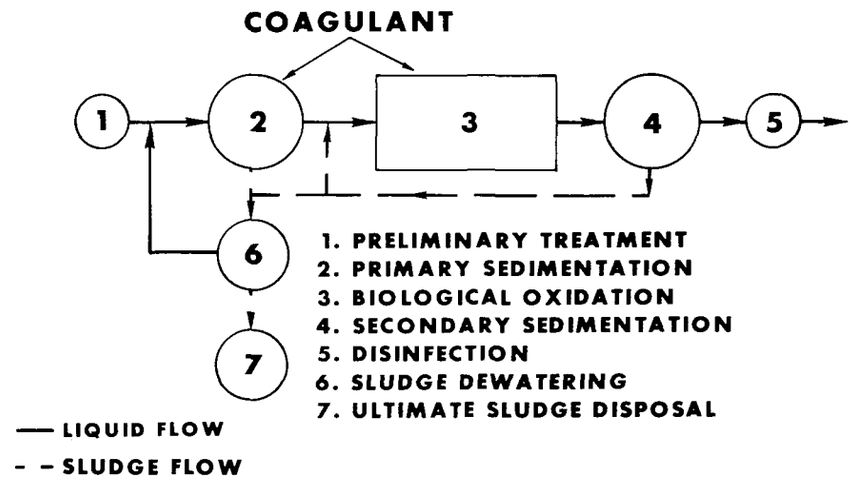


FIGURE 8–28 *Biological-Chemical Treatment System.*

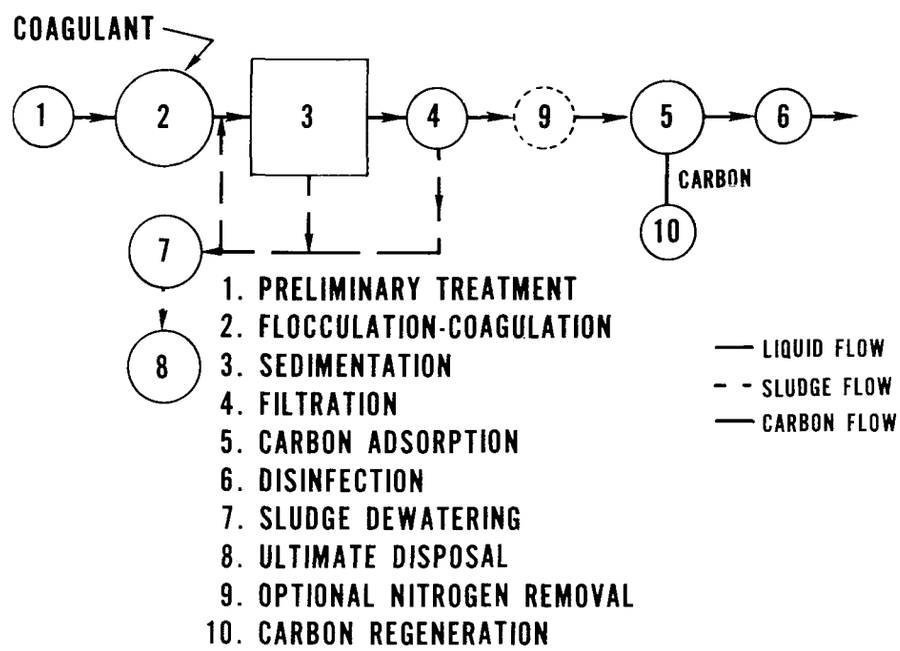


FIGURE 8–29 *Physical-Chemical Treatment.*

Table 8–14

TREATMENT PERFORMANCE SELECTED WASTEWATER TREATMENT SYSTEMS
Percent Removal

System Parameter	Conventional	Biological Physical	Biological Chemical	Physical Chemical	Biological Physical Chemical
Organics	80–90	85–95	90–95	95–99	99+
Suspended Solids	85–95	90–95	95–99	95–99	99+
Phosphorus	0–40	0–50	90–95	95–99	99+

8.2.12.1 4-R Wastewater-Renovation Conservation-Concept. One way of explaining the concept of liquid waste renovation and conservation is by considering it as a 4-R cycle, as depicted in Figure 8–30. The four R's being: Return, Renovation, Recharge and Reuse. *Return* of liquid wastes to the land is through an irrigation system. Surface soil layers *Renovate* this wastewater. The renovated water is *Recharged* into the ground water supply. Both the nutrients and the renovated water are available for *Reuse*. Each of these R's will be discussed briefly.

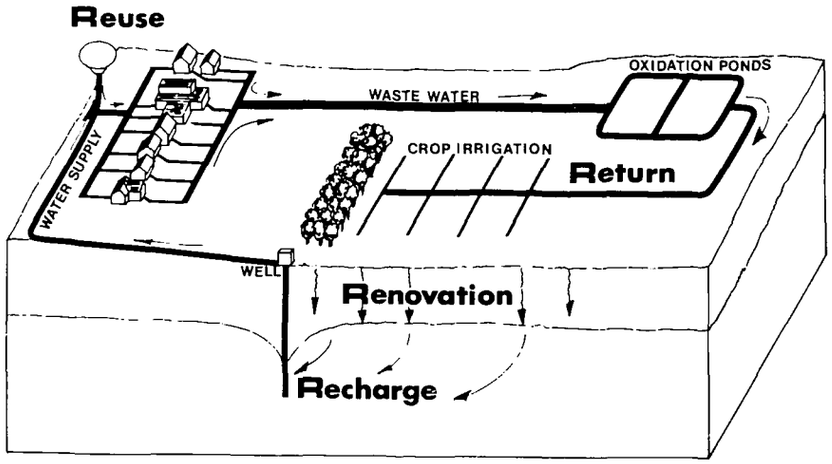


FIGURE 8–30 *Sprinkler Irrigation Disposal System.*

8.2.12.2 Return. Domestic wastewater ordinarily is returned to the land only after it has received a secondary level of treatment and chlorination. Industrial and cannery liquid wastes usually need to be chlorinated only if they also contain domestic wastes. Agricultural liquid manures frequently are irrigated in the form they are produced, as long as they are fluid enough to be pumped.

Three additional factors concerning the return phase of the cycle are important to effective operation. The liquid wastes must be distributed uniformly over the area. The rate of application must be sufficiently low so that all the water infiltrates through the soil surface. (It must move through the soil so that it can adequately be renovated.) The amount that is actually applied per week or the amount per year must be compatible with the soil type so that renovation can be assured.

