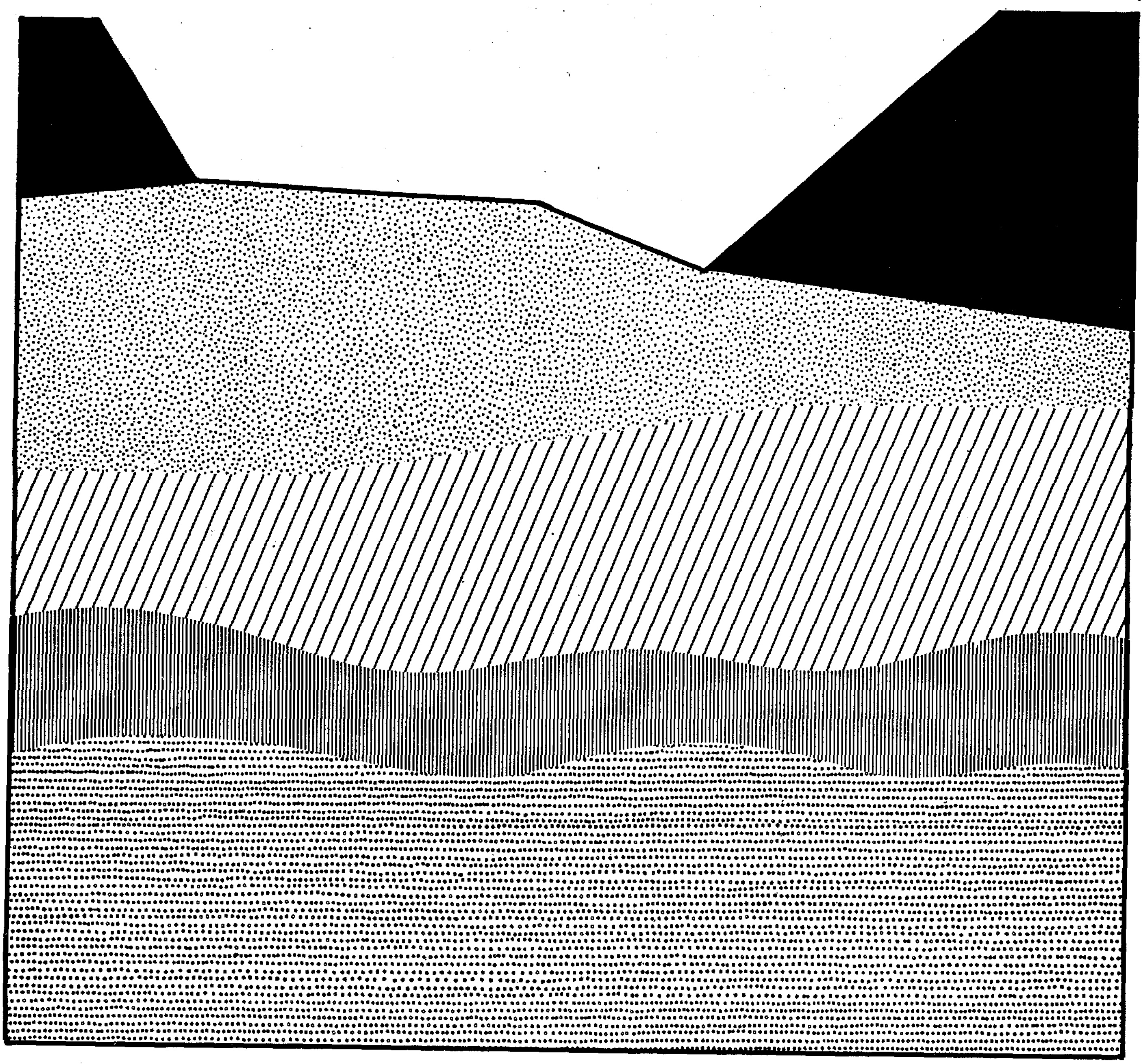
BOILING SPRING LAKES, N.C.



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City of Boiling Spring Lakes

NORTH CAROLINA
28461

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CHAPTER I

PURPOSE AND OVERVIEW

The development of sinkholes in the Boiling Spring Lakes area continues to be a source of annoyance and expense. The sinkholes, which develop as a result of the solution and breakdown of the limestone substructure, make the area unsuitable for both a railroad and a dam (and the associated residential development). Given, however, that substantial investments have been made, the need exists to prepare for actions which will reduce potential hazards and stabilize the situation (i.e., sinkhole development) to the extent feasible and practical.

