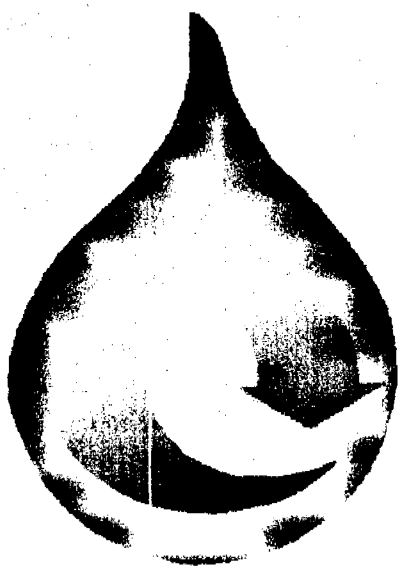
A USER'S MANUAL FOR WAWTTAR

(Version 4.0 for MS-Windows)

fout gemaakt by Humbolt Uni = auteurs

A Decision Support Model for Prefeasibility Analysis of

WATER AND WASTEWATER TREATMENT TECHNOLOGIES APPROPRIATE FOR REUSE



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1.1.1 Critical Factors

The WAWTTAR program was designed to assist financiers, engineers, planners, and decision-makers in improving their strategies for sustainable water and sanitation coverage while minimizing impacts on water resources (Figure 1.1). The history to date in these areas is laden with failures of infrastructure investments. Fatal flaws in past activities by non-government organizations (NGO), bi-lateral, multilateral, and local governments fall into several categories. The most common failure mode is system failure due to lack of ability/capability to ensure ongoing operation and maintenance. Many factors lead to these conditions. The most critical factor is the inappropriateness of the technology. This most often is seen in examples where donors are exploiting their national business interests by tying aid to a particular technology. Willingness to pay for capital and Operation and Maintenance (O&M) cost is another essential factor in these fatal flaws. The inappropriateness and lack of willingness to pay are not necessarily mutually exclusive factors. Although dispersed populations are among the group which is in great need, actions to alleviate the situation could be made more effective if they were concentrated on groups such as nucleated units or small to medium size communities.

There is a need to differentiate between that which is nucleated and that which is not, as concepts of community differ, particularly among professions (such as engineers, ecologists, sociologists, health workers, or economists). It is proposed here that a nucleated settlement begins at or above that population concentration level where there exists a physical water system and an associated managerial system. In general, the management system in a nucleated settlement will no longer be a volunteer operation, and this breakpoint occurs at a population of about 300 or more. At a higher population level of about 3,000 persons, piped water becomes cheaper than unpiped water. Piped water requires a distribution system and a higher level of technology than does a system of unpiped water. Population density is a significant factor in determining the cost of a piped water system and a wastewater collection system

1.1.2 WAWTTAR Objectives

This program focuses on the concept that when equipment or technology is supplied, it should be only after a means of supply for repair parts and operational and maintenance resources are known to be available. This includes having trained and equipped operators to insure that the environmental and monetary investments are protected. Many existing facilities are in bad conditions due to poor selection of technology, inappropriate design, insufficient maintenance (including preventive maintenance), lack of spare parts, and a lack of trained personnel. Locally obtainable materials should be utilized whenever possible and maintenance of equipment should be manageable by local people.

Involvement of the target population from the beginning of a water supply and wastewater treatment project is important. Sometimes much persuasion and education are necessary to get people to use safe water and to realize the value of treated wastewater. Local decision-makers need to understand the basic principles of the various processes and support the ideas introduced. People must learn to view water treatment and reuse as a cycle for managing scarce resources (see Figure 1.1). Ways to help bring this about includes handbooks in simple language for laymen, pilot demonstration plants, short courses, and experimental plants connected with plants in operation.

The WAWTTAR program is a decision support platform developed to assist planners select suitable water and wastewater treatment processes appropriate to the material and manpower resource capabilities of particular countries at particular times. The technique should eliminate the problem of overlooking good processes for water and wastewater treatment and minimize system failures due to inappropriate treatment technologies.

1.2 RANGE OF APPLICATION

The WAWTTAR program is a decision support system designed to assist in the evaluation of infrastructure investments in the areas of water treatment, wastewater treatment, and water reclamation. The target audiences for the program include engineers, planners, public works directors, environmental specialists, public sector development specialists, public health officials, and managers of water and wastewater treatment systems. The program is designed to assist decision-makers dealing with the following types of issues.

1) Given a community with its characteristic socio-economic conditions, and geographical characteristics, what is the least cost (total construction and/or operation and maintenance) system to meet the community needs?

2) Given a specified potential technological system/s (water, wastewater, and/or reclamation) by a potential donor or government agency, what are the implementation risks to long-term sustainability?

3) Given a community with an existing wastewater treatment facility, what are the combinations of technologies available to meet a water reuse standard or guideline?

4) Given a high-density peri-urban community that is fast growing, what are the least cost (socially and environmentally) sustainable wastewater collection and/or wastewater treatment options?

5) Given a set amount of financial investment in infrastructure (water, wastewater, sanitation, and reclamation), which treatment technologies allow for maximum coverage while reducing the risk of system failure (resources, labor, materials, management, and technology)?

6) Private investors and manufacturers are interested in developing and marketing sustainable technologies (water, wastewater, and reclamation) in specific areas with their unique and characteristic profiles. Where is the need the greatest?

7) A regulatory and/or water reclamation agency is interested in identifying the potential BMPs (Best Management Practice). Which technologies currently available can meet new or different water quality standards and water reclamation standards? This would include estimating the cost, for example, of meeting new standards.

8) A research and development group (either private or governmental) is interested in investing in the research and development for a needed technology in water treatment, wastewater treatment, and/or water reuse. Where are the treatment gaps with existing processes?

9) An organization, agency, or profession is interested in sensitizing their human resources to the issues of sustainable solutions in the water, sanitation, wastewater, and/or reuse sector.

1.3 THE ON-SITE PERI-URBAN CHALLENGE

Removing and safely disposing of excreta and wastewater is a critical environmental health need for most cities in much of the world. Improper disposal and inadequate drainage of sewage and wastewater leads to pools of polluted water which convey diseases including diarrhea, dysentery, intestinal parasites, and provide breeding grounds for mosquitoes which spread filariasis, malaria, and other diseases. The reuse of untreated wastewater in areas of water shortage is a common irrigation practice fraught with health dangers for both farmers and consumers of farm products. Cholera remains a constant threat.

In consideration of the critical shortage of clean water supplies, protection from pollution must be given to surface and groundwater sources. Water reuse must be practiced where possible to extend these supplies. Efficient treatment is needed to return the wastewater to a condition that is acceptable for useful purposes, thus expanding the water resource base.

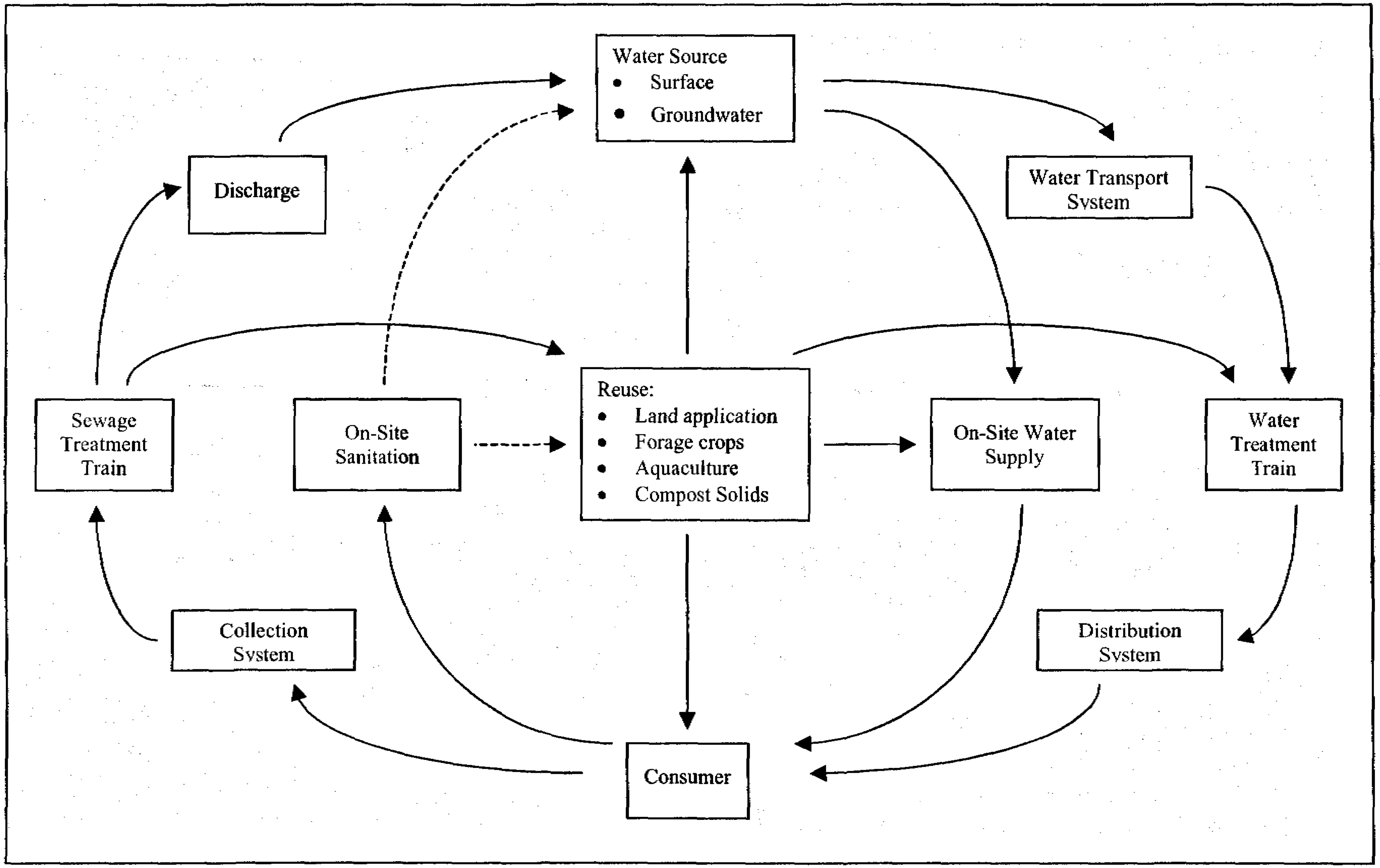
In the cities of many developing nations, access to adequate sanitation is available for most residents in large urban centers although this varies considerably between countries. Large cities typically have several sanitation systems in use with many residents in the affluent and commercial sections connected to sewers and others to individual septic tanks. Many others, especially in peri-urban zones, are without acceptable sanitation facilities. Wastewater treatment facilities and approaches generally follow conventional designs although the extent of treatment may vary considerably.

Outside of the large cities, there are hundreds of urban centers in developing nations with less than 10,000 people. Each community will have its own particular set of environmental problems which are influenced by such factors as the size and density of the population, the scale and nature of the production base, climate, topography, water resources, and the type and distribution of flora and fauna in and around the town. What appears as a particularly pressing problem in one town may represent minor problems in other towns in that same country, while other nations may have an entirely different set of problems.

For the smaller towns, there is more of an ad hoc approach to sanitation, resulting in inadequate coverage and the use of inappropriate methods. Conventional treatment approaches are costly and are difficult to sustain in small towns. USAID recognized this problem in the mid 70's and produced a manual, "Appropriate Methods of Treating Water and Wastewater in Developing Countries." The manual considered not only technical considerations but also economic and institutional issues in choosing appropriate methods. However, the state of the art has advanced in recent years and different economic and social conditions apply in many countries suggesting the need for reevaluating the current situation. There are also advances in non-technical approaches emphasizing pollution prevention through economic and policy means that need to be considered.

There is a range of potential methods for treating wastewater. Each method has a unique set of technical, economic, and institutional conditions which must be evaluated. The analysis and decision process would be aided by an iterative approach of comparing the various possibilities. There is currently no computer software designed for this purpose. The development of this software and the input of current technical and economic data improves the selection process and potentially expands sanitation coverage, water reuse, and sustainable water and wastewater treatment systems to many areas in developed and developing countries. WAWTTAR and its attendant database is an attempt to provide this capability.

FIGURE 1.1 THE TREATMENT - REUSE CYCLE



2.0 INTRODUCTION TO THE PROGRAM

This manual is intended to supply basic information about the operation of WAWTTAR. It provides an overview of the information display and editing conventions that have been adopted as well as the functions performed by each of the program's commands and dialogs. It is assumed that the users of WAWTTAR will have some background in water and wastewater treatment and planning. It is also assumed that users will be familiar with the MS-Windows operating system, and have basic keyboard and mouse skills. This manual is not intended to be a tutorial in either water or wastewater treatment or the MS-Windows system.

WAWTTAR's main use is as a tool for persons with some technical background to screen and research possible water and wastewater treatment options. The program has been designed to incorporate wastewater reuse as an equal criterion in the selection of feasible solutions. It also assists in addressing a community's public health, water resource, and ecological condition. WAWTTAR does not exclude conventional options and is of equal usefulness in the screening and research of such options as well. WAWTTAR is a decision support tool intended to assist planners in selecting suitable water and wastewater treatment options appropriate to the material and manpower resources available to particular countries at particular times. It is hoped that WAWTTAR will assist planners in improving sanitation coverage in rural and developing areas. The performance and cost of a large number of possible systems can be estimated with WAWTTAR for any location and condition for which basic information on the problem to be solved is available. WAWTTAR should therefore alleviate the problem of overlooking good processes for water and wastewater treatment, and help screen out treatment technologies which are inappropriate for given locales and situations. The selection of inappropriate technologies often results in facilities that perform poorly and fall into disrepair due to a lack of basic resources such as spare parts, operations and maintenance personnel, and technical expertise. Hopefully, design errors of this kind can be significantly reduced or eliminated via the use of WAWTTAR by persons with some background in water and wastewater treatment issues.

2.1 HARDWARE/SOFTWARE

WAWTTAR 4.0 requires an IBM-PC compatible computer running Microsoft Windows 95 or later. 32 MB of RAM and a minimum graphics resolution of 800x600 with 256 colors are required to run the program. Depending on your current computer configuration, between 30 and 40 megabytes of disk space is required to install WAWTTAR.

2.2 INSTALLATION

In addition to the install program, the WAWTTAR CD-ROM includes this users manual in the file **WAWTTAR Users Manual.pdf.** This file can be viewed using the free Adobe Acrobat reader. The latest version this program is available from the Adobe WWW site at www.adobe.com. For your convenience, the Windows 95 and Windows NT version of this program is located on the WAWTTAR CD-ROM, and can be installed by double clicking on the file **acroread.exe**.

2.3 OVERVIEW OF WAWTTAR OPERATION

In the basic operation of WAWTTAR, basic problem parameters such as performance standards, material costs, raw water or wastewater quality, community needs and capabilities, and planning horizon are entered by the user into easily editable data fields (see Figure 2.1). The user can then construct several possible treatment trains from a supplied, comprehensive list of available treatment processes. WAWTTAR first screens these options by the needs, capabilities and resources of the community in question, and discards those options that are infeasible (see Figure 3.1). WAWTTAR then calculates the performance, construction costs and operations and maintenance costs of the remaining possible treatment systems based on simple mathematical models of each of the treatment processes. The results of the initial screening and of the calculations are sent to either a Feasible Solutions File or an Infeasible Solutions File based on whether or not community needs, resource limitations and performance requirements are met. Infeasible treatment systems can be analyzed for deficiencies caused by data entry errors or improper assumptions concerning the community resources that are available to commit to this project. These deficiencies can then be corrected and the cost and performance of the corrected system can be calculated again. Feasible options can be compared based on performance and annualized costs. In this way, WAWTTAR can assist in analyzing far more options more accurately and completely than can be done with more conventional "rule of thumb" techniques.

WAWTTAR

An interactive program used at the pre-feasibility phase for selecting water treatment and wastewater treatment and reuse systems

Program Attributes

- Editable process data base containing cost, performance, and resource requirements for a wide range of treatment processes.
- Editable standards data base containing drinking water, wastewater discharge, and reuse standards and guidelines.
- Editable treatment train data base containing standard configurations of water and wastewater treatment processes. Processes can be arranged in as many configurations as experience dictates.
- Editable community data base allows incorporation of demographics, climate, and resource availability in process selection.

Program Output

- Treatment trains meeting resource limits and effluent standards ranked by capital cost, O/M cost, or total cost on an annualized basis.
- Value of five water quality parameters tracked though each treatment processes.
- Index of flexibility and expandability for each feasible treatment train. Infeasible treatment trains with the limiting component identified.

FIGURE 2.1 WAWTTAR INPUTS AND OUTPUTS

2.4 LIMITATIONS OF THE PROGRAM

WAWTTAR is not a dynamic program and does not directly analyze the response of a given system to variable influent conditions. WAWTTAR does not build the treatment trains to be evaluated. The building of treatment trains must be done by a user familiar with these processes and their general capabilities. Sensitivity to varying influent values must be explored by multiple trials of treatment systems with different influent quality.

WAWTTAR is primarily intended for use on real world water and wastewater treatment and reuse problems, although it can be used for theoretical or academic problems as well. While efforts have been made to provide accurate cost and performance data, the user should validate the reasonableness of all construction cost, operational cost, and performance data for all processes relative to the problem setting. The user is encouraged to add new processes to the database and exchange this new data with other users and the WAWTTAR developers.

3.0 GETTING STARTED

3.1 OPEN THE PROGRAM

If WAWTTAR is properly installed, a new Start Menu group titled WAWTTAR will appear. To launch the program, simply select the WAWTTAR program from the WAWTTAR group in the Start Menu. The program opens with two graphics, the title screen, and the screen illustrated in Figure 2.1. After viewing each of these screens, you can move to the next screen by clicking the mouse anywhere on the image. After the two graphics images have been displayed, the program displays the main menu, a window entitled WAWTTAR with several pull-down menus (Figure 3.2). WAWTTAR operates exclusively through these pull-down menus and their associated windows and dialog boxes. The graphic interface makes using WAWTTAR straightforward and intuitive.

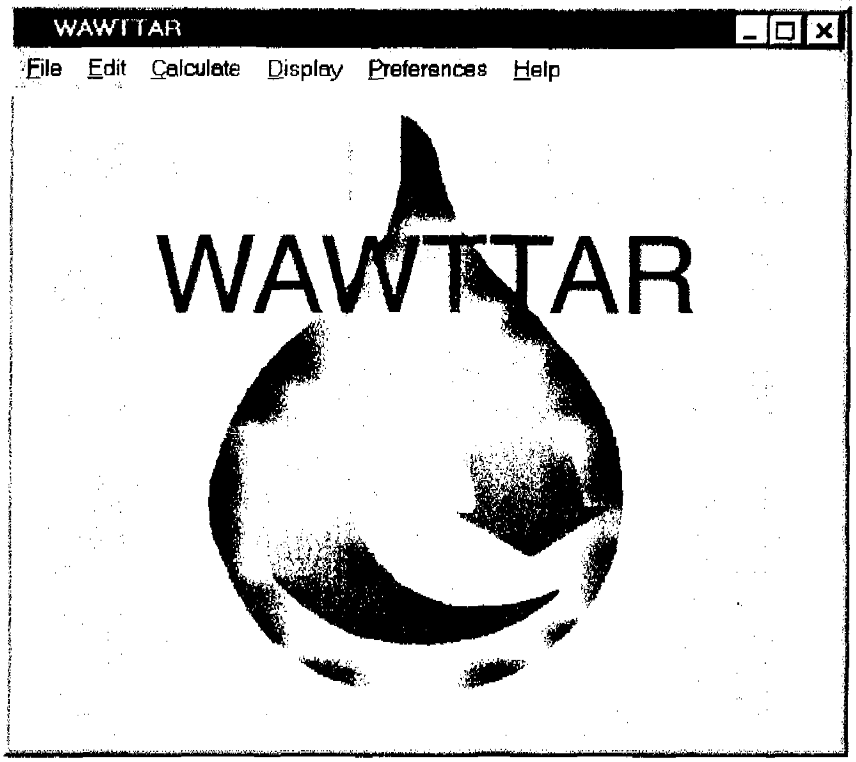
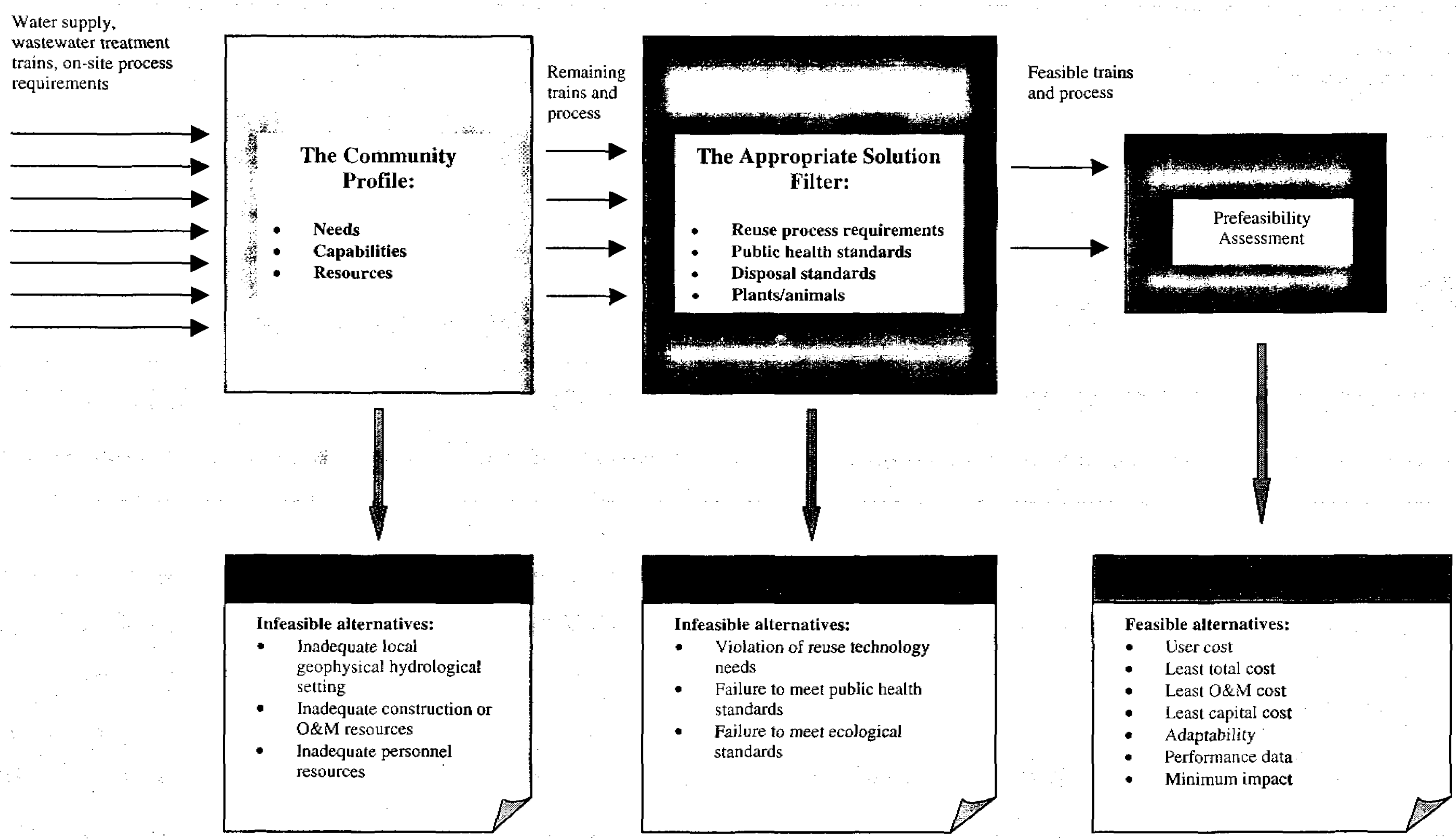


FIGURE 3.1 OPENING WINDOW WITH PULLDOWN MENU

3.2 EDIT FILES

When beginning work on a new problem, the Edit menu is the one to begin with. It leads to all of the editable data tables that are used to describe the problem under consideration and the criteria for the solution. Upon selecting Edit, you will be given a choice between five different data tables: **Collection System Data, Community Data**, **Process Data**, **Standards**, and **Train Descriptions**.