8.2.12.3 Renovation. Under renovation, one usually considers mechanical, biological and chemical cleanup. Some industries are interested primarily in mechanical removal of organic material from the liquid wastes, followed by biological degradation. Municipal liquid waste disposal usually involves chemical renovation. That is, nutrients are removed from a solution through chemical reaction or transfer. This process is similar to that involved in agricultural, golf course or lawn fertilization.

In lawn fertilization, the fertilizer is placed on the surface of the soil and then irrigated or leached by rain. The fertilizer is taken into solution in the water. There is essentially no difference between this water and municipal sewage effluent. Each has nutrients in solution and as the water moves through the soil profile, these nutrients are chemically fixed in the soil or attached to the soil chemical complex where they stay until they are needed by the crop. Nutrients, such as nitrates, may be used directly by the crops or by soil microbes.

Farmers have been familiar with and have used this type of nutrient cycle for years. The nutrients are picked up by the crop and removed from the field with the crop. The same procedure is true when applying the various liquid wastes. Here, however, the nutrients are first applied to the soil and then a crop is grown in order to remove these nutrients. Harvesting of a crop makes room for the removal of the nutrients from the next application of wastewater.

8.2.12.4 Recharge. Before water is recharged, it must be adequately treated. Systems must be designed for each specific purpose and use intended for the irrigated liquid wastes.

8.2.12.5 Reuse. Potential reusers include agricultural, industrial and domestic. Agricultural reuse for crops is obvious. Distribution of wastewater over industrial and domestic water supply areas could frequently help alleviate waste disposal, as well as water supply problems.

8.2.13 Waterless Composting Toilet (Clivus Multrum)

Originally developed in Sweden, the composting toilet (or clivus multrum) is very similar in operation to the backyard "privy." Both toilet and solid, organic kitchen wastes are discharged to and then composted in a specially designed bin in the home. Shower and sink wastewater are disposed of by different mechanisms such as a cesspool or septic tank system.

In the clivus multrum system, the bin is nine feet long, four feet high and five feet wide. The bin holds the organic wastes of a family for several

years. During that time, microbial decomposition takes place to digest the waste and the end product (after two to four years) is a humus that can be used in a garden. Gasses and other volatile material that are produced are vented through a stack. The temperature of the chamber is sufficient to create a positive ventilation pattern with air entering through two tubes and leaving by way of the vent stack. See Figure 8–31.

Since the clivus multrum type of system does not use water, it results in a significant water savings (as much as 40 percent in a typical household). It requires little maintenance. Bacterial populations in the final humus product were shown to be consistent with typical soil bacteria types and levels. In addition, fecal coliform bacteria have not been shown to be present in the mulch.

Manufacturers claim that 90 to 95 percent of the original volume of waste has been converted to waste gas which is vented to the atmosphere. Typical end-product generation rates are three to ten gallons of humus per person per year after the two to four year digestion period.

8.2.14 Individual Home, Aerobic Biological Treatment Units

Traditional on-lot wastewater disposal systems for individual homes include cesspools or septic tank/tile field systems. In each, waste materials are decomposed by bacteria which do not require oxygen for their life systems. Hence, the processes are anaerobic or septic; *i.e.*, devoid of oxygen.

In recent years, equipment has been developed to provide for the aeration of home sewage in individual on-lot systems, thus achieving aerobic decomposition. Waste treatment utilizing aerobic microorganisms is more biologically efficient because the free oxygen dissolved in the wastewater allows the organisms to rapidly feed on and degrade both the suspended and dissolved organic matter. In a few hours, up to 90 percent of the organic matter is destroyed and a similar amount of suspended solids are removed.

A typical household aerobic treatment unit is depicted in Figure 8–32. It consists of two chambers, one for aeration and one for settling. Raw sewage (or septic tank effluent) enters the first chamber and is quickly mixed with the aerobic microorganisms by the air flow from the blower. The mixing brings the microbes into intimate contact with both the dissolved and undissolved waste matter. The nutrient material is rapidly absorbed by the organisms which utilize it for energy and cell growth, thus converting the majority of the organics in the waste to carbon dioxide, water and settleable sludge solids. In the second chamber, the sludge which contains the microorganisms settles out by gravity and is returned to the aeration chamber to continue the treatment process. The clarified effluent leaves the unit low in organic matter and suspended solids with partially reduced levels of fecal coliform bacteria. The aerobic home treatment units, however, do not remove nitrates from the wastewater.

While these units can produce a higher quality of effluent without odors, they require electrical energy, regular maintenance and servicing.