The sinkhole problem in Boiling Spring Lakes (BSL) has received considerable study by various groups to include the U.S. Army, Army Corps of Engineers, Reeves Telecom Corporation (BSL Developer) and the State Department of Natural Resources and Community Development (NRCD). While much has been learned about the character of sinkholes in BSL, the Town itself has not been provided a means by which to consider the alternative courses of action it may take given the range of possible disasters which could occur from sinkhole development. In an effort to develop an action plan for the Town, Mayor Toney appointed a Mayor's Committee for the Boiling Spring Lakes Hazard Reduction Plan, chaired by Ed Stanley. Following this appointment, the committee made application for, and received funds through the N.C. Coastal Area Management Act (CAMA) for development of this Sinkhole Hazard Reduction Plan for Boiling Spring Lakes.

PURPOSE

The purpose of this plan is two-fold. First, this plan is to serve as a guide to decisions relative to the short term and long term courses of action taken in response to sinkhole activity. Second, through its methodologies, this plan is to serve as a demonstration to other coastal communities plagued with a similar set of scientific, political, and economic circumstances.

Regarding the first of these purposes, the overall goal of the Boiling Spring Lakes Sinkhole Hazard Reduction Plan established by the Mayor's Committee is:

> To maintain the stability of the main lake at Boiling Spring Lakes, to continue to operate the railroad safely, and to provide emergency access to the east side of the tracks, all in a manner which: 1) improves the long-term mutual compatibility of the lake and the railroad, 2) serves the interests of community pride, and 3) is consistent with the adopted Land Use Plan.

OVERVIEW

The Mayor's Committee considered several types of action plans before making a selection. Those considered may be grouped into the following three categories:

1. Prevention.

A prevention plan is one which identifies hazards or causes of hazards before they occur and prioritizes the magnitude and severity of each, and then sets forth a strategy for eliminating the causes or reducing the impact of the hazard over time. This is the kind of plan that one undertakes when he realizes that toys on the staircase causes home accidents, and then sets about the house to clear the stairway of toys and other items.

2. Reaction.

A reaction plan catalogues disaster situations in great detail and articulates, step by step, which party will react in which situation and in which way, organized by level of situation. Emergency Management Plans and Military reaction plans are set forth in this format.

3. Policy Strategy.

A policy plan and strategy plan which assumes a particular level of catastrophe, sets out mutually agreeable objectives among the parties involved, and identifies and analyzes suitable technical solutions. This plan would provide a basis for coordinated and effective action toward collective objectives in the event of an incident within a narrow range of solutions, rather than dwelling upon the details of each isolated incident and a multitude of solutions.

The latter category, Policy Strategy, was the planning framework adopted for the Boiling Spring Lakes effort.

Within the Policy Strategy framework a number of planning methodologies were utilized based upon the need to address both technical and political concerns and stimulate new ways of thinking about a situation which has existed for years. The following is an overview of the methods used with the details of their application (and respective results) presented in each subsequent chapter.

In order to establish a representative base of the community, Mayor Toney appointed the Mayor's Committee for the Boiling Spring Lakes Hazard Reduction Plan. This group provided invaluable information regarding the history of the problem, previous efforts to study it, relationships between parties involved and contacts for interviews and data collection.

In order to gain as much technical information and expertise into the product as possible, the Chairman of the Mayor's Committee appointed a Technical Adivsory Committee (TAC) comprised of representatives of the governmental and scientific community (see credits page in the front of this document). After having studied the technical background papers related to the project (see bibliography, Appendix C), the consultant interviewed members of the TAC individually to collect their perceptions and references for collection of additional technical material. These findings were placed into a working paper which became the foundation for the problem identification phase of the project (See Chapter III).

In addition to the Mayor's Committee and TAC, the U.S. Army became an important component to the planning effort. Invitation to participate on the TAC was extended to Colonel Heizman at Sunny Point, who due to legal constraints, was only able to participate through written correspondence and selected interviews. The information provided by the U.S. Army was essential and the method of contact provided the necessary "methodological link" between the TAC and the Army.

The Corps of Engineers declined the invitation to participate on the TAC, primarily due to the fact that they are a representative of the U.S. Army.

The Brunswick County Planning Department opted not to attend the TAC meeting, but rather respond in writing. The Resources Development Commission did send a representative.

Over the course of the project, the Mayor's Committee and the TAC met alternately, allowing the consultant to structure working papers and assignments accordingly. It was through this design that the technical and political aspects of the problem were kept in proper balance.

Following the establishment of the TAC, creative analysis of the technical material was undertaken through group work sessions which focused on scenario writing (see Chapter III). This exposed many of the ways in which the major parties would react to future sinkhole-related problems.

Subsequent work sessions, regarding the interview and research material, produced alternative (technical) courses of action (see Chapter IV).

Later, cost-benefit analyses were performed and other selection criteria were developed upon which action choices were made (see Chapter V).

This process has produced this document which is organized under six chapter headings, the first five of which outline the problem solving method, from a definition of the problem through creative solution identification exercises, development of alternative courses of action and finally, recommended courses of action. Chapters II through V are organized under four subheadings to include: Introduction, Methodology, Findings and Conclusions. Readers from other communities interested in the plan's application to their respective jurisdictions are encouraged to focus their review on the "Methodology" sections and Chapters I and VI.