FIGURE 3.2 GRAPHIC OVERVIEW OF PROGRAM CALCULATIONS



Selecting any of these five data tables presents a dialog box with the same set of possible actions accessed via buttons. The first button is entitled **Edit**. The **Edit** button opens the indicated table, allowing the user to review the database for each of the categories and/or to add new data if the data record is not locked. If a new record is to be created and is named, new information can be placed in the data file. All existing processes in the Process, Collection System, and Standards data tables are locked (read only) preventing the data from being changed. New data, updated, or corrected data can easily be added by copying the record (process, collection system, or standard), giving the copied item a new name, and then changing the data associated with the copied data.

The second button to the right side of the selection window is entitled **New**. This allows one to create a new record as mentioned above (be sure to give the file a unique name). The third button is the **Copy** button and allows the user to quickly add or change data to an existing record with a new name. The fourth button is the **Delete** button that allows the user to delete a record. A warning window comes up to verify the delete action. The fifth button is a **Print** button which allows the user to print the information associated with the selected item (the print mode is strictly informational, not presentation quality).

After the database has been accessed, the **Done** button is selected which automatically saves any changes made. Select **Cancel** to move back to the previous window master menu without saving the last set of changes to the database.

3.3 COMMUNITY DATA

3.3.1 Introduction

The community profile questions are listed in Section 3.3.2 through 3.3.7. A short explanation, description, data source, etc. is found after each question. Each section of questions is organized under the various tabs found on the Community Data Window (see Figure 3-3). This data should be gathered in collaborative manner with local planners and engineers. There will always be concerns about the information requirements found in this profile. It is important to understand how and when the data in the community profile is used in the decision support program. Some of the data needs to be as exact as possible, while in other cases, rough data estimates are sufficient.

The questions fall roughly into several categories: General (location), Demographic, Resources, HydroMet (hydro-meteorological), Financial, and On-Site. The importance of the questions concerning population, water demand or wastewater production, planning horizon, influent characteristics, effluent standards and geological and hydrological conditions, should be known to anyone with a background in water and wastewater treatment. Their discussion is beyond the scope of this manual. Any standard text on water and wastewater treatment will have detailed information for those who need or desire further elaboration on the importance of this information.

Other categories are just as important, but frequently overlooked. The **location and responsible institutions**, for instance, have a major impact on what technology is feasible to use. A complex and highly technological treatment system may be a good option in terms of strict influent physical characteristics and treatment requirements, but will likely fail in remote areas or where there is little in the way of government support or training opportunities.

The **availability and cost of resources** can dramatically affect the feasibility of treatment and reuse options in every project stage from construction to everyday operations and maintenance. Resources in this case include the type and reliability of power supply, manpower from simple unskilled labor to technical and professional personnel, treatment chemical availability, and any other type of human or physical capital that might be necessary.

Finally, **cultural factors** of the community in question are of high importance but are infrequently recognized. Cultural attitudes and norms regarding defecation, waste handling, gender relations, preferred dwellings and family structure can affect everything from raw waste quality to what kinds of technology are permissible. Failure to adequately characterize and account for these factors in planning and design can result in the selection of inappropriate technology, and ultimately in the failure of any treatment system, no matter how well designed from a physical and technological standpoint.

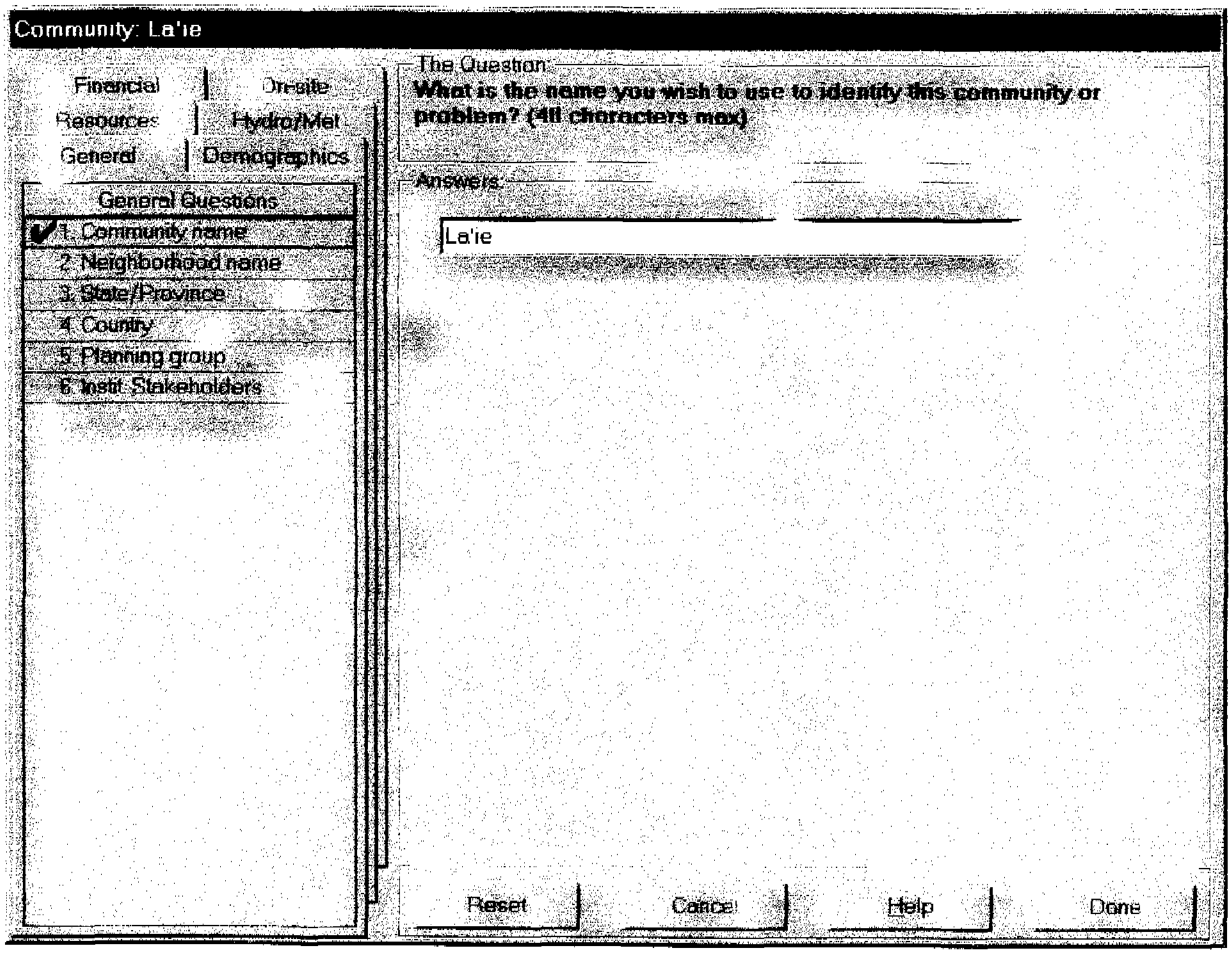


FIGURE 3.3 COMMUNITY DATA OPENING WINDOW

Once a new community is named or an existing community file is selected, the **Edit Community** button is selected (Figure 3.3). This button opens a window which has six tabs arranged in the upper left-hand corner. The six tabs have a total of 53 questions in the following categories 1) **General**, 2) **Demographics**, 3) **Resources**, 4) **Hydro/Met**, 5) **Finances**, and 6) **On-site**.

When the window opens, the **General** tab questions 1 through 7 are displayed. When selecting the first question for example, Community name, a 40 character input slot opens in the answer section of the window on the right side. All of the questions in the "General" category require typing in input data. Some questions in the other categories require checking a box and or typing in numbers. Once a question has been answered with new data, a green checkmark will appear on the left side of the question. The green checkmark serves as an indication that this question has been answered.

After responding to all of the questions in the "General" category, select the **Demographics** tab. This group of nine questions (question 8 through 16) requires a good understanding of the community, and how it works. Each community demographics question requires typing in a response. After answering the "Demographics" questions, select the **Resources** tab. There are 10 "Resource" questions, numbered 17 through 26.

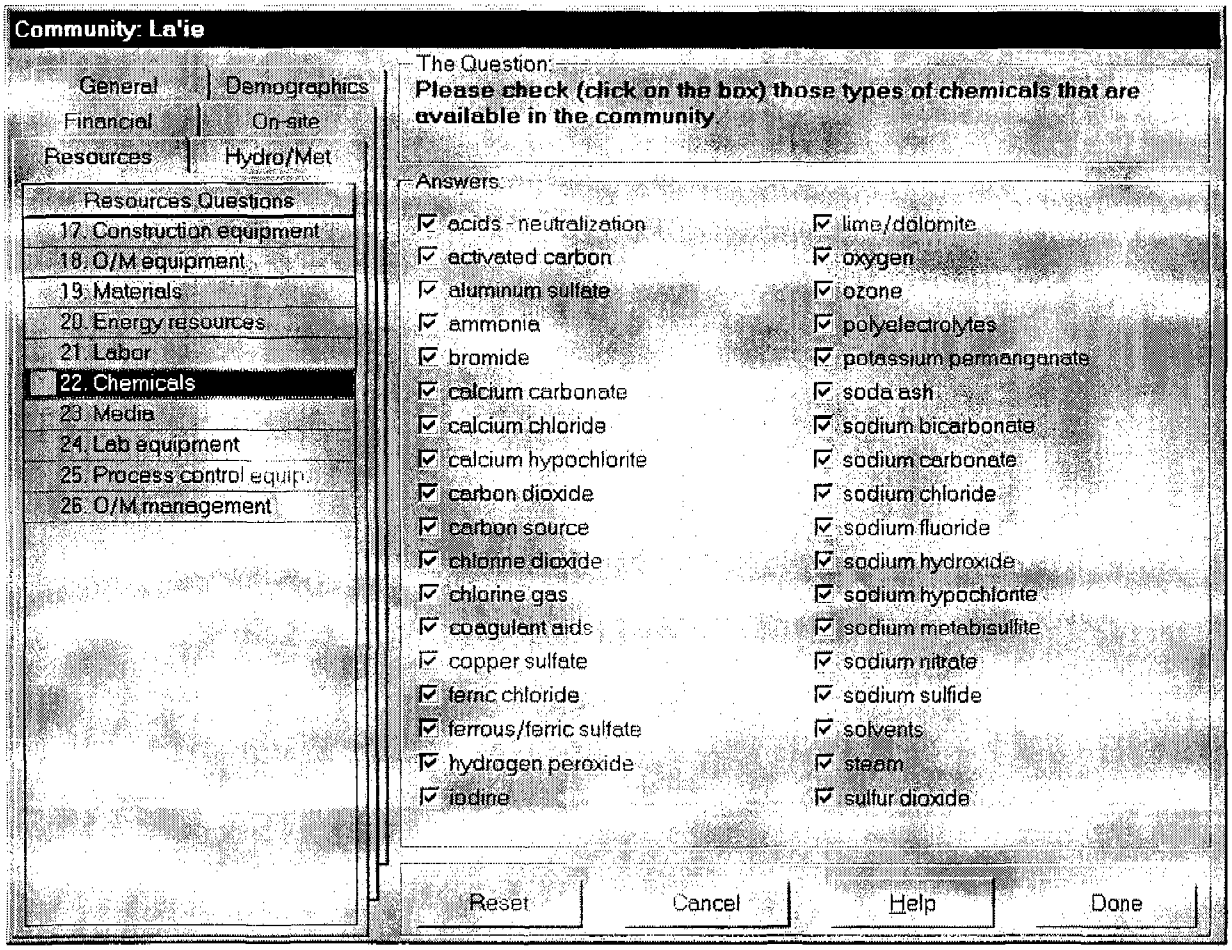


FIGURE 3.4 TYPICAL COMMUNITY TAB WINDOW - COMMUNITY RESOURCES

The questions in the "Resources" Section of the community data attempt to characterize the support the community can supply to the development and the maintenance of the treatment technologies being considered (Figure 3.4). These questions require the user to indicate the availability of that particular resource in the community. The default condition for these questions assumes that all of the resources are available. To indicate that a resource is not available, the user clicks on the box, which removes the checkmark. In case of doubt, it is recommended that the user start by assuming a resource is NOT available. If this causes a particular treatment train to be deemed unfeasible by the program, this will be detailed in the Infeasible Solutions File (Section 5.1), and the user can decide whether making the resource available is justified.

After answering all of the "Resource" questions, the user should click on the **Hydro/Met** tab that contains seven questions numbered 27 through 33. These questions pertain to the hydrological and meteorological conditions of the proposed treatment site.

There are nine questions numbered 34 through 42 in the **Financial** tab category. The "Financial" questions relate to applicable currency, cost indices, and inflation rate.

The last tab is the **On-site** tab, which contains eleven questions numbered 43 through 53. The "On-site" condition specifications are factors in evaluating on-site treatment, as opposed to centralized treatment.

After answering all applicable questions, save the input data and return to the "Choose a Community" dialog by pressing the **Done** button. To return to the "Choose a Community" dialog without saving the input data, press the **Cancel** button. From the "Choose a Community" dialog, data can be entered for another community, or the user can return to the main menu by pressing the **Exit** button.

3.3.2 General Tab Questions (1-7)

1. *What is the name you wish to use to identify this community or problem?* __________________
   (40 char., max.)____________________
   The name given the community should be specific enough to be able to both locate the site on local maps and to communicate to the users the approach being taken in the process. In some cases, this might be a village, a town, a city, or an informal peri-urban area.

2. *What is the name of the neighborhood?* ____________________
   (20 char., max.)____________________
   The name of the neighborhood should be specific enough to be able to relate to the community user group. If several neighborhoods are involved, they should also be listed. If the problem involves a large city that would include a large list of neighborhoods then this section need not be filled in. For some on-site treatment cases, if the community has distinctly differing conditions and cultural values, the problem must be divided into these sub-components. The program does not allow wide variations in geophysical and/or cultural differences to be placed into a single community profile (a limitation.)

3. *In what state or province is the community located?* ______________________
(20 char., max.)______________________
This information should be specific enough to identify the formal macro governmental unit responsible for water and wastewater to the local community and to the national government.

4. *In what country is the community located?* ______________________
(20 char., max.)______________________
Country or autonomous political area.

5. *What is the planning group or department?* ______________________
(20 char., max.)______________________
The local planning group should be the closest governmental unit to the community that is involved in the planning, the financing, and the designing of water and sanitation services.

6. *What is the name of the responsible Agency, Ministry, or institutional stakeholders?* ____________
(60 char., max.)______________________
This refers to the highest governmental unit(s) within the country that plans, approves, finances, and/or designs water and sanitation services (including water reuse).

7. *Specify the base year for the demographic data, land value, and water use data?* ____________
The population should represent the best estimate for the community. The year entered here represents the year in which demographic and water use data are available. These data will be brought up to date using growth rate data supplied below.

3.3.3 Demographic Tab Questions (8-16)

8. *What is the population of the community (in 1,000s of people) in the base year?* ____________
The population of the community represents one of the three important factors in determining the design flow. The other two factors are the indoor water use and the rate of growth of the population for a specific design period. The population given should be the base year target population for the project. Sometimes the target population is less than the population in the demographic unit. For example, a project might be proposed to supply sanitation coverage for a fraction of the population in demographic unit.

9. *What is the annual population growth rate (in percent) for the community?* ____________
The population growth rate should be conservative at best and could include potential immigration factors associated with the delivery of water and sanitation services. If governmental policies are such that the magnet effect should not be considered, then use of the model at two different growth rates to predict unserviced population for the project period. A population growth rate of 1% per year results in about a 22% increase in population in 20 years, while a 3% growth rate results in an 80% increase in population in 20 years.

10. *What is the base year gross population density of the community (in persons per square km)?* ________
The habitation density is used to estimate the construction costs for wastewater sewerage systems and to select appropriate on-site treatment processes. This unit cost for collective systems is based upon the density and the total number of people. In cases where the communities served have distinctly different densities, the problem must be separated into those different communities and the results combined on a spreadsheet. Certain on-site alternatives are not feasible, for example, under conditions of high density.

Typical Population Densities

Landuse	Persons/km^2
Residential single family dwelling, large lots (0.5-1.0 ha)	1270-3700
Single family dwelling small lots	3700-8700
Multiple family dwelling, small lots	8700-25000
Multiple story multiple families	25000-250000
Commercial	3700-7500
Industrial	1250-3700

11. *What is the average number of persons living in a single dwelling in the community?* ______
    The number of persons living in a single dwelling is used to: 1) normalize cost data to service units (dwellings), and 2) size decentralized on-site treatment system units.

12. *What is the estimated annual growth rate (in percent) in community land area?* ______
    The estimated annual growth rate in community land area is used to calculate the collection cost for a given project period. In many cases, the land area growth is zero. This becomes an important issue in sprawl-type development where sanitation services are being considered.

13. *What is the base year per capita water use rate per day (liter/day/person)?* ______
    The per capita water use should be based upon current indoor and outdoor water uses at the home. The assumption is that both of these needs will be met with a distributed water supply service. If excessive irrigation and animal watering exists in the community and the present (existing) source can continue to meet this need, then only indoor water use value should be used. The WHO minimal water need is 80 liters/capita/day. Collected wastewater systems add significantly to this basic need quantity. Water use can vary from 250 to 600 l/c/day in developed countries.

14. *What is the estimated expected annual rate of change per capita water use (percent per year)?* ______
    The change in water use should reflect the change in socio-economic conditions causing water use to change due to the supply-demand for water. In the case of water conservation, the water use can go down to some minimal rate, and in the case of a new system in a water-starved community, the water use can go up to some maximum value. In many cases, in more developed countries, the water usage is decreasing due to water conservation requirements. A good target for a water-conserved system is 185 to 200 l/c/day.

15. *What is the base year per capita wastewater production (liters/day/person)?* ______
    The estimated per capita wastewater flow rate should be based upon the water use rate. In developed countries, the indoor water use is usually 70-80% of the total water use. This number can be considerably different if excessive horticultural and home agricultural irrigation is done, if it is used in air-conditioning, and if swimming pools exist in a large portion of the population. It is best to build a simple indoor water use model to estimate this number using local plumbing guidelines, cultural factors (bathing and praying), technology limitations, etc.

16. *What is the estimated expected annual rate of change in per capita wastewater production (percent/year)?*
    The estimated annual change in wastewater flow rate is a function of the socio-economic changes (increasing rate) and/or water conservation policies. In some cases, both of these factors exist. This represents a net change in indoor water use. See question 15.

3.3.4 Resource Tab Questions (17-26)

17. *Please check (click on the box) those construction equipment types that are available in the community:*
    ___ *heavy equipment*
    ___ *light equipment*
    ___ *manual equipment*

This question assists the planner, especially working in remote, inaccessible, and/or politically detached sites to determine the basic (minimum) level of construction equipment available. In the vast majority of projects, all of these types of equipment are available. Heavy equipment is differentiated from light equipment in that heavy equipment would require a skilled operator and would normally be brought into small communities for a specific task in the construction process. In some cases, community participation can significantly reduce the cost of the project by minimizing the need for expensive and technologically complex construction equipment. This is especially true with on-site treatment systems and alternative wastewater collection systems.

18. *Please check (click on the box) those O&M equipment types that are available in the community:*

____ *Electric motors*	____ *Portable generators*
____ *Electronic test equipment*	____ *Portable water pumps*
____ *Hand tools*	____ *Water sampler*
____ *Hoist*	____ *Welding equipment*
____ *Laboratory instruments*	

The list of O&M equipment types is designed to represent the "general types" of equipment necessary to operate and maintain various "technical classifications" of water and wastewater treatment systems. The list was not meant to be inclusive of all equipment requirements. Studies performed in the mid-1970's indicated that this equipment list comprised the principal components related to the supportable water and wastewater treatment technologies. Many examples exist where items on this list can be replaced with other items in a community or are not necessarily needed. Not available has many meanings in this regard. It might be available but no one locally knows show or wants to use it. It might mean it is locally available by importing via complicated shipping and customs processes.

"Available" can be interpreted several ways by the user. The strictest interpretation is that the equipment is on-site and spare parts and tools are also on-site. Another interpretation might be that the equipment is locally available, either by sharing with organizations and/or by hiring local contractors. Another interpretation of available might be that there is a regional/country level stock supply of equipment. It is important to keep this interpretation in mind in the planning process.

19. *Please check (click on the box) those construction and O&M materials that are available in the community:*

____ *Building Blocks*	____ *Mixers*
____ *Cement*	____ *Motorized Pumps*
____ *Clay*	____ *Motors*
____ *Clay liner*	____ *Plastic Pipe & Fittings*
____ *Cobble Stone*	____ *Programmed Logic Controllers*
____ *Corrugated Aluminum or Tin*	____ *Rebar/Reinforcing Steel*
____ *Fiber Reinforced Plastic*	____ *Sand/Gravel for Concrete*
____ *Fiberglass*	____ *Small Barrels*
____ *Geotextile Liner*	____ *Steel/Fabricated Tanks*
____ *Hand Pumps*	____ *Steel Pipes & Fittings*
____ *Hand Tools*	____ *Wire/Electrical Supplies*
____ *Imported Processes*	____ *Wood/Lumber*

The list of construction and O&M materials represents the types of material commonly required for various technologies. Again, this is not an inclusive list of all the material necessary to operate and maintain systems, only a principal component list of those found in a wide range of technology types. The most critical items found on this list are those associated with higher technology types. Simpler technologies generally require simpler materials to construct, operate and maintain. Again, "available" can be interpreted many ways (see question 18).