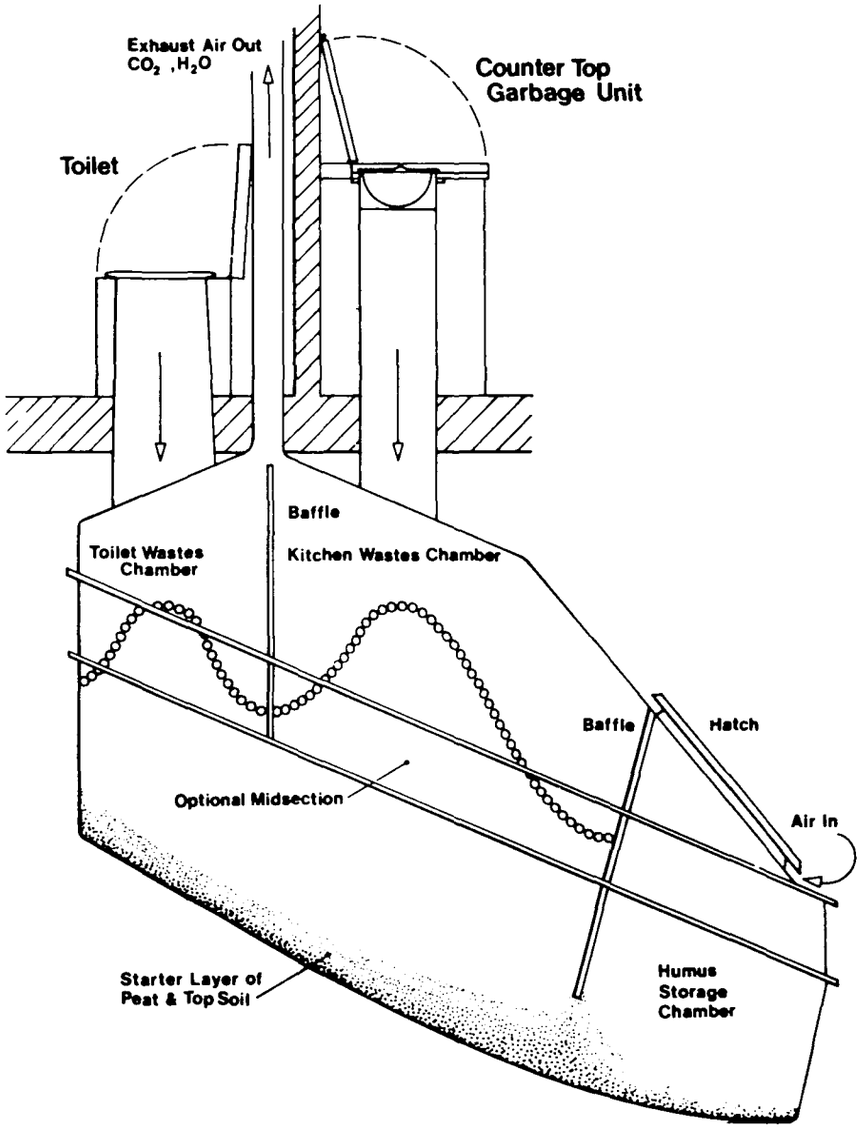


FIGURE 8–31 *Clivus Multrum Toilet.*

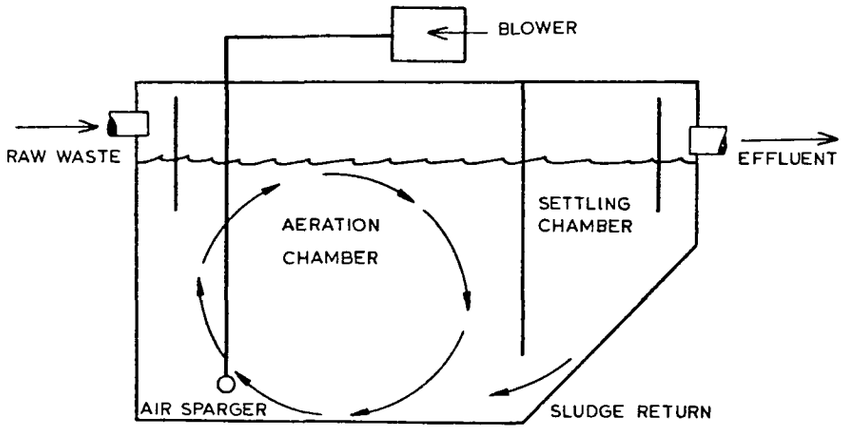


FIGURE 8–32 *Aerobic Biological Treatment System.*

Because they may reduce the amount of solids carried over to the tile field, manufacturers claim a longer life of the tile field in tight soils. However, the treatment process is easily upset thus causing high discharges of solids to the disposal field.

Household aerobic treatment units are considerably more expensive to install and operate than a septic tank/tile field system. They require constant maintenance whereas a septic tank system requires essentially no maintenance. The aerobic system appears to offer advantages in areas of tight, impermeable soils or where other leaching problems may occur.

8.2.15 Meadow/Marsh/Pond (M/M/P) System or Marsh/Pond (M/P) System

A meadow/marsh/pond system is an attempt to utilize aesthetically pleasing, natural systems for wastewater treatment. The approach depends upon long detention times for the slow, but effective, removal of suspended and disssolved pollutants. It utilizes physical removal of pollutants as well as biological reduction.

The process usually begins by screening the sewage to remove bulky objects. It may then pass through a degritter to remove sand and other non-degradable, coarse materials. The solid materials are then comminuted (shredded and chopped) to reduce degradables to fine, small particles. The waste stream then flows to basins where it is aerated and wherein biological decomposition begins.

Following aeration, the blend is normally pumped to a distribution box feeding two lined, sloped meadows. Only one meadow need be in operation at a given time while the other meadow is being dried out for harvesting of the crop. Meadows are alternated – the time intervals being determined by the sewage strength, the application rate, the condition of the crop and the season of the year. Meadowgrasses and crops are planted which assist in the removal of dissolved pollutants materials.

Gravity flow through the sloped meadow terminates in a lined marsh which merges with the meadow. The choice of plantings in the marsh depends on the geographic area and nature of the waste and generally will include harvestable crops which will flourish in the local climate.

In turn, the marsh terminates in a lined stabilization pond stocked with harvestable aquatic species which are indigenous to the area. A constant level is maintained in the marsh and pond by a fixed-invert overflow structure through which the treated waste can be recharged or disposed of in a different manner. Again, the biota of the pond are selected based upon the wastewater to be treated and the geographic area of the County.

Effluent levels of suspended solids, BOD and nutrients have been shown to be within regulatory agnecy standards. With high summer temperatures, bacteria populations may be higher than acceptable and a disinfection step would be necessary.

Since the entire M/M/P system has an underlying, impervious membrane liner there is no loss of contaminants to the groundwater environment. The entire process is thus controled prior to discharge.

The marsh/pond design is the same as the meadow/marsh/pond–without the meadows. The system requires less land and produces about the same quality effluent. It handles shock loadings fairly well but, like the full M/M/P system, has not been tested extensively in non-controlled conditions.

The M/M/P or M/P systems significantly reduce pollutants, including nitrates, if a system of cropping is instituted. Nitrogen in the wastewater is uptaken by the plants and becomes part of the biostructure. Unless that structure is removed, it will eventually die, decompose and release the nutrients back to the aquatic environment. See Figure 8–33.

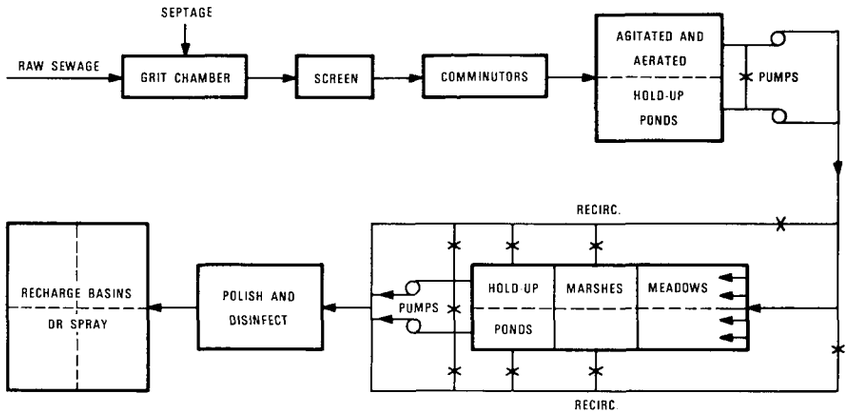


FIGURE 8–33 *Marsh/Pond System.*

8.2.16 Subsurface Denitrification of Septic Tank Effluents

In a granular type of soil, cesspool and septic tank systems, working in conjunction with the soil, are ideal for removal of organics and suspended solids. However, nitrates cannot be effectively removed without substantial modification.

