FLOOD DAMAGE REDUCTION TECHNIQUES FOR WASTEWATER TREATMENT FACILITIES

by

John Joseph Aulbach

Thesis submitted to the Faculty
of the Virginia Polytechnic Institute and State
University in partial fulfillment of the
requirements for the degree of

Master of Science

in

Environmental Engineering

APPROVED:

J. H. Sherrard, Co - Chairman

W. E. Cox, Co - Chairman

D. K. Jamison

November, 1987

Blacksburg, Virginia

FLOOD DAMAGE REDUCTION TECHNIQUES FOR

WASTEWATER TREATMENT FACILITIES

by

John Joseph Aulbach

Committee Chairmen: Joseph H. Sherrard

and William E. Cox

Environmental Engineering

(ABSTRACT)

Wastewater treatment facilities, due to design practices and physical location, may be highly vulnerable to flooding. The implementation of flood proofing and flood damage reduction measures can reduce the economic losses and environmental impacts of a flood.

Effective training and guidance is currently unavailable from the Virginia regulatory agencies. The Commonwealth of Virginia Sewerage Regulations contain the fundamental principal of avoiding construction within the 100-year flood plain. However, information is not included to discuss flood damage reduction measures or flood protective design standards. The Division of Water Programs within the Virginia Department of Health currently has an internal memorandum to govern their response to flood damaged facilities. The memorandum is general in nature with a limited discussion of assistance to wastewater

treatment facilities. Specific flood damage reduction training is currently unavailable within the Virginia Department of Health. This research is intended to provide the necessary material to a) update current regulations and b) establish the basis of a training manual for use during presentations, seminars, and daily activity of regulatory engineers.

ACKNOWLEDGEMENTS

The author would like to acknowledge the following persons for their help in completing this project:

Dr. Joseph H. Sherrard, Dr. William E. Cox, and Dr. Donald K. Jamison for their assistance and supervision while members of the Author's graduate committee. Special appreciation is given to Dr. Sherrard for recommending the Author's research topic.

My wife, Mrs. Lisa S. Aulbach, for her patience and support of my educational endeavors and for the encourgement given during this course of study.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1. INTRODUCTION

In November 1985, a major flood swept through Virginia due to Tropical Storm Juan. The damage was primarily confined to the James River Basin, with Planning Districts 5, 6 and 7 receiving the majority of the damage (1). Within these areas 15 of 102 public water utilities reported water outages or damage. In contrast 26 of 65 public wastewater treatment facilities suffered damage (2). Nearly one-half of the wastewater facilities received damages rated from minor to extreme. These figures indicate that wastewater facilities are apparently more subsceptible to flooding and; therefore, deserve greater attention from state regulatory officials and design engineers.

Two major facilities, the City of Roanoke and the City of Lexington received extensive damages and were out of operation for 3 and 12 months, respectively.

The Roanoke treatment facility has a design flow of 35 million gallons per day (mgd) and provides tertiary treatment. The City of Lexington has a design flow of 2 mgd and provides secondary treatment. As a result of their individual responsive actions to the 1985 flood, the City of Roanoke was nominated for an award by the U.S. Environmental Protection Agency and the City of Lexington was placed under a Court ordered completion schedule. These two facilities and their responses in the flood aftermath will be discussed and reviewed in the upcoming chapters.

The Virginia Department of Health (VDH) internal Action Memorandum No. 291 dated October 4, 1983 presents the draft version of an internal Working Memorandum regarding disaster response (3). The memorandum discusses the response actions in general terms, and refers to a previous more detailed section regarding the responses to water treatment facilities.

The Virginia Sewerage Regulations are currently under revision and a draft has been printed. The draft revision contains additional information regarding flood proofing and emergency preparedness planning than presently availble in the current regulations.

The purposes of this study are to a) review and present the concepts previously developed in the literature regarding flood damage reduction at wastewater treatment facilities, b) prepare a flood damage reduction and emergency preparedness planning manual for the Virginia Department of Health which can serve as a reference and instruction guideline for training VDH engineers and wastewater treatment facility personnel, c) prepare proposed revisions to the Virginia Sewerage Regulations, regarding flood damage reduction and emergency preparedness planning, and d) provide case studies of the response of two localities to an actual flood event.

CHAPTER 2. BACKGROUND

Human development and industrial progress has been associated with watercourses since the beginning of western civilization. Access to water has been essential and has often resulted in the development of low-lying areas. Subsequently, the need to deal effectively with the flooding of such areas has arisen. A flood has been defined by the Water Resources Council as "a general or temporary condition of partial or complete inundation of normally dry areas from the overflow of inland or tidal waters and/or the unusual and rapid accumulation or runoff of surface waters from any source" (4,5).

Flooding is the most common and unpredicatable global hazard. Flood events may be widespread or localized within one drainage basin. Flood events are generally of a high intensity with a low frequency of occurrence. Therefore, it is convenient to believe that it will "happen to the other guy." As a result, gaining both financial support and personnel for disaster preparation is not always attainable. Flood impacts on a utility are particularly damaging because services are disrupted, components damaged or destroyed, and stockpiled equipment and repair parts are rendered unusable, which further increases the length of time normal services are disrupted (6,7,8). The impact of flood events are the easiest of any disaster to predict and planning to deal with them can be effectively accomplished (8).

Flooding reduces the effectiveness of wastewater treatment and creates problems in the resumption of effective treatment. While the facility is responding, restrictions may be placed on the quantity of wastewater entering the collection system, thus placing additional burdens on the citizens and industry. Also downstream water treatment facilities will have to make process adjustments to adequately handle the increased levels of untreated wastewater in their raw water source while also coping with their own flood damages. Rapid resumption of operations allows the service area and downstream users to return to normalcy. Recommended flood damage reduction measures include flood proofing and protection, emergency preparedness planning, equipment modification, and quick operational recovery (8,9).

FLOOD PROOFING AND FLOOD DAMAGE REDUCTION

Flood Proofing.

Construction of facilities within the floodplain combined with ineffective flood reduction measures creates the primary cause of flood hazards to property. Therefore, design engineers must adapt to the problem if construction within the floodplain is to continue. As the majority of wastewater treatment facilities are located within low-lying areas, protective measures are a basic consideration (6).

Total protection of a facility against flood damage is not only impossible but impractical. Recent trends have been towards flood proofing, not flood prevention. Flood proofing is used to isolate buildings and equipment from hazards and to reduce damages. Flood proofing is defined as "the modification of individual structures and facilities, their sites, and their contents to protect against structural failure, to keep water out, or to reduce the effects of water entry" (5,6).

Flood protection measures may be classified as structural or nonstructural. Structural methods are the more traditional approach; however, a greater reliance has been placed upon nonstructural methods. Structural methods are defined as "major engineering works constructed to control the flood water" (10). Nonstructural methods may be defined as "(a) increasing the capability of individual buildings or other facilities to withstand the damaging effects of flood waters; (b) modifying the way people occupy or use floodplain land; (c) increasing the effectiveness of attempts to deal with a flood emergency situation; and (d) partially controlling flood waters by methods other than major engineering works" (10). More specifically, nonstructural methods include floodplain regulation and development policies, warning systems, and disaster preparedness planning. Additionally, nonstructural measures may be either temporary or permanent in nature. Temporary measures include the blocking of entrances and windows and the preparation of mechanical equipment for flooding by removal, covering or heavy greasing. Temporary measures are dependent upon awareness of the potential hazard and a reasonable warning period. Permanent measures include the raising of structures and installation of below ground pumping facilities for removal of flood waters from sub-surface structures. Permanent techniques are preferable since they do not require a warning or response period (5,6).

Flood proofing is a provision of the National Flood Insurance Program which requires that new structures raise utility and sanitary facilities to above the 100-year flood level. Since the majority of wastewater facilities are principally constructed below ground, they have a difficult time obtaining insurance coverage under this program. Flood loss reduction measures such as structural and nonstructural methods require evaluation of the potential damages and the associated economic costs and benefits. Additionally, flood proofing techniques result in reduced property losses and an early return to normal routines and activities (5,11).

Flood Damage Reduction.

Hydrologic and hydraulic evaluation of the flooding problem is a prelude to the economic evaluation. By relating the estimated damages for a broad range of floods to the probability of occurrence, the expected annual damages can be determined. These annual damages are used as the basis for flood insurance rates and should be used in the benefit-cost evaluation of flood reduction methods (11). To justify a flood reduction plan for a facility the expected annual benefits must be greater than the annual costs. This is expressed as a benefit-cost ratio greater than 1.0.

Flood damage reduction measures up to the 100-year flood level are considered as a minimum goal. In addition to preventing or limiting physical damage and maintaining operatons, the degree of protection, and design is based upon a comparison of benefits and costs (9).

Reduction in facility damages and the enhanced usefulness of the floodplain may be considered as benefits. Benefits may be classified as flood reduction and intensity reduction. Annual cost or damage cost estimates should only include replacement or restoration costs to the pre-flood conditions. These costs and estimates should also consider salvage costs and prior depreciation on the buildings and equipment. The damage figures should not be inflated to provide an overall enhancement that was not previously available, nor should they be under estimated to achieve a desirable benefit-cost ratio. A percent damage factor, related to the water depth, may be used to determine the acceptable degree of flooding within a structure of plant site (10,12).

VULNERABILITY ANALYSIS AND EMERGENCY PREPAREDNESS PLANS

Vulnerability Analysis.

A vulnerability analysis may be defined as "the determination of the degree to which the system is affected adversely, in relation to its responsibility, by stress situations" (8). The analysis will identify the effects of flood levels with regards to power supply, communications, equipment, supplies, access, personnel, and emergency procedures. The vulnerability analysis is the basis for development of an emergency preparedness plan (9).

Emergency Preparedness Plans.

Emergency preparedness planning will enhance existing flood damage reduction methods that are inadequate or unsuccessful. Emergency planning is essential to ensure timely, efficient, and productive recoveries. The plan will discuss the mission to be accomplished and the methods of resource utilization. Additionally, the plan should be operationally oriented and not a description of organization and duties (8,9).