Chapter VI, "Demonstration Value for other Coastal Communities" is a critique of the methodologies used in this planning effort and their demonstration application to other communities.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

This research and planning process confirmed the ultimately complex nature of the sinkhole problem. Several conclusions from this work are presented below.

1. Sinkholes existed long before the development of the U.S. Army Railroad or Boiling Spring Lakes Dam (see Appendix B1).

2. Sinkholes in the Boiling Spring Lakes area are caused by a dissolving and eroding limestone substructure. The impact of other compounding factors is yet unknown.

3. To date, methods have not been established by which to predict if and when the next sinkhole will develop.

4. The residential and recreational development of Boiling Spring Lakes and the U.S. Army Railroad are both viable and well established land uses in the Boiling Spring Lake's area. The parties involved, therefore, must seek a solution which foster a mutual co-existence.

5. Recommended short-term action call for the development of an emergency access plan (across the railroad), conduct a vibration study of the train traffic and undertaking a deliberate fund-raising strategy to enlarge the Lake Maintenance Fund.

6. Recommended long-term actions call for a "wait and see" posture, making minor repairs as needed utilizing the single grant curtain method, and shifting to consideration of alternative measures should major repairs be needed.

CHAPTER II

A REVIEW OF THE PROBLEM

INTRODUCTION

The breakdown of the limestone substructure and resulting sinkhole development has caused considerable havoc to the Boiling Spring Lakes area. The desire to identify short-term and long-term solutions to stabilize the U.S. Army railroad and Boiling Spring Lake's dam has resulted in a substantial amount of study over the last twenty years. Many theories, views and opinions have been aired from the various perspectives, and at times, tumultuous encounters have ensued.

Prior to consideration of alternative solutions (i.e., courses of action), a clear definition of the problem must be presented and generally agreed upon. The following is a statement of the problem, enumerated as major findings and conclusions which have been gleaned from selected reports, studies, hearing records and interviews with key people (see Appendix C, Bibliography). This summary attempts to present a balanced perspective of the problem.

METHODOLOGY

The Boiling Spring Lake's sinkhole problem has been couched by many as "studied to death." The aim of this planning effort is not to add to the "study" library, but rather focus on the "solution" phase of the planning cycle. To avoid an unnecessary rewriting of the history of the BSL sinkhole problem, the consultant extracted findings and conclusions from the various studies and interview summaries, and organized them under the following topic headings for better understanding.

The Mayor's Committee and Technical Advisory Committee has concurred with the following set of findings and conclusions.

FINDINGS

General

Boiling Spring Lakes is located in Brunswick County along Highway 87 (see maps in appendices A and B2). Boiling Spring Lakes was originally designed as a "planned retirement community" in the late 1950's.

From 1970 to 1980, Boiling Spring Lakes had the highest population growth rate in Brunswick County.

The community contains approximately 17,000 acres within its municipal boundary — one of the largest in the area in the state.

Boiling Spring Lakes does not contain any AECs as defined in the "State Guidelines for Areas of Environmental Concern" (15 NCAC 7H).

Boiling Spring Lakes has other fragile areas: recharge area for regional groundwater aquifer, pocosins, scenic freshwater lakes and pine forest, and habitat for endangered plants and wildife.

The community is not participating in the National Flood Insurance Program, yet there are areas thought to be subject to flooding.

Boiling Spring Lakes is without the benefit of a water supply system or a wastewater disposal system. These systems may not be economically feasible. Every precautionary measure must be taken to insure that present and future development does not adversely affect the community.

The community has sufficient land area to accommodate anticipated and unanticipated growth, even with fragile areas, soils with severe limitations and the absence of major facilities.

Nearly all lake front lots are sold with approximately 75-80 percent of all interior lots sold.

Soil and Hydrology Characteristics

Boiling Spring Lakes is cited as a "very sensitive area" in the Land Use Plan, referring to the fact that this area is a major recharge area for the Castle Hayne Acquifer.

Lot sizes are generally one half acres or more in Boiling Spring Lakes. Given the unsuitability of the soil for acceptance of septic tank and field absorption systems, and the importance of this area as a recharge area, the half acre lot size may be too small.

The existence of sinkholes is common throughout the world where the bedrock is composed of limestone. Areas near Los Angeles, Houston, Mexico City, Tokoyo, Johannesburg, South Africa and Florida are areas characterized by sinkholes with limestone bases.

Sinkhole activity may increase with a manipulation of the water level, either a drawing down through heavy pumping or loading the water table through impoundment. This change acts as the final triggering device for a set of pre-existing physical circumstances.

The Boiling Spring Lake area is characterized as being environmentally sensitive.