20. *Please check (click on the box) those energy resources that are available in the community:*

____ *electricity - intermittent*	____ *electricity - reliable*
____ *gasoline/diesel - intermittent*	____ *gasoline/diesel - reliable*
____ *natural gas - intermittent*	____ *natural gas - reliable*

The energy resources available to operate the water and/or wastewater treatment system refer to the primary source of energy. This question relates to both the dependability and availability of the energy source. This assumes that gasoline and diesel generators for example also require fuel supply, fuel transport, and local fuel storage, which is more dependable than an electric grid.

Quite often electrical energy is available but is only available at certain times. This question needs to be answered in the most pessimistic climate the planner can imagine since power failure is a critical factor in the failure of many water and wastewater systems. A process called backup power is available when building treatment trains to minimize system failure due to power outages.

21. *Please check (click on the box) those types of labor that are available in the community:*

____ *Contractor*	____ *Skilled Construction*
____ *Driver*	____ *Skilled Maintenance*
____ *Laboratory*	____ *Skilled Operational*
____ *Management*	____ *Technician*
____ *Professional*	____ *Unskilled*

Labor types to support the operation and maintenance of the system is another critical constraint on the type of water and wastewater technology. This factor combined with availability of O&M equipment and material has accounted for the greatest proportion of failed and/or poorly functioning water and wastewater systems. Each of the labor types might have a unique cultural definition.

- Contractor refers to available private sector businesses who can construct to specification unit process requiring; 1) concrete forming, 2) pipe fitting and laying, 3) electrical, and 4) excavation/terraforming. In addition, a contractor must have the skills to estimate job costs, organize subcontractors, follow plans and specifications, prepare invoices, etc.

- Laboratory refers to personnel who have been trained to perform routine performance and monitoring analytical tests and to fill out necessary monitoring reports.

- Management refers to personnel necessary for both a level of technology and size of system. Management positions are usually found in systems with five or more operation and maintenance personnel with more complex tasks and experience required with large systems, and it could be an engineering position.

- Skilled construction usually refers to personnel who can operate simple equipment, perform limited operational tasks, and have construction level skills (carpentry, plumbing, electrical, etc.)

- Skilled maintenance refers to personnel who have been trained and also have experience in; 1) pipe fitting and mechanical processes, 2) electric motor and controls, 3) welding, 4) concrete forming and placement, 5) electronic instrumentation, etc.

- Skilled operator refers to a trained and experienced operator for medium to high technology treatment systems. The skilled operator can be a transitional personnel familiar with industrial processes such as refineries, food processing, irrigation pumping/distribution systems, etc. or have similar skills.

- Technician usually refers to a person with specialized training to operate/maintain technical processes or support equipment (e.g. computer systems, process control, etc).

- Unskilled labor usually refers to personnel who can perform repetitive tasks requiring hand tools with little to no training and a maximum of supervision.

22. *Please check (click on the box) those types of chemicals that are available in the community:*

____ *Acids - neutralization*	____ *Coagulant aids*	____ *Sodium bicarbonate*
____ *Activated carbon*	____ *Copper sulfate*	____ *Sodium carbonate*
____ *Aluminum sulfate*	____ *Ferric chloride*	____ *Sodium chloride*
____ *Ammonia*	____ *Ferrous/ferric sulfate*	____ *Sodium fluoride*
____ *Bromide*	____ *Hydrogen peroxide*	____ *Sodium hydroxide*
____ *Calcium carbonate*	____ *Iodine*	____ *Sodium hypochlorite*
____ *Calcium chloride*	____ *Lime/dolomite*	____ *Sodium metabisulfate*
____ *Calcium hypochlorite*	____ *Oxygen*	____ *Sodium nitrate*
____ *Carbon dioxide*	____ *Ozone*	____ *Sodium nitrite*
____ *Carbon source*	____ *Polyelectrolytes*	____ *Solvents*
____ *Chlorine dioxide*	____ *Potassium permanganate*	____ *Steam*
____ *Chlorine gas*	____ *Soda ash*	____ *Sulfur dioxide*

These chemicals represent the cumulative list of chemicals that are required in the water and wastewater treatment processes included in this program. None of the processes requires all of the chemicals, and many processes do not require any chemicals. Availability of chemical supplies can be interpreted several ways. The most restrictive definition would be to indicate only those chemicals that are immediately available at the local or regional level. This means a local supplier has the chemicals in their inventory at all times. For example, liquid bleach might always be available, commercially white gaseous chlorine might not always be available. If the chemical needs to be imported only for this use, then it should not be listed as available. There are many examples in a variety of socio-economic cultural settings where systems have failed due to unavailability of a critical chemical. A good example would be lack of gaseous chlorine for a community water supply system.

23. *Please check (click on the box) those types of media supplies that are available in the community:*

____ *Activated Carbon*	____ *Gravel*	____ *Resins*
____ *Anthracite*	____ *Membranes*	____ *Rock*
____ *Aquatic macrophytes*	____ *Plastic*	____ *Sand*
____ *Diatomeceous Earth*	____ *Porous aeration material*	____ *Wood*
____ *Garnet*		

Media supplies refer to process support media that is lost, saturated, consumed, eroded, and or corroded in use. Often only sufficient media supplies are available at the time of after many years of use. Substitution of media is most often the solution to this problem. In some cases this is an appropriate solution in other cases it is not appropriate.

24. *Please check (click on the box) those types of laboratory equipment that are available in the community:*

____ *Non-Electrical Lab Equipment*	____ *Simple Electrical Lab Equipment*
____ *Process Control Testing*	____ *Sophisticated Lab Equipment*

Laboratory equipment refers to the availability of the equipment, spare parts, and technical manuals for O&M.

- Non-electrical equipment refers to color comparators, refractometers, thermometers Imhoff Cones, methylene blue DO testing, etc.

- Process control equipment refers to digital or analog sensors integrated into control system to allow for remote operations based upon process condition. This would include pH system, DO system, chlorine/dechlorination systems, remote equipment operators, etc.

- Simple electronic laboratory equipment refers to incubators, vacuum pumps, drying ovens, probe/meter instruments, simple spectrophotometers, and volumetric testing equipment.

- Sophisticated laboratory equipment refers to GC, AA, fluometers, mercury analyzer, complex dual beam spectrophotometers, computers coupled with analytical equipment output, incubators, etc.

25. *Please check (click on the box) those types of process control equipment that are available in the community:*

____ *Analog/meter controls*	____ *PLC process controllers*
____ *Mechanical controls*	____ *Pneumatic controls*
____ *PLC status indicators*	

This list refers to the type of control system in the treatment system. It is assumed that many plants will have all of these types of control equipment. The answer should be directed at the communities capability to support these types of systems by direct hire of technicians, contractor, direct technical assistance, parts and repair tools rather than available for purchase at the time of construction.

26. *Is there a state/central government agency or institution that would provide institutional supervision for operation and maintenance of distribution/collection and treatment facilities?*____________

This question deals with the existing or potential long-term sustainability of a project as it relates to management and technical support for operation and maintenance of a system. This is a specific type of organization that supports water and wastewater treatment systems by: 1) standardization of equipment and parts, 2) operator training, 3) technical assistance for operation and maintenance, 4) laboratory assistance and training, etc. A "yes" answer to this question indicates strong institutional support for the system. If an institution exists but is not effective, then the answer should be "no", or an assessment should be made to determine the level of support to insure effectiveness.

3.3.5 Hydro/Met Tab Questions (27-33)

27. *Please provide the average monthly precipitation and evaporation rates (in mm/month) in the community.*

The monthly hydrological data for the site is critical for the calculation of reuse rates of the programs. If no irrigation reuse is being proposed, this information is not necessary. If irrigation is being proposed, this information is used to determine the area required to dispose of the wastewater and to determine the size of the storage volume necessary to store wastewater during those months irrigation is not possible.

If local precipitation and evapotranspiration data is not available, data from the closest similar climatological zone can be used. Quite often, knowing only the annual millimeters of the dominant wet and dry seasons is enough to be useful in this calculation. Simple approximations can be made by dividing the annual rainfall into seasons and by using local irrigation requirements for ET losses.

Month	Evaporation mm/month	Precipitation mm/month
January	____________	____________
February	____________	____________
March	____________	____________
April	____________	____________
May	____________	____________
June	____________	____________
July	____________	____________
August	____________	____________
September	____________	____________
October	____________	____________
November	____________	____________
December	____________	____________

28. *What is the average annual minimum ground surface temperature (in degrees C)?* ________________
This question relates to the potential for the use of composting systems.

29. *What is the average depth to the frost line (in meters)?* ________________
This question determines the applicability of some treatment processes in extremely cold climates.

30. *Provide information on results of tests on the quality of raw water intended for use as a potable water supply for the community:*
The information provided in this question is only used for problems related to water supply. The list includes both primary and secondary drinking water contaminants. In most cases, a community will not have a full description of all these constituents. In general, all of the non-critical constituents should be set to zero or left blank. The critical constituents for surface drinking water are shown in the list below. Within this group, only a few constituents are commonly used in standards and in reporting treatment efficiencies. It is important in certain situations to include constituents not found in the short list, especially when dealing with long-term chronic exposures to organics and metals. The **bold** items are the most common constituents listed in standard or goals. The full list is presented in Table 3.2.

Constituent	Units	Measurement
Solids, coarse	Kg/m^3	________
S.S.	mg/l	________
TDS	mg/l	________
Turbidity	**NTU**	________
Coliform, total	**#/100 ml**	________
Coliform, fecal	**#/100 ml**	________
Enteric viruses	PFU/L	________
Salmonella	#/100 ml	________
Shigella	#/100 ml	________
Cyst	#/100 ml	________
Helminths (ova)	#/100 ml	________
pH	**pH**	________
Color	**TCU**	________
THM	ug/l	________
THM precursors	ug/l	________
Alkalinity	mg./	________
Hardness, total	mg/l	________
Iron	**mg/l**	________
Manganese	mg/l	________
Taste & odor	**FTN/OTN**	________
Temperature	deg C	________
Fluoride	**mg/l**	________
Nitrate	**mg/l**	________

31. *Provide information on the quality of wastewater that is produced by the community:*
The principle constituent normally considered in domestic wastewater include:
1) CBOD
2) settleable solids
3) suspended solids
4) pH
5) oil and grease
6) fecal/total coliform

The other constituents are critical for advance secondary, tertiary, reuse and industrial treatment systems. Second tier constituents could be:

1) nitrogen forms
2) phosphorus forms
3) metals
4) oocysts
5) COD

Under many conditions of reuse, other constituents must be considered. The full list of constituents considered by WAWTTAR is presented in Table 3.2.

The list of wastewater constituents is designed to be inclusive of all types of biological material, inorganic constituents, and organic constituents found in domestic and industrial waste. Since industrial waste can be either a minor contribution or a sole contribution to a wastewater treatment system, this list must be inclusive of all possible constituents. The program was designed to perform pre-feasibility analysis for most of the major industrial waste types. Typical domestic effluent composition is found below. These values can vary by a factor of 2 to 3 on either side of the stated value. These values are based on 360 liter/c/d of indoor water use.

Composition of Domestic Sewage - Can be 50% to 150% of these values

Constituent	Average
Solids, total	500
Volatile	350
Fixed	150
Suspended, total	300
Volatile	250
Fixed	50
Dissolved, total	200
Volatile	100
Fixed	100
BOD (5-day, 20°C)	200
Oxygen consumed	75
Dissolved oxygen	0
Nitrogen, total	50
Organic	20
Free ammonia	30
Nitrites (NO_2)	0.05
Nitrates (NO_3)	0.20
Estimated wastewater production	320 liters/capita/day

The followings table can be used to estimate the mineral addition to indoor water use. This can be a critical factor in water reuse.

Range of Mineral Pickup in Domestic Sewage

Mineral constituent of property	Normal range, parts per million
Dissolved solids	100-300
Boron (B)	0.1-0.4
Percent Sodium	5-15*
Sodium (Na)	40-70
Potassium (K)	7-15
Magnesium ($CaCO_3$)	15-40
Calcium ($CaCO_3$)	15-40
Total Nitrogen (N)	20-40
Phosphate (PO_4)	20-40
Sulfate (SO_4)	15-30
Chloride (Cl)	20-50
Total Alkalinity ($CaCO_3$)	100-150

*In percent

32. *If the wastewater treatment system receives a point source input other than the collection system, please provide the name of the point-source loading file:* ______________________
*(30 characters, max.)*______________________
The point source loading file allows the user to co-mingle wastewater (treated or untreated) with the new problem's wastewater flow. For example if an industrial facility's effluent was to be added to the problem's wastewater flow, then the new combined flows and mass loading would be calculated. If the problem's wastewater flow is coming from a newly constructed collection system and is co-mingled with an existing collected system, then the flows and mass loadings are combined. The file whose name is specified here would normally be generated as the "Optimal Conc." File (specified on the Go dialog) by WAWTTAR itself from a previous run of the program. The file must reside in the directory named "results" under the WAWTTAR home directory.

33. *Is a central wastewater collection system in existence for the community? (Yes/No)* ______________
This refers to the condition where an existing collection system exists and the problem is to select a wastewater treatment system only.

3.3.6 Financial Tab Questions (34-42)

34. *What year is the project scheduled to begin (first year in the planning horizon)?* ______________
The program calculates the cost of the project for a given project period including updating costs to reflect inflation from the base year at which process costs were computed (1992) and starting year of the project.

35. *How many years are to be included in the planning horizon (length of the proposed project)?* ________
This represents the end of the project economic calculation not the end of the utility of the project. In most cases, the economic life (period used to recoup capital investments) is less than the "useful life of the project". In most cases, this is a 20 or 30-year period but may be 10 to 15 years for on-site sanitation projects.

36. *What is the name (or abbreviation) for the local currency? (10 char., max.)* ______________
The name of the currency unit is placed here.

37. *What is the US dollar exchange rate for the local currency (i.e., U.S.$1.00 = how many units of local currency)?* ______

The exchange rate for the US dollar is important in converting the unit cost of processes (data was collected in US dollars) to local currency. The program accounts for inflation but does not account for currency de-evaluation policies.

38. *What is the annual interest rate or public works discount rate (percent per year) that should be used in evaluating costs of water and wastewater treatment facilities?* ______

The annual interest rate should be the value commonly used in funding public works projects by central banks and/or by bilateral and multilateral development organizations. In some cases, these are highly discounted rates.

39. *What is the anticipated annual rate of inflation (percent per year)?* ______

The most conservative answer to this question would be the predicted inflation rate based upon past data. In most cases, this is not a constant and its actual value is highly dependent on local and global economic conditions and national political and socio-economic conditions.

40. *Construction cost indices: Please give an estimate for the ratio of the following construction cost categories in the community to the cost in the U.S.:*

Item	*Ratio*
Concrete	____
Earthwork	____
Labor	____
Manufactured equipment	____
Pipes, valves, fittings	____
Steel	____
Structures	____

The construction cost indices are based upon work done in the United States showing the percentage of dollar effort attributed to the seven categories for various water and wastewater technologies. In the U.S. study, the total cost (engineering and construction) was distributed amongst the seven categories and normalized to represent 100 percent of the total cost. Each community problem must estimate the relative difference between the US cost and the local cost in whole number units. For example, if labor cost is 50% in the community of interest compared to the US, then 0.5 is placed next to labor. If chemical cost is 2.5 times more in the community of interest, then 2.5 is placed next to chemical in the item column.

Data for this information can be obtained from national statistical records, multilateral funding organizations, Engineering News Record (ENR) cost comparisons, etc. These indices can be adjusted to calibrate the economic component of the model. Since the output is used to compare alternatives - a good first guess still gives a good comparison among alternatives. If the user would like to converge on the estimated actual construction costs, then calibration is necessary by adjusting the indices (usually the estimated cost at this stage of planning is +50/-30 percent of as-built cost).

41. *O&M cost indices: Please give an estimate for the ratio in the community of the following O&M cost categories to the cost in the U.S.:*

Item	*Ratio*
Chemicals	____
Energy	____
Labor	____
Materials	____

The O&M cost indices are based upon work done in the United States showing the percentage of dollar effort attributed to the four categories for various water and wastewater technologies. In the U.S. study, the total cost (engineering and construction) was distributed amongst the four categories and normalized to represent 100 percent of the cost. Each community problem must estimate the relative difference between the US cost and the local cost in whole number units. For example if labor cost is

50% in the community of interest compared to the US labor cost, then 0.5 is placed next to labor in the item column. If the manufacturing equipment is 5 times more costly in the community of interest then 5 is placed next to manufacturing equipment in the item column.

Data for this question can be obtained from national statistical records, multilateral funding organizations, Engineering News Record cost comparisons, etc. These indices can be adjusted to calibrate the economic component of the model. Since the output is used to compare alternatives - a good first guess still gives a relatively good comparison. If the user would like to converge on the estimated actual costs then calibration is necessary by adjusting the indices to local cost by comparing WAWTTAR output with as build system cost in the community/country of interest.

42. *What is the base year value of land (in 1000 U.S. dollars per hectare) where treatment facilities would be built?* ______

Land value can be an important determinant in the cost and location of a wastewater treatment/reuse facility. This should only be used if in fact land will be purchased for the treatment plant. In most cases, the value of the land should reflect the fair market value of the land, not the speculative value of the land. If the land is being supplied by the government, then no cost should be attached to the land. If the land is in extremely short supply and other uses for the land are needed, then the opportunity cost of the land could be used.

3.3.7 On-Site Tab Questions (43-53)

43. *Which of the following is the predominant surface soil/ground type to a depth of 2 meters?*

_______ *gravel, coarse sand*
_______ *coarse to medium sand*
_______ *fine sand to loamy sand*
_______ *sandy loam, loan*
_______ *loam, porous silt loam*
_______ *silty clay loam, clay loam*
_______ *rocky*
_______ *boulder*
_______ *bedrock*

The predominant soil depth question addresses several criteria for selecting on-site treatment systems. Since the majority of on-site receptacles require excavation, the workability of soil to down to 1.5 meters is critical. Predominantly rocky soils are ideal for excavations. Predominantly sandy soils require special construction techniques to maintain sidewall structural integrity. Subsurface geological formations (1.5 to 3.0) are important in terms of the separation between wastewater infiltration trenches and groundwater levels. Certain soil types (clay loam) can provide excellent receptacle structures that are more or less water tight with a minimum of infiltration.

44. *What is the characteristic percolation rate for the area? (seconds /cm)* ______

While the percolation rate (rate at which clean water moves through (the soil) has limited value in establishing loading rates, it is commonly used to establish areal requirements to dispose of treated effluent. Most soils, including highly porous soils, will reach the same percolation resistance if loaded continuously with partially treated effluent. Intermittent loading with high quality effluent produces an effluent that performs closer to the infiltration rate of clean water.

Recommended Rates of Wastewater Application for Trench and Bed Bottom Areas

Soil Texture	Percolation Rate	
	min/in.	sec./cm
Gravel, coarse sand	<1	<25
Coarse to medium sand	1-5	25-120
Fine sand, loamy sand	6-15	121-360
Sandy loam, loam	16-30	361-720
Loam, porous silt loam	31-60	721-1440
Silty clay loam, clay loam	61-120	1441

45. *What is the minimum wet weather depth to the water table (meters)?* ______

    The minimum depth to the highest level of groundwater affords optimum protection of a groundwater resource utilized for drinking water.

46. *What is the minimum horizontal distance (in meters) between the boundaries of the proposed treatment and disposal sites and a potable water well?* ______

    The minimum distance between a sanitation device (receptacle/treatment disposal/reuse) and a natural potable water source minimizes the potential for water borne disease transfer to humans drinking, bathing, cooking, and/or collecting food supplies.

47. *What is the minimum horizontal distance (in meters) between the boundaries of the proposed treatment and disposal sites and a natural watercourse (e.g., stream, lake, estuary, etc.)?* ______

    The minimum distance between a sanitation device (receptacle/treatment disposal/reuse) and a natural watercourse minimizes the potential for water borne disease transfer to humans drinking, bathing, cooking, and/or collecting food supplies.

48. *Do the majority of community members live in multistory buildings?* ______

    This question relates to on-site technology options available for multi-story buildings. There are limited technologies available for sanitation for multi-story buildings.

49. *In the community, is squatting the most predominant position for defecating?* ______

    This question only pertains to on-site/decentralized treatment alternatives. The alternative treatment trains for on-site treatment systems require a different approach than treatment trains developed for centralized collection/treatment systems. An on-site treatment train begins with the initial point of deposition of human waste.

50. *In this community, are there cultural/religious factors that require males and females to use different structures for defecating?* ______

    In many cultures, sanitation facilities may be gender specific. Male and female community members may be prohibited from using the same sanitation facility. If the answer to this question is yes, two sanitation facilities are required for each dwelling.

51. *Please check (click on the box) those types of anal cleansing materials used in the community.*

    ____ *bulky, degradable* ____ *non-bulky, non-degradable*
    ____ *bulky, non-degradable* ____ *non-bulky, degradable*
    ____ *water*

    The type of cleaning materials relates to a series of constraints and sizing issues as the treatment trains are developed and sorted through the community profile. For example, water cleansing requires an aqueous receptacle, collection, and treatment component. Non-bulky/non degradable (rocks) cleansing material requires a complete different set of conditions for the feasible alternatives.

52. *Please check (click on the box) those types of waste handling categories for which cultural/religious barriers exist in the community:*

    ____ *urine* ____ *treated sludge*
    ____ *nightsoil* ____ *treated and composted sludge*

In many cultures, a community is dominated by negative values associated with the handling of various levels of treatment of human feces and/or urine. The levels run from composted waste, human urine, treated sludge, and raw human waste (night soil). The answer to these questions insures that a treatment train does not violate the community's predominant cultural beliefs.

53. *Which of the following street widths best describes the accessibility to 90% of the dwellings of the community?*

_____ *<0.8 m (foot paths)*
_____ *0.8 m - 2.75 m (carts)*
_____ *>2.75 m (automobiles)*

This ensures that any treatment train containing a vehicle transport system matches the conditions in the community.