Emergency planning measures generally include actions taken during design as well as prior to, during, and after the disaster (8). The plan will generally include methods of flood warning, designation of a decision making authority, task assignments for personnel, and arrangements for additional equipment and personnel. Flood losses can be reduced through floodplain management, effective designs, and emergency preparedness planning (13).

The utility that is prepared to minimize the effects of a disaster or that has an emergency preparedness plan will be able to reduce the inherent effects. Such success is a direct result of preparation, training, and experience. Preparation, so that a state of readiness is maintained, is a basic requirement of every utility manager (7).

LEGISLATION, REGULATION AND GUIDELINES

Federal.

In 1965 Congress began to update federal flood control policies. The Water Resources Planning Act of 1965 created the Water Resources Council (WRC). The WRC later developed the Unified National Program for floodplain management which provided administrative guidelines relative to flood control. The Uniform National Program document was issued in 1976 and provides information regarding management strategies, implementation methods, and recommendations for effective responses. The Water Resources Development Act of 1974 authorizes federal involvement in nonstructural flood damage reduction projects. The act states that "In the survey, planning, or design by any Federal Agency of any project involving flood protection, consideration shall be given to nonstructural alternatives to prevent or reduce flood damages..."(4)

The National Flood Insurance Act of 1968 established an insurance program and provides incentives for floodplain management for those areas in which a floodplain ordinance is enacted. A 1969 amendment established an emergency insurance program for communities not having adequate information for the establishment of floodplain regulations.

The Disaster Relief Acts of 1970 and 1974 established a relief program to assist in natural disasters. The program is administered by the Federal Emergency Management Agency (FEMA). The 1974 act also requires mitigation actions as a condition for receipt of the disaster relief funds (4). The funds may be either in the form of grant funding or low interest rate loans. These actions may be undertaken prior to or following a natural disaster and are intended to reduce the inherent effects. The mitigation actions are to reduce the vulnerability to future disasters, thereby reducing property losses and financial assistance.

The Flood Insurance Acts and the Disaster Relief Acts directly impact wastewater treatment facilities as they are located primarily below ground, within the 100-year flood plain, and are not adequately protected from flooding; therefore, the facilities are generaly not eligble for federal assistance. If federal assistance is not available, the localities must be capable of funding the flood response efforts.

State.

Several states are concerned with emergency planning and have devoted time and effort to flood damage reduction studies and public awareness programs.

The State of Florida Department of Environmental Resources (DER) annually reminds public utilities of measures to assist in efficient operations during their upcoming storm season. They include a listing of procedures to be followed for emergencies, a discussion of DER staffing and functions, and a flow chart of disaster operations. Additionally, they detail what is expected of the utility and where the DER can provide assistance upon request (14). Their annual reminder appears to be an effective method in promoting public awareness and effective emergency planning.

The Pennsylvania DER requested the U.S. Army Corps of Engineers conduct a study to provide recommendations for flood damage reduction. The study found that many Pennsylvania facilities had been frequently flooded, resulting in excessive repair costs, and extensive periods of inoperability. It was also determined that many facilities lacked adequate emergency preparedness plans, training, and vulnerability assessments (13). As a result the Corps published recommendations and guidelines for flood damage reduction and the Pennsylvania Susquehanna River Basin Commission published a manual for flood evacuation and emergency planning.

It is significant to note that the Corps recognized the importance of and recommended formal training to make up for the lack of flood reduction knowledge among facility personnel. It was also suggested that a) facilities be required to develop written emergency preparedness plans, b) the agency reviewing new designs should review for flood resistant design features and plant evacuation, and c) the DER should instruct operators through their existing program of regular inspections.

Currently, the Virginia Sewerage Regulations contain information regarding emergency preparedness plans, vulnerability analysis, and flood reduction/protective designs (15). The regulations require that operational components be located above the 100-year flood elevation, while emergency preparedness plans, and the vulnerability analysis are described for inclusion in the operations and maintenance manual. The two concepts are combined under the "Emergency Operating and Response Program" section of the operations and maintenance manual appendix. The section states the program objectives and a definition of a vulnerability analysis. The appendix also requires that methods to reduce vulnerability be established; however, no alternatives other than training are indicated.

The regulations are currently under draft revision and some additional information and detail has been added (16). The proposed draft regulations have increased the emphasis of locating above the 100-year flood level, in that it is discussed within several design related sections. However, the discussions of emergency planning and vulnerability anaysis have remained general in nature within the operations and maintenance manual appendix and no substantial information has been added. The draft regulations have expanded the existing standards to specifically mention mechanical and electrical equipment subject to damage by water. Also they have drawn attention to need for equipment removal capabilities.

The Virginia Department of Health Action Memorandum #291 is the basis for staff response to disaster situations. The memorandum outlines the organization of emergency operations in that they will be coordinated through the Bureau of Emergency Medical Services, with the Division of Water Programs responsible for Environmental Sanitation. Additionally, the document discusses the chain of command and duties of each individual in the Regional Offices. The

Regional Director is charged with overall coordination of efforts and each District Engineer must consult with and advise local authorities regarding restoration of treatment facilities. The memorandum discusses the restoration of a water treatment facility, with the reference that the efforts at wastewater treatment facilities are essentially the same. Response actions after the disaster are discussed; however, the concepts of preventive actions, such as emergency prepardness planning, vulnerability analysis, and flood protection methods are not included.

CHAPTER 3. FLOODING OF VIRGINIA WASTEWATER FACILITIES

As a result of the significant rainfall produced by Tropical Storm Juan between 31 October to 4 November 1985 the wastewater treatment facilities in the cities of Lexington and Roanoke Virginia were severely damaged by flooding. Within three months the City of Roanoke advanced wastewater treatment facility was fully operational. At that time the City of Lexington secondary treatment facility was continuing the process of repairs and renovation and did not regain full operations until nine months later.

The events of the 1985 flood and the aftermath for each facility to include responses by operational personal to minimize damages, repairs, and renovations and discussion of the efforts to restore each facility to full operation are included in this chapter. Actions taken at each facility will be discussed and compared to review the positive responses.

The City of Roanoke operates an advanced wastewater treatment facility. Originally built in 1952 as a conventional activated sludge plant with a design flow of 14 mgd, it was expanded to 21 mgd in 1960. In 1971 the facility began research into and implemented treatment for phosphorous removal. In 1977 an expansion to the current design flow of 35 mgd was initiated. The expansion included biological nitrification and tertiary filtration for suspended solids removal. The facility flow diagram is shown as Figure 1.

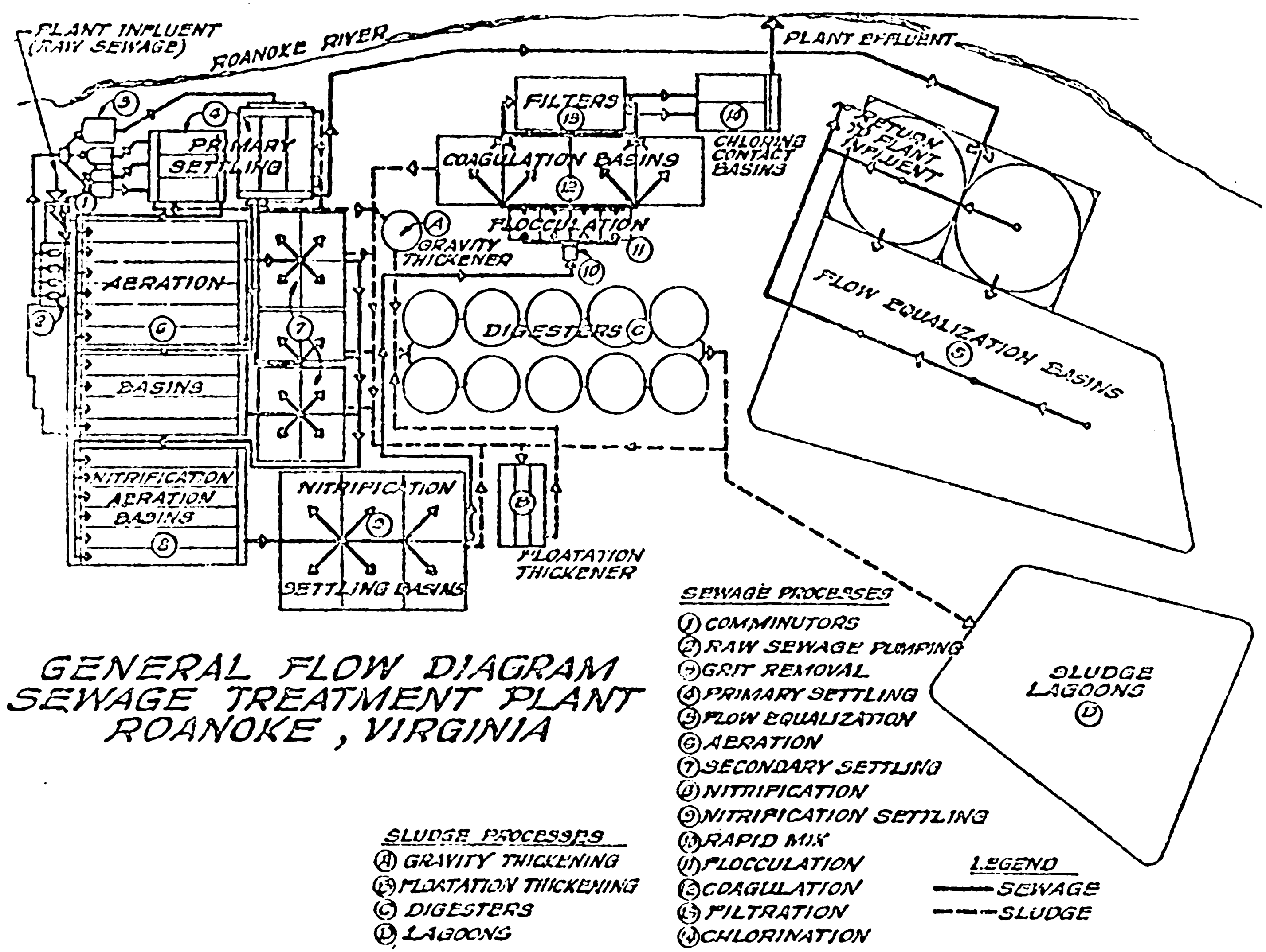

Figure 1. City of Roanoke Wastewater Treatment Facility

The Lexington facility is a 2 mgd conventional activated sludge system that provides secondary treatment. The facility was originally constructed in 1954 as a primary treatment facility. In 1975 it was upgraded to the current level of treatment, in accordance with federal requirements under the Federal Water Pollution Control Act Amendments of 1972. The facility flow diagram is shown as Figure 2.