The Suffolk County Department of Health Services is conducting a research project to demonstrate the feasibility of removing nitrogen in modified residential subsurface sewage disposal systems. An experimental disposal system has been constructed, consisting of a septic tank, leaching tile field system and denitrification system (see Figure 8–34). The disposal system is being fed with controled quantities of sewage from an apartment complex. The wastewater first enters a conventional septic tank and tile field. An impermeable membrane deflector is located six feet below the bottom of the tile field and is sloped as to intercept and deflect the wastewaster to a large impermeable pan.

Nitrogen compounds in the wastewater are first nitrified (converted from ammonia to nitrate) in the aerobic layer of native soil immediately below the tile field and above the membrane deflector. Once in the nitrate state, denitrification by certain types of bacteria (denitrifiers) will occur when anaerobic (devoid of oxygen) conditions are achieved in the pan. Methanol must be fed as a food source for the bacteria. This method of denitrification is commonly used in conventional waste treatment plants.

The denitrification process converts the nitrogen which is in the form of nitrate (NO_3) to a gaseous state (N_2). A venting mechanism for releasing the nitrogen gas to the atmosphere is provided.

Investigation is currently underway to eliminate the necessity of feeding methanol, which has drawbacks when applied to individual sanitary disposal systems. The most promising alternate method would be the diversion of part of the septic tank effluent to the anaerobic zone.

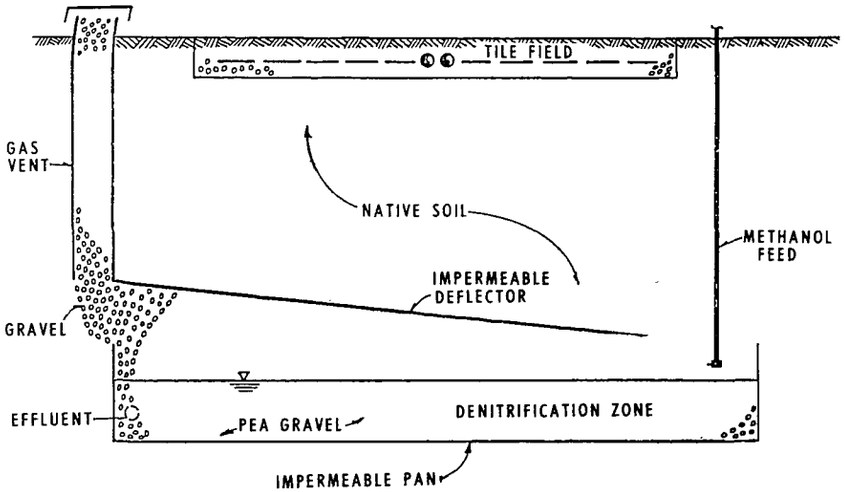


FIGURE 8–34 *Denitrification of Septic Tank Effluents.*

Section 9 Population Projections 1975-1995

9.0 INTRODUCTION

Population Estimates and Projections, 1975—1995 contains estimates of the present (1975) population and of the population at zoned capacity for each of the 108 municipalities, the 126 school districts and the 30 drainage basins in Nassau and Suffolk counties. It also contains the Nassau-Suffolk Regional Planning Board's projection of the population of those same geographic areas for the years 1980, 1985, 1990 and 1995, together with an explanation of the methodology used to develop the projections. There is a brief discussion of the major changes in town and school district population indicated by the projections, and of the relation of the projected totals to the "saturation population"; that is, the population of the projection areas at zoned capacity. This is followed by a consideration of gross residential densities. A brief discussion of the changes in zoned capacity and of the differences between the Nassau-Suffolk 1966 and 1975 projections conclude the body of the text. A comparison of the Nassau-Suffolk projections with those of other agencies is included in the Appendix.

The intended use of the projection influenced the selection of the geographic areas for which projections were developed. The 208 Study requires the production of "baseline" or trend projections in order to determine the magnitude of future needs and to evaluate the effects of various wastewater management alternatives on future population. Since large-scale wastewater management planning generally deals with drainage basins or sizable sub-basins it was necessary to provide the engineers, hydrologists, soil scientists and other technical personnel with population projections for drainage basins. However, a number of considerations—among them the Board's dependence upon readily available data, the potentially limited usefulness of projections for what were often extremely large, irregularly shaped drainage areas and the probable need for a subsequent breakdown of basin totals for sub-basins or other smaller areas for "208" or "201" (facilities planning) purposes, the desire for flexibility without loss of consistency, and the great number of requests for municipal and school district projections for general planning purposes—led the Planning Board to undertake the development of projections for the thirteen towns, the school districts or the portions thereof contained in each town, and the cities and villages or portions thereof in each town and school district. The availability of demographic and housing data and of zoning information for municipalities and school districts proved a most persuasive argument for the selection of these areas. The relative ease with which school districts or portions of school districts could be aggregated to drainage basins was an important consideration. The enhanced usefulness for general planning purposes and the simplicity of periodic revision, as necessary to reflect significant changes, were further reasons for the tabulation of data and the projection of data and the projection of population by municipality and school district.

9.1 CURRENT POPULATION ESTIMATES

The Nassau-Suffolk Regional Planning Board considers the Long Island Lighting Company's population estimates for January 1, 1975 as the most accurate available for the Bi-County area and has adopted them as the base year numbers for its population projections.