3.4 TRAIN DESCRIPTIONS

3.4.1 Introduction

Developing a collection of processes to met a particular standard, guideline, and/or reuse goal is referred to as "building treatment trains". The developers of the WAWTTAR program assumed that the program users would have at the very least an acquaintance with water and wastewater treatment processes. At best, the user should be familiar with conventional and non-conventional treatment processes. This familiarity should include process performance ability, equipment description, operation and maintenance requirements, human resource requirements, effective combinations of processes, and area requirements. The program does not automatically build treatment trains. The user must select processes and arrange them in logical order in terms of the flow of the water, wastewater, and/or solids. There are no default treatment trains in the database. The program developers feel strongly that the user should develop the trains from a variety of information sources (i.e., textbooks, past experiences, technical journals, research activities, observation/discussions with operators). It is suggested that users not familiar with treatment process spend time with the resources listed above, familiarizing themselves with the processes and associated applications, constraints, and requirements.

The development of a wide range of alternative treatment trains is at the heart of the WAWTTAR program. There are large numbers of uniquely different treatment trains possible by combining the various unit processes found in the process database. The number and types of alternatives developed is a decision the user must make early in the facility planning process. The wider the variety and the greater the number of treatment train alternatives, the greater the probability that a sustainable solution will be found. This initial step in the facility planning process is referred to as the prefeasibility step. Allowing infrastructure planners to consider the community's capabilities along with wider range of technological processes maximizes the utility of the decision process in terms of the investment contributions by all concerned parties. The power of the WAWTTAR decision support system is the ability to compare the appropriateness of standard treatment trains to indigenous and innovative treatment trains. In most cases, the number of alternatives used in the facility planning process is too small, and not inclusive of potentially useful treatment trains. The diagnostic nature of the program (Infeasible Solutions file, see Section 5.1) allows the user to identify the specific resources or conditions which would not support a particular process within a treatment train. This aspect of program is as valuable as the program's ability to select those trains and processes that can be supported in a community.

3.4.2 Operation

Under the Main Menu Edit pulldown menu, the last item in the list is **Train Descriptions**. Selecting "Trains Descriptions" opens a window that can be used to build and edit treatment trains. Select **New Train** if a new train is to be developed. Enter a short descriptive name for the train in the text box that opens at the bottom of the dialog box. This name will appear in the scrolling window under select a train to edit. Once the name is placed in the text box, the **Edit Train** button activates. The next step is to select this Edit Train button. The **Build a Train** window opens (Figure 3.5). The first thing to enter is the **Train ID** code, name, or number in the upper right-hand corner. This should be a unique alphanumeric of 5 to 10 characters, which will label the alternative in the graphic output of the program if the alternative is feasible. The next thing to select is the **Train Type** (water supply, wastewater treatment, and wastewater on-site), immediately below the Train ID input slot. Clicking on the circle in front of the appropriate solution will select that type.

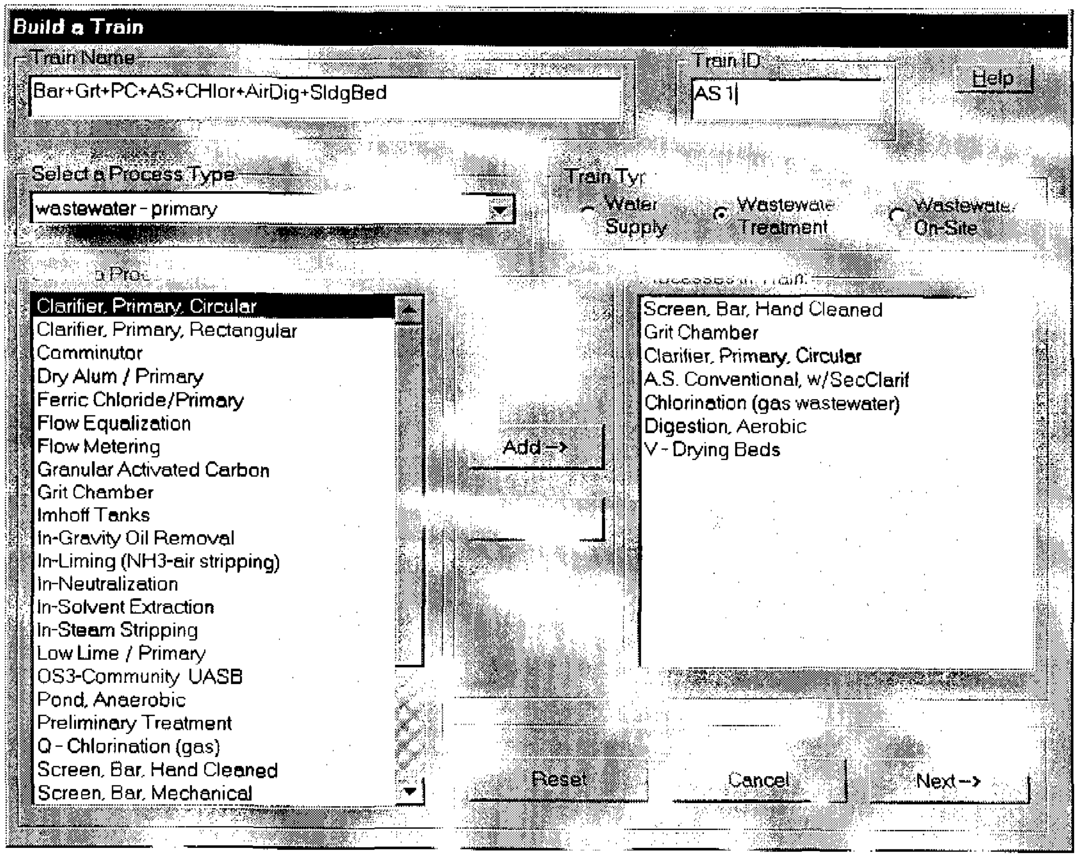


FIGURE 3.5 TRAIN DESCRIPTION INITIAL WINDOW

If wastewater is selected, for example, six categories of processes show up under **Select a Process Type**, to the left of the Train Type selection. This list is designed to assist the user in selecting process in the general order of occurrence in the treatment train. When "wastewater – primary" is selected, for example, a list of primary treatment processes appears in the left-hand part of the window. Some processes are found in more than one "Train Type". Listed below are the process categories found in each of the three train types.

To build a train, a process is selected by clicking on the desired process name under the Select a Process scrolling window and adding the process to the list of train processes by clicking on the **"Add →"** button. The process now appears on the right side under the **Processes in Train** window. If a process needs to be removed from train, the process name is selected under the "Processes in Train" column and the **"← Delete"** button is selected. Once the user becomes familiar with the procedure, processes can be found quickly by selecting the first letter of the process name. The scrolling window on the left will move to that particular area in the list. The full list can be viewed by either moving the down arrow on the list or by moving the scroll bar on the left side of the window.

After all the potential processes for a particular train have been selected and added to the "Processes in the Train" list by the **"Add"** button on the Build a Train window, the user moves the next window by clicking the mouse on the "**Next →**" button found at the bottom right of the screen. The next windows gives the user an opportunity to place the processes of interest for this particular train in their correct flow sequence, and to identify the solids receiving processes. This second "Build a train" window shows the processes selected on the left side of a two-column table (Figure 3.6). This window allows the user to place the processes in their train sequence (in the direction of liquid or solids movement).

To begin placing the processes in order, click the arrow on the top entry on the left side of the window entitled **"Process"**. Clicking on the arrow opens a dropdown list in which all of the processes selected in the previous window are available. At this point, the user should identify the first process in the new treatment train by clicking on the process name. Next, move to the second position in the list, click on the arrow again to bring the dropdown list, and select the second process. Continue until you have all of the processes you want in the correct order. Repeat for the processes receiving solids in the right-hand column. This is the train configuration stored under the ID you have given it. If you fail to do this step, you will not have processes under the indicated name.

You can repeat this procedure for as many treatment trains as you want to evaluate. Since the purpose of WAWTTAR is to act as a screening tool for options, the user is encouraged to generate as many different potential trains as possible in the early stages.

TABLE 3.1 PROCESS TYPES (WATER, WASTEWATER, AND ON-SITE)

Select a Process Type - Wastewater Treatment

Wastewater primary
Wastewater secondary
Wastewater tertiary
Wastewater disinfection
Wastewater disposal
Solids handling
Storage

Select a Process Type - Wastewater On-Site

On-site (dry)	-	receptacle
On-site (dry)	-	structure
On-site (dry)	-	temporary storage
On-site (dry)	-	collection
On-site (dry)	-	treatment
On-site (dry)	-	disposal
On-site (wet)	-	receptacle
On-site (wet)	-	structure
On-site (wet)	-	temporary storage
On-site (wet)	-	collection
On-site (wet)	-	treatment
On-site (wet)	-	disposal
Solids handling		
Storage		

Select a Process Type - Water Supply

Water supply	-	groundwater
Water supply	-	surface water
Water supply	-	surface and groundwater
Water supply	-	wastewater
Solids handling		
Storage		

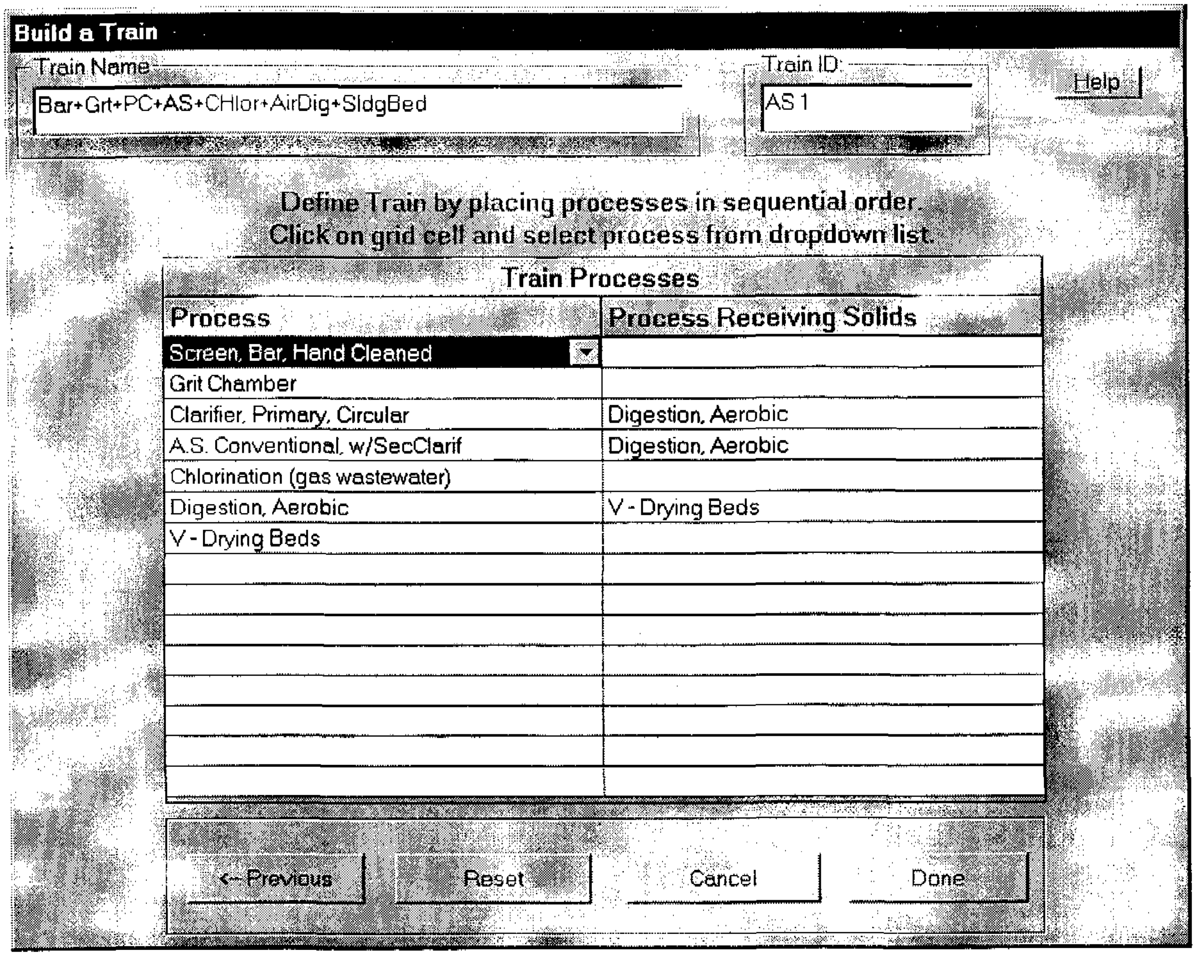


FIGURE 3.6 TRAIN DESCRIPTION SECOND WINDOW

3.5 STANDARDS

The user must choose a standard to be applied to the treatment train(s) selected ("no standard" is an available option). The Standards data table, found under the Edit pulldown menu as **Standards**, can be viewed and modified as necessary. WAWTTAR uses the standard you specify to evaluate the feasibility of each treatment train you constructed or chose. Treatment standards can be created and edited by clicking the Standards option, generating a screen much like the other ones described earlier (Figure 3.7).

Editing standards require four pieces of information: the name of the standard, description (application), the standard type (wastewater or water), and constituent limits (the same list found in the community file and the process file). The constituent list allows the entry of an upper limit (usual situation) and a lower limit (dissolved oxygen, for example).

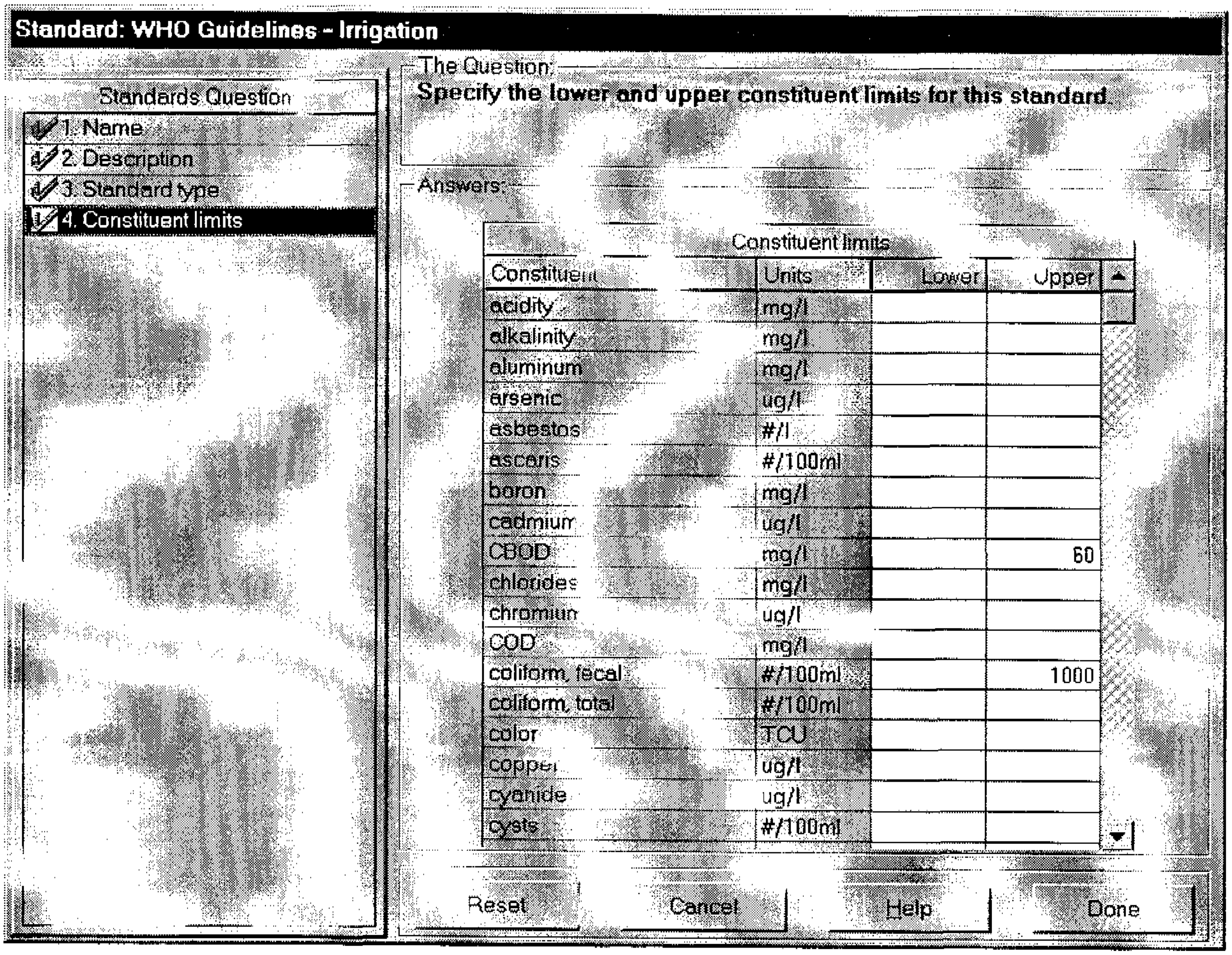


FIGURE 3.7 EDITING STANDARDS

Not all of the constituents need a value. Again, this list is all-inclusive and constituents that are not of interest can be left blank. In most cases, only limits for the most common constituents need to be defined. Remember that this program was designed to allow evaluation of industrial waste streams entering municipal wastewater systems. In those cases and in the case of industrial waste treatment, the non-traditional constituents are significant. The full list of constituents for which standards can be defined is listed in Table 3.2.

TABLE 3.2 WATER QUALITY PARAMETERS

Constituent	Units	Constituent	Units
Acidity	mg/L	Nickel	µg/L
Alkalinity	mg/L	Nitrate	mg/L
Aluminum	mg/L	Nitrite	mg/L
Arsenic	µg/L	Nitrogen, ammonia	mg/L
Asbestos	No./100 mL	Nitrogen, organic	µg/L
Boron	mg/L	Nitrogen, total	mg/L
Cadmium	µg/L	Oil & grease	mg/L
CBOD	mg/L	Pesticides	µg/L
Chlorides	mg/L	pH	pH
Chromium	µg/L	Phenols	µg/L
COD	mg/L	Phosphorus, total	mg/L
Coliform, fecal	No./100 mL	Protozoa	No./100 mL
Coliform, total	No./100 mL	Radium	pCi/L
Color	TCU	Salmonella	No./100 mL
Copper	µg/L	Selenium	µg/L
Cyanide	µg/L	Silver	µg/L
Cysts	No./100 mL	Solids, settleable	mL/L
Detergents	mg/L	Solids, suspended	mg/L
Enteric viruses	PFU/L	Solids, total dissolved	mg/L
Flow	m^3/day	Solids, total dry weight	kg/m^3
Fluoride	mg/L	Strontium	pCi/L
Grit	kg/m^3	Sulfate	mg/L
Hardness, total	mg/L	Sulfides	µg/L
Helminths (ova)	No./100 mL	Taste and odor	FTN/OTN
Hydrogen sulfide	µg/L	Temperature	°C
Iron	mg/L	THM	µg/L
Lead	µg/L	THM precursors	µg/L
Manganese	mg/L	TOC	mg/L
Mercury	µg/L	Turbidity	NTU
Molybdenum	µg/L	VOCs	µg/L
NBOD	mg/L	Zinc	µg/L

3.6 COLLECTION SYSTEM DATA

The Edit Collection System Data window is laid out like the previous windows. Select a collection system and the **Edit** button will bring up the "Collection Systems" data window (Figure 3.8). The questions are few and straightforward. The name, description, photo files, drawing files, text files, references and the construction cost curve (based on dollars versus population density) are asked for. A plot of the cost curve can be displayed and printed. When the collection system is described, return via the **Done** button (lower right-hand corner) to the WAWTTAR main menu.

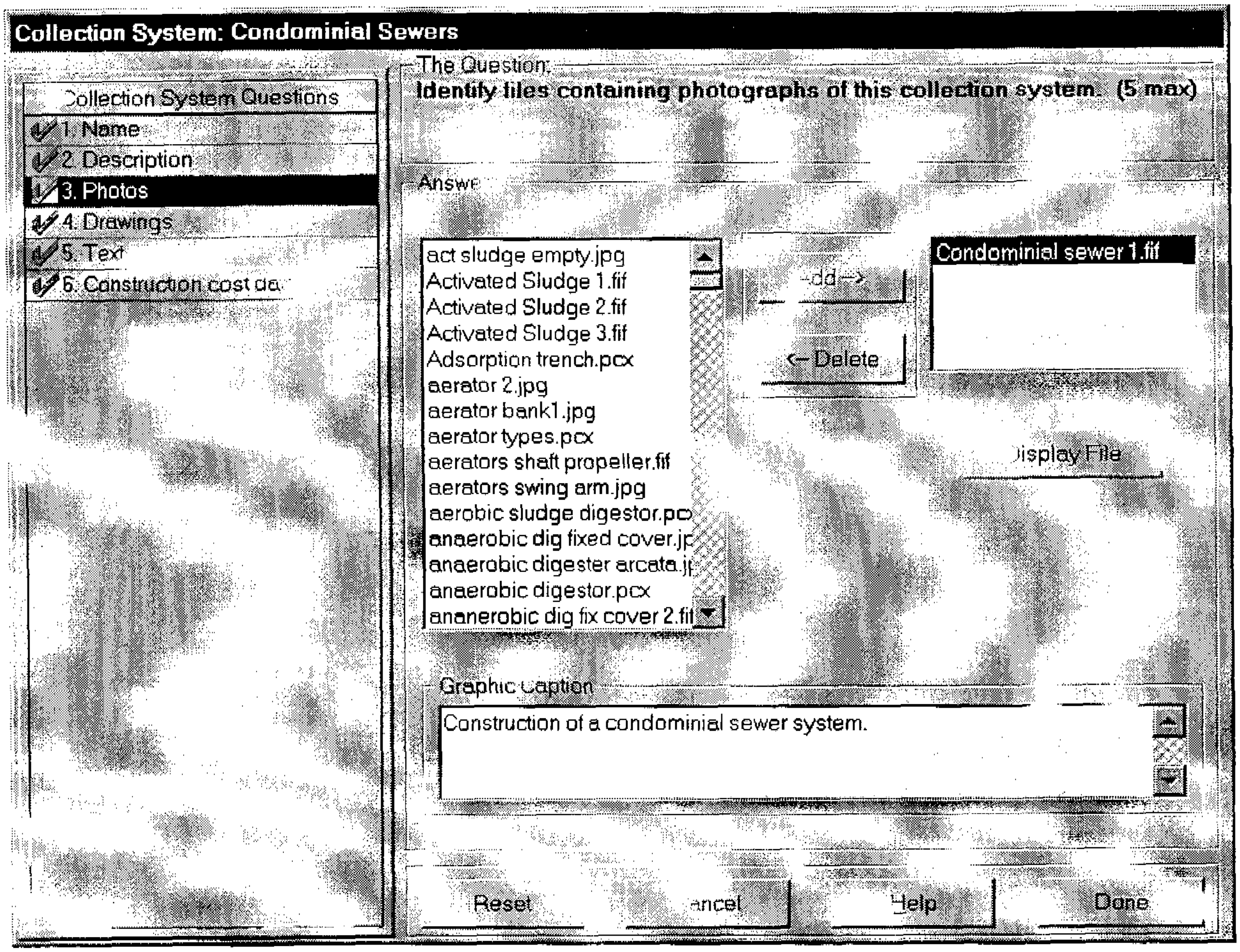


FIGURE 3.8 EDITING THE COLLECTION SYSTEM DATA

4.0 GETTING RESULTS

4.1 CALCULATIONS

Select the **Calculate** option of the main menu. There will be five choices: Include/Exclude Processes, Include Trains, Track Parameters, Go - Water Supply and Go - Wastewater Treatment. Select the "Track Parameters" option first.