The sinkhole problems at the Boiling Spring Lakes site are directly related to the solution activity in the top portion of the Castle Hayne limestone formation. The problem is related directly to the highly permeable condition due to the solution activity in the top 10 feet of the formation and not the problems associated with the large cavities or large openings in the Castle Hayne formation. The large opening evidenced at the ground surface has developed in a "funnel" shape from a much smaller shape in the limestone rock.

The impoundment of the water at Boiling Spring Lakes established a higher recharge area, thus creating a steeper hydraulic gradient between the recharge and the discharge area. This gradient change causes the water to move faster through the limestone and agitate the overlying soil which bridge the cavities, causing accelerated sinkhole development.

The "Allen" stream bed is five to fifteen feet above the top of the limestone. This upper level of soils and cavernous limestone allows water to easily percolate, while the limestone below this level is not as permeable, thus forming a recharge area.

Discharge is to Allen Creek and to a lesser extent Orton Creek, with a concentrated discharge area downstream (about 200 to 2,000 feet downstream of the railroad).

Sand cavities located between five to twenty-five feet below the surface of the land have been present for tens of hundreds of years.

As these cavities enlarge, the overlying soil bridges until the cavities become so large that the soil collapses forming a sinkhole.

There exists no method, as yet, for locating these cavities nor for determining when these cavities will collapse.

Many of the sinkholes are old, having been formed naturally hundreds of years ago. Some are more recent since the construction of the Boiling Spring Lakes Dam in 1962. The present circulation of the water, both past and present, can account for the solution of the limestone.

The nature of the soils and limestone are not prone to produce large, sudden drop-outs, but rather develop over a period of time. This will permit the problem to be identified and warnings issued to stop rail travel.

Boiling Spring Lakes Dam

The Boiling Spring Lakes Dam was designed by Henry Von Oesen, Engineer, and constructed in 1961. It is an earth dam, 32.5 feet high and 1,560 feet long with 6,137 acre/feet storage capacity. The 250 acre lake was built on Allen Creek, 200 feet upstream of the U.S. Army railroad.

The Town of Boiling Spring Lakes took over ownership of the dam from Lake Owners Corporation, on March 2, 1981.

Sinkholes appeared adjacent to the U.S. Army Railroad in 1962.

The U.S. Army constructed a bridge across the most active sinkhole area after a 1964 investigation.

Reeves Telecom Corporation was required to make repairs (grouting) to the dam in 1964 and again in 1969.

In 1976, a sinkhole developed on the upstream slope of the dam, partially draining the lake. The Reeves Plan for Boiling Spring Lakes Dam repairs was approved in 1977 by the State which called for the drainage of the lake and one line of grout along the dam. The plan was approved conditioned upon placement of piezometers at intervals below the dam and several beyond the right abutment for 2,000 feet (should the lake be refilled). The piezometers were to be closely monitored and results furnished to the Military Ocean Terminal at Sunny Point. Repairs to the dam were made during 1978 to 1979. The lake was refilled in the Spring of 1979.

As a result of the lake being drained for repairs (1977-1979), the Brunswick County assessor reduced the valuation assessment of water front properties (land only) by about 50 percent.

The U.S. Army Corps of Engineers requires a permit be issued for dams where the stream flow exceeds five cubic feet per second. Since Allen Creek does not meet this threshold, a Corps of Engineers permit to fill or refill the Lake is not required.

The Army proposed a three line grout curtain along the Dam with costs estimated at approximately $750,000. The Reeves Telecom Corp., however, proposed a one line of grout along the dam with costs aproximated at $40,000. Since the Army failed to prove that the three line grout curtain was clearly superior to the one line grout curtain, the one line curtain was judged adequate.

Since construction of the dam, boils have developed downstream of the dam (generally 600, to 2,000 feet south of the dam).

Boils were identified downstream in 1963 and following dam repairs, again in the same location in 1976.

The dam safety program of 1979 - 1981 requires all dams with high hazards classification to be inspected. North Carolina used the Federal 1964 list which identified 297 dams of this high hazard class, with Boiling Spring Lakes being one of them. From this list, North Carolina set up a priority inspection program.

The dam repairs of 1978-1979 were completed just prior to the Corps of Engineers inspection.

There are no habitable dwellings downstream from the dam and therefore loss of life due to any breach in the dam is unlikely. The high hazard classification of the dam results from the fact that the Army railroad is the only railroad access to Sunny Point Military Ocean Terminal, which crosses below the dam.

Analysis indicates an inadequate spillway and hence an overtopping of the dam will occur resulting from a 0.5 pmf (Probable Maximum Flood). This inadequacy, however, does not meet the Corps of Engineers "seriously inadequate spillway" criteria.

Overtopping will only occur during weather conditions that would be so severe that the rail traffic would be stopped.

According to the Corps of Engineers Savannah District Representative, Mr. Earl Titcom, there is no evidence of water flowing from the old boil areas between the railroad embankment and the dam and no evidence of new boils have been seen at the downstream toe of the present railroad embankment.