The LILCO figures are part of a continuing series of estimates, produced on an annual basis. They are essentially an up-date of the latest decennial census and of special censuses, where available, adjusted to reflect changes in the population as indicated by increases or decreases in the

number of occupied housing units. The changes in the number of housing units are obtained from company records of active meters, new connections and discontinuances of service. The meter count for each area is multiplied by a factor for household size to produce an estimate of the area's population. The household size multipliers are generally derived from the decennial census data and may be somewhat outdated and inaccurate by the latter half of the intercensal period. Nassau-Suffolk suspects that there may be areas in Nassau and in western Suffolk where the LILCO household size factors fail to reflect the full magnitude of recent changes in family size; however, such inaccuracies, if they do exist, are of little significance. The LILCO estimates for January 1,1975 have been used as the base year figures for projection purposes. The relatively small increase in population that has been projected for the period 1975–1980 is expected to compensate for any possible overstatement of the 1975 population.

Table 9–1 indicates the estimated population of the Nassau-Suffolk 208 Planning Region, the two counties, and the fifteen major municipalities as of 1975. Comparable estimates for school districts, villages and drainage basins are shown in Appendix Table A-1.

Table 9–1

ESTIMATED POPULATION OF THE NASSAU-SUFFOLK 208 PLANNING AREA

County and Region	Municipality	Population 1/1/75
	Glen Cove City	26,880
	Hempstead	814,050
	Long Beach City	34,766
	North Hempstead	238,559
	Oyster Bay	341,692
Nassau County		**1,455,947**
	Babylon	217,923
	Brookhaven	317,489
	East Hampton	13,053
	Huntington	213,643
	Islip	312,010
	Riverhead	21,184
	Shelter Island	1,918
	Smithtown	122,498
	Southampton	41,239
	Southold	18,733
Suffolk County		**1,279,690**
Nassau-Suffolk S.M.S.A.		**2,735,637**

9.2 SATURATION POPULATION

The methodology used by Nassau-Suffolk to develop the area-wide and sub-area projections combines the concept of land capacity; that is, holding capacity under existing zoning, with trend analysis on a small area basis. The following paragraphs describe the step by step procedure that was followed.

Step 1. *Identification and tabulation of all vacant land zoned for residential uses, including land in large estates.* Aerial photographs, tax maps and assessment records were used to identify vacant acreage, zoning exempt lots (filed subdivisions) and scattered parcels in built-up areas. Zoning maps were consulted to determine the zoning category of vacant acreage and scattered lots in developed areas. Field reconnaisance was employed when necessary to supplement aerials and office records. The number of acres of vacant land in each zoning category, in each municipality or school district was recorded for use in calculating the total number of potential building sites. The number of zoning exempt lots, if any, was also noted.

Step 2. *Calculation of existing vacant and potential building sites.* The number of already subdivided vacant parcels, including zoning exempt lots was tabulated. (The category "Zoning Exempt Lots," which is found most frequently in the eastern portion of Suffolk County, refers to lots on old filed maps that pre-date most of the local zoning ordinances. In areas characterized by considerable numbers of zoning exempt lots, the present zoning ordinance offers few clues as to the course of future development. For example, in some parts of the East End, the current zoning ordinance requires a minimum plot size of one acre or more; however, many parcels of 1/4 acre or less may constitute legal building sites because they were legal lots when the land was originally subdivided and have remained in single and separate ownership from that date to the present time. Wherever necessary an analysis of the tax map was undertaken in order to determine the magnitude of single and separate ownership and to permit evaluation of its impact on the ultimate utilization of the land. In built-up areas, any vacant parcels that appeared to be larger than necessary to conform to existing zoning were reviewed to determine whether they might yield more than a single building site. The computation of the potential yield of as yet unplatted acreage was accomplished through the application of a yield per acre factor for each zoning category to the total number of acres in that category. The yield per acre factors used are listed in Table 9–2. They represent average values based upon recent Nassau-Suffolk experience with conventionally designed subdivision plats.

The saturation estimate is based on existing zoning, so that if land were to be zoned for a higher or lower density, from or to non-residential use,

Table 9–2

ESTIMATED NUMBER OF DWELLING UNITS BASED ON EXISTING ZONING

Zoning Lot Size	Lots Per Acre	Zoning Lot Size	Lots Per Acre
4,000	6.8	16,000	1.9
5,000	5.4	16,500	1.8
6,000	4.5	18,000	1.7
6,500	4.1	18,500	1.6
7,000	3.8	20,000	1.6
7,500	3.6	20,500	1.5
8,000	3.4	21,780	1.5
8,500	3.3	22,000	1.4
9,000	3.1	25,000	1.3
10,000	2.7	30,000	1.0
11,390	2.6	40,000	0.8
12,000	2.5	43,560	0.7
12,500	2.4	60,000	0.6
13,000	2.3	2 Acres	0.4
14,000	2.1	3 Acres	0.27
14,500	2.0	4 Acres	0.20
15,000	2.0	5 Acres	0.16

or acquired for public purposes such as recreation or farm preservation, the saturation figure would have to be adjusted. Recent observations suggest that the pattern of zoning on Long Island has become relatively stable. Changes to higher density are often offset by other changes to a lower density or by a land acquisition, thus minimizing the impact of any change in the ultimate saturation calculation.

Step 3. *Identification and tabulation of housing units by occupancy status.* The 1970 Census housing counts for all units and for vacant, seasonal and occupied units were listed for each municipality and school district. Building permit data for the years 1970 through 1974 were employed to estimate the increase in the housing stock between 1970 and 1975. Where multi-family units constituted a sizeable percentage of the new housing, the number of single-family and multi-family units were noted separately. Long Island Lighting Company meter records were used in combination with 1970 census and 1970–74 building permit data to estimate the total number of dwellings and the number of occupied units in 1975.

Inasmuch as housing data in general and building permit data in particular are rarely tabulated for areas whose boundaries coincide with or even approximate those of school districts, it was necessary to employ allocation procedures utilizing aerial photographs, office records, and field verification in order to assign both pre-1970 and post 1970 housing to the appropriate school districts.

Step 4. *Calculation of the total number of housing units permitted under existing zoning.* The total number of housing units now in place and the total number of existing and potential building sites, each of which could be used to accomodate an additional unit, were summed to obtain an estimate of the number of potential housing units and households.

The saturation figure reflects the assumption that all existing housing units that are currently not occupied will be utilized and that seasonal and vacant year-round units will continue to exist in the five eastern towns of Suffolk County until after year 2000. Few seasonal and second homes are anticipated elsewhere on the island.