4.2 "TRACK PARAMETERS" OPTION

WAWTTAR will display the discharge concentration of up to ten water quality parameters of your choice from a comprehensive list. The Select Water Quality Parameters to Display window is set up similar to previous windows, with the list of water quality parameters on the left, and the parameters of choice displayed on the right along with the "**Add →**", "**← Delete**", **Reset,** and **Done** buttons (Figure 4.1). These buttons will allow you to choose and alter the parameters you wish to have displayed. When this is complete, return to the WAWTTAR menu.

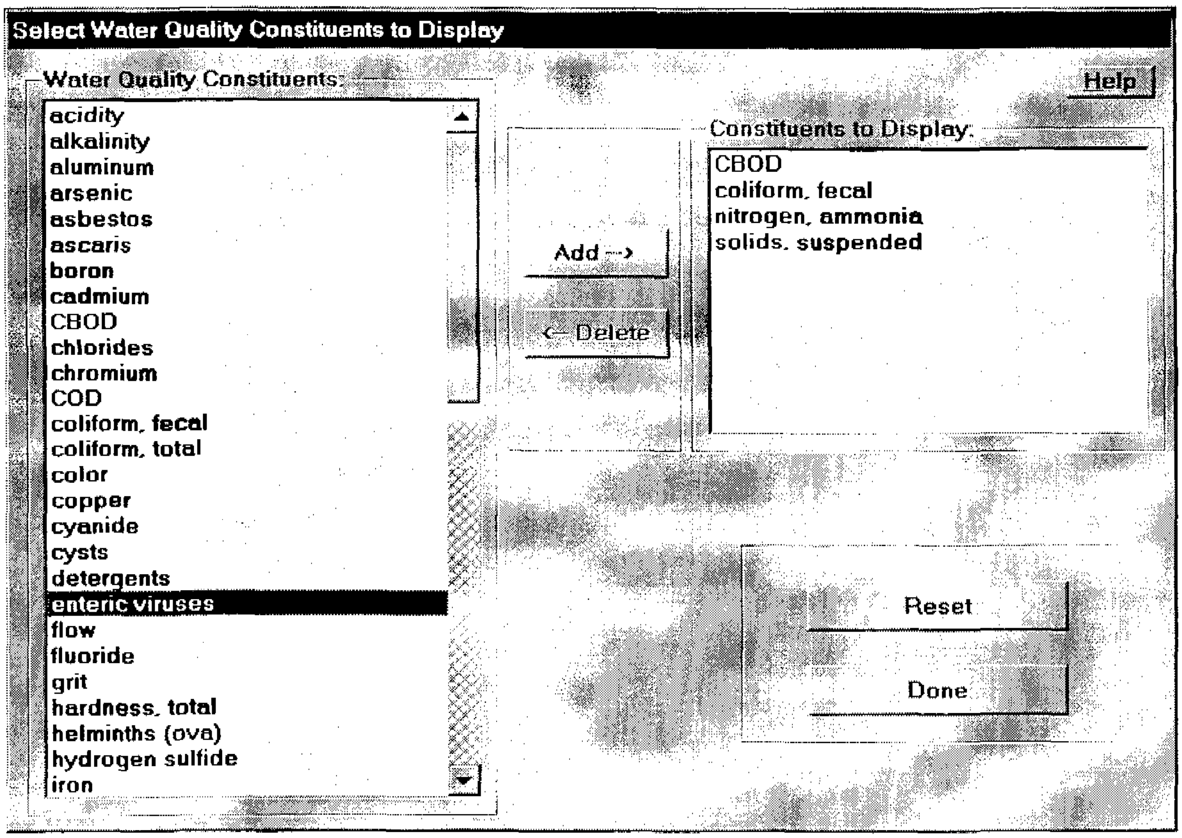


FIGURE 4.1 TRACK PARAMETERS WINDOW

4.3 "INCLUDE/EXCLUDE PROCESSES" OPTION

Selecting the **Include/Exclude Processes** option will bring up the "Specify Processes to Include or Exclude" window (Figure 4.2). The user can specify which processes in the database may be included in a feasible treatment train, must be included in a feasible train, and must not be included in a feasible train. The **May Include All Processes** button will allow every treatment process in the database to be included. Unless otherwise specified, all treatment processes can be included. This feature is used to compare only those trains sharing certain characteristics, for example using a specific primary process (wastewater treatment) but different secondary treatment processes. This is particularly useful when there are many trains to compare.

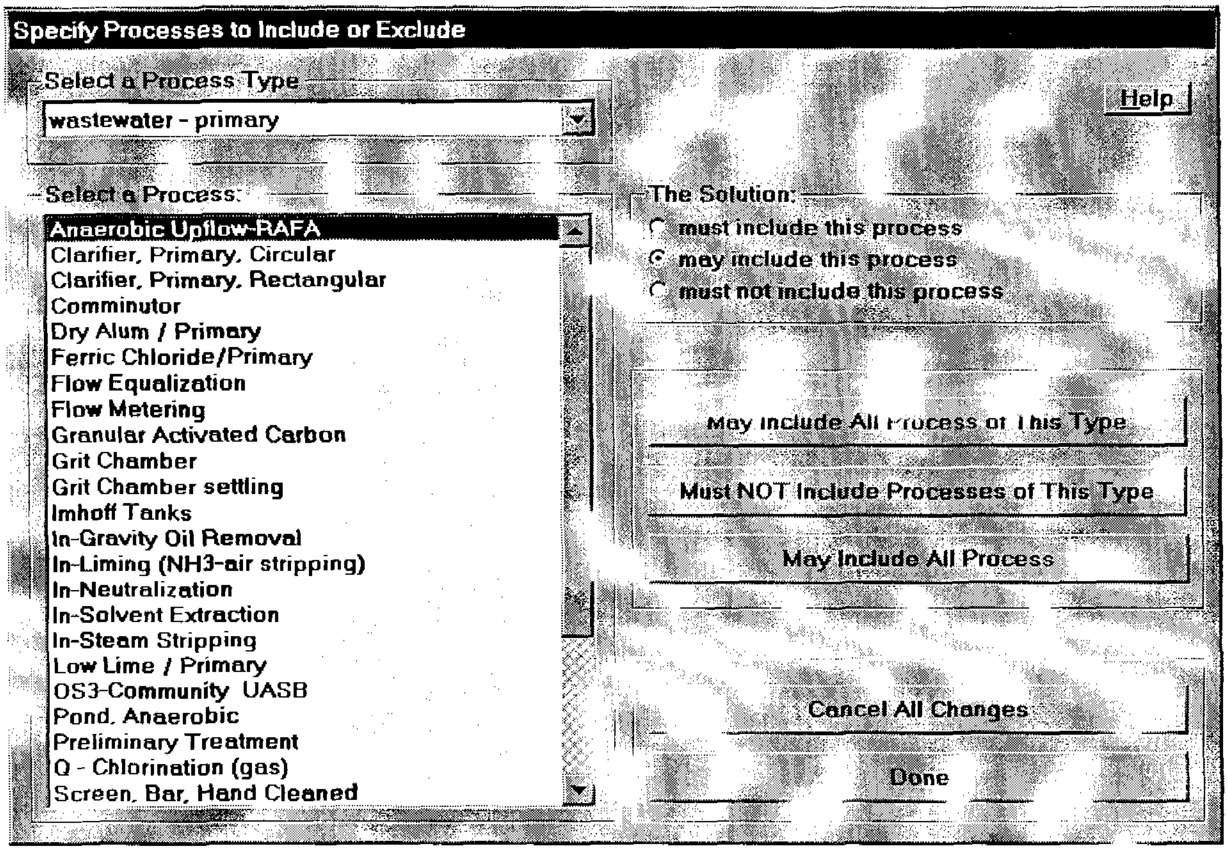


FIGURE 4.2 INCLUDE/EXCLUDE PROCESSES

4.4 "INCLUDE TRAINS" OPTION

By default, all treatment trains are available for consideration for the target community. In some cases however, the user may wish to limit the evaluation to a select group of treatment trains. Selecting the **Include Trains** option brings up a window that has all the trains on the left-hand scrolling list box (Figure 4.3). By highlighting their names and clicking "**Add →**", these trains to be considered can be specified. The selected trains will appear on the right-hand side-scrolling list box. If all trains are to be included, click on "**Add All →**". If trains are to be removed from consideration, click on the train in the right hand list, then click on "**← Remove.**

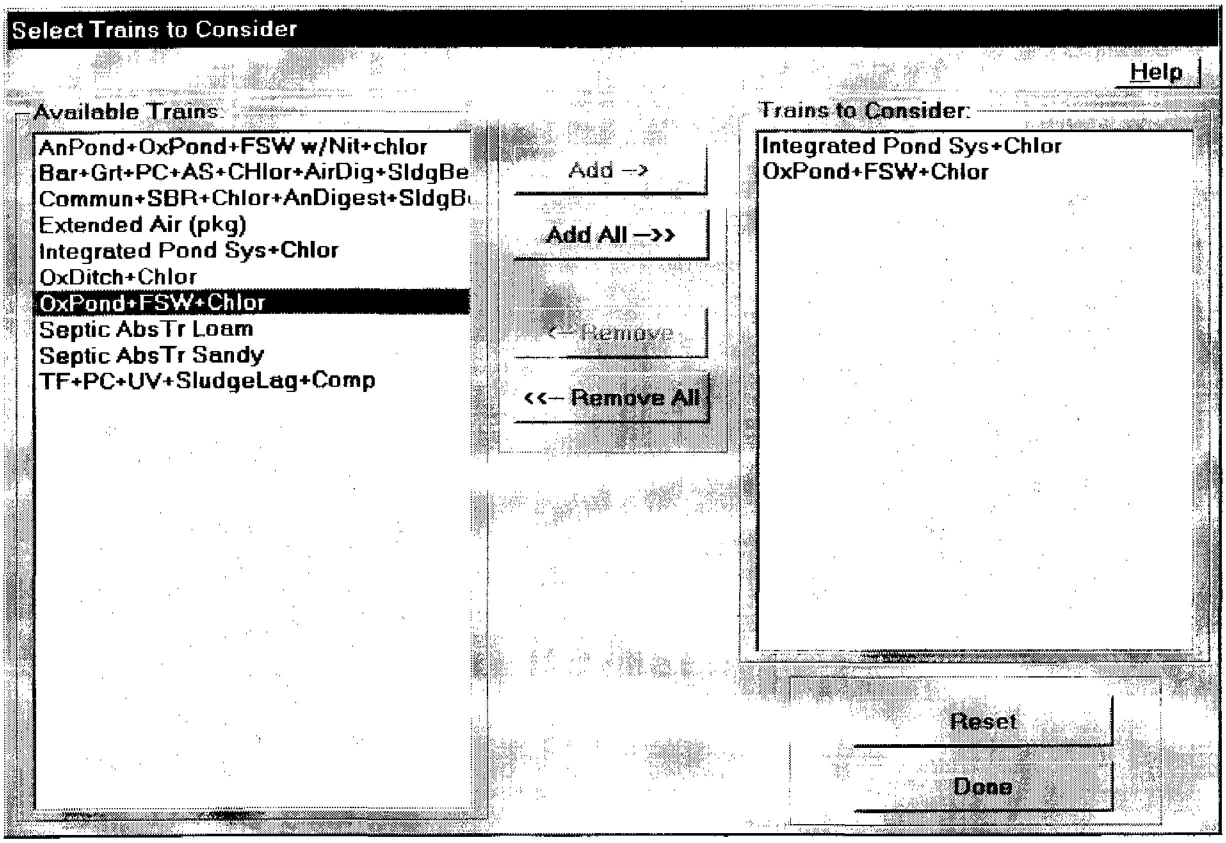


FIGURE 4.3 INCLUDE TRAIN

4.5 "GO" COMMANDS

The "Go" commands instruct the program to perform calculations either for water supply or wastewater treatment problems. There are two **Go** commands; **Go - Water Supply** and **Go - Wastewater Treatment**. The Go - Wastewater Treatment, which brings up the Setup Treatment Option Calculations screen is shown in Figure 4.4.

The user must choose a community by selecting the **Community** button that displays all the community names. Choose a community by highlighting the community. The name of the community should appear opposite the Community button.

If the community does not have a collection system (Community profile Question 33), click on the **Collection Sys** button, and then select a collection system from the available choices. The "without collection" choice is available if you do not want to include the cost of a collection system in this analysis. If the community already has a collection system, leave this entry blank. The small button to the right of the response box can be used to clear the input.

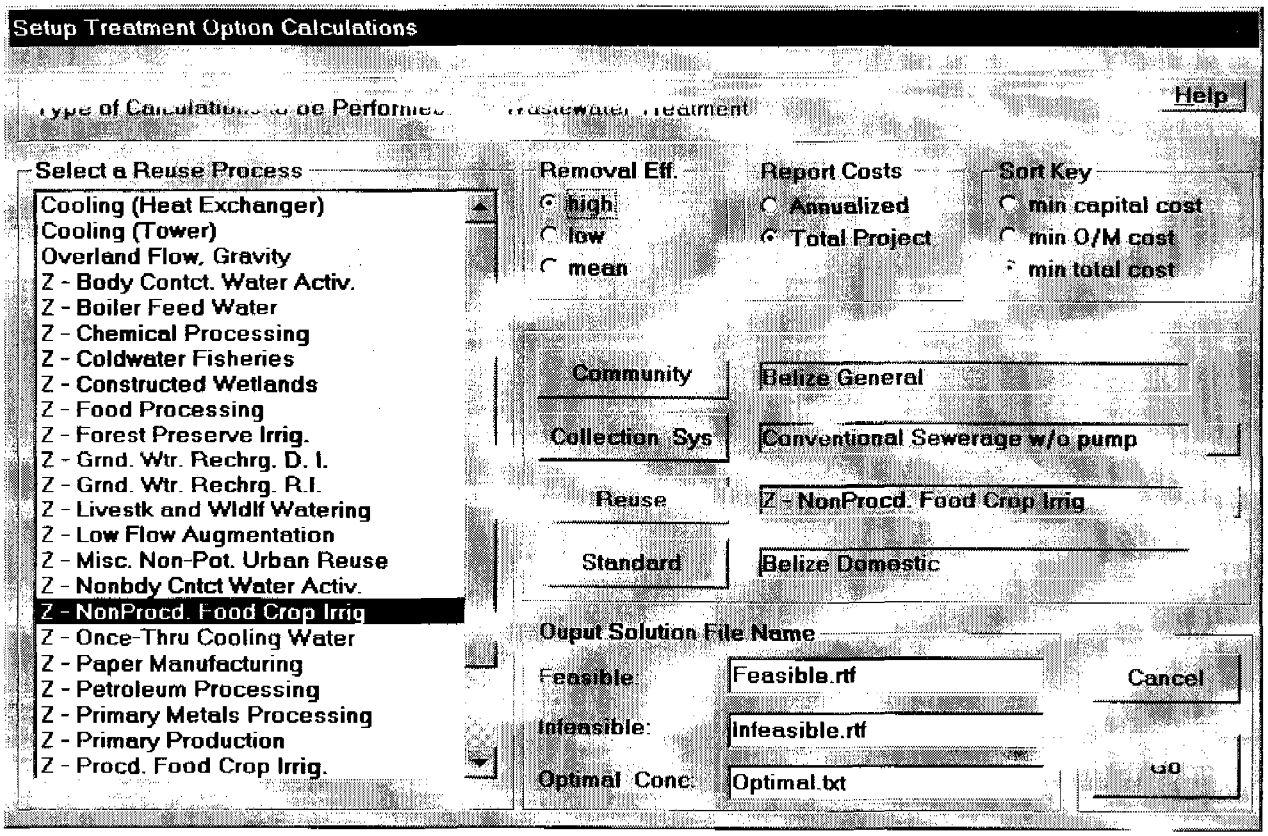


FIGURE 4.4 GO – WASTEWATER TREATMENT WINDOW

If a reuse option at the end of the treatment trains is desired, select it by clicking the **Reuse** button, then selecting a reuse process from the list box. If reuse is not desired, leave this entry blank.

The desired treatment or discharge standard for the community is selected in a similar fashion. A "no standard" response is available if no treatment limits are required.

The choices for **Removal Efficiency** allow the user to chose calculations of treatment process performance based on the maximum efficiency, the minimum efficiency, or the mean efficiency. By choosing one of three levels of treatment; high, low, and mean, the user can test the sensitivity of treatment efficiency against the various treatment alternatives.

The user can also specify the names of the **Feasible** and **Infeasible** solution files and **Optimal Conc.** file by entering new names in the displayed text boxes (the extensions are *.rtf* for the Feasible and Infeasible Solution files, and *.txt* for optimum concentration). The Optimal Conc. file is the concentration of each water quality constituent for the highest ranking treatment train. These files will appear in the results directory in the WAWTTAR home directory.

The three choices for "Sort Key" (upper right-hand corner) specify whether the feasible treatment trains to be sorted by minimum capital cost, minimum O&M cost, or minimum total cost. This question allows the user to sort the alternatives based upon these cost factors. For example, a community member might be interested in the least cost appropriate solution for their community. A donor agency might be interested in knowing the capital cost sort. A government agency (public entity) might be interested in the total cost (up from capital cost and user cost) in practicing the infrastructure investments.

Finally, the user can select whether the costs should be computed as **annualized costs** or **total project costs**. The equations used in these cost calculations are given in Appendix C.

When these criteria are selected, press the **Go button**. WAWTTAR will perform the specified calculations for each of the treatment trains you have constructed. A message to the effect that calculations are in progress will appear. When the calculations are complete, the WAWTTAR main window will be displayed.

5.0 DISPLAYING RESULTS

After WAWTTAR is finished with the calculations, the program output is written to the two output files specified on the Go menu. These files are the Feasible Solution File and the Infeasible Solution File. The Display menu can be used to view these files, along with other output files.

Opening the Display menu will give you several options. The user can select the Infeasible Solution File, Feasible Solution File, the Feasible Solution Graph command, the Impact Reference File, Bibliographic Reference File, WAWTTAR Image Gallery, or Raster Image File.

5.1 INFEASIBLE SOLUTION FILE

A description of any treatment train that does not meet the criteria established by the user will be sent to the Infeasible Solution File. The design or performance criteria not met will be listed for each process in the train responsible for making the train infeasible. Frequently, infeasible trains can yield more insight into the current problem and design process than feasible trains, so the user is encouraged to examine, edit and re-calculate the performance of infeasible trains. A good train may be found infeasible by the inclusion of a given process that is incompatible with influent quality, and may be rendered feasible with a relatively minor alteration.

5.2 FEASIBLE SOLUTION FILE

Detailed descriptions of any feasible treatment trains will be written to the Feasible Solution File. Per process breakdowns of capital cost, O&M cost, land requirements and land cost, as well as total cost for the train, total per capita cost & total cost per dwelling for each treatment train will be provided. Adaptability Indices, ranging from 1-4, rating the adaptability of each train to upgrading, varying hydraulic loading and changes in influent quality are reported. Solids Production is detailed on a process by process basis. Final Effluent Quality for the tracked constituents is reported. Finally, Potential Social and Environmental Impacts are reported as code numbers which are explained at the end of the file.

The treatment trains are ranked by the chosen cost factor and listed with construction, O&M and total costs after the individual treatment train breakdowns. A list of the annualized costs, project costs, land requirements and social and environmental impacts for the optimal train follows. The impact code numbers and associated impacts are listed. Like the Infeasible File, the Feasible File is exportable to a text editor and can be printed using the toolbar at the top of the screen.

5.3 FEASIBLE SOLUTION GRAPHS

The Feasible Solution Graph command yields two types of three-dimensional graphs showing construction, O&M and total cost for each feasible treatment train (Figures 5.1 and 5.2). The trains are identified by their ID numbers. This graph can be printed with the **Print button** on the right.