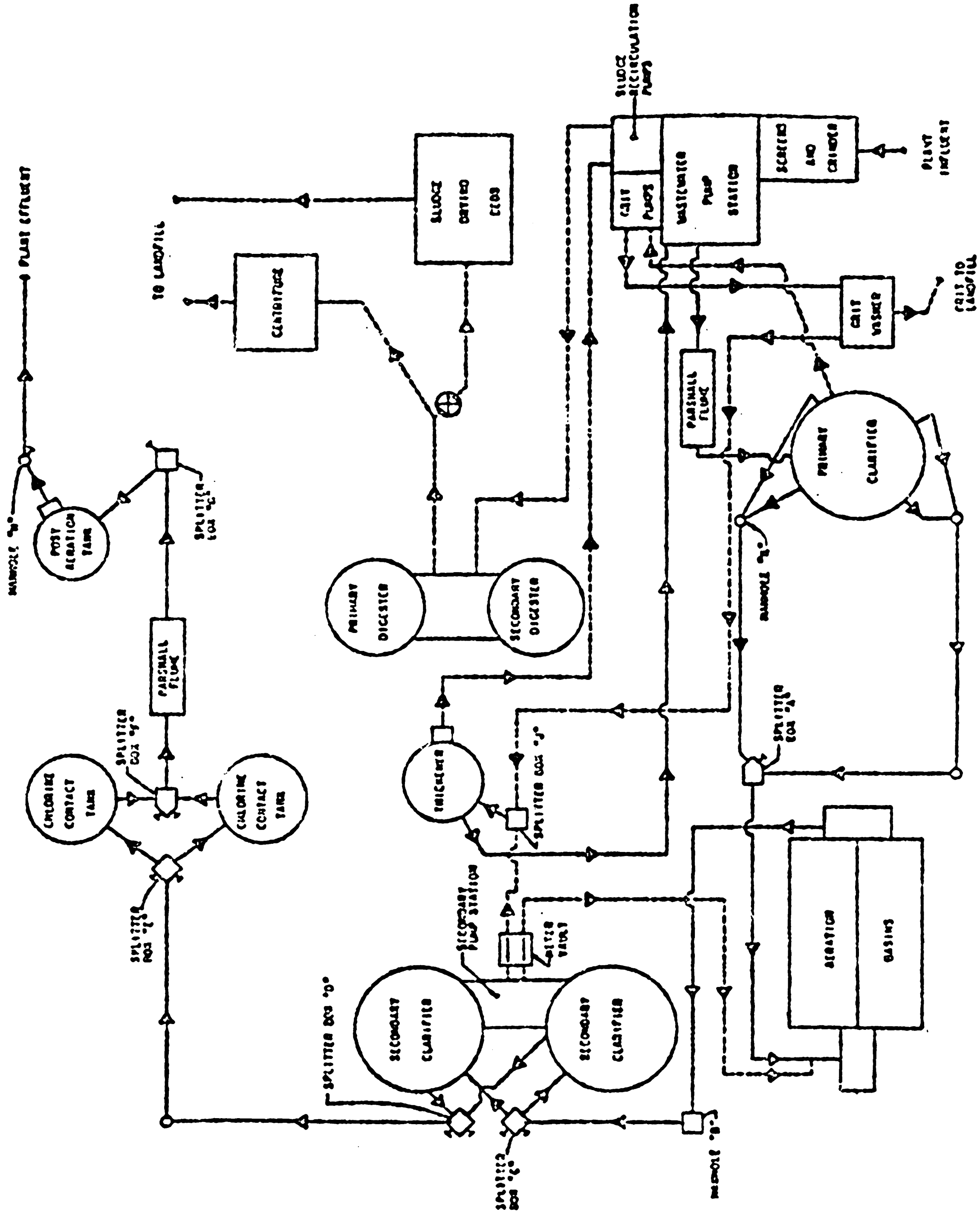

Figure 2. City of Lexington Wastewater Treatment Facility

CITY OF ROANOKE AWT FACILITY

The City of Roanoke AWT facility was severely damaged by Tropical Storm Juan in November 1985. Raw sewage was discharged for seven days after the 1985 flood prior to the startup of the primary treatment units. All treatment units were operational within 3 months, and all National Pollutant Discharge Elimination System effluent limits were consistently achieved by May 1986. A total of 6.6 personyears of labor were expended at the facility as a direct result of the flood, and repair costs totaled in excess of $1,000,000.

Background.

The 1985 flood began on October 31 and ended November 4 1985. A total of 10.7 inches of rain fell on the city, with 6.6 inches on November 4. The Roanoke River, which is adjacent to the facility, has a flood stage of 10 feet. The river crested at 23 feet. As a result of the storm the facility was flooded and operations were ceased. Flood waters ultimately rose to a level below the second floor of the main control building and personnel were rescued from the roof.

The 1985 flood was the fourth major flood in the past 16 years with floods occurring in 1969, 1972, and 1978. The U.S. Army Corps of Engineers began studying the flood problem with the city in 1970. Channel modifications for the Roanoke River have been proposed. Negotiations are currently ongoing regarding the $22,000,000 Roanoke River channelization project. The Corps estimates that $40,000,000 to $60,000,000 in damage from the 1985 flood could have been prevented if the channelization project had been implemented earlier. The total damage within the city was approximately $125,000,000.

Emergency Preparedness Plan.

The City of Roanoke has an existing Emergency Flood Plan to direct their response to a flood event. The plan was developed to assist in preventing lengthy periods of raw sewage discharges and the minimization of damage to buildings and equipment. Upon a flood warning notice from the Civil Defense Office, the Utilities Director or the Plant Manager will initiate the Emergency Flood Plan. During the 1985 flood, the plan was implemented and followed throughout the event.

The flood plan provides positive control of all personnel, details the number of personnel required to complete the efforts, and assigns personnel to specific duties. Additionally, the plan includes equipment requirements, equipment location, and telephone numbers for key personnel.

Generally the plan is well thought out and includes identification of required actions, necessary personnel, and overall floodproofing efforts. Procedures are outlined for placing sandbags at vulnerable locations and the protection of windows and doorways susceptible to flooding. In addition provisions are provided for the removal of vehicles, the recording and monitoring of the flood progression, and status of flooding.

Facility Damage and Operational Response.

The physical damage at the Ronoke AWT facility was mostly to the electrical equipment. Additionally, there was breakage of windows, destruction of doors, and presence of large amounts of debris throughout the facility.

The flood waters entered the basement and first floor levels of the main control building after breaching exterior entrances. All electrical switches, pumps, and motors contained in the basement and first floors were inundated. The switches located near the equipment were not required for shutting off the power to the units since this was performed at the main switch box located on the second floor of the control building. None of the flooded equipment was waterproof, and repairs were required. Chemical tanks located throughout were partially full prior to the flood and floated in the flood waters. The unsecured chemical tanks resulted in chemical spills as well as damaged piping. The tertiary filtration building was flooded through outside basement vents and as a result of backflow through the filter effluent line from the chlorine contact tanks. Damage to the filter controls and other electronic instruments was extensive. Additional flooding of facility buildings occurred due to backflow of flood waters through floor drains connected with the influent channel.

No significant structural damage occurred to any of the treatment units. Interior doors were damaged as a result of water pressure. The emergency generator, which is located at ground level, was flooded and required repairs. While no significant structural damage to the treatment units occurred, all basins were filled with debris. Total facility damage from the flood was approximately $1,000,000. Pumps, motors, and other susceptible electrical equipment could not be removed prior to being flooded. Similar damage occurred throughout the facility as all outside pumps, motors, and switches associated with the treatment units were flooded. All power supplies were shut off prior to the pumps and motors being flooded to prevent further damage from short circuiting. The facility's main electrical switch gear was not damaged due to its location on the second floor of the main control building.

In preparation for the flooding of the facility plant personnel followed the response plan. They covered doorways and windows with precut plywood panels and placed sandbags at designated locations as flood proofing measures. These measures were an effort to minimize damage to the buildings from both the flood waters and debris. Prior to unit operations and related appurtenances becoming flooded the units were taken out of service and electrical components turned off to prevent additional damage due to short circuiting. In addition to removal of City owned and personnel vehicles, vulnerable office equipment, and records were also removed. Due to the time involved and the lack of available hoists and lifts items such as pumps and motors were not removed. Difficulty would have also been encountered in disconnecting electrical connections for personnel other than electricians.

On November 5, 1985 plant personnel initiated clean up operations and removal of damaged equipment for repair. Portable pumps were placed into operation to remove flood waters from all enclosed or underground locations to allow removal of equipment and debris. Personnel from other departments within the City were detailed to the plant and were assigned to work crews supervised by plant personnel. The work crews were detailed to perform specific duties on 12 hour shifts. Equipment was removed for inspection and repair as physical access was gained. Facility personnel priortized all efforts to start with the raw influent processes first. The efforts were in anticipation of having those items returned first so that treatment operations could be restarted quickly. However, for overall efficiency of equipment removal the established priorities were not strictly adhered to.

The facility maintenance personnel developed a recording and tracking procedure for all equipment. Prior to each piece of equipment being removed from the plant site it was delivered to the maintenance building where it was recorded and tagged. The information included the date, name of the item, identification code from established maintenance records, and name of the vendor providing repair service. Repair shops were instructed not to remove these tags during their repair procedures. Duplicate items were sent to separate vendors in anticipation of earlier returns and timely start up of the facility. Upon return of the equipment each item was recorded and the identification code used to identify its proper location within the facility.