Step 5. *Estimation of household size at saturation.* Census counts of total population in households and occupied housing units were used to calculate the 1970 household size for each municipality and school district. Population and occupied housing unit estimates for 1975 were employed to calculate the significant changes, if any, that had occurred between the two dates. Following a review of the 1970 and 1975 figures and consideration of such relevant factors as the sharp decline in births, the age composition of the community, income, ethnicity, and of the increasing proportions of multi-family dwellings in a few localities, a probable average household size at saturation was selected for each of the projection areas. Appendix Tables A-2 through A-14 indicate the type of background information available for each of the towns and the format used for tabulations.

Increases have been projected for some communities presently characterized by a relatively small household size but having considerable potential for growth. Decreases have been projected for others now characterized by large households, little remaining land and declining school enrollments. Where the potential for apartment or condominium construction is greater than that for single family home construction, family size is expected to decrease. It is also expected to decrease in some Eastern Suffolk areas since these areas tend to attract small, elderly households despite the overwhelming predominance of single family homes.

The Nassau-Suffolk staff has made several assumptions that directly affect the selection of the household size factor for school districts and municipalities. It has been assumed that the overall trend towards smaller households that has been observed for more than a decade in much of Nassau and Suffolk will continue as both the national and local birth rate decline and as more and more young adults and the elderly choose to maintain their own households.

It is expected that an aging population will further reduce the number of births in many communities in Nassau and western Suffolk. As older households leave the area, the high cost of their former dwellings generally

precludes purchase by young families in the primary child-bearing age groups. The head of the household of the new family is likely to be between 35 and 49 years of age with a spouse of similar age and children in the 10 to 19 year age group. Some growth is expected to occur even in the absence of net natural increase. Although the new or in-migrant family may be somewhat smaller than that of the original occupants of the dwelling, it may be larger than the original family minus the grown children that have left to establish their own households. In communities where this type of change is occuring, a period of gradually decreasing household size is followed by a period of increasing household size that results in population gains.

Step 6. *Estimation of population at zoned capacity.* The number of existing and potential housing units, calculated in Step 2 was multiplied by the appropriate household size, selected in Step 5, to obtain the saturation population for each school district and municipality. The final line in Appendix Tables A-2 through A-14 indicates the estimated population at zoned capacity for each of the projection areas.

9.3 POPULATION PROJECTIONS

The twenty year projections are, in the first instance, town-wide projections. Figures for the school districts, cities, and villages were derived from the town projections by means of a step-down apportionment technique that permitted the allocation of anticipated growth to sub-areas. The following paragraphs summarize the procedures followed and describe some of the considerations that influenced the selection of growth rates and the assignment of shares.

As the initial step in the projection process, the growth patterns of the towns and sub-areas for the years 1970–1975 were subjected to detailed scrutiny and analysis. After in-depth study of the annual changes in population as estimated by Long Island Lighting Company, of building permit data, and of school enrollment figures, average annual growth rates were selected for each of the thirteen towns for the 1975–1980, 1980–1985, 1985–1990, and 1990–1995 projection periods.

The 1975–1980 rates were applied to the base year estimates to obtain figures for projected growth for the first five year period. Projected population increments and base year estimates for each town were summed to produce the 1980 projections. The rates for each of the three subsequent five year periods were applied to the projected population at the beginning of each period to obtain figures for anticipated growth and to permit calculation of the total population at the end of the respective five year projection period. Table 9–3 shows the base year estimates and the projected population for the thirteen towns, two cities, the counties and the Nassau-Suffolk Region.

Table 9–3

NASSAU AND SUFFOLK TOWNS AND CITIES
FIVE YEAR POPULATION PROJECTIONS: 1975–1995

	1975	1980	1985	1990	1995
Glen Cove	26,880	27,878	28,339	28,699	28,981
Hempstead T.	814,050	817,353	819,568	821,390	823,268
Long Beach	34,766	35,716	36,491	37,241	37,941
North Hempstead T.	238,559	240,706	242,994	245,424	246,650
Oyster Bay T.	341,692	346,136	348,302	349,067	349,725
Nassau County	**1,455,947**	**1,467,789**	**1,475,694**	**1,481,821**	**1,486,565**
Babylon T.	217,923	230,175	239,530	243,144	244,362
Brookhaven T.	317,489	378,654	438,904	494,346	546,198
East Hampton T.	13,053	15,549	18,992	22,066	25,637
Huntington T.	213,643	225,546	234,761	241,089	244,759
Islip T.	312,010	339,044	367,156	388,290	399,895
Riverhead T.	21,184	23,412	26,529	30,363	34,752
Shelter Island T.	1,918	2,228	2,790	3,324	3,960
Smithtown T.	122,498	128,913	134,810	141,534	147,381
Southampton T.	41,239	47,200	54,837	64,352	75,518
Southold T.	18,733	21,016	23,814	26,716	29,972
Suffolk County	**1,279,690**	**1,411,737**	**1,542,123**	**1,655,224**	**1,752,434**
Nassau-Suffolk S.M.S.A.	**2,735,637**	**2,879,536**	**3,017,817**	**3,137,045**	**3,238,999**

The apportionment of town growth to sub-areas was accomplished by the assignment of a share or percentage of the total growth to each school district or municipality or portion thereof located within the town. The prediction of long term change in small areas is difficult at best, and it was frequently necessary to develop not only a preliminary set but one or more revised sets of percentages before achieving an acceptable formula for the distribution of town growth. The shares, which varied considerably by area and projection period, were determined on the basis of staff assessment of relevant factors. The factors considered included, among others, the general development trends; the growth of the sub-area as compared with other sub-areas and the town as a whole; the availability of land; the desirability of sub-area, including accessibility; the type and cost of housing; and the presence or absence of impediments to development.

In some areas that are presently experiencing or are expected to experience population losses, the shares are characterized by negative values. The school districts or municipalities with negative shares were generally those in the older developed portions of the Region where the present population is close to or even exceeds the projected saturation population or where the losses resulting from a sharp decrease in household size are expected to more than offset the gains resulting from new development.

A comparison of the population estimates for 1975 and the figures for

the saturation population at zoned capacity indicates that many school districts and municipalities in Nassau County have already reached or exceeded the saturation figures. Several facts can be cited to explain this apparent contradiction. In most sub-areas the projected household size is smaller than the present household size and therefore the same, or possibly, even a slightly greater number of households can be expected to produce a smaller population at saturation than in 1975. In a few areas there are significant numbers of existing and potential illegal two or more family dwellings in single-family zones; however, in the absence of precise information as to their present number and as to local enforcement intentions, these had to be excluded from the saturation calculations. In every area having a sizeable institutional population, that population, or the population that could be accomodated at the one or more institutional facilities located in the school district or municipality was also excluded from the saturation calculation. The institutional population residing in such places as the state psychiatric centers, the Northport Veterans Hospital, and several universities was projected separately and then added to the household population to produce a combined total for both household and institutional population.