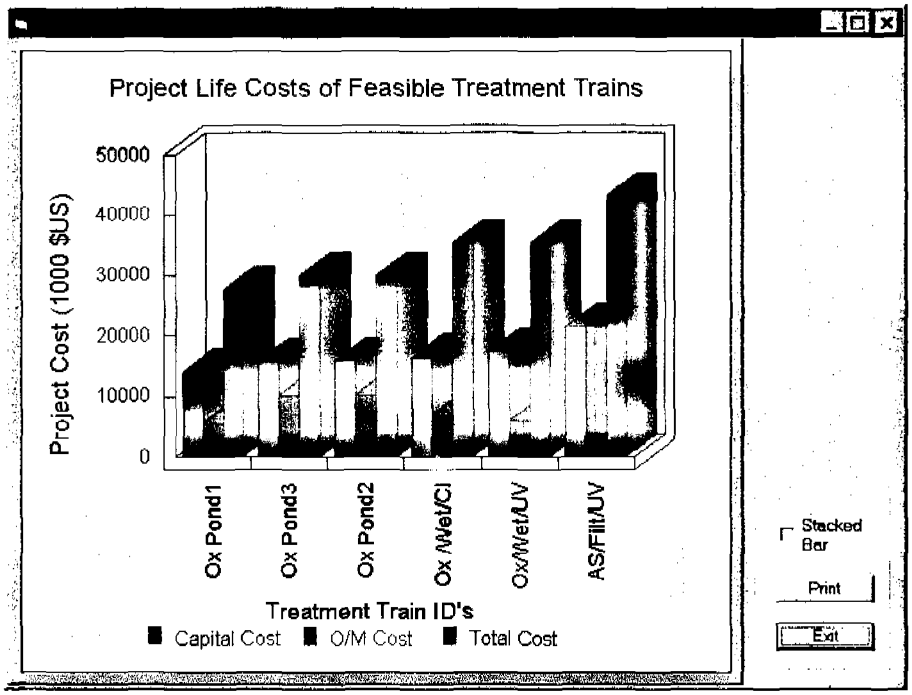


FIGURE 5.1 COST COMPARISON, BAR GRAPH

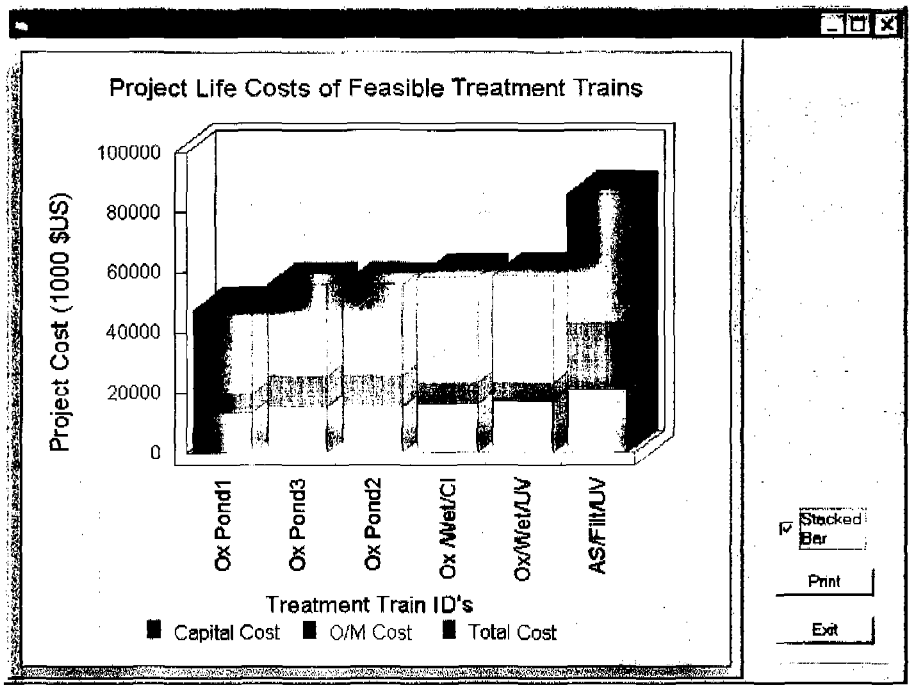


FIGURE 5.2 COST COMPARISON, STACKED BAR GRAPH

6.0 INTERPRETATION AND EDITING OF RESULTS

6.1 TRAIN DATA

The Infeasible Solution file diagnoses why specific processes within trains did not meet the community and/or the standards specified. A full header showing community location, flow, population, removal efficiency specified, and standard is printed out in this file. The first thing to check is the demographic and flow information in this header. Often a data error is made in the community profile that results in treatment trains being infeasible due to these data errors. In addition, check to be sure that any resource limit that eliminates a process is reasonable for the community, and that standards are not being met by an insignificant amount.

The Feasible Solution file will also give a header with the location, flow, population, removal efficiency and standard used. Each train is then listed with its processes. The construction cost, O&M cost and areal requirement are given. The unit cost per capita and dwelling is listed after each treatment train. If parameters are being tracked, their values are listed. Do not be concerned with significant figures on the concentrations of the water quality parameters as the computer "predicts" removal rates with more "precision" than can be measured.

The treatment train adaptability indices are also given. Each process has been rated from 1 (low) to 4 (high) on its ability to: 1) be upgraded, 2) handle varying flows, and 3) handle changes in influent constituent. The train index is the average of the index for each process in the train. The closer the "treatment" index is to 4.0, the more flexible the train, and the closer to 1.0 the index is, the less flexible the train. This can be used as a secondary criterion in choosing treatment alternatives or could be used to eliminate an otherwise appropriate solution if flexibility is important.

At the end of the file, all feasible trains are summarized for easy comparison, with the train construction cost, O&M cost, and total cost. The lowest cost (O&M, construction, or total) alternative is summarized.

Impact reference number(s) are also shown if appropriate, after each feasible treatment train. This applies only to on-site processes. A list of the impacts can be found at the end of the file. A complete explanation of each impact can be viewed using the Display Impact Reference File option from the WAWTTAR main menu.

6.2 OTHER FACTORS TO CONSIDER

6.2.1 Land Requirement Significance

This criterion category refers to those wastewater treatment processes, often referred to as "natural treatment systems", which utilize ponds, wetlands, fields, soil mantle, forested areas, etc., as the ecological substrate for treatment. While these processes have many positive attributes, their application might be limited in areas that are highly urbanized, and that have difficult geological conditions, competing agricultural activities, and hydrological hazards. Many of these types of systems have multiple benefits that can be used to justify the expense of purchasing land that might be highly valued. Examples of multiple benefits associated with land-intensive treatment processes are:

1) open space/green belt,
2) park - passive recreation,
3) storage for irrigation and/or intermittent discharges,
4) habitat value, i.e., wetlands, freshwater supply, wetland habitat, etc.
5) agronomic return on irrigated crop,
6) horticultural watering,
7) aquaculture units.

One of the most important considerations in the use of land-intensive systems is that it establishes a footprint which subsequent facility planning activities can utilize without the need for "new" space. This constitutes a positive impact in a perspective of long-term planning of infrastructure i.e., 30-70 year horizon. For example, the large footprint of an oxidation pond can later be used to build a more compact system (e.g., activated sludge system) to handle demand growth.

6.2.2 Specialized Operation and Maintenance Requirement

Some water and wastewater treatment processes require highly specialized technicians to both operate and/or maintain certain wastewater treatment processes. Good examples would be automatic chlorine analyzers which pace the amount of dechlorination chemicals (SO_2 for example). Another example would be SBR (Sequencing Batch Reactors), which have program logic control systems that are adjusted by company representatives. This criterion is to alert the planner, who might casually indicate in the Community Data that the community has this capability, that these types of systems are highly dependent on specialized technicians supplied by service contracts or by vendors.

6.2.3 Solids Production

While solids removal, treatment, storage and disposal is an integral part of a water or wastewater treatment system, some processes require significantly more attention than others. This criterion category is to alert the planner to the fact that time and money issues must be considered in handling the solids. Criterion for inclusion in this category are the production of solids with potential pathogens, solids which have been chemically treated, solids which have significant degradable organic material remaining, etc. For example, an oxidation pond treatment train (oxidation pond the only process) would have no impacts in this category. On the other hand, a high-rate activated sludge, chemically treated and dewatered by a belt press, would have a higher impact score in this category.

6.2.4 High Electrical Requirements

This impact category is to identify processes which are energy-intensive. There are few examples where no electricity is needed to either collect, treat, and or dispose of water, wastewater and/or solids. Some processes are energy-intensive and therefore require a dependable high quantity of electrical energy. In most cases, this can best be estimated by determining the backup power requirements for energy-demanding processes. These processes are those that have to function all the time to achieve treatment. A good example is activated sludge. Air blowers or oxygen generators need to be available all the time to insure that oxygen is available to the organism and that mixing can occur. Energy-intensive systems can also require significant maintenance associated with pumps, aeration devices, etc. This category is designed to alert the planner to those systems that require an uninterrupted electrical supply. In those communities where electrical energy is intermittent and unpredictable, energy-intensive processes *should not* be used *without* backup primary energy generating capacity.

7.0 TREATMENT PROCESS DATA

The main purpose of the Process data table in WAWTTAR is to provide information on the capabilities, physical and cultural limitations, costs, resource requirements, and possible environmental impacts of water and wastewater treatment and reuse processes. The significance of the physical capabilities and limitations of a given treatment process should be obvious to anyone with a background in water or wastewater treatment, as should the significance of costs and resource requirements (where a resource is any kind of human or material requirement of a process). Cultural limitations and environmental impacts are also of prime importance, but are often not given sufficient attention. Cultural limitations are significant for the reasons discussed previously - a treatment technology that is in conflict with cultural norms of a given location is of little use. Environmental impacts are important since water and wastewater treatment systems have byproducts and influence local conditions. It is important to avoid substituting one set of environmental problems for another, such as a wastewater treatment process that negatively impacts groundwater or drilled wells due to byproducts and hydrological conditions. Alternatively, some processes such as constructed wetlands can have beneficial environmental impacts, and scenarios exist where such possible benefits should be taken into account in a positive sense.

Nearly 200 water and wastewater treatment processes are provided in the WAWTTAR database. All of the data associated with each process is available for review by the user. In addition, while the list includes a wide range of processes, user can easily add new processes to take into account factors such as local conditions and new technologies. The general approach to accessing (either viewing or changing) the process data is the same as with the other data tables as described in Chapter 4. Reviewing or adding processes can be accomplished by clicking on **Process Data** under the Edit menu.

7.1 OVERVIEW OF PROCESS DATA

To access the data associated with a particular process, select the process on the left-hand side of the alphabetically sorted list box (Figure 7.1). Once the process has been highlighted, select the **Edit Process** button. A window appears that has six tabs in the upper left corner. Each of the tabs has a set of questions that define the process characteristics. The tabs are: General, Construction, O/M (Operation and Maintenance), Siting, Impacts, and On-Site Miscellaneous. The questions associated with some of these tabs are shown in Figures 7.2 and 7.3. Clicking on a question number opens the response window for that question. Some responses require typing in descriptions or words, some responses require clicking on boxes (required/not required), and some responses require numbers. A list of the 67 process data questions along with a discussion of each question is in Section 7.3.

Each process can have up to three generic construction, cost, O&M cost and land requirement curves based on hydraulic loading, organic loading, and solids loading. If more than one cost curve is defined, the one that produces the highest cost (or highest land area) is used. The majority of the cost and landuse data came from U.S. EPA references. All costs were brought forward to a common base year of 1992 based on an ENR (Engineering News Record) index of 4985. Costs are brought up to the first year of the project based on inflation rate data provided in the community profile. Most of the cost curves are average costs in the United States for a wide variety of geographical and economic settings. These cost curves can be indigenized by adjusting based on component cost factors for the community of interest using data provided in Question 40 and 41 in the Community profile. For construction costs, the relevant component cost categories are labor, earthwork, manufactured equipment, structures, concrete, steel, and appurtenances (pipes, valves and instruments). For O&M cost, the relevant categories are labor, chemicals, materials, and energy.

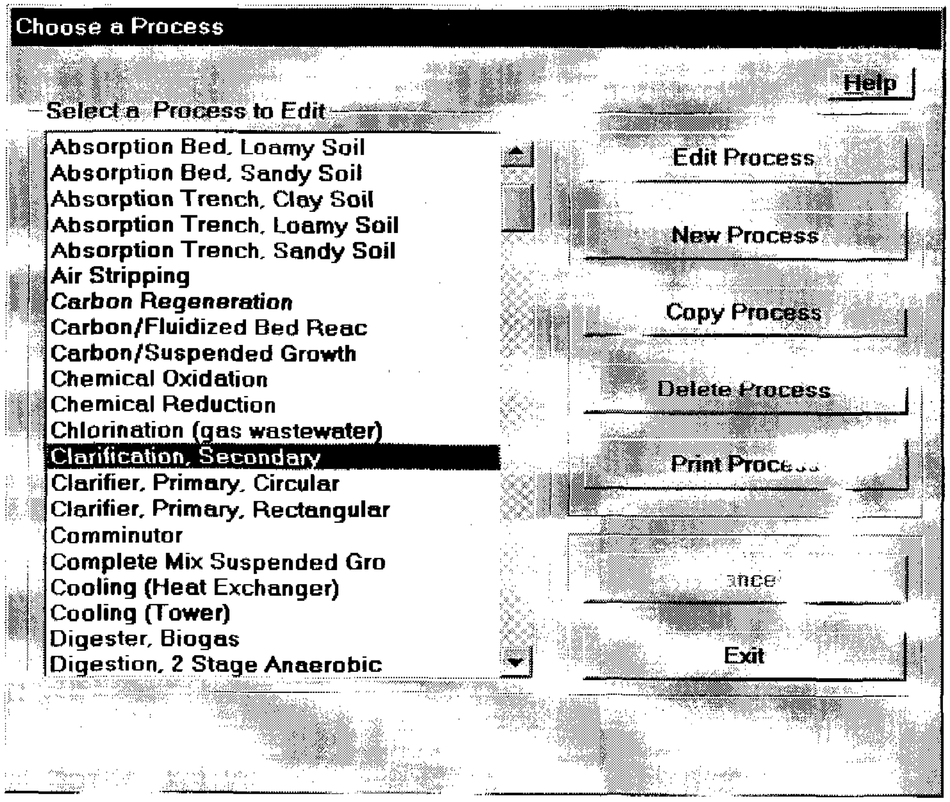


FIGURE 7.1 PROCESS SELECTION SCREEN

7.2 CREATING NEW PROCESSES

The user has the option of constructing new processes at any time. Processes supplied with the WAWTTAR program cannot be modified, but they can be copied and those copies can be freely modified. While entering data for a new treatment process is easy, gathering the necessary data requires a detailed understanding of the process.

The easiest way to create a new process is to select an existing one it resembles, and click on the **Copy Process** button. A green input box will open at the bottom of the screen, asking for a name for the new process. After entering the name, click on **Edit Process** at the top.

After each question has been answered, a green check mark will appear to the left of the question. The **Cancel** button returns to the master menu. The **Close** button saves the new data. A listing of all data associated with the selected treatment process can be printed by clicking the **Print** button.

7.3 PROCESS PROFILE

7.3.1 General Tab Questions (1-7)

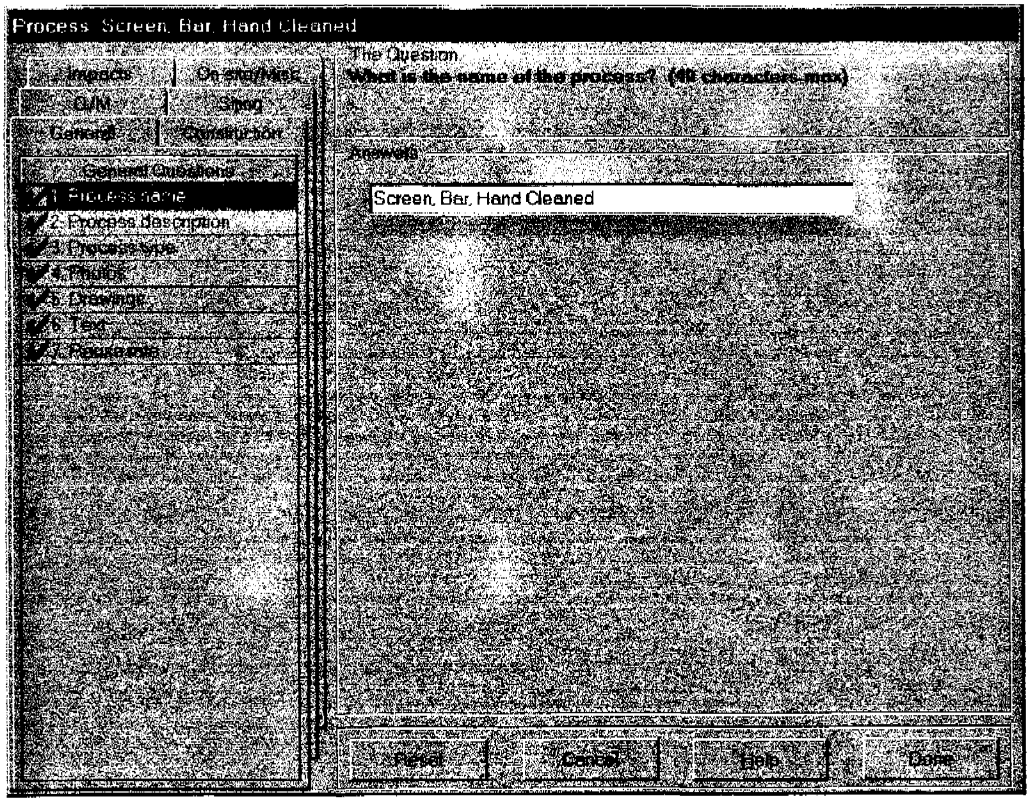


FIGURE 7.2 PROCESS PROFILE: GENERAL QUESTIONS SCREEN

1. *What is the name of the process? (40 char. max.)* ____________________

2. *Please enter a description of the process. (200 char. max.)* ____________________

3. *Please select the process type:*

Wastewater – Primary
Wastewater – Secondary
Wastewater – Tertiary
Wastewater – Disinfection
Reuse – Areal distribution
Reuse – Known volumetric use rate
On-site (dry) – Receptacle
On-site (dry) – Structure
On-site (dry) – Temporary storage
On-site (dry) – Collection
On-site (dry) – Treatment
On-site (dry) – Disposal
On-site (wet) – Receptacle
On-site (wet) – Structure
On-site (wet) – Temporary storage
On-site (wet) – Collection
On-site (wet) – Treatment
On-site (wet) – Disposal
Water supply - Groundwater
Water supply - Surface water
Water supply – surface and groundwater
Water supply and wastewater
Solids handling
Storage

These correspond to the categories available in the "Train Description" first "Build a Train" edit window (see above, Section 3.4.2). Failure to check a category, or checking an incorrect one, could be a source input error, so care should be taken when entering a new process to insure that the correct category is listed.

4. *Identify files containing photographs of this process (5 max.)* ________________

   WAWTTAR can serve as a simple encyclopedia of water and wastewater treatment technologies. To that end, photos, drawings, and text files can be associated with a process. Graphics file formats that can be displayed include .BMP, .JPG, .PCX, and .FIF. Due to the outrageous licensing fees and restrictions imposed by UNISYS, .GIF and .TIFF files are not supported. Graphics files must be placed in the *graphics* directory under the WAWTTAR home directory. Select a graphics file name from the list on the left, and click the **Add→** button to associate it with the process. Graphics files can be unassociated from the process by selecting the file name in the right list box and clicking on the **←Delete** button. A graphics file can be displayed after it is selected by clicking the **Display** button. Descriptive captions can be viewed (and entered) in the caption text box.

5. *Identify files containing line drawings of this process (5 max.)* ________________

   See the discussion for question 4 above.

6. *Identify files containing text information for this process (2 max.)* ________________

   WAWTTAR can serve as a simple encyclopedia of water and wastewater treatment technologies. To that end, photos, drawings, and text files can be associated with a process. Text file formats that can be displayed include .TXT and .RTF. Text files must be placed in the *textinfo* directory under the WAWTTAR home directory. Select a text file name from the list on the left, and click the **Add→** button to associate it with the process. Text files can be unassociated from the process by selecting the file name in the right list box and clicking on the **←Delete** button. A text file can be displayed after it is selected by clicking the **Display** button.

7. *Please indicate the monthly reuse rate*

Month	*Reuse Rate mm or 10^3m^3*
January	________
February	________
March	________
April	________
May	________
June	________
July	________
August	________
September	________
October	________
November	________
December	________

The reuse rate units are mm for areal application processes, and 10^3m^3 for volumetric reuse processes.

7.3.2 Construction Tab Questions (8-16)

8. *Please check (click on the box) those equipment items that are required for construction of this process.*

   ____ *heavy equipment*
   ____ *light equipment*
   ____ *manual equipment*

   This question addresses the minimal equipment requirement. The issue is whether the process can be constructed with manual labor only, light equipment and/or heavy equipment. It is assumed that less sophisticated and natural systems have some minimal manual equipment requirement as compared to more complex and sophisticated systems requiring light to heavy construction equipment. In most cases, these relate the need and/or type of contractor needed to construct the plant.

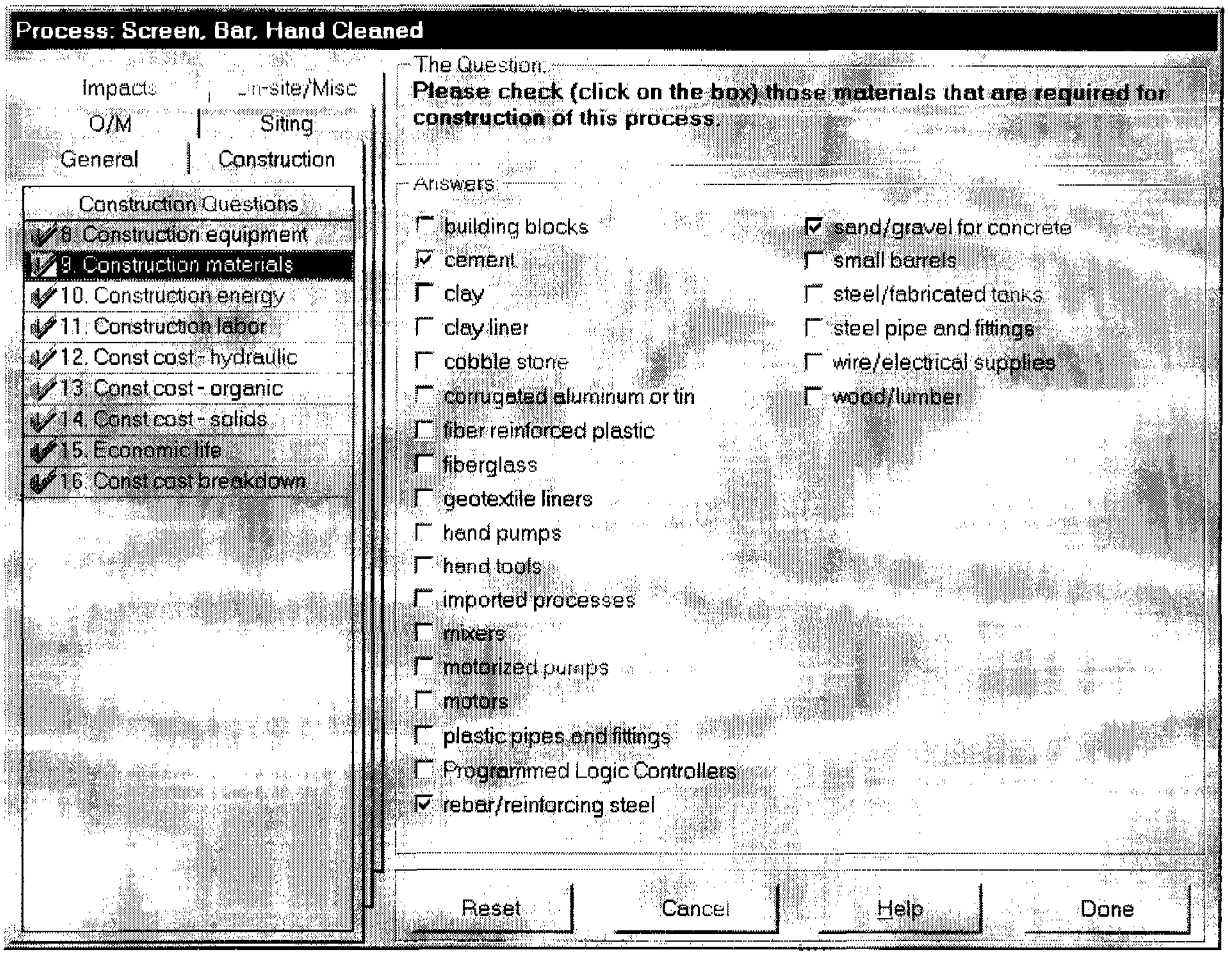


FIGURE 7.3 PROCESS PROFILE: CONSTRUCTION MATERIALS SCREEN

9. *Please check (click on the box) those materials that are required for construction of this process.*

____ *Building Blocks*	____ *Mixers*
____ *Cement*	____ *Motorized Pumps*
____ *Clay*	____ *Motors*
____ *Clay liner*	____ *Plastic Pipe & Fittings*
____ *Cobble Stone*	____ *Programmed Logic Controllers*
____ *Corrugated Aluminum or Tin*	____ *Rebar/Reinforcing Steel*
____ *Fiber Reinforced Plastic*	____ *Sand/Gravel for Concrete*
____ *Fiberglass*	____ *Small Barrels*
____ *Geotextile Liner*	____ *Steel/Fabricated Tanks*
____ *Hand Pumps*	____ *Steel Pipes & Fittings*
____ *Hand Tools*	____ *Wire/Electrical Supplies*
____ *Imported Processes*	____ *Wood/Lumber*

This question addresses the minimal materials required for constructing the process. This list is not meant to be all-inclusive, but to be representative of the general types of construction equipment required for different types of processes.