From the time operations were ceased on November 4, sufficient equipment was removed, repaired, and replaced to allow primary treatment of sewage to resume on November 11. During the period of November 4-11, an average 25 mgd of raw sewage was by - passed to the Roanoke River. Due to the quick startup of the primary treatment units in a normal operation mode temporary treatment measures were not attempted.

Plant personnel acted as their own general contractor by organizing work efforts, arranging for outside contractors and vendors to perform work at the plant, and for equipment repair. Plant maintenance personnel maintained contact with repair shops to insure that equipment was returned quickly. The majority of equipment was returned to the plant by November 15.

Analysis of treatment processes for operational parameters and effluent quality began on November 14. The aeration basins were restarted on November 19, and sludge from the primary sedimentation basins was pumped to the sludge thickeners on November 15. Sludge was then transferred to the digesters on November 15, and digester gas production resumed on November 27. The biological nitrification basins were restarted on December 28. From December 14, 1985 to January 26, 1986 the filtration units were backwashed to prepare them for operations which subsequently resumed on January 27, 1986.

Since the November 1985 flood ongoing repairs and maintenance that are related to the flood have been normal. Prior to the flood the maintenance personnel were on schedule with the preventive maintenance program; however, schedules have not been adhered to since the November 1985 flood. Deviation from established schedules is attributed to the long term effects of the flood waters on the equipment. To accomplish the overall goal of restarting treatment operations, as quickly as possible, the equipment was not overhauled entirely. Plant officials and maintenance personnel decided that to overhaul each piece of equipment completely would significantly delay the resumption of treatment. Therefore, equipment is removed for overhaul and flood related repairs as the need arises.

An additional problem noted is standing water within electrical conduits, including the main electrical power line into the plant, which has caused shortcircuiting problems within various pieces of equipment. As a result, approximately 50%, of the wiring has been replaced and the main power lines to the plant have been raised to reduce their susceptibility to flooding.

All equipment repairs, debris cleanup, and other actions immediately following the flood were without the benefit of federal disaster aid or insurance payments. On December 17, 1985 the Roanoke Times and World News reported that the Roanoke City Council approved $1,600,000 to repair the treatment facility and water and sewer lines. At that point estimated damages to the facility were $1,000,000, and $666,159 had already been spent.

Flood Impact Upon Unit Operations and Processes.

Review of the grit collection data showed a substantial increase in volume immediately following the flood. The increase in grit has the potential for inflicting damage upon the treatment units and equipment if not properly removed. Therefore, restoration of these units to operation prior to other treatment processes is essential. Severe damage to the comminutors is possible if bar screens are not present to protect them from large items being flushed through the sewer system.

The flood caused a complete washout of the mixed liquor suspended solids (MLSS) within the aeration basins. In the two months following the flood, the monthly average values for the five day biochemical oxygen demand (BOD5) and suspended solids (SS) of the plant's effluent were extremely high. This observation corresponded with the low MLSS concentration in the aeration basins. However, as the MLSS concentrations were increased and a new microbial population established the BOD5 and SS concentrations decreased. By March 1986 and May 1986 NPDES effluent limitations were being met for SS and BOD5, respectively.

The biological nitrification process was severely affected by the flood and did not return to normal operation until June 1986. From the time of the flood through May 1986 the facility exceeded required effluent limits for total Kjeldahl nitrogen (TKN). The violation can be attributed to the period of acclimation required by the autotrophic organisms that were hampered by the low winter temperatures following the flood. To reestablish the microbial population, sludge wasting was ceased.

The Roanoke facility violated each of its discharge permit limits except for chlorine and pH. Each parameter and its associated process was affected for a varying length of time. However, all violations appear to be a result of acclimizing new organisms or process adjustments and not a result of prolonged downtime following the flood.

Although the treatment processes were in a period of adjustment following the flood, the State Water Control Board (SWCB) cited the City of Roanoke as being in Significant Non Compliance (SNC) for TKN for the months of January 1986 - May 1986. However, due to the efforts of the plant personnel to regain effective operations and due to the extenuating circumstances of the flood, the SWCB granted the City of Roanoke an exception to the SNC citing for effluent TKN values. No formal enforcement actions against the City of Roanoke, other than the SNC citing, were iniated by the SWCB with regards to the effluent limit violations.

CITY OF LEXINGTON SECONDARY TREATMENT FACILITY

The City of Lexington facility was also severely damaged as a result of the flood. The facility discharged raw and/or chlorinated sewage for 3 months prior to the startup of the primary treatment units. All treatment units were operational by May 1986 and all NPDES effluent limits were consistently achieved by September 1986. Total repair costs were in excess of $800,000. In direct contrast to the City of Roanoke facility, the City of Lexington facility was the subject of a SWCB investigation into the delayed repairs and postponement of restoration of service, resulting in a court order providing construction deadlines and completion dates.

Background.

A total of 10.7 inches of rain fell on the City of Lexington from October 31 to November 4, 1985. The Maury River adjacent to the facility has a flood stage of 913.5 feet for a 100-year occurrence and 917 feet for a 500-year occurrence flood. On November 4 the flood stage was reached and the river crested at 923.3 feet. As a result, the facility was flooded and ceased operations. The flood waters ultimately reached a level of 8 feet and 10 inches in the main control building.

The 1985 flood was the fourth major flood since 1950. The City of Lexington, on the whole, does not have a flood problem; however, the treatment facility is located on an island in the Maury River. Consequently it is within the floodplain. A February 1978 Flood Insurance Study was conducted to assist in the administration of the National Flood Insurance Act of 1968 (18). This study identifies a City ordinance which prohibits or restricts development within the floodplain. The study also identifies several old dams on the river, which are not flood control structures, that present the possibility for increasing the effects of floods in the area by production of backwater. One such dam is located adjacent to the wastewater treatment facility.

Facility Damage and Operational Responses.

The majority of the physical damage caused by the flood was to the electrical equipment. Additionally, there was damage of a minor nature to buildings and handrails. Large amounts of debris were scattered throughout the grounds, treatment units, and buildings. One component of treatment facilities that did receive severe damage was the enclosed sludge drying beds. The fiberglass enclosure was destroyed as were the sand beds and underdrain systems. All treatment units and equipment were completely under water except for the digesters. A November 21, 1985 letter from the City's engineering consultants provides the following assessment: "the damage was generally confined to an accumulation of silt and debris in the treatment units and flooding of electrical motors and switchgear" (19).

The flood waters rose to a height of 8 feet and 10 inches within the control building, or a river stage of 923.3 feet. The control building contained all of the main electrical equipment, laboratory space, boiler facility, and an emergency generator adjacent to the structure. None of the flooded equipment was protected and required repair or replacement.

No significant structural damage occurred to the treatment units with the exception of the sludge drying beds. All treatment units were filled with debris and required cleaning prior to resumption of normal operations. Vulnerable equipment was unprotected and the capability for equipment removal was not present, thus increasing the level of damage.

Because the wastewater facility is located on an island it bore the brunt of the storm and floodwater. In addition to the previously described damage, several vehicles were washed down river, fencing was destroyed, and personnel had to be rescued. The facility was totally unprepared for the flood and for the subsequent recovery operations.

The wastewater facility is located close to the headwaters of the river making early flood warning difficult. The facility site and all components were without protection and completely vulnerable to the full effects of the flood. Additionally, an established emergency preparedness plan to aid in the recovery process was not available. The need of both flood warning and emergency preparedness planning is evident considering the length of the recovery period.

Immediately after the flood, the responses seemed to be appropriate. City personnel proceeded with debris removal, removal of electrical equipment, consulting with contractors and engineers, and general cleanup efforts. However, the

City of Lexington exceeded the reasonable time period for placing the treatment facility back into operation. The consulting engineer was asked to redesign the electrical system. A contract was not signed with the contractor until 7 months following the flood. The treatment units were returned to better than preflood conditions as were the pumps, motors, and electrical systems. For a considerable period of time, chlorinated raw sewage was discharged, and only after regulatory action did attempts at partial treatment occur while repairs continued.

In reviewing the timeline of response events and related documents, it was noted that not until March 20, 1986 did the Lexington City Council approve the signing of a contract or the obligation of funds. Also at this time the City declared a state of emergency (20). Why did it take 5 months to authorize expenditures and declare the emergency? Why were the emergency funds that were available in the City's budget not utilized earlier? The May 21, 1986 edition of the Roanoke Times and World News included an article regarding this situation, which in part stated"... at least one member of the Lexington City Council said last week that one reason it's taken more than six months to get reconstruction under way was that the City's insurance carrier was slow to decide how much of the damage it would cover." Additionally, the City Manager stated "... finances were not an important factor" (21). A December 3, 1985

Virginia State Water Control Board (SWCB) memo quotes a city official as saying "the City Manager has not authorized any expenditures for equipment pending receipt of the consultant's report and the FEMA and insurance company's funding decisions" (22). Other facilities went forward with what needed to be done, without the guarantee of reimbursement.

Debris cleanup and equipment removal continued well into February and March 1986. The grit pumps removed for repair in February were returned in April. Primary operations resumed in February and rehabilitation work continued throughout the Spring in an effort to continually upgrade treatment capabilities. Another point of interest is that not until March were 24 hour workshifts initiated as part of the recovery effort (23). It appears that had this been done at an earlier date, recovery would have taken less time.

In reviewing the history of the City of Lexington flood response, it is evident that the City of Lexington did not commit enough resources to their response, did not recognize the nature of the emergency soon enough, and did not schedule priorities efficiently (20). It is obvious that regulatory agencies and facility personnel should try to learn from past mistakes and enhance the ability to cope with flooding in the future. Also evident is the need for enhanced cooperation and working relationships between municipal facilities and regulatory agencies. Stricter regulations to require methods of flood damage reduction and emergency preparedness planning, as well as enhanced enforcement capabilities to prevent needless delay in returning facilities to normal operations, are needed.