Appendix Tables A-15 through A-26 present the base year population, the five year change in the number of persons, and the total projected population for school districts and municipalities for the years 1980, 1985, 1990 and 1995.

Appendix Table A-27 summarizes the same data for the 21 school districts and 7 villages that include land in more than one town. Projections for drainage basins may be found in Appendix Table A-28. Appendix Tables A-30 through A-42 list the saturation population at zoned capacity and indicate the percent of saturation represented by the projected population for the school districts, the municipalities, and the districts and municipalities with land in more than one town.

A review of the school district and municipality projections reveals that in many of the areas already at or above saturation the population is expected to decrease somewhat but to remain above or near saturation throughout the twenty year period. It is anticipated that by 1995 the population of many other areas, particularly those in eastern Nassau and western Suffolk, will be at or near saturation. It appears unlikely that saturation at zoned capacity will be reached in most parts of central and eastern Suffolk until some time after the year 2000.

The reader should be aware that it is often even more difficult to project the precise timing of growth than it is to project its magnitude; and that consequently, the projection dates should be regarded as nothing more than the best possible approximations, given present uncertainties. For example, areas where lots in existing built-up neighborhoods or on mapped rapid change as large scale, well-financed developers proceed to convert estates, nurseries, clubs and preserves, and farmland to new communities.

Recent efforts to preserve farmland, shorefronts, wetlands and other areas of great environmental or recreational value have been taken into account in the projections and it has been assumed that should these efforts succeed, the growth rate in the affected areas will be slower than might otherwise be anticipated. It has also been assumed that as the population of a school district or municipality approaches saturation, the rate of growth will decline since the most desirable, moderately priced, easy to develop land will already have been utilized. The land that remains is frequently characterized by physical or legal impediments that deter its use for housing or, in other instances, is the subject of belated community efforts to preserve the last remaining local open space.

9.3.1 Projected Twenty Year Changes in Town and School District Populations.

According to the current series of projections, 93.1% of the Region's twenty year growth of approximately one half million persons will occur in streets constitute a large proportion of the vacant land can be expected to experience relatively slow, steady growth through most or all of the projection period; however, areas where large tracts of presently unsubdivided land constitute most of the vacant acreage can be expected to experience sudden, Suffolk County. Two towns, Brookhaven and Islip, each with a present population in excess of 300,000 persons, are expected to accommodate more than five-eighths of the additional residents. Table 9—4 indicates the number of persons and the share of the total Bi-County growth projected for the two counties and each of the fifteen major municipalities.

As might be expected, the population projections generally indicate little change in the number of residents in the Nassau County school districts; moderate change in the western Suffolk school districts; great change in the central Suffolk school districts; and little to moderate change, in the eastern Suffolk school districts.

Only four districts totally within Nassau County—Long Beach, Hempstead, Glen Cove, and Oyster Bay-East Norwich—and two Suffolk districts that include portions of Nassau—Cold Spring Harbor and Amityville—are projected to gain more than 2000 persons during the twenty year period. Another seven are projected to gain from 1000 to 2000 persons, while the remainder are projected to add fewer than 1000 persons or to lose population.

In contrast, four districts in Suffolk County—Connetquot in the Town of Islip, Sachem in the towns of Islip, Brookhaven and Smithtown, and Middle Island and William Floyd in the Town of Brookhaven—are expected to

add more than 20,000 new residents. Seven other districts—Smithtown in western Suffolk; Middle Country, Patchogue, Miller Place, Rocky Point and Shoreham-Wading River in central Suffolk; and Riverhead in eastern Suffolk—are expected to add between 10,000 and 20,000 new residents. Twenty districts are expected to add from 5000 to 10,000 persons. Three of these districts are in the Town of Huntington; two, in the Town of Babylon. One is in the Town of Smithtown; eight are in the Town of Islip; four, in the Town of Brookhaven; and two, in the Town of Southampton. Twenty-four districts, nine of them in the towns of Huntington and Babylon, are expected to add between 2000 and 5000 persons while the remaining sixteen districts—all but one of them located in eastern Suffolk—are expected to add fewer than 2000 persons.

Table 9–4

THE COUNTIES AND MAJOR MUNICIPALITIES: AMOUNT AND DISTRIBUTION OF PROJECTED TWENTY YEAR GROWTH

	Projected Growth 1975–1995 (No. of Persons)	Share of Regional Growth (%)
Glen Cove	2,101	0.4
Hempstead T.	9,218	1.8
Long Beach	3,175	0.6
North Hempstead T.	8,091	1.6
Oyster Bay T.	8,033	1.6
Nassau County	**30,618**	**6.1**
Babylon T.	26,439	5.3
Brookhaven T.	228,709	45.4
East Hampton T.	12,584	2.5
Huntington T.	31,116	6.2
Islip T.	87,885	17.5
Riverhead T.	13,568	2.7
Shelter Island T.	2,042	0.4
Smithtown T.	24,883	4.9
Southampton T.	34,279	6.8
Southold T.	11,239	2.2
Suffolk County	**472,744**	**93.9**
Nassau-Suffolk S.M.S.A.	**503,362**	**100.0**

9.3.2 Gross Residential Density

Gross residential density; that is, the average number of persons per acre provides a crude indicator of probable need for the design and construction of local or area-wide wastewater collection and treatment facilities. Appendix Table A-30, which was originally prepared at the request of the 208 Study's consulting engineers, indicates gross densities for each of the

Table 9–5

SUMMARY OF EXISTING AND PROJECTED GROSS RESIDENTIAL DENSITIES IN PERSONS PER ACRE FOR NASSAU AND SUFFOLK TOWNS AND SCHOOL DISTRICTS, 1975 and 1995

Town	Town Average		School Districts Maximum		School Districts Minimum	
	1975	1995	1975	1995	1975	1995
Hempstead	11.82	11.99	21.04	21.11	7.37	7.39
N. Hempstead	6.99	7.17	20.07	20.10	0.42	0.83
Oyster Bay	5.26	5.40	13.33	13.17	0.85	0.90
Babylon	6.82	7.64	13.47	15.30	1.13	1.43
Brookhaven	1.92	3.27	5.29	6.73	0.05	0.19
East Hampton	0.29	0.56	1.56	2.11	0.08	0.18
Huntington	3.56	4.08	5.96	6.84	0.88	1.29
Islip	4.72	6.05	8.35	8.85	0.08	0.11
Riverhead	0.49	0.80	0.51	1.23	0.30	0.76
Shelter Island	0.26	0.54	0.26	0.54	0.26	0.54
Smithtown	3.57	4.29	5.98	8.20	0.59	1.30
Southampton	0.46	0.84	1.72	2.90	0.21	0.36
Southold	0.55	0.88	0.72	1.39	0.15	0.23

thirteen towns and 126 school districts. Portions of school districts comprising land in more than one town are listed under their respective towns. Gross residential densities for the total area of the split districts can be obtained by dividing the sum of the population of the component sections by the sum of the acreage of those sections.