10. *Please check (click on the box) those types of energy that are required for construction of this process.*

____ *electricity - intermittent*	____ *electricity - reliable*
____ *gasoline/diesel - intermittent*	____ *gasoline/diesel - reliable*

This question applies to the primary (prime) source of energy necessary to operate the processes. Does the process require one of the general types of energy listed?

11. *Please check (click on the box) those types of labor that are required for construction of this process.*

____ *Contractor*	____ *Skilled Construction*
____ *Driver*	____ *Skilled Maintenance*
____ *Laboratory*	____ *Skilled Operational*
____ *Management*	____ *Technician*
____ *Professional*	____ *Unskilled*

Labor types to support the operation and maintenance of the system is another critical constraint on the type of water and wastewater technology. This factor combined with availability of O&M equipment and material has accounted for the greatest proportion of failed and/or poorly functioning water and wastewater systems. Each of the labor types might have a unique cultural definition.

- <u>Contractor</u> refers to available private sector businesses who can construct to specification unit process requiring; 1) concrete forming, 2) pipe fitting and laying, 3) electrical, and 4) excavation/terraforming. In addition, a contractor must have the skills to estimate job costs, organize subcontractors, follow plans and specifications, prepare invoices, etc.

- <u>Laboratory</u> refers to personnel who have been trained to perform routine performance and monitoring analytical tests and to fill out necessary monitoring reports.

- <u>Management</u> refers to personnel necessary for both a level of technology and size of system. Management positions are usually found in systems with 5 or more operation and maintenance personnel with more complex tasks and experience required with large systems, and it could be an engineering position.

- <u>Skilled construction</u> usually refers to personnel who can operate simple equipment, perform limited operational tasks, and have construction level skills (carpentry, plumbing, electrical, etc.)

- <u>Skilled maintenance</u> refers to personnel who have been trained and also have experience in; 1) pipe fitting and mechanical processes, 2) electric motor and controls, 3) welding, 4) concrete forming and placement, 5) electronic instrumentation, etc.

- <u>Skilled operators</u> refer to a trained and experienced operator for medium to high technology treatment systems. The skilled operator can be a transitional personnel familiar with industrial processes such as refineries, food processing, irrigation pumping/distribution systems, etc. or have similar skills.

- <u>Technician</u> usually refers to a person with specialized training to operate/maintain technical processes or support equipment (e.g. computer systems, process control, etc).

- <u>Unskilled labor</u> usually refers to personnel who can perform repetitive tasks requiring hand tools with little to no training and a maximum of supervision.

12. *Enter information relating construction costs (1992 US$) for this process to hydraulic loading (m^3/day) (or storage capacity for storage processes):*

Point	*Capacity* m^3*/day*	*Cost 1000 1992 US$*
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Be sure to report cost in 1992 US$. Costs will be brought up to the first year of the project using inflation rate data provided in the community profile. If more than one cost curve is defined (in Question 13 and 14), the one producing the highest cost will be used. Costs are adjusted to the local community using the cost factors reported in Question 40 and 41 in the Community profile.

13. *Enter information relating construction costs (1992 US$) for this process to organic loading (metric tons BOD/day):*

Point	*Capacity tons BOD/day*	*Cost 1000 1992 US$*
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Be sure to report cost in 1992 US$. Costs will be brought up to the first year of the project using inflation rate data provided in the community profile. If more than one cost curve is defined (in Question 12 and 14), the one producing the highest cost will be used. Costs are adjusted to the local community using the cost factors reported in Question 40 and 41 in the Community profile.

14. *Enter information relating construction costs (1992 US$) for this process to solids loading (metric tons dry solids/day):*

Point	*Capacity tons BOD/day*	*Cost 1000 1992 US$*
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Be sure to report cost in 1992 US$. Costs will be brought up to the first year of the project using inflation rate data provided in the community profile. If more than one cost curve is defined (in Question 12 and 13), the one producing the highest cost will be used. Costs are adjusted to the local community using the cost factors reported in Question 40 and 41 in the Community profile.

15. *What is the economic life span (years) of this process?* ______________________

The economic life of a process is an important factor in calculating the project cost. This is commonly referred to as the life cycle period for a process. For example, if a process has a 10 year economic life and the project period is 20 years, then the process would need to be built twice, once in the first year, and once in year 11 of the project. If the economic life is greater than the project life, then only one unit is considered in the calculation. Processes are assumed to have no salvage value at the end of the project.

16. *Please give the breakdown of construction costs by percentage distribution in the categories below:*

Category	*Percent*
Concrete	______
Earthwork	______
Labor	______
Manufactured Equip.	______
Pipes, Valves, Instrumentation	______
Steel	______
Structures	______

The EPA study that provided the majority of cost data distributed the total construction cost over seven categories. The total cost included the design cost, the construction management cost, and a contingency subtotal of the above listed items was about 35 to 40% of the construction cost. In some cases, these percentages might vary and could be adjusted.

7.3.3 Operation and Maintenance Tab Questions (17-37)

17. *Enter information relating land requirements (ha) for this process to hydraulic loading (m^3/day) (or storage capacity for storage processes):*

Point	*Capacity* m^3*/day*	*Land Area hectare*
1	________	________
2	________	________
3	________	________
4	________	________
5	________	________
6	________	________
7	________	________
8	________	________
9	________	________
10	________	________

If more than one land requirement curve is defined (in Question 18 and 19), the one producing the highest land area will be used.

18. Enter information relating land requirements (ha) for this process to organic loading (metric tons BOD/day):

Point	*Capacity tons BOD/day*	*Land Area hectare*
1	______	______
2	______	______
3	______	______
4	______	______
5	______	______
6	______	______
7	______	______
8	______	______
9	______	______
10	______	______

If more than one land requirement curve is defined (in Question 17 and 19), the one producing the highest land area will be used.

19. Enter information relating land requirements (ha) for this process to solids loading (metric tons dry solids/day):

Point	*Capacity tons dry solids/day*	*Land Area hectare*
1	______	______
2	______	______
3	______	______
4	______	______
5	______	______
6	______	______
7	______	______
8	______	______
9	______	______
10	______	______

If more than one land requirement curve is defined (in Question 17 and 18), the one producing the highest land area will be used.

20. Equipment items that are required for operation and maintenance of this process:

- ____*Electric motors*
- ____*Electronic test equipment*
- ____*Hand tools*
- ____*Hoist*
- ____*Laboratory instruments*
- ____*Portable generators*
- ____*Portable water pumps*
- ____*Water sampler*
- ____*Welding equipment*

The list of O&M equipment types is designed to represent the "general types" of equipment necessary to operate and maintain various "technical classifications" of water and wastewater treatment systems. The list was not meant to be inclusive of all equipment requirements. Studies performed in the 1970's indicated that this equipment list comprised the principal components related to the supportable water and wastewater treatment technologies.

21. *Chemicals that are required for operation and maintenance of this process:*

____ *Acids - neutralization*	____ *Coagulant aids*	_____ *Sodium bicarbonate*
____ *Activated carbon*	____ *Copper sulfate*	_____ *Sodium carbonate*
____ *Aluminum sulfate*	____ *Ferric chloride*	_____ *Sodium chloride*
____ *Ammonia*	____ *Ferrous/ferric sulfate*	_____ *Sodium fluoride*
____ *Bromide*	____ *Hydrogen peroxide*	_____ *Sodium hydroxide*
____ *Calcium carbonate*	____ *Iodine*	_____ *Sodium hypochlorite*
____ *Calcium chloride*	____ *Lime/dolomite*	_____ *Sodium metabisulfate*
____ *Calcium hypochlorite*	____ *Oxygen*	_____ *Sodium nitrate*
____ *Carbon dioxide*	____ *Ozone*	_____ *Sodium nitrite*
____ *Carbon source*	____ *Polyelectrolytes*	_____ *Solvents*
____ *Chlorine dioxide*	____ *Potassium permanganate*	_____ *Steam*
____ *Chlorine gas*	____ *Soda ash*	_____ *Sulfur dioxide*

These chemicals represent the cumulative list of chemicals that are required in the water and wastewater treatment processes included in this program. No process requires all of the chemicals, and many processes do not require any chemicals. Availability of chemical supplies can be interpreted several ways. The most restrictive definition would be to indicate only those chemicals which are immediately available at the local or regional level. This means a local supplier has the chemicals in their inventory at all times. For example, liquid bleach might always be available, commercially white gaseous chlorine might not always be available. If the chemical needs to be imported only for this use, then it should not be listed as available. There are many examples in a variety of socio-economic cultural settings where systems have failed due to unavailability of a critical chemical. A good example would be lack of gaseous chlorine for a community water supply system.

22. *Types of media that are required for operation and maintenance of this process:*

____ *Activated Carbon*	____ *Gravel*	_____ *Resins*
____ *Anthracite*	____ *Membranes*	_____ *Rock*
____ *Aquatic macrophytes*	____ *Plastic*	_____ *Sand*
____ *Diatomeceous Earth*	____ *Porous aeration material*	_____ *Wood*
____ *Garnet*		

Media refers to process support media that is lost, saturated, consumed, eroded, and or corroded in use.

23. *Laboratory supplies that are required for operation and maintenance of this process:*

____ *Non-Electrical Lab Equipment*	____ *Simple Electrical Lab Equipment*
____ *Process Control Testing*	____ *Sophisticated Lab Equipment*

Laboratory equipment refers to the equipment, spare parts, and technical manuals required for O&M.

- Non-electrical equipment refers to color comparators, refractometers, thermometers Imhoff Cones, methylene blue DO testing, etc.

- Process control equipment refers to digital or analog sensors integrated into control system to allow for remote operations based upon process condition. This includes pH system, DO system, chlorine/dechlorination systems, remote equipment operators, etc.

- Simple electronic laboratory equipment refers to incubators, vacuum pumps, drying ovens, probe/meter instruments, simple spectrophotometers, volumetric testing equipment.

- Sophisticated laboratory equipment refers to GC, AA, fluometers, mercury analyzer, complex dual beam spectrophotometers, computers coupled with analytical equipment output, incubators, etc.

24. *Material Required for Operation and Maintenance*

- ____ *Building Blocks*
- ____ *Cement*
- ____ *Clay*
- ____ *Clay liner*
- ____ *Cobble Stone*
- ____ *Corrugated Aluminum or Tin*
- ____ *Fiber Reinforced Plastic*
- ____ *Fiberglass*
- ____ *Geotextile Liner*
- ____ *Hand Pumps*
- ____ *Hand Tools*
- ____ *Imported Processes*
- ____ *Mixers*
- ____ *Motorized Pumps*
- ____ *Motors*
- ____ *Plastic Pipe & Fittings*
- ____ *Programmed Logic Controllers*
- ____ *Rebar/Reinforcing Steel*
- ____ *Sand/Gravel for Concrete*
- ____ *Small Barrels*
- ____ *Steel/Fabricated Tanks*
- ____ *Steel Pipes & Fittings*
- ____ *Wire/Electrical Supplies*
- ____ *Wood/Lumber*

The list of O&M construction material list represents the type of material commonly found with various technology types. This is not an inclusive list of all the materials necessary to operate and maintain systems, only a principle component list of those found to exist in a wide range of technology types. The most critical items found on this list are those associated with higher technology types. Simpler technologies generally require simpler construction materials to operate and maintain.

25. *Process control equipment required for operation and maintenance of this process:*

- ____ *Analog/meter controls*
- ____ *Mechanical controls*
- ____ *PLC status indicators*
- ____ *PLC process controllers*
- ____ *Pneumatic controls*

The items in the list refer to the type of control system in the treatment process. It is assumed that many plants will have all of these types of control equipment.

26. *Types of energy required for operation and maintenance of this process:*

- ____ *electricity - intermittent*
- ____ *gasoline/diesel - intermittent*
- ____ *natural gas - intermittent*
- ____ *electricity - reliable*
- ____ *gasoline/diesel - reliable*
- ____ *natural gas - reliable*

27. *Enter information relating operation and maintenance costs (1992 US$) for this process to hydraulic loading (m^3/day) (or storage capacity for storage processes):*

Point	*Capacity* m^3*/day*	*Cost 1000 1992 US$*
1	______	______
2	______	______
3	______	______
4	______	______
5	______	______
6	______	______
7	______	______
8	______	______
9	______	______
10	______	______

Be sure to report cost in 1992 US$. Costs will be brought up to the first year of the project using inflation rate data provided in the community profile. If more than one cost curve is defined (in Question 28 and 29), the one producing the highest cost will be used. Costs are adjusted to the local community using the cost factors reported in Question 40 and 41 in the Community profile.

28. *Enter information relating operation and maintenance costs (1992 US$) for this process to organic loading (metric tons BOD/day):*

Point	*Capacity tons BOD/day*	*Cost 1000 1992 US$*
1	______	______
2	______	______
3	______	______
4	______	______
5	______	______
6	______	______
7	______	______
8	______	______
9	______	______
10	______	______

Be sure to report cost in 1992 US$. Costs will be brought up to the first year of the project using inflation rate data provided in the community profile. If more than one cost curve is defined (in Question 27 and 29), the one producing the highest cost will be used. Costs are adjusted to the local community using the cost factors reported in Question 40 and 41 in the Community profile.

29. *Enter information relating operation and maintenance costs (1992 US$) for this process to solids loading (metric tons dry solids/day):*

Point	*Capacity tons BOD/day*	*Cost 1000 1992 US$*
1	______	______
2	______	______
3	______	______
4	______	______
5	______	______
6	______	______
7	______	______
8	______	______
9	______	______
10	______	______

Be sure to report cost in 1992 US$. Costs will be brought up to the first year of the project using inflation rate data provided in the community profile. If more than one cost curve is defined (in Question 27 and 28), the one producing the highest cost will be used. Costs are adjusted to the local community using the cost factors reported in Question 40 and 41 in the Community profile.

30. *Please give the breakdown of operation and maintenance costs by percentage distribution in the categories below:*

Category	*Percent*
Concrete	______
Earthwork	______
Labor	______
Manufactured Equip.	______
Pipes, Valves, Instrumentation	______
Steel	______
Structures	______

31. *What is the solids production rate (kg/m^{3}dry weight) for this process?* ______________________

This question "estimates" the amount of dry solids produced by a process. This is not a weight produced dynamically based upon the influent constituent level, and subject to chemical dosage and removal efficiency. This is an average number and is only useful at the planning level.

32. *What is the percent moisture of solids?* ______

This information is used to calculate a bulk density of the solids material based upon its water content. The percent moisture of solids vary depending upon the processes, the relative humidity, and the type and length of storage.

33. *For each water quality constituent (including flow rate), provide the minimum and maximum value allowable in the water entering the process for it to function properly.*

This question places influent upper and lower limits on constituent concentrations entering a process. A train is infeasible if these limits are violated for a process in the train. Only enter data for those constituents for which upper or lower bounds are known. These limits enforce to some extent the integrity of the ordering of processes in the treatment train since placing a process out of order frequently produces a constituent influent value exceeding a design limit. The full list of constituents is available in Table 3.2.

34. *For each water quality constituent, provide the mean, minimum and maximum percent treatment removal efficiency that can be expected of this process.*

This question identifies the effectiveness of the process in removing water borne constituents. The data in this section comes from textbooks, reports, literature values, vendor material, and personal communication. A range of removal efficiencies (high, mean, and low) is listed for those parameters in which data can be obtained.

An attempt was made to obtain the highest quality data available for the key water, wastewater, and or reuse constituents. In all cases, there is not a complete set of removal efficiency for all constituents. As new removal data is developed, the process can be copied and the new data can be added. The full list of water quality constituents is provided in Table 3.2.

35. *What is the level of adaptability of the process to upgrading?* ______

____ *Low* ____ *Medium* _____ *High*

This question deals with the ability of the process to be upgraded in its capacity to process constituents by not significantly increasing the footprint and/or infrastructure within the processes. This does not necessarily apply to simple modularization of the processes. An example would be replacing the sand in a rapid sand filter with a dual media.

36. *What is the level of adaptability of the process to variable flow?*

____ *Low* ____ *Medium* _____ *High*

This question deals with the processes ability to handle wide fluctuations in flow. This is most important when dealing with communities that have high inflow and infiltration in their sewage system. An oxidation pond has high adaptability to flow variation, compared to complex mixed activated sludge that has low adaptability to flow variation.

37. *What is the level of adaptability of the process to change in influent?*

____ *Low* ____ *Medium* _____ *High*

This question addresses the processes ability to handle wide variations in the influent concentration of a particular constituent. A good example would be the low adaptability of UV disinfection to wide variations of turbidity level.

7.3.4 Siting Tab Questions (38-45)

38. *Enter the maximum allowable monthly precipitation (mm) for proper functioning of this process:*______

39. *Please enter the minimum allowable ground surface temperature (°C) for proper functioning of this process*______

This question relates to the potential for the use of composting systems.

40. *Please enter the maximum allowable depth to frostline (m) for proper functioning of this process.* _______
This question relates to the potential for any water carriage component of a system or burial treatment process as it relates to freezing conditions.

41. *Check all soil types at depths from 0 to 2 meters for which this process can be constructed and function properly.*
_______ *gravel, coarse sand*
_______ *coarse to medium sand*
_______ *fine sand to loamy sand*
_______ *sandy loam, loan*
_______ *loam, porous silt loam*
_______ *silty clay loam, clay loam*
_______ *rocky*
_______ *boulder*
_______ *bedrock*

The predominant soil depth question addresses several criteria for selecting on-site treatment systems. Since the majority of on-site receptacles require excavation, the workability of soil to down to 1.5 meters is critical. Predominantly rocky soils are ideal for excavations. However, predominantly sandy soils require special construction techniques to maintain sidewall structural integrity. Subsurface geological formation (1.5 to 2.0m deep) is important in terms of the separation between wastewater infiltration trenches and groundwater levels. Certain soil types (clay loam) can provide excellent receptacle structures which are more or less water tight with a minimum of infiltration.

42. *Please enter the minimum soil percolation rate (sec/cm) for proper functioning of this process:* _________
This question addresses the processes use of percolation/infiltration for the movement of liquid into the soil. A low value here would suggest the processes would not be appropriate for this setting due to surface pooling; a high value might also be inappropriate due to the rapid movement of leachate into potential groundwater drinking water supplies.

43. *Please enter the minimum allowable wet weather depth to the water table (m) that this process can accommodate:* _________
The minimum depth to the highest level of groundwater affords optimum protection of a groundwater resource utilized for drinking water.

44. *What is the minimum horizontal separation distance (m) from this process to groundwater source?* ______
The minimum distance between a sanitation device (receptacle/treatment/disposal/reuse) and a groundwater source minimizes the potential for water borne disease transfer to humans drinking, bathing, cooking, and/or collecting food supplies.

45. *What is the minimum horizontal separation distance (m) from this process to natural watercourse?* ______
The minimum distance between a sanitation device (receptacle/treatment/disposal/reuse) and a natural watercourse minimizes the potential for water borne disease transfer to humans drinking, bathing, cooking, and/or collecting food supplies.

7.3.5 Impact Tab Questions (46-55)

46. *Is this process a potential source of ammonia or nitrate/nitrogen in the percolate?* _________
This question addresses a liquid stream from a wastewater treatment process which has the potential to contaminate a groundwater drinking water supply by the addition of ammonia, nitrite, and or nitrate.

47. *Is this process a potential source of pathogenic organisms in shallow groundwater?* _________
This question addresses a liquid stream from a wastewater treatment process which has the potential to contaminate a groundwater supply by the addition of human pathogens.

48. *Does this process produce the potential of nutrient loads (e.g. phosphorus) to freshwater receiving systems?*______
    This question addresses the potential for eutrophication and/or hyper-eutrophication conditions to exist in freshwater surface waters receiving treated effluent.

49. *Does this process produce the potential of nutrient loads (e.g. nitrogen) to marine or estuarine receiving systems?*______
    This question addresses the potential for eutrophication and/or hyper-eutrophication conditions to exist in estuarine and nearshore marine coastal waters receiving treated effluent.

50. *Does this process produce the potential for waterborne diseases in receiving surface waters?*______
    This question addresses a liquid stream from a wastewater treatment process that has the potential to contaminate surface receiving water by the addition of human pathogens.

51. *Does this process produce the potential for pathogenic water- or fomite-borne diseases from flies, cockroaches, or rodents?* ______
    The question addresses the potential source of human pathogens via vectors such as flies, rats, cockroaches resulting from this process.

52. *Does this process produce the potential for mosquito vector borne diseases?*______
    This question addresses the potential for creating mosquito habitat (standing water).

53. *Does this process require a significant and ongoing user and health education component for its successful implementation?* ______
    This question addresses the need for community participation and health education as an element in the successful implementation of a water supply/sanitation project. The considerations for this component should include time and budget for all phases of a project (planning, design, construction, management, and operation and maintenance). WAWTTAR does not cost the education component.

54. *Does this process produce the potential for odors within the sanitation device?*______
    This question addresses the potential for odors from within a sanitation device.

55. *Does this process produce the potential for odors outside the sanitation device?* ______
    This question addresses the potential for odors outside a sanitation device.

7.3.6 On-Site/Miscellaneous Tab Questions (56-67)

56. *Does this process require a government agency or institution to provide institutional supervision for operation and maintenance?*______
    This question addresses the long term sustainability and expansion of an on-site treatment and collection system. This could be the most critical factor in terms of both the safe use and health education component, the maintenance and operation of a community on-site system, and the expansion in coverage of on-site systems for a community.

57. *Can this process be used in multi-story buildings?*______
    This question relates to the on-site technology options available for multi-story buildings. There are limited technologies available for sanitation for multi-story buildings.