There is a natural tendency for the discharge points to migrate downstream of the major recharge area. Hence, with the dam in place, it is anticipated that springs will develop downstream from the dam. These new discharge points will become progressively larger, ultimately draining the lake (this is evidenced by two new springs which were located on each side of the railroad below the dam when the dam was drained on December 1, 1976).

If new spring developments took place at the base of the dam, such upwelling of water could cause a failure of the dam. A dam failure would likely damage the rail system directly or indirectly.

Given the natural migration of the discharge point downstream, the Boiling Spring Lakes reservoir is not permanent, with a life expectancy predicted to last between a few weeks and several tens of years.

The sinkhole problems at the Boiling Spring Lakes site are directly related to the limestone solution erosion activity in the top portion of the Castle Hayne limestone formation. The problem is related directly to the highly permeable condition problems associated with the large cavities or large openings in the Castle Hayne formation. The large opening evidenced at the ground surface has developed in a "funnel" shape from a much smaller shape in the limestone rock.

The Town of Boiling Spring Lakes has a Lake Fund (i.e., dam maintenance/repair fund) in the amount of $13,500 (January, 1983).

U.S. Army Railroad through Boiling Spring Lakes

The U.S. Army Railroad began operation in its present location through Boiling Spring Lakes in 1955.

The railroad provides train access to the Sunny Point Military Ocean Terminal, the Carolina Power and Light Brunswick Nuclear Power Plant and Pfizer Industries. The train traffic averages about one per day, with a maximum of three per day. The following is a summary of train traffic over the last three years:

(1)Army Trains	(2)CP&L Trains	(3)Pfizer Industries Trains
FY80 - 2872 Cars	FY80 - 14 Cars	FY80 - 528 Cars
FY81 - 1878 Cars	FY81 - 78 Cars	FY81 - 709 Cars
FY82 - 1325 Cars	FY82 - 17 Cars	FY82 - 651 Cars

There is an average of 8 to 10 cars per train with a maximum of about 55 cars. Based upon a car length of 60 feet, the average train length is 480 to 600 feet with a maximum length of 3300 feet.

There are various types of cargo being transported along the U.S. Army rail line. Cargos for the Army include: Class A, B, & C Explosives, ammunition components, POL Products and Lumber. Chlorine and an occasional car of spent fuel are transported for CP&L, and for Pfizer Industries, lime, starch and perlite are needed.

As noted earlier, a sinkhole developed adjacent to the U.S. Army Railroad in 1962. Subsequent investigations in 1962, '63, and '64 resulted in the construction of a bridge across the active area.

In 1976, sinkholes again began to appear along the U.S. Army rail line.

Following the 1976 sinkhole development, Sunny Point adopted a special operating and inspection procedure for the section of track downstream from the dam.

Speed Indicators have been installed on the Locomotives that are used to cross the Boiling Spring Lakes area. Locomotive Engineers have been instructed to travel at 5 MPH or less when in this area. Slow Boards have been erected at both ends of Boiling Spring Lakes which set the train speed at 5 MPH. The Rail Maintenance Crew inspects the roadway bed each day, Monday through Friday.

Between 1978-1979, a 1360 foot section of the railroad bed was widened to permit cars to derail and fall over on their sides without sliding down the slope, and thus reducing the risk of explosion due to derailment.

The United States of America (U.S. Army) filed suit against Reeves Telecom, Inc. on July 29, 1981, claiming damages in the amount of $688,318.28. The claim was based upon repair costs to establish the U.S. Army railroad after sinkholes developed subsequent to the construction of the BSL dam. The jury found in favor of the USA but due to statutes of limitation, the U.S. Army was only awarded $91,500.

The most critical area of Sunny Point access railroad downstream of the dam is the timber trestle. Derailment on the trestle or a failure of the trestle would allow cars to fall 35 plus/minus feet to the stream bed.

A failure of the dam would likely cause the railroad trestle to be destroyed and substantial damage would occur to the railroad embankment.

Vibrations from rail traffic may cause some breakdown of the limestone and sand bridges (i.e., accelerate the rate of sinkhole development). It is unlikely that harmful levels of vibration are transmitted through the existing railroad bed (which is over 30 feet in depth to the natural grade). It is possible, however, that harmful levels of vibration are transmitted through the pilings and caissons which support the trestle and railroad bridge.

Only one company proposed a coal terminal in the Southport Area which would have required use of the Army rail line through Boiling Spring Lakes. Williams Terminals proposed to develop a 400 acre tract just north of Southport on the Cape Fear River. The initial capacity was estimated at 10 million tons per year with an ultimate capacity at twice that amount. It was concluded that the Army rail system through Boiling Spring Lakes "will probably need upgrading."