It is important to note the potentially critical limitations of a measure such as gross residential density. Its usefulness varies directly with the homogenity of development patterns and inversely with the proportion of the total acreage in non-residential uses in any particular area. As an average, it tends to mask extreme values and therefore fails to signal the presence of small sectors where existing or anticipated densities may be sufficient to warrant the provision of services not justified for the area as a whole. The presence of relatively large parcels devoted to industry, parks, airports or other public facilities often distorts the gross residential density calculation, making the area as a whole appear far less intensively utilized than is actually the case. In addition, for areas subject to seasonal variations in population, the figure for gross density, which is based on the number of year-round-residents, will be unduly low; for areas characterized by large numbers of persons in hospitals or other group quarters, it will probably be somewhat high.

9.3.3 Changes in Projected Population at Zoned Capacity

Table 9–6 facilitates comparison of the most recent figures for population at zoned capacity, or saturation population, and those figures that were

Table 9–6

NASSAU-SUFFOLK SATURATION PROJECTIONS

	Saturation Population		Changes in
Nassau County	**Current Series**	**1966 Series**	**Number of Persons**
Glen Cove City	31,140	29,900	1,240
Hempstead Town	834,272	816,123	18,149
Long Beach City	41,707	43,137	– 1,430
North Hempstead Town	261,896	249,167	12,729
Oyster Bay Town	353,015	365,912	– 12,897
County Total	**1,522,030**	**1,504,239**	**17,791**
Suffolk County			
Babylon Town	246,194	276,920	– 30,726
Brookhaven Town	820,709	887,380	– 66,671
East Hampton Town	92,366	164,640	– 72,274
Huntington Town	251,192	308,140	– 56,948
Islip Town	410,633	375,790	34,843
Riverhead Town	207,203	313,870	– 106,667
Shelter Island Town	16,983	18,370	– 1,387
Smithtown Town	153,529	169,500	– 15,971
Southampton Town	202,510	264,050	– 61,540
Southold Town	72,921	245,080	– 172,159
County Total	**2,474,240**	**3,023,740**	**– 549,500**
Nassau-Suffolk S.M.S.A.	**3,996,270**	**4,527,979**	**– 531,709**

developed a decade ago as part of the resource information for the Nassau-Suffolk Comprehensive Plan.

The new saturation population statistics for Nassau County show a potential increase of just under 15,000 persons, while those for Suffolk County show a decrease of over one half million. The small increase in Nassau is a result of a more accurate determination of available lots, rezonings to increase density, additional conversions to two family use and redevelopment of underutilized land. The reduction in the City of Long Beach is attributable to a density limit on major apartment buildings.

The significant decrease in Suffolk County has occurred largely as a result of municipal action by the eastern towns to implement plan recommendations calling for reductions in overall density in order to limit the demand for costly services, while maintaining the basically recreational-agricultural environment. The Town of Southold figures are a good example and show the result of a rezoning from lot sizes generally of 1/4 acre to lot sizes of one acre or more in most of the undeveloped parts of the Town. In contrast, the statistics for the Town of Islip reflect the acceptance and construction of higher density housing throughout the Town since the date of the earlier survey.

Table 9–7

NASSAU-SUFFOLK POPULATION PROJECTIONS FOR THE YEAR 1985

	1985 Population		
	Current Series	**1966 Series**	**Difference**
Glen Cove City	28,339	31,000	– 2,661
Hempstead Town	819,568	885,000	– 65,432
Long Beach City	36,491	37,000	– 509
North Hempstead Town	242,994	260,000	– 17,006
Oyster Bay Town	348,302	356,000	– 7,698
Nassau County	**1,475,694**	**1,569,000**	**– 93,306**
Babylon	239,530	267,000	– 27,470
Brookhaven Town	438,904	515,000	– 76,096
East Hampton Town	18,992	22,000	– 3,008
Huntington Town	234,761	260,000	– 25,239
Islip Town	367,156	374,000	– 6,844
Riverhead Town	26,529	44,000	– 17,471
Shelter Island Town	2,790	2,600	190
Smithtown Town	134,810	165,000	– 30,190
Southampton Town	54,837	67,000	– 12,163
Southold Town	23,814	28,000	– 4,186
Suffolk County	**1,542,123**	**1,744,600**	**– 202,477**
Nassau-Suffolk S.M.S.A.	**3,017,817**	**3,313,600**	**– 295,783**

9.3.4 Comparison of Present and Earlier Series of Small Area Projections

The latest population projections reflect a slower growth rate than that anticipated in the projections developed in the previous decade. Table 9–7 lists the 1985 projections of both series and indicates the magnitude of the difference between them. It should be noted that 1985 represents the mid-point of the current projection period, only ten years removed from the present; whereas it represented the final date, some twenty years from the present when the earlier series was developed a decade ago.

The Bi-County area is expected to have just over three million people in 1985 or 300,000 fewer people than were projected earlier. The new projections are approximately 200,000 lower in Suffolk and 100,000 lower in Nassau County. The 1985 Suffolk County projected totals, contained in the earlier report, may very well be reached in the period between 1995 and 2000, while the earlier 1985 Nassau projected totals should not be reached in the foreseeable future. The high cost of new housing, which prices younger or poorer families out of the housing market, and an overall slowdown in the economy appear to be the major reasons for the slowed growth in Suffolk, where land is still available for extensive housing developments. The Nassau decrease is related to the same factors; however, less land is available and new housing on this land is very costly. The reduction in projected family size and revised plans drastically limiting housing at Mitchel Field also help to explain the markedly slower growth now projected for Nassau County.