VIRGINIA DEPARTMENT OF HEALTH RESPONSE TO THE 1985 FLOOD

Currently, the responses and actions of the Virginia Department of Health (VDH) to natural disasters are governed by Action Memorandum 291, the purpose of which is "to provide Division of Water Program Staff with an information and data base enabling them to face an emergency situation in a professional manner" (3). During times of disaster the VDH staff will implement the State regulatory responses regarding restoration of public drinking water quality and municipal wastewater disposal. The memorandum was used as guidance for the VDH response to the 1985 flood.

In response to the 1985 flood, the VDH expended 1.54 personyears of labor at an approximate cost of $50,000 of nonbudgeted funds (17). The majority of the damage was within the area controlled by the Lexington Regional Office. Additional engineers from other offices were assigned to assist in the disaster response. The first priority was the restoration of public water supplies. Personnel were also assigned to federal disaster teams for damage surveys. A significant portion of the time was expended in providing assistance to public water supplies in the restoration of treatment and water quality monitoring. In direct contrast assitance in facility restoration was only done to a limited extent at the wastewater facilities. The majority of the effort at the wastewater facilities involved damage surveys and investigation of repair status.

Based on the opinion of this author (who was a response team participant), the wastewater facilities were overlooked and given last priority. The priority may be attributed to a) Action Memorandum 291 which provides minimal information regarding reaction to a disaster at a wastewater facility and b) the overall perception that wastewater facilities were of secondary importance. As a deterrent to potential public health hazards, restoration of wastewater facilities should be given higher priority both in documented instructions, actions, and distribution of personnel resources.

The possibility exists that, if the VDH staff had been better informed and trained regarding the specifics of assisting a wastewater facility during or immediately after a disaster, unnecessary delays in restoration of effective wastewater treatment may have been avoided. Training of the VDH staff and facility personnel would have helped to reduce delays in treatment restoration. Supplementary information must be provided to enhance response to disasters. The intent is not to imply that the responses by the VDH were inadequate or irresponsible, but to suggest that responses and assistance can be enhanced for future disasters.

It is apparent from reviewing the present and draft regulations that the Virginia regulations can be enhanced with a more detailed discussion of requirements for flood proofing, vulnerability analysis, and emergency preparedness planning. Also an appendix could be added to discuss flood damage reduction. This change would provide design engineers with additional guidance and information regarding content and preparation of flood protective designs and emergency preparedness plans. The appendix would not only assist the designer but also facility personnel regarding recommended or required actions and state regulatory agencies in their design review and inspections. It is evident that the Corps recommendations to the Pennsylvania DER, as previously presented, are applicable in Virginia and as such should be considered for implementation.

SUMMARY

As shown in the preceding sections the two facilities had a great deal in common as a result of the flood, but with differing final results. While the City of Roanoke was able to restore its facility to full operation in a short period of time the City of Lexington waited in excess of one-half year prior to signing a construction contract. Roanoke did only what was necessary to quickly return to operation while Lexington went well beyond what was required for restoration of services and thereby increased the length of time the facility was inoperable.

Why were there extreme differences in the two responses? Four reasons are apparent a) Roanoke had an emergency preparedness plan and Lexington did not, b) Roanoke apparently put greater emphasis on the repair and/or replacement of needed equipment, while allowing for additional repairs later on, c) Roanoke saw the true nature of the emergency and the need for timely and well planned efforts in the aftermath, and d) Roanoke provided greater cooperation with the regulatory agencies and support organizations to establish an overall sense of cooperation. This is not to say that the City of Lexington did not do their utmost in the months after the flood, but that their efforts may have been misdirected or inappropriate given the nature of the effects their actions yielded. This conclusion is upheld in that they were involved in a Court decision to establish enforceable compliance dates by the SWCB. That they did not receive financial penalties as well was a result of ineffective regulations and a SWCB Board of Directors decision not to seek penalties. Had the threat of financial penalties been a reality and more enforceable, the situation may not have developed as it did. Additionally, better information, planning, and cooperation would have been of assistance. Currently there is inadequate direction and guidelines for regulatory involvement and assistance in disasters involving wastewater treatment facilities. Therefore, the opportunity for improvement is available.

CHAPTER 4. RECOMMENDED FLOOD DAMAGE REDUCTION ACTIONS

Flooding of wastewater facilities results in both economic and environmental hardships that may be prevented or limited if necessary flood damage reduction actions are taken. Guidance and information to both VDH and wastewater facility personnel will be provided in this chapter in an effort to reduce flood damages. This chapter proposes expansion of existing VDH guidelines and is intended to be used as the basis for a training manual. If adopted the manual could be made available upon request to the VDH or through training seminars and workshops.

Existing design practices and regulations address the flood issue for new facilities. However, many facilities were designed with no consideration of potential flood problems. All facilities can benefit from flood damage reduction methods and emergency preparedness planning.

The vulnerability of facilities is directly related to design factors such as site location, equipment, and construction materials. Although facilities may be rendered vulnerable, current Federal and State requirements for new facilities are limited regarding flood protection. All new facilities should achieve the maximum amount of protection available and current regulations, which require protection up to the 100-year flood level, should be considered the minimum standard. Flood problems at wastewater facilities are the result of regulatory standards at the time of design. Vulnerable facilities are mostly older (prior to 1970) due to lack of guidance at that time. Newer facilities have been floodproofed and better located for two reasons a) federal influence regarding financial assistance for construction and b) public awareness resulting from recent flood events (9).

To effectively reduce flood damages regulations and guidance must become more stringent and the current level of public awareness increased. Wastewater treatment facilities may be readily returned to operation following a disaster if the following are adhered to a) effective emergency preparedness planning, b) relevant instruction and training of facility personnel regarding flood damage reduction and followup measures, c) effective procedures to insure flood proofing, and d) cooperation with regulatory agencies to ensure that the necessary planning is accomplished and that the correct responsive actions are executed, prior to, during, and after a flood event.

EMERGENCY PREPAREDNESS PLANNING

Proper planning for an emergency is essential to limit confusion regarding establishment of priorities, operational procedures, equipment removal or protection and individual responsibilities. Planning should include emergency preparedness and responses, evacuation procedures, local flood warning systems, and a vulnerability analysis of the facility.

Each facility can effectively and efficiently reduce flood damages through the development and implementation of an emergency preparedness plan. The plan should be written with annual updates. Emergency preparedness plans can also provide additional protection where other reduction methods are impractical or have failed to provide adequate results. The plan should not be an organizational chart solely indicating the responsibilities and duties to be carried out by each person. However, these descriptions should be included as they are necessary for a successful effort. More importantly, the plan should detail the mission and capabilities or needs to complete the mission. An effective plan requires planning, disaster analysis, and coordination. Adequate flood warning and resources are essential. It should be recognized that the impacts of flooding may be effectively dealt with once the flood threat is recognized, a plan of action exists, and the capability to implement the plan is available (9,13,14).

Flood Recognition.

Information regarding the magnitude of the flood event and the likely time of occurrence are essential for implementing an emergency response. The amount of warning depends upon rate of flood water rise, rate of water entering the watercourse, and facility location. The ability to respond depends upon the ability to recognize a potential flood threat. A flood warning and recognition system should be implemented to measure precipitation and water levels, to predict timing, and determine magnitude of the event (4,8).

The National Weather Service (NWS) operates two independent flood warning systems the Flash Flood Warning System and the River Forecasting System. The NWS flash flood watch will usually precede an actual flash flood warning. These warnings will provide the necessary information regarding the potential situation and extent of flooding. River forecasts will provide information regarding river stages at a specific location and time. This information is useful if the river stage is known where the facility will be flooded and to what extent. The NWS will provide assistance to local governments in implementing forecast procedures (9,24).

Upon recognition of an imminent flood this information must be made available to those responding. On watercourses monitored by the NWS this information can be obtained through news releases on the National Oceanic and Atmospheric Administration (NOAA) radio or teletype service, or through the local disaster coordinator. The local coordinator is responsible for monitoring local weather conditions, developing forecasts, and issuing local warnings as required (9).

One or more persons responsible for facility operations and decision making should be aware of the flood warning systems operating in the area and how they are implemented. These individuals in turn know how to react to various warnings. An understanding of local watercourses and warning systems will assist in the proper responses and effective damage reduction or prevention (24).

The overall effectiveness of an emergency operations plan is influenced by accurate and timely warning and effective responses. Early warnings may result in inaccurate information, but more reaction time, whereas later warnings do not allow sufficient reaction time. Therefore, forecast accuracy is essential to allow for the correct responses to be implemented. For a recognition and flood warning system to be effective the amount of warning time must equal or exceed the anticipated response time (9).

Flood warning may be enhanced by maintaining relative information regarding flood warning systems in the local area. The warning time available vs the warning time required for preparation must be compared and evaluated.

The amount of warning time required and the decreased reliability of early warnings must be considered in decision making. Overall planning efforts should include the required time to accomplish each action (24).

Vulnerability Analysis.

If a facility is located in a flood prone area, treatment efficiency and performance will be affected. The design of most facilities inadequately addresses or corrects their inherent vulnerability. A vulnerability analysis is essential to determine the effects on each facility and to investigate remedial actions through design or response. In short the most common effects to be considered are loss of power, access, communications, and failure of processes and/or equipment (9,13).

The vulnerability analysis should estimate the degree to which the system is affected adversley in relation to its responsibility. The vulnerability analysis can be completed only in terms of one specific facility and event. The analysis must be conducted for a range of flood events to identify the most vulnerable components of the system (14). Upon identification of the most vulnerable facility components, planning should be conducted and plans implemented for their protection or to reduce their overall vulnerability.

A vulnerability analysis will involve the following

(9):

a) Listing the components of the treatment system,

b) Determining the potential flood event,

c) Estimating effects on each component,

d) Estimating the system's ability to function,

e) Identifying components responsible for failure,

f) Reiterating for another flood event.

The vulnerability analysis will identify the effects different flood occurrences will have upon the facility. With this information the flood elevations for different events can be included on cross-sectional plans of the facility and will graphically indicate which system components are likely to be affected for each flood event. If flood profiles are available for nearby river gauging stations, the river stage forecasts can be correlated to flood stages at the facility site. Therefore, the vulnerability assessment and emergency preparedness plans may be directly related to river stages (9).

The vulnerability analysis should be completed using the following information:

a) Flood History,

b) Flood Source Identification,

c) Flood Stages,

d) Flood Warning System,

e) Flood warning and Evacuation Time.

The analysis will determine the relative vulnerability for each building, system component and evacuation priority. The areas being flooded first and the locations with critical equipment should be given the highest priority (24). Each area of the analysis is discussed in the following sections.

Flood History. Historical information pertaining to previous floods should be reviewed and pertinent data obtained. The data should include date of flood event, height of water level in plant, flood elevation, damage experienced, and the source of flooding.

Flood Source Identification. Each potential source of flooding should be identified prior to determination of the available options. Each source will be affected individually by the location, duration and amount of rainfall. Additionally, the soil conditions and topography of the watershed and location of the facility will all impact the extent of flooding. Flooding may occur through accumulation of localized runoff, ponding or creation of backwater due to downstream obstructions. The maximum water elevation for each source, based upon a given flood event should be determined along with the amount of rainfall or storm intensity required to produce the event (24).

Flood Stages. The flood stage (river stage) for each watercourse during varying flood events should be identified. Previous flood histories or information from NWS, USGS, and state regulatory agencies can be used to estimate these levels.

Flood Warning And Evacuation Time. In the planning process and for the vulnerability analysis the warning times for previous flood events must be determined. The warning time is the elapsed time between issuance of a warning and the arrival of flood waters. The actual warning time should be used to estimate expected warning times for planning purposes. The rate of rise and total rise of the stream are also useful for planning. The rate of rise is the warning time divided by the total feet of rise and the feet of rise is the difference between the pre-storm water level and it's crest. These estimates will assist in scheduling evacuation efforts or flood proofing. The evacuation time scheduled must not exceed the expected warning time.

Plan Content.

The emergency preparedness plan should implement measures to mitigate the vulnerable areas identified in the vulnerability analysis. These measures may be either preventive or restorative in nature. The plan should not be complicated or cumbersome, but it should provide necessary information for well coordinated and efficiently executed actions (9,24).

Preventive measures include flood proofing (structural and nonstructural), evacuation, and operational adjustments. Flood proofing may reduce damages to critical equipment or permit uninterrupted operations. Evacuation of equipment and supplies should be discussed in addition to flood proofing methods (9).

Adjustments to facility operations or the ceasing of plant operations may be necessary to allow for flood proofing and evacuation. This action is justified if overall damages are prevented. Likewise this may aid in the reduction of facility downtime and repair requirements (9).

An emergency preparedness plan has seven basic components:

a) Assumtion of potential flood damages,

b) Estimation of remaining treatment capabilities,

c) Estimation of treatment Requirements,

d) Match capabilities to requirements,

e) Specification oftreatment and restoration priorities,

f) Discussion of efficient resource usage,

g) Presentation of personnel assignments.

The plan should also detail what actions are to be initiated and who is responsible. Implementation of the actions are related to floodstage predictions through previously established river stage criteria and the related effects on the facility, priority of evacuation, and facility cleanup and restoration actions (9).

Once a decision is made that a flood will affect a facility the emergency preparedness plan must be reviewed to determine what actions are required for the expected situation, their relative priority, and when they should be implemented. Their implementation must be prior to reaching the critical flood stage. If evacuation is included in the plan the following should be considered a) removal of files, records, equipment, b) personnel and equipment required, and c) storage location (9).

The electrical system, due to its relative importance, should be given a high priority for both evacuation and protection to reduce startup problems. Duplicate units should be removed early to provide a more rapid startup following flooding. All equipment at time of removal prior to or after the flood should be tagged to allow for more efficient reinstallation. An equipment removal and repair tracking system should be developed to identify the location of each item not physically installed and its anticipated date of return (24).

During development a plan should be coordinated with local municipal and state officials as well as those persons providing outside assistance such as trucking or repairs (9). During implementation, the progress must be carefully monitored for timing with the rising floodwater, and adjustments made as required (24). The rapid resumption of plant operations can be influenced by the inclusion of a plan for cleanup and restoration. Personnel must be identified to complete these actions and the equipment and materials required. Cleanup actions should begin as soon as the facility is safe to enter. Restoration and repairs can be accomplished more efficiently by coordination and planning with the vendors and repair personnel involved. Each item of equipment should be tagged and identified to reduce confusion during reinstallation and for tracking purposes. Standby emergency generators may be required until normal electrical power is restored, portable emergency lighting should be obtained and facility personnel should not be overworked; therefore, outside manpower may be required for additional workshifts (24).

Facility personnel should not wait until all units are fully operational prior to attempting startup. Attempts to enhance the facility to better than pre-flood conditions should not be implemented. Restoration should be such that the preliminary and primary process are brought online and the discharge disinfected while the other units are bypassed. Every attempt should be made to allow as much treatment as possible during the repair process. If possible treatments units should be made functional and later when dual units are working additional repairs and equipment overhaul should be completed. Thus a tradeoff between treatment and future equipment malfunctions must be made. The plan must include methods and requirements for additional equipment necessary to implement partial and/or temporary treatment measures.

FACILITY DESIGN

Facility designs and locations are such that plants are more vulnerable to flooding than necessary. Many facilities utilize underground electric services and below ground locations for pumps, motors, and costly equipment situated with no reasonable method of removal to prevent damage or any form of protection. Adjustments to existing facilities and awareness in new designs is essential to reduce flood damages and to aid facility evacuation. Flood damage reduction can be accomplished through structural or nonstructural methods. Structural changes require extensive engineering and will not be discussed within this chapter. Nonstructural methods are more commonly referred to as floodproofing and are more apt to be considered (24).

Flood proofing measures may range from small levees or dikes to watertight doors and windows in and around individual buildings and units to delay or reduce the entry of floodwater to plant equipment modifications. Modifications include elevating critical or expensive equipment, electrical controls, emergency generators, and other vulnerable equipment. Buildings, treatment units, and equipment may be modified to aid in evacuation by the use of loading ramps, vertical access, portable and stationary lifts and hoists, prevention of equipment flotation, quick disconnects on pumps and motors, color coding of connections to be removed, lift bars and eyelets, and centralized power switches to aid in shutting off power to inundated areas while maintaining power elsewhere in the plant (24). These modifications will aid in equipment removal, replacement. and will allow for personnel other than qualified personnel to assist in their removal and reinstallation.

Facilities should be protected to a minimum of the 100-year flood level, while still being cost effective. A benefit-cost ratio must be conducted to determine the economically achievable flood reduction actions. Benefits should include the value of flood damages prevented. Costs should include a) construction costs and required equipment modifications, b) flood insurance premiums, c) costs of evacuation and clean-up, and d) uncompensated damages (9).

Stage-frequency and stage damage relationships should be developed for the facility and utilized to compute expected annual damages. These relationships should be used to assist in determining the required flood damage reduction measures. These concepts along with those pertaining to benefit-cost analysis will be presented in the following sections.

Design Issues.

The vulnerability of a treatment facility to flooding depends upon location, layout, equipment, and treatment processes. The major processes in wastewater treatment are physical, biological, and chemical. Flooding of the physical or primary units is significant since the effectiveness of the entire facility is reduced. Physical damage will not usually occur to these facilities but performance will be affected because the design level of solids removal will not be achieved (9).

Biological processes are extremely vulnerable since the mass of microorganisms is subject to being washed off or out of the treatment unit. Restarting of biological processes may require seeding of the reactor unit, or period of microbial acclimization and effective operations to aid the start-up of the unit. The facility's consulting engineer or the regulatory agencies should be contacted if assistance is required to regain effective operations. History indicates that discharge limitations will be exceeded during this period (9).

If chemical treatment units are not completely inundated, their effectiveness will be decreased due to dilution of the wastewater and a reduction in detention times (9).

Facilities are designed and situated to promote gravity flow, resulting in underground equipment locations, and decreasing unit elevations. Therefore, vertical elevation is critical in determining a facilities vulnerability to flooding. Below ground locations are subject to total inundation, equipment flooding, difficulty of evacuation, and should be avoided or protected. Facilities should be designed and sited to minimize use of low lying areas or the elevation of vulnerable equipment should be accomplished (9).

Flood Damage Reduction Measures.

Flood damage reduction measures include flood proofing and flood protection, equipment modifications, and quick recovery of operations. Flood proofing measures may be either wet or dry. Dry flood proofing prevents floodwater from entering the structure. Dry flood proofing is accomplished by permantly or temporarily sealing all possible points of water entry up to a specific elevation. Points of entry would include doors, windows, vents, and utility conduits. Low level openings can continue to be functional if surrounded by a low wall. Sandbag enclosures or walls and removable flood shields are effective. Temporary flood proofing measures have disadvantages over permanent ones since they require periodic maintenance and sufficient flood warning time, personnel, and equipment to react (9).

The degree of protection attainable from dry flood proofing is limited by the strength properties of the structure. The structure must be able to withstand additional flood related forces; otherwise, structural failure could occur. Dry flood proofing should be discussed with a qualified engineer (9).

To achieve dry flood proofing it will be necessary to prevent the entry of water through other entry points and to install internal drains. Backup of floodwater through pipes can be prevented by installation of an anti-backflow device (9).

Wet flood proofing involves changes to the building contents to reduce their vulnerability to flooding. This approach is suitable where inundation poses no problem but where contents are susceptible to damages. The primary way to achieve this is to raise or elevate equipment. Flood protection modifies the area, depth, and duration of flooding. These measures can either prevent the entry of floodwater into the protected area or allow additional time to complete emergency response actions (9).

Changes to plant equipment can also help the flood proofing operation. These changes include provisions for quick removal and reaction to the floodwater. To effect the quick removal of equipment requires the following a) ability to remove rapidly, b) easy and direct access, and c) ability to lift the equipment. Removal can also be delayed by electrical connections. An economical remedy is to use an electrical quick disconnect. With the power supply shut off these enable quick removal and reinstallation of equipment. Reconnection of complex wiring can be simplified by using waterproof labels and color coding. Mechanical connections may also be modified through color coding (9).

Ideally, all equipment should be accessible with a hoist and easily transported during evacuation. To enable lifting equipment should be fitted with a lifting eye or ring. Enclosed tanks which are subject to flotation should be properly secured to prevent damage elsewhere.

FLOOD DAMAGE RELATIONSHIPS

Frequency-damage relationships are the most widely used methods to estimate flood damage reduction benefits and requirements. The expected annual damage is determined from all possible flood events. Four steps are involved a) stage-frequency relationship, b) stage-depth relationship, c) depth-damage relationship, and d) determination of the frequency-damage relationship. Flow frequency relationships may also be developed and a rating curve to relate water elevation to flow and to transform flow-frequency to elevation-frequency relationships. When the relationships are combined with elevation-damage data, annual damages can be determined (12,13).

Stage-frequency relationships present water surface profiles showing water elevations for different flood events at a determined river location. Stage-damage relationships consist of two parts a) location of the structure relative to flood profile and b) determination of structure elevation. The damage to the structure and contents is estimated according to the flood stage profiles. The total volume of the property and percentage of damage with regards to flood levels must be known. Depth-damage relationships apply a percent damage factor related to the depth of water. This is determined based upon depth of flooding and property value (12).

Frequency-damage relationships proportionally weight the damages from each flood event by the probability of occurrence. Large floods with low probabilities contribute less to the determination of expected annual damages than do smaller floods with a high probability of occurrence. As a result, frequency-damage relationships must be more accurately determined for higher probability events (12).

Estimation of damage to more than one structure at a time can be accomplished by the flood profile method. The stage-frequency relationship at the river location, the property value and elevation, depth-damage relationships, and damages from each flood event are determined. Damages are determined for each structure and then summed. The damage values are then converted to expected annual damages

(12).

Benefit-Cost Analysis.

Benefit-cost analyses are useful in determining the feasibility and cost effectiveness of a proposed flood damage reduction measure. Occasionally other factors may indicate a flood reduction measure other than that which is most economical (10).

Each alternative is evaluated by comparing the benefits and costs. To be feasible economically the benefits must equal or exceed the costs. Discounting techniques should be used to reflect the time value of money. The discount rate should be determined in accordance with the procedure provided by the Water Resources Development Act of 1974. Benefits may be considered as prevented damages. Prevented damages are the differences between damages with and without implementation of the project. Since flood control or damage reduction benefits are a classic public good the benefits may be determined in this manner, as rational people would be willing to pay up to the expected damage value to avoid the damage (10,12).

The cost function should include flood damages, disaster relief, intangible effects, remedial measures, and administration costs. Overall, the analysis may be biased by inacurrate estimates of structure elevations, excluding unemployed labor use as a benefit, and failure to evaluate structure replacement as an alternative (12,25).

The Federal Emergency Management Agency (FEMA) has determined through many investigations and studies that floodproofing is cost effective. These studies have indicated that dry flood proofing methods are more justifiable than are wet flood proofing measures (4).

RECOMMENDATIONS FOR VIRGINIA DEPARTMENT OF HEALTH ASSISTANCE

Design Review.

All new wastewater treatment facility designs must be reviewed with flood damage reduction and evacuation in mind. If designed adequately the potential for flood damage may be eliminated or reduced. It is the responsibility VDH engineers to insure that this issue is adequately addressed for facilities located within flood prone areas. The following is a list of suggestions to assist the review process:

a) Insure that the operations and maintenance manual is prepared in accordance with the Sewerage Regulations,

b) Review the vulnerability analysis and Emergency Preparedness Plan for completeness,

c) Determine if the most efficient and practical methods of flood proofing are included,

d) Determine flood elevations as related to river stages and include on a cross-sectional drawing of the facility,

e) Determine the ability to bypass units and provide temporary or partial treatment,

f) Determine if provisions to assist in evacuation are included,

g) Provide technical assistance as required to ensure an effective floodproofed design.

Flood Damage Reduction Inspections.

Routinely scheduled inspections of wastewater treatment facilities by regulatory agencies provide opportunities for discussing flood damage reduction with facility personnel. The following is a list of suggestions:

a) Become familiar with the flood history of the facility and document for office files,

b) Encourage training of facility personnel regarding flood damage reduction,

c) Identify potential flood damage areas,

d) Identify existing flood protection measures,

e) Identify and discuss needed flood protection measures, provide assistance as needed to implement,

f) Review the operations and maintenance manual and emergency preparedness plan for completeness,

g) Encourage cooperation between facilities and regulatory agencies.

Flood Damage Response.

Each engineer and operator should have an understanding of the damage potential resulting from a flood event. Prior knowledge will aid in the response and ability to make informed decisions. One of the major difficulties to be encountered will be debris. Extensive personnel and machinery will be required for removal. It is imperative that all debris be removed quickly to allow access to damaged areas. The ultimate goal is to provide as much treatment as possible in the shortest time. Complete repairs on dual units should not be attempted. One may be completely restored while the other is quickly returned to operation with additional work at a latter date. These guidelines should be tailored to individual needs and included in the emergency preparedness plan along with pre-flood actions. Regulatory personnel should offer assistance whenever possible. The following will discuss potential situations and responsive actions:

a) If the facility has been partially or totally submerged by flood waters all debris should be removed and the extent of damage determined.

b) Equipment needed to restore partial operations should be identified for immediate purchase, removal, replacement or repair. All equipment should be tagged to aid in reinstallation. The units most basic to operations should be returned to service with the highest priority. If possible, concentrate the majority of initial efforts on one-half of dual train systems so that partial treatment may be restored quickly.

c) Engineering staff and contractors should be consulted with as necessary regarding repairs, design needs and scheduling of contracts. Emphasis the importance of the situation and that timely service is expected. Utilize various contractors and repair companies to enhance turn around times. Duplicate items should not be sent to the same location to prevent backlog and to enhance probability of timely returns. Deliver and pickup equipment to repair centers as practical.

d) Coordinate with state and federal agencies regarding financial assistance. Seek advice and involve your regulatory agency in all aspects of the restoration process. Cooperation is essential to achieving a beneficial outcome.

e) Do not turn on lights or any other electrical item until the entire system has been inspected for short circuits. An electrical system that is or has been partly submerged is dangerous and should be approached with caution. All submerged motors will have to be baked out before placing back into operation. All mechanical equipment will have to be cleaned and lubricated before placed into service.

f) Resumption of operations should be fairly straight forward for the preliminary screening and primary treatment units. Resumption of operations in biological treatment units may require the use of a "seed" and a period of acclimation. Contact consulting engineers or a regulatory agency for assistance in this, if needed. Tertiary filtration units should have the mud and silt removed from their surface. The filter must not be allowed to dry out. The filter should be repetitively run through filtration and backwash cycles until a clear product is produced, and the filter is adequately cleaned prior to resuming operations.

g) Salvage as much of the equipment and records from the laboratory and office areas as practical. The restoration efforts should be continually documented in writing and by photographs for later reference.

h) Emergency generators, pumps, and lighting must be made available immediately. For best results and quicker recovery, 24-hour workshifts must be utilized, additional personnel maybe required to accomplish this. However, individuals should not be worked beyond their capacities to accomplish this.

i) Notify the public of ongoing efforts, to prevent unnecessary concern and to request their cooperation in reducing wastewater flows to the facility.

Regulatory Assistance.

The following guidelines should be implemented by regulatory agencies to assist the facility prior to or following a flood event:

a) Assist in implementation of the Emergency Preparedness Plan,

b) Provide assistance regarding bypassing, partial or temporary treatment methods,

c) Provide assistance regarding efficient methods of clean-up and restoration,

d) Provide advice regarding establishment of priorities,

e) Show positive involvement and develop a good working relationship,

f) Provide constant follow-up on-site,

g) Provide assistance during the evacuation or post evacuation decision period,

h) Become involved in relative meetings and discussions with the facilities engineers and contractors,

i) Reinforce the concepts of quick, efficient return to operations. Enforce the concept of partial treatment and allowing for equipment repair to continue after operations are resumed,

j) Be responsive, stay informed and provide regulatory control as needed.

SUMMARY

As discussed in the preceding sections, if guidance and training is provided to VDH engineers and wastewater facility personnel overall flood related damages will be reduced. This chapter is intended to be transformed into a manual for use by the VDH. Implementation of this chapter as in the form of a manual will provide the needed information with regards to emergency planning and design considerations.

These recommended actions should be considered for all new facilities from their conception and implemented at all existing facilities, as needed. Existing facilities with a flood history should pay particular attention and strive to implement emergency planning measures and remedial design features.

CHAPTER 5. RECOMMENDED REVISIONS TO THE VIRGINIA SEWERAGE REGULATIONS

The previous concepts of flood damage reduction in the form of recommended revisions to the Virginia Sewerage Regulations are presented in this chapter. Only those portions applicable to the intent of this chapter will be included and they will follow the format of the existing draft regulations. Recommended additions have been underlined.

Implementation and inclusion of these revisions will serve to provide better guidance for those individuals concerned with flood damage reduction. It is recommended that the revisions be located within several portions of the regulations. A location in the Manual of Practice would be most influential as it is required for compliance with the regulations and is considered as a "shall do" rather than a "should". Additional information is needed within the existing appendix regarding Operations and Maintenance Manuals, and a new appendix to discuss flood damage reduction methods should be added. These last two areas would provide the necessary information for implementation of the Manual of Practice.

RECOMMENDED REVISIONS

MANUAL OF PRACTICE

ARTICLE 3

SEWAGE TREATMENT WORKS

3.18 Plant Location

A. General

A sewage treatment works site shall be located as far as practicable from any existing built-up commercial or residential area, or any area which will probably be built up within the design life of the plant. The treatment works site shall be protected by a buffer zone, located to avoid flooding within the 100-year flood level, provided with year round access, and provided with ample area for any foreseeable future expansion.

C. Flood Protection

All mechanical and electrical equipment which could be damaged or inactivated by contact with or submerged in water shall be physically located above the 100-year flood level or otherwise protected. All other components and tankage of the treatment works shall likewise be protected against the 25-year flood/wave action damage. New facilities shall be designed and constructed in accordance with the flood damage reduction principles contained within the appendices. Existing facilities shall implement these principles on an ongoing basis, to reduce their vulnerability to flooding. Specifically, the issues of emergency preparedness planning, plant site evacuation, ceasing and resumption of operations, removal methods for equipment,and flood damage reduction must be addressed. These must be discussed within the operations and maintenance manual and incorporated within the design as appropriate.

ARTICLE 2

SEWAGE PUMP STATIONS

3.11 Design - General

A. Location

...All mechanical and electrical equipment which could be damaged or inactivated by contact with or submergence in water (motors, control equipment, blowers, switch gear, bearings, etc.) shall be physically located above the 100-year flood/wave action damage. Provisions shall be included to assist in evacuation of equipment for flood events in excess of the 100-year occurrence. All stations shall be designed to remain fully operational during the 25-year flood/wave action.

APPENDIX A

PRELIMINARY ENGINEERING REPORT FORMAT

A.03 Summary

A.03.01 Findings

i. Determination of potential flood sources affecting the proposed site, and an estimation of the effect on the proposed treatment process.

A.06 Investigative Considerations - Existing Facilities Evaluation

A.06.02 Existing Site

g. Flooding - Discussion of the sources of flooding, flood history and previous damages, existing flood damage reduction methods, and stage-elevation-damage relationships.

A.07 Proposed Facility Evaluation

A.07.02 Site Requirements

Comparative advantages and disadvantages as to cost, hydraulic requirements, flood control and vulnerability analysis,...

APPENDIX F

CONTENTS FOR AN OPERATIONS AND MAINTENANCE MANUAL

F.04 Operation and Control of Treatment Works of Sewerage

System

h. Emergency Operation and Failsafe Features

The manual shall include an emergency preparedness plan to discuss the emergency operating procedures for the normally expected range of emergencies and failsafe features, particulary flood events, for each sewage treatment unit and process.

F.09 Emergency Operations and Response Program

An emergency operating and response program (also referred to as an emergency preparedness plan) will be prepared for each facility.

a. Objectives

2. Development of procedures for properly responding to emergencies. Particular attention should be given to flood events.

b. Content

The following information is provided to assist in preparing the plan. These are minimal guidelines only and should be expanded as required by your facility.

1. Develop a flood history. The history should include the frequencies of occurrence for floods of various magnitudes based on stream flow records and other information as necessary. From the severity/frequency estimate, a priority listing of treatment components can be established for use in performing the various system

vulnerability analyses.

2. Perform a vulnerability analysis of the treatment system. Expected natural disasters and their effects must be investigated. Compare the analyses results and identify the most vulnerable system components. List these components and indicate priorities for repair, replacement or alternative equipment or treatment provisions.

3. The manual shall include a discussion of the protection of essential documents.

4. Additional emergency equipment required, based upon existing inventory and the vulnerability analysis will be stockpiled or made available. Emergency and standby equipment will be placed into service periodically. All emergency equipment will be located safely away from potential disaster sites.

5. Designate the area to serve as the emergency operations center. List the staffing and equipment requirements.

6. List the procedures to be followed for reporting damages to the facilities insurance carriers as well as state and federal agencies.

7. Prepare treatment process diagrams to show how units may be bypassed during emergencies and to assist in locating problem areas during emergencies.

8. Coordinate with local utilities and service companies to establish repair priorities.

9. To reduce vulnerability personnel training and flood damage reduction measures shall be indicated.

APPENDIX W

SUGGESTED FLOOD DAMAGE REDUCTION MEASURES

A. General

This appendix is prepared as a source of suggestions and information regarding flood damage reduction. The appendix shall be referred to during the design process and development of the emergency preparedness plan. A more detailed discussion may be obtained from your regional VDH office, in the form of a manual.

Flood protection is an important consideration in the design of all new facilities, and in upgrading of existing processes. Without adequate flood damage protection, costly repairs, regulatory fines and the discharge of improperly treated sewage may occur.

B. The following guidelines shall be considered:

1. Preparation of an adequate, practical and tested emergency preparedness plan. The plan should be updated at least annually.
2. Training and instruction of personnel.
3. Development of or participation in a flood

recognition system.

4. Adequate site selection to minimize the flood risk.

5. Incorporation of flood resistent design.

   a. Flood shields for windows, doors or low elevation openings.

   b. Watertight doors, windows and utility conduits.

   c. Elevation of mechanical and electrical equipment and control units.

   d. Ability to bypass individual unit processes.

   e. Backflow prevention.

6. Increase the evacuation capability of the facility

   a. Quick disconnects and color coding for wiring.

   b. Easy and direct access to equipment.

   c. Provisions for hoists and lifts.

   d. Lifting points on all equipment.

   e. Color coding of fasteners to be removed for each item of equipment.

   f. Maximize the potential for use of unskilled labor during evacuation.

7. Minimize damage by removing equipment prior to flooding and early shutdown of the facility.

CHAPTER 6. SUMMARY AND CONCLUSIONS

Many of Virginia's wastewater treatment facilities due to their construction, design, and location are highly vulnerable to flood events. The facility personnel, design engineers, and regulatory agencies are not knowledgeable of, or trained in, flood proofing and flood damage reduction measures. Through the use of flood proofing and flood damage reduction measures in the design process for new facilities, or for retro-fitting of existing facilities, the economic losses and environmental impacts of a flood can be effectively reduced. In addition, training of those involved with facility operations and design will aid in reducing future losses and operational downtime.

The existing sewerage regulations must be revised to provide strict requirements and guidance for flood proofing and flood damage reduction. Additionally, training sessions must be developed to instruct facility personnel and regulatory engineers in the possible approaches towards reducing the effects of flooding.

The concepts of flood proofing and flood damage reduction, the effects of a flood upon two wastewater treatment facilities, recommended revisions to the current Virginia Sewerage Regulations, and a proposed training manual have been presented. The value of appropriate and adequate planning, design, and operational procedures during and after a particular flood event have been compared and contrasted between the two facilities. Based upon conclusions drawn from these actual events and background information presented, the recommended training manual and regulatory revisions were developed.

As a final conclusion and recommendation the proposed regulatory revisions and training manual should be considered for adoption. Furthermore, the training manual should be used as the basis for seminars; workshops; and presentations to facility personnel, regulatory officials, and design engineers.

REFERENCES

1. Bartch, Eric H., Memorandum to James B. Kenley, November 8, 1985.

2. Bartch, Eric H., Memorandum to James B. Kenley, November 12, 1985.

3. Action Memorandum Number 291, Virginia Department of Health, October 4, 1983.

4. AIA Research Corporation, Design Guidelines for Flood Damage Reduction, October 1981.

5. Veissman, Warren and Welty, Claire, Water Management Technology and Institutions, Harper and Row, Publishers, New York, N.Y. (1985).

6. Smith, K. A., and Tobin, G. A., Human Adjustments to the Flood Hazard, Longman Group Limited, (1979).

7. Novak, J. T., "Planning for Emergencies at Water Utilities." Journal of the American Waterworks Association, p.164-166, April 1975.

8. American Waterworks Association, "Emergency Planning for Water Utility Management." Manual of Water Supply Practices M19, Denver, Colorado (1973).

9. U.S. Army Corps of Engineers, "Flood Plain Management Planning Assistance for the Pennslyvania Department of Environmental Resources, General Recommendations and Procedures for Flood Damage Reduction at Wastewater Treatment Plants." Flood Plain Management Services Branch, Baltimore District, Baltimore, Maryland (1983).

10. Wurbs, R. A., "Economic Feasibility of Flood Control Improvements." Journal of Water Resources Planning and Management, 109, 29-47 (1983).

11. Emergency Management Institute, National Emergency Training Center , Federal Emergency Management Agency, "Flood Protective Design Course" (1985).

12. Plazak, D. J., "Flood Control Benefits Revisited." Journal of Water Resources Planning and Management, 112, 265-276 (1986).

13. Johnson, W. K., "Significance of Location in Computing Flood Damage." Journal of Water Resources Planning and Management, 111, 65- (1985).

14. State of Florida, "Hurricane Disaster Preparedness and Procedure." Department of Environmental Regulation, Tallahassee, Florida (1977).

15. Commonwealth of Virginia, "Sewerage Regulations." State Department of Health and State Water Control Board (1977).

16. Commonwealth of Virginia, "Draft Sewerage Regulations." State Department of Health and State Water Control Board (1986).

17. Hammer, Allen R., Memorandum to Philip A. Shaheen, January 13, 1986.

18. U. S. Department of Housing and Urban Development, Federal Insurance Administration, "Flood Insurance Study, City of Lexington, Virginia." (1978).

19. Wiley and Wilson, Architects Engineers Planners, Letter to City of Lexington, November 21, 1985.

20. Aulbach, John J., personal notes from meeting with State Water Control Board, June 6, 1986.

21. Roanoke Times and World News, "Lexington Waste May Spark Suit." May 21, 1986.

22. Preston J. A., Memorandum to W. L. Woodfin, December 3, 1985.

23. City of Lexington, "Chronology of Actions Taken by the City of Lexington in Response to the Wastewater Treatment Plant Damage Caused by the Flood of November, 1985." June, 1986.

24. Susquehanna River Basin Commission, "A User's Manual for Flood Evacuation Planning of Water and Wastewater Treatment Plants." (1984).

25. McCroy, J. A., James, D., and Jones, D. E., "Dealing With Variable Flood Hazard." Journal of the Water Resources Planning and Management Division, 102, 193-208 (1976).

The vita has been removed from the scanned document