An Environmental Impact Assessment would likely be required either by the federal or state governments, before the various permits could be issued for development of a major coal terminal.

While the possibility for locating a coal terminal at/or near Southport (necessitating the need to traverse Boiling Spring Lakes) is extremely unlikely, the results from coal train impact studies are applicable to the U.S. Army railroad/Boiling Spring Lakes dam situation. Study findings include:

> Medical, fire and police emergency responses can be delayed at grade crossings by passing trains. Also delayed are volunteers on their trip to the station to pick up emergency vehicles.
>
> Boiling Spring Lakes traffic delay and related impacts and grade crossing accidents were rated as high priority. The solution called for improved grade crossing protection. These improvements, including flashing lights, have been installed at Fifty Lakes Drive and East Boiling Spring Lakes Road.
>
> Boiling Spring Lakes has an average annual medical call and fire call rate of 78 and 28, respectively. The potential delays due to current or future road traffic is identified as negligible.

The yearly accident rate for the three railroad crossings at Boiling Spring Lakes is .04 for the current status and .14 for the future status.

Anticipated land use effects from coal train movements are esthetics, noise, vibration, effects on historic structures, and conflicts with land use.

Due to the heavy cars, accelerated wear of the rail structure is anticipated, making derailment more likely.

Noise levels have not been qualified for locomotives, warning whistles, or rolling track. Facility studies suggest that any noise from this type of operation must be judged relative to the other noise generators of the area. Welded rails, locomotive mufflers and modified engine casings are suggested as ameliorating measures.

The rail system within Boiling Spring Lakes was not determined as a "significant land use compatability problem" in the Boiling Spring Lakes Land Use Plan, but is cited as a "problem and implication from unplaned developed growth."

The Boiling Spring Lakes Land Use Plan cites the U.S. Department of the Army's rail spur in Boiling Spring Lakes as a man-made hazard. It notes that Sunny Point is the largest ammunition terminal on the east coast and serves all branches of the military. The train and its cargo both present potential hazards. The Land Use Plan for Boiling Spring Lakes proposes the adoption of the following policies relative to the railroad, dam, and sinkhole problems:

Policy Statement A1. The Town of Boiling Spring Lakes recognizes the value of waterfront property. The Town also recognizes the potential adverse impact upon the quality of the lakes and limiting of access with continued development. Consequently, the Town shall seek to minimize all adverse impacts and to insure reasonable access to the lakes.

Policy Statement A4. The Town of Boiling Spring Lakes is aware of the potential threat of life and property associated with the ammunition terminal railroad, and the nuclear power plant. The Town is also aware of some of the mitigating measures each of the facilities has employed. The Town shall continue to seek information regarding those measures in order to inform its citizens and to cooperate with the facility management and appropriate regulatory agencies to minimize the risk.

Policy Statement C7. Considering all the needs of Boiling Spring Lakes, the limited resources available and the long term impact, wastewater control has to be a top priority for funding. Other programs can be initiated which are not capital intensive and can be implemented with the policies in the Boiling Spring Lakes Land Use Plan related to federal and state assistance, (Flood Insurance, Wastewater Control and Public Access).

Policy Statement C9. The Town is aware of the critical importance of the railroad to the region, state and nation. Due to the concern of the community, the Town shall require all development to provide a buffer along the right-of-way. In return, the Town expects the U.S. Army to assure appropriate maintenance and install the necessary safety measures which the railroad warrants.

In November, 1981, the U.S. Army Engineer Division, Savannah, Corps of Engineers completed a "Study of the Access Railroad Sinkhole Problem" for the Military Ocean Terminal at Sunny Point, North Carolina. This study proposed five alternative courses of action the U.S. Army could take to deal with the occurance of sinkholes along the access railroad bed (i.e., need for relocating the existing railroad). Alternative I was the recommended strategy, namely: operate as is with a contingency plan to relocate the railroad along the Boiling Spring Lakes dam as the emergency arises. (See Appendix D).

The only viable solution available which would assure full immobilization capability for the U.S. Army Terminal would be the construction of a land bridge (i.e., Alternative IV, estimated cost $7.4 million).

The Corps of Engineers, 1981 study called for the following engineering considerations (i.e., need for further study).

a. Confirm extent of problem (i.e., local or widespread).

b. Confirm sequence of potential failure and probability of a catastrophic failure.

c. Confirm factors influencing development of sinkholes along the MOTSU ARR.

d. Confirm technology for and probability of detecting sinkholes.

e. Confirm the effects of a failure on operations.

f. Determine feasibility and effect of only partially lowering/ emptying the lake.

g. Determine feasibility:

1. Raising/lowering the lake to compact the sinkholes.
2. Vibratory compaction of the sinkholes.
3. Reinforced earthfill.
4. Pile support of ARR.

5. Floating or mat foundation.
6. Incremental bridging.

h. Develop repair plan.

Conclusions from the Corps of Engineers 1981 study include:

a. There is no effect on MOTSU throughput as a result of the current slow order. The slow order does add 10-15 minutes to the transit time for a train.

b. The possibility of a catastrophic failure is extremely remote under current procedures and the possibility of a derailment is minimal.

c. The sinkholes along the Allen Creek reach of the MOTSU ARR are directly related to the impoundment of Boiling Spring Lakes.

d. Legal and community impacts are integral parts of the sinkhole problem.

e. Funding requirements for other MOTSU work dictate that we seek the most economical solution to the problem.

CONCLUSIONS

Due to the limestone substructure and sinkhole development, the Boiling Spring Lakes area is not a good place to build either a railroad or a dam.

While the impoundment of water (Boiling Spring Lakes dam) and the subsurface flow of water has presumably accelerated the solution and erosion of the limestone resulting in sinkhole development, the rate of increase beyond that of the natural rate cannot be determined (given the state of the art and costs).

The nature of the soils and limestone are not prone to produce large, sudden drop-outs, but rather to produce sinkholes which develop over a period of time. This will permit the problem to be identified and warnings issued to stop rail travel.

The U.S. Army's only viable solution to assure long-term stability of the railroad would be the construction of a continuous land bridge. This solution, however, would result in the placement of 42" caissons into the bed of the limestone creating an avenue for the transmission of vibration which may, in turn, accelerate the breakdown rate of the limestone and sand bridges (i.e., the solution becomes part of the problem).

Given the need for national security and the expense of relocation, the possibility of closing down Sunny Point and/or relocating the railroad outside of the BSL area (i.e., the railroad will go away) is extremely unlikely.

Given the investment of the property owners and Town of Boiling Spring Lakes in development of the dam, it is extremely unlikely that "the dam will go away". However, given the natural migration of the discharge points downstream, the reservoir is considered temporary with an unpredictable life expectancy.

Thus, the issues recognized above are complicated by the desire of both the Army and the Town to coexist in Boiling Spring Lakes. It is within this context that Chapter III presents various scenarios of how coexistence may best be achieved.

CHAPTER III

SCENARIO DEVELOPMENT

INTRODUCTION

As indicated in Chapter II, the problems in the Boiling Spring Lakes area are caused by the dissolving and crumbling of limestone beneath intense lands uses including the U. S. Army Railroad and the BSL dam. This situation is extremely complex because it has a long and intense history, it involves many parties with diverse interests and viewpoints, it has been analyzed from a number of technical disciplines and it has the potential to last as long as geologic time itself.

Initial interviews with selected experts and an examination of the technical material has indicated that any work toward a "solution" must cover several fronts simultaneously. These fronts include the political (i.e., need to identify interest and weave an acceptable level of understanding or at least mutual tolerance among them), the technical (i.e., need to identify the chemical and physical nature of the limestone problem and prescribe scientific/engineering steps to retard the rate of increase of the problem), and the strategic (i.e., need to identify alternative ways to provide emergency access in the case of significant blockage of roads due to sinkhole activity or train derailment).

In order to operate on these fronts simultaneously, a scenario writing approach was undertaken with the Technical Advisory Committee. The following briefly defines and describes scenarios, and presents the results of the developmental scenario writing/work session.

METHODOLOGY

As Mr. Hirschhorn indicates in his article titled "Scenario Writing: A Developmental Approach,"[1] scenario writing is a generic term encompassing a broad range of approaches, assumptions and techniques. All, however, share in common an attempt to describe or write a "history of the future."

Scenarios can be written from several perspectives and categorized in three separate ways:

1. state vs. process scenarios
2. end state vs. beginning state scenario
3. prediction vs. planning and decision making scenario

[1] Larry Hirschhorn, Scenario Writing: A Developmental Approach, Journal of the American Planning Association, April 1980, Vol. 46, Number 2, page 175.

First, state scenarios simply posit what the world or relevant context will be like a number of years from the present, without describing at the same time how the world "gets to be that way." Process scenarios, in contrast, specify the sequence or chain of events that lead up to a particular future state.

Second, in end state scenarios, some conception of a future state determines how the scenario is written. They are goal oriented. . .how you get there depends largely on where you said you wanted to go. However, in the beginning state scenario, the beginning, not the end, functions as the starting point or benchmark for the scenario and the scenario specifies how or why future states emerge. The occurrence of events along the way determines the destination.

Third, scenarios can be used for either the purpose of prediction or for planning and decision making. In the former, the scenario writer looks primarily for accuracy, validity and, where meaningful, statistical tests of plausibility. In the latter, the scenario writer looks primarily for usefulness, surprise, richness and the power of the scenario to provoke unexpected ideas for plans.

These types of scenarios can be brought together into several parings. For example, a process scenario may be end state driven to be used for prediction, and so on.

Because the Boiling Spring Lakes situation has such an unpredictable end state and because of its planning needs, a process--beginning state--planning scenario was selected. This choice used a methodology known as a "developmental scenario" put into the context of the Boiling Spring Lakes situation:

> "A development scenario begins with an initial state (our current understanding or "mind set" of today's problem in Boiling Spring Lakes) and describes a process through which a particular social system (the Town Board and residents, the Army, the Developer, the State and others) can arrive at one or a series of end states (action strategies) that are not specified prior to the construction of the scenario itself." (Hirschhorn, p. 175).

This involved constructing "linear developmental chains" composed of cause and response events: environmental circumstance, problematic or driving forces, institutional action or response, failure or success modes (which blocks or enhances success), and a set of alternative or new responses (which lead to a new chain).

To create such chains, the Boiling Spring Lakes Technical Advisory Committee (TAC) and its consultant used a "working-wall chart" method of recording and a structured brainstorming method of generating ideas. The consultants prepared a list of "problematic or driving forces" in terms of level of sinkhole activity, etc. upon which the group stated likely responses from their personal perspectives or from the perspectives of their agency. The focus of the effort was to learn, in a creative setting, what reactions would likely be, and where opportunities for coordinated response and potential conflicts in response were.

FINDINGS

With the Technical Advisory Committee (TAC) as participants, the scenario writing worksession began with the following set of circumstances and categories for action:

Issues: There are three major factors around which all "issues in the Boiling Spring Lakes problem revolve: (1) Railroad Operation; (2) Securing the Lake; and (3) Emergency Access across the Railroad.

Actors: The Town, the U. S. Army and the State of North Carolina. These are the parties with stakes in the process and with concern for positions in the forthcoming action plan.

Environmental Circumstances: These are broad classes of incidents which may stimulate action on the part of the community of Boiling Spring Lakes, the U. S. Army, the State of North Carolina or any combination of these (in a coordinated manner). So far there are four such classes:
(1) Recurrence of sinkholes that result in drainage of the lake or in damage to the railroad, or both—these may be of major or minor magnitude and severity; (2) Railroad derailment unrelated to sinkholes (again, of major or minor magnitude and severity); (3) Periods of limited access for emergency vehicles to cross the railroad (short periods and long periods); and (4) Renewed sinkhole activity of no immediate impact to the lake or to the Railroad (major or minor activity levels).

Problematic driving forces: These are the actual incidences (in varying degrees or levels of magnitude or severity) which actually cause action by one of the parties. They are the "precipitating incidents" to action which can be either uncoordinated and impulsive, or well-planned and coordinated.

Array of Actions: These range from actions which are highly predictable and possible to a dream list of what's really desired regardless of its feasibility. They range from solutions which are feared or avoided at all costs to those which are the most likely.

Scenario or event-chain construction: These are cause-and-effect linkages between actors and the actions of other actors. In other words, what response will the Town have to a certain action by the Army who is acting in response to one of the instances (problematic driving forces). How do these responses fit together? Do they expose overlaps or conflicts which are better dealt with now and planned for, than left unsaid? What are the plausible develomental sequences?

Factors of Success or Barriers to Success: See Chapter II

Alternative Actions: See Chapters IV and V

Commentary: See Chapter VI

At the worksession, emphasis was placed on identifying the position of the two major actors, the Army and the Town, and crystallizing their opportunities to:

go separate ways, or

cooperate but end up in about the same place, or

cooperate and push for fulfillment of mutually acceptable objectives, particularly in the face of a catastrophe with relation to the limestone substructure.

Within that context, the TAC produced the following scenarios to six hypothetical "environmental circumstances:"

1. Minor sinkholes along the sides of the dam and the railroad itself.

In this case, the Town would contact the County Commissioners and call their attorney and begin to study the relationship between the Army and the Town. They would report the incident to the State (NRCD).

The State would report it to the Corps of Engineers and encourage the Town to hire Henry Von Oesen or some other engineering consultant to study the condition of the dam.

The Army might stop traffic, add inspectors to inspect the tracks, notify the State in Raleigh or in Wilmington, and follow up the report with an immediate response for their contingency plan. The County, through Cecil Logan, the new Emergency Management Officer, would inspect the site and review the situation along with the State in order to assure the preparedness of alert or emergency responses.

2. 100-foot sinkhole in the railroad bed but no damage to the dam.

In this case, the Town would contact the Army and the State.

The State would notify the Army and then notify the Town, and start immediately to drain the lake to make it safe. The State and Corps of Engineers people would come in and study the situation. They would notify the owners of the dam (the Town). Boiling Spring Lakes would not need to do a study if the Army makes repairs and the State okays the repairs. Then the lake could be refilled.

Since this is federal property, the Army would want to make repairs first. Everybody else would be in a responsive mode.

The County would take no responsibility.

Industries would put pressure on the County to help get the railroad moving.

3. <u>A major sinkhole develops along the