58. *What is the maximum population density (persons/km^2) that this process can accommodate?* ______
    Some on-site treatment systems are relatively land intensive, and are inappropriate in high-density urban areas.

59. *Is this process easily adapted/upgraded into a waterborne collection and treatment system?* ____________

This question deals with potential use of an on-site process in an upgraded waterborne collection and treatment system. In most communities, investment in on-site sanitation is the first step in a community wastewater collection and treatment system. Some processes lend themselves more easily to incorporation into a collected/wet wastewater system. For example, septic tanks could be used in STEP centralized collection and treatment systems.

60. *Does this process require defecating in a squatting position?* ____________________________________

61. *Does this process require darkness at the receptacle?*

Processes that require darkness at the receptacle can also provide habitat for vectors and vermin. Darkened structures, usually cooler than surrounding areas, can harbor snakes, spiders, etc., which deter the use of facility by children and adults.

62. *Is this process easily adapted to unisex use?* ____

63. *Is this process easily used by children less than 4 years old?* ____________________________________

64. *Does this process require a daily addition of a carbon source (e.g. wood chips, paper, green waste, etc.)?*

65. *Please check each of the anal cleansing materials that can be accommodated by this process.*

____ *bulky, degradable* ____ *non-bulky, non-degradable*
____ *bulky, non-degradable* ____ *non-bulky, degradable*
____ *water*

The type of cleaning materials relates to a series of constraints and sizing issues as the treatment trains are developed and sorted through the community profile. For example, water cleansing requires an aqueous receptacle, collection, and treatment component. Non-bulky/non degradable (rocks) cleansing material requires a complete different set of conditions.

66. *Please check each of these types of waste handling by users required by this process.*

____ *urine* ____ *treated sludge*
____ *nightsoil* ____ *treated and composted sludge*

In many cultures, a community is dominated by negative values associated with the handling of various levels of treatment of human feces and/or urine. The levels run from composted waste, human urine, treated sludge, and raw human waste (night soil). The answer to these questions insures that a treatment train does not violate the community's predominant cultural beliefs.

67. *Please check each of the street widths that can be accommodated by this process:*

______ *<0.8 m (foot paths)*
______ *0.8 m - 2.75 m (carts)*
______ *>2.75 m (automobiles)*

Some transport and collection processes require a cart or vehicle. This question insures that a process does not require street access widths in excess of the communities street widths.

APPENDIX A WATER REUSE

A.1 OVERVIEW OF WATER REUSE

Water reuse is a common occurrence. Water shortages and the recent recognition in much of the world of the need to conserve water has focused attention upon the value of intentional reuse. Planners recognize the need for a hierarchy of water use in the community. Not all water need be of the same quality, and the wastewater of a community should be considered a resource. Wastewater should be seen as a source of usable water and a source of valuable nutrients, such as nitrogen and phosphorus. As a resource, it has value that has been enhanced by its collection and treatment.

Abundant supplies of clean surface and underground waters in the world have been taken for granted until recent years. Severe contamination of many surface supplies has occurred. Increasing instances of groundwater contamination are being found. Thus, our relatively fixed volume of water may become less and less usable. Adequate pollution control measures must be taken and conservation and reclamation of resources must become the rule.

Water has always been used and reused by humans. In the natural water cycle, evaporation and precipitation is one form of reuse. The return of wastewater to the streams and lakes of the country is common. The unplanned reuse of wastewater is not new. The planned reuse of wastewater for beneficial purposes has been done in some areas for many years, but it is here that we need to concentrate our efforts for far greater use of our wastewater.

The quality and quantity of wastewater produced by a community depends upon such factors as the source of supply, population density, industrial practices, and even the attitudes of the local population. The quality of the environment can be improved by reducing pollution at the source, providing adequate treatment of the wastewater, and by recycling and reusing wastewater. Public support and some change in social behavior will be required in most instances. Since there are many different types of wastewater reuse and the term "reuse" has different meanings to different people, the following definitions are offered:

- Municipal Wastewater: The spent water of a community, consisting of water-carried wastes from residences, commercial buildings, and industrial plants and surface or groundwater that enter the sewerage system.

- Advanced Waste Treatment: Treatment systems that go beyond the conventional primary and secondary processes. Advanced waste treatment systems may include biological processes, the use of chemicals, activated carbon, filtration or separation by membranes.

- Indirect Reuse: Indirect reuse of wastewater occurs when water already used one or more times for domestic or industrial purposes is discharged into fresh surface or underground waters and is used again in its diluted form.

- Direct Reuse: The planned and deliberate use of treated wastewater for some beneficial purpose such as irrigation, recreation, industry, prevention of saltwater intrusion by recharging of underground aquifers, and potable reuse.

Potable reuse can be further divided into two categories as follows:

- Indirect Potable Reuse: The planned addition of treated wastewater to a drinking water reservoir, underground aquifer, or other body of water designed for potable use that provides a significant dilution factor.

- Direct Potable Reuse: The planned addition of treated wastewater to the headwork of a potable water treatment plant or directly into a potable water distribution system.

A.2 SPECIFIC CONSIDERATIONS GOVERNING REUSE

The reuse of treated effluents is most applicable where large volumes of water are used and the wastes are not highly contaminated. The location and type of the treatment plant and the possible transport of the renovated water are important considerations. A wastewater reclamation plant need not always be located at the same place as the wastewater disposal point, nor should the renovation process be dependent upon treating the total flow. Treatment processes work most efficiently and economically when dealing with a steady flow of wastewater rather than with the irregular flow normally experienced from urban sources. This condition can be obtained by withdrawing only a part of the urban wastewater. As wastewater--treated or untreated--has been reused in agriculture for a long time, many countries have developed standards for this purpose.

An important question is whether the reuse will result in multiple recycle. Multiple recycle produces a buildup of refractory materials, especially inorganic ions, and may require the use of demineralization or other specialized processes. In-plant reuse of industrial water, where actual consumption is small, may lead to a high degree of recycle. However, reuse of municipal wastewater, except for domestic reuse, probably would not lead to multiple recycle.

Another consideration in reuse is the character of the wastewater entering the treatment plant, especially with respect to industrial pollutants. Care must be used to exclude materials that would be detrimental to the reuse application. This is especially true for domestic reuse, but also applies to less sophisticated reuse applications. These materials may not be those usually considered toxic. For example, waters having heavy metal contamination or high total dissolved solids should be considered unacceptable. Each reuse options has its own unique water quality requirement.

Another point that must be considered is distribution of the renovated water. A multiplicity of piping systems, each one containing different quality renovated water may not be practical. If the consumers are widely distributed, however, one piping system in addition to the existing municipal water system is almost certain to be the most that will be economically realistic.

A.3 INDIRECT REUSE

As treatment of wastewater improves, future effluents will be less damaging to receiving water quality. In the treatment of polluted rivers, the methods employed at present are based upon those developed over the years for the treatment of relatively unpolluted river water. It appears that sufficient note may not have been taken of the increasing proportion of wastes in many rivers.

It appears, therefore, that the public health aspects of the production of potable water from polluted rivers should be reviewed. When rivers contain a high proportion of effluent, the production of water from them should be regarded as analogous to the direct recovery of water from a sewage or industrial effluent, and safeguards appropriate to the situation should be imposed. There is a need for appropriate safeguards for the unintentional reuse of wastewater occurs widely because of the use of river water for agriculture, recreation, and industrial supply.

A.4 DIRECT REUSE

Treated wastewater may be deliberately used in a planned way for a variety of purposes. If the planning of wastewater treatment facilities can incorporate potential reuse options in the facility planning process both environmental and economic benefits may be realized.

A.5 ECONOMICS OF REUSE

Pricing of water and all of the costs that go into the acquisition, purification, power and pumping, transmission and distribution and support services is vastly complicated. Subsidies and variable bookkeeping practices add to the difficulty of finding the true cost of water. The following is a checklist for determining if wastewater reuse is potentially practical:

- ❑ existing or future fresh water supply is limited
- ❑ existing or future fresh water supply is relatively expensive
- ❑ the area presently includes or will include individual entities who use high volumes of water
- ❑ municipal wastewater of relatively high quality is presently discharged for disposal
- ❑ for improved wastewater effluent are impending or are anticipated

Water-short areas of the world may not have a choice--they will have to reuse wastewater. WAWTTAR emphasizes the need for appropriate technologies consonant with local socio-economic conditions. Some of the factors, which severely handicap projects to provide safe drinking water and efficient sewage disposal, are:

- shortage of resources (including trained personnel and finances)
- lack of governmental support within the developing countries
- inadequate institutional structures (insufficient organization and administration)
- lack of local interest and acceptance of the project
- capital and O&M cost recovery

Planning for adequate water supply and sanitation must be considered an integral part of the development process, and overall national plans should be formulated and implemented. Each country should make use of its own water resources agency to collect pertinent data and to plan with a regional approach rather than a case-by-case approach. Efforts should be made to innovate and test treatment technologies that are appropriate for their setting. Strong ties should be established between water agencies and universities. Planning tools should be made available to assist governments in the implementation of water supply and sewage schemes. Frequently, proper sewage treatment and excreta disposal have been given such a low priority that pollution control has been postponed until the problem was too great for a solution using available community resources. A national plan and greater governmental involvement will help to alleviate this problem. National planning efforts should serve as the framework for technology selection, institutional development, and financing/cost recovery.

APPENDIX B DELPHI PROCESS

B.1 SYSTEM COMPARISON SPREADSHEET

One of WAWTTAR's main uses lies in helping the user go through a true design process, examining as many options as possible rather than narrowing down on one favored technology from the start. We have included a spreadsheet example showing how the information supplied by WAWTTAR can be used in a Delphi selection process. The spreadsheet *Delphi1.xls* is located in the directory *support* in the WAWTTAR home directory as a Microsoft Excel 5.0 file.

B.2 DESCRIPTION OF WORKSHEETS

The workbook file contains four sheets: two data entry sheets and two calculation sheets. Data to be entered by the designer are in shaded (light blue) cells; other cells perform automatic calculations and generally do not need to be changed by the user. The first sheet, entitled *Parameters*, lets the designer pick selection criteria and enter basic information.

- Six selection criteria are already entered: construction cost in thousands of US$, O&M cost in thousands of US$, land requirements in acres, and the three dimensional adaptability indices (adaptability to changes in influent quality, adaptability to varying hydraulic head, and adaptability to upgrades).

- Space has been reserved for up to seven water quality constituent concentrations. In our example, we use five (suspended solids, CBOD, NBOD, phosphates as phosphorus, and nitrates as nitrogen).

- For each criterion, including the ones already entered, the designer picks a weight, and the spreadsheet calculates the total point value. All treatment trains evaluated will be automatically ranked from zero to 10 for each criterion by the spreadsheet; this will then be multiplied by the weight picked by the designer for this criterion. The maximum point value is given by the sum of all criterion weights multiplied by 10 (maximum rating for a given criterion). In our example, the criteria add up to 2.00, yielding a maximum point value of 20.

- In addition, the *Parameters* sheet also asks some financial data: the base inflation rate, the number of periods a year (in our example, it is quarterly), the year of reference, and the land cost in 1992 dollars.

The second sheet is called *Basic Data*, and allows the designer enter the information on each treatment train to be used in the selection process.

- Space has been reserved for 30 systems.

- For each system, the user enters a name or identification number, and the values obtained for each criterion form the WAWTTAR output (feasible trains).

The third sheet, *Comparison*, performs the ranking calculations for each system using the information supplied by the designer in the first two sheets. These systems will now receive a score, from zero to the maximum point value (0 to 20 in our example). The highest score is the preferred alternative according to the designer's selection criteria and weight.

It is important to remember that this is an indicative score, not a final optimization result. Slight changes in the weighing criteria could change the scores dramatically, as could slightly differences in the WAWTTAR community data (causing different WAWTTAR output results). However, when there are many alternatives to compare, this scoring method allows the designer to narrow the options to the "top" five or six.

The *Comparison* sheet will not sort the alternatives by rank, but this can easily done by the user by copying the value (not the formulas) into another sheet and performing a Sort operation.

The fourth and last sheet, *Current Cost*, brings WAWTTAR's 1992 costs to current value for the year of reference (1999 in our example.)

APPENDIX C ECONOMIC CALCULATION METHODOLOGY

WAWTTAR allows the user to specify whether costs are computed on an annual or total project basis. The following section presents the economic calculation methodology used by WAWTTAR for both the total cost basis and annual cost basis.

C.1 TOTAL COST BASIS

If the total cost basis has been selected, WAWTTAR calculates capital, O&M and land costs according to the following methodology.

C.1.1 TOTAL CAPITAL COST

The total capital cost of each treatment process is drawn from the capital cost vs. flow/loading curves stored in the corresponding process file in 1992 US dollars. The cost of each treatment process is multiplied by the percentage contribution of each cost category and the local cost index corresponding to each category, to yield the adjusted capital cost per category in 1992 US dollars.

$$AC_{jk}^{\$92} = TC_{jk}^{\$92} X_{ik} Y_j \qquad (1)$$

where;

$AC_{jk}^{\$92}$ = adjusted cost of treatment process k in cost category j, 1992 dollars.

$TC_{jk}^{\$92}$ = total cost of treatment process k, 1992 dollars.

X_{ik} = fraction of the total cost of treatment process k in cost category j.

Y_j = local cost index corresponding to category j.

The total adjusted cost of a treatment process in 1992 dollars is the sum of the adjusted costs of each cost category.

$$AC_{k}^{\$92} = \sum_{\forall j} AC_{jk}^{\$92} \qquad (2)$$

where;

$AC_{k}^{\$92}$ = total adjusted cost of a treatment process k, 1992 dollars.

$AC_{jk}^{\$92}$ = adjusted cost of a treatment process k in cost category j.

The total cost of a treatment process in the base year is calculated by inflating the 1992 total cost via the inflation rate.

$$TC_{k}^{\$IY} = \left(AC_{k}^{\$92}\right)(1+r)^{(IY-1992)} \qquad (3)$$

where;

$TC_{k}^{\$IY}$ = total cost of treatment process k in the initial year of the project.

$AC_{k}^{\$92}$ = total adjusted cost of treatment process k.

r = inflation rate.

IY = initial year of the project.

The total capital cost of a treatment train is the sum of the total capital costs of all treatment processes in the train.

$$TC^{\$IY} = \sum_{\forall k} TC_{k}^{\$IY} \qquad (4)$$

where;

$TC^{\$IY}$ = total capital cost of a treatment train in the initial project year.

$TC_k^{\$IY}$ = total capital cost of treatment process k in the initial project year.

C.1.2 TOTAL LAND COST

The land use requirements for each treatment process in hectares are drawn from the x-y plots of land use vs. flow, BOD loading, or solids loading. The land requirements are then multiplied by the land value in 1992 US dollars per hectare stored in the community file to obtain the total land cost per treatment process in 1992 dollars.

$$TLC_k^{\$92} = \left(LC^{\$92}\right)\left(LR_k\right) \quad (5)$$

where;

$TLC_k^{\$92}$ = total land cost for treatment process k in 1992 dollars.

$LC^{\$92}$ = 1992 land cost per hectare.

LR_k = land requirement for process k in hectares.

The land cost is then inflated to the initial project year using the inflation rate for the given community.

$$TLC_k^{\$IY} = \left(TLC_k^{\$92}\right)\left(1+r\right)^{(IY-1992)} \quad (6)$$

where;

$TLC_k^{\$IY}$ = total cost of land for treatment process k in the initial project year.

$TLC_k^{\$92}$ = total land cost for treatment process k, 1992 dollars.

The total land use and land cost for a treatment train are the sum of the land use and land cost for all treatment processes.

$$TLC^{\$IY} = \sum_{\forall k} TLC_k^{\$IY} \quad (7)$$

where;

$TLC^{\$IY}$ = total land cost for the treatment train in the initial project year.

$TLC_k^{\$IY}$ = total land cost for treatment process k in the initial project year.

C.1.3 OPERATIONS AND MAINTENANCE COST

Annual O&M costs are drawn directly from curves of annual O&M cost vs. flow/loading in each process file. The annual O&M cost of each treatment process is multiplied by the percentage contribution of each O&M cost category and the local cost index corresponding to each category, to yield the adjusted annual O&M cost per category in 1992 US dollars.

$$AOM_{jk}^{\$92} = OM_k^{\$92} X_{jk} Y_j \quad (8)$$

where;

$AOM_{jk}^{\$92}$ = adjusted annual O&M cost of process k in cost category j, 1992 dollars.

$OM_k^{\$92}$ = annual O&M cost of treatment process k, 1992 dollars.

X_{jk} = fraction of the annual O&M cost of treatment process k in cost category j.

Y_j = local O&M cost index corresponding to category j.

The annual adjusted O&M cost of a treatment process in 1992 dollars is the sum of the annual adjusted costs of each cost category.

$$AOM_k^{\$92} = \sum_{\forall j} AOM_{jk}^{\$92} \tag{9}$$

where;

$AOM_k^{\$92}$ = adjusted annual O&M cost for treatment process k, 1992 dollars.

$AOM_{jk}^{\$92}$ = adjusted annual O&M cost of treatment process k for cost category j.

The annual O&M cost of a treatment process in the initial project year is found by inflating the 1992 annual O&M cost by the inflation rate.

$$OM_k^{\$IY} = \left(AOM_k^{\$92}\right)\left(1 + r\right)^{(IY-1992)} \tag{10}$$

where;

$OM_k^{\$IY}$ = annual O&M cost for treatment process k in the initial project year.

$AOM_k^{\$92}$ = annual adjusted O&M cost for treatment process k, 1992 dollars.

The annual O&M cost in the initial project year for the treatment train is the sum of the annual O&M costs for all treatment processes.

$$OM^{\$IY} = \sum_{\forall k} OM_k^{\$IY} \tag{11}$$

where;

$OM^{\$IY}$ = annual O&M cost for the treatment train in the initial project year.

$OM_k^{\$IY}$ = annual O&M cost for treatment process k in the initial project year.

The O&M cost for each succeeding year in the planning period is calculated by inflating the previous year's O&M cost by the inflation rate.

$$OM^{\$CY} = \left(OM^{\$PY}\right)\left(1 + r\right) \tag{12}$$

where;

$OM^{\$CY}$ = O&M cost the treatment train in the current year of the planning period.

$OM^{\$PY}$ = O&M cost of the treatment train in the previous year of the planning period.

This calculation results in a series of l annual costs starting with the initial O&M cost and ending with the O&M cost in the last year of the planning period. This series is summed to obtain the total O&M cost.

$$TOM^{\$IY} = \sum_{l=1}^{n} OM_l^{\$CY} \tag{13}$$

where;

$TOM^{\$IY}$ = total O&M cost of the treatment train over the planning period.

$OM_l^{\$CY}$ = annual O&M cost in year l of the planning period

l = year of the planning period.

n = last year of the planning period.

C.1.4 Total Project Cost

The total project cost is the sum of the total capital costs, the total land costs, and the total O&M costs for the entire treatment train.

$$TPC^{\$IY} = TC^{\$IY} + TLC^{\$IY} + TOM^{\$IY} \tag{14}$$

where;

$TPC^{\$IY}$ = total project cost in the initial year of the planning period.

$TC^{\$IY}$ = total capital cost for the train in the initial year of the planning period.

$TLC^{\$IY}$ = total land cost for the treatment train in the initial year of the planning period.

$TOM^{\$IY}$ = total O&M cost for the treatment train over the planning period.

C.2 Annual Cost Basis

If the annual cost basis has been selected, WAWTTAR calculates annual capital costs, annual land costs and annual O&M costs according to the following methodology.

C.2.1 Annual Capital Cost

The total cost of a treatment process k in the initial project year is calculated as in equations (1) through (3). The total cost in the initial project year is amortized by the capital recovery factor (CRF) appropriate for the interest rate and planning period specified in the community file.

$$AnC_k^{\$IY} = \left(TC_k^{\$IY}\right)CRF(i,n) \tag{15}$$

where;

$AnC_k^{\$IY}$ = annual capital cost of treatment process k in the initial project year.

$TC_k^{\$IY}$ = total capital cost of treatment process k in the initial project year.

$CRF(i,n)$ = capital recovery factor for interest rate i and planning period n in years.

A special case arises if the planning period is longer than the economic life of a process stored in the process file. In this case, the cost of the treatment process is amortized over the economic life.

The annual cost of the treatment train is the sum of the annual costs of all treatment processes.

$$AnC^{\$IY} = \sum_{\forall k} AnC_k^{\$IY} \tag{16}$$

where;

$AnC^{\$IY}$ = annual cost of the treatment train in the initial project year.

$AnC_k^{\$IY}$ = annual cost of treatment process k in the initial project year.

C.2.2 Annual Land Cost

The total cost of land for a given treatment process in the initial project year is calculated as in equations (4) through (7). The total land cost in the initial project year is amortized by the CRF to obtain an annual cost.

$$AnL_k^{\$IY} = (LC^{\$IY})CRF(i,n) \tag{17}$$

where;

$AnL_k^{\$IY}$ = annual land cost for treatment process k in the initial project year.

$LC^{\$IY}$ = total land cost for treatment process k in the initial project year.

The annual cost of the treatment train is the sum of the annual costs of all treatment processes.

$$AnL^{\$IY} = \sum_{\forall k} AnL_k^{\$IY} \tag{18}$$

where;

$AnL^{\$IY}$ = annual land cost for the treatment train in the initial project year.

$AnL_k^{\$IY}$ = annual land cost for treatment process k in the initial project year.

C.2.3 Annual Operations And Maintenance Cost

Annual O&M costs are drawn directly from curves of annual O&M cost vs. flow/loading in each process file. The annual O&M cost of each treatment process is multiplied by the percentage contribution of each O&M cost category and the local cost index corresponding to each category, to yield the adjusted annual O&M cost per category in 1992 US dollars, as in equation 8. The adjusted O&M cost for each treatment process in 1992 US dollars is found via equation 9. The annual O&M cost for each treatment process in the initial project year is then found via equation 10.

C.2.4 Total Project Cost

The total project cost given by WAWTTAR is the sum of the capital costs, the land costs, and the O&M costs for the entire treatment train over the planning period. Capital, O&M and land costs are all assumed uniform over the planning period; therefore, the total costs are simply the annual costs multiplied by the length of the planning period.

$$TPC^{\$IY} = n\left(AnC^{\$IY} + OM^{\$IY} + AnL^{\$IY}\right) \tag{19}$$

where;

$TPC^{\$IY}$ = total project cost in the initial project year.

$AnC^{\$IY}$ = annual cost of the treatment train in the initial project year.

$OM^{\$IY}$ = O&M cost for the treatment train in the initial project year.

$AnL^{\$IY}$ = annual land cost for the treatment train in the initial project year.

n = length of the planning period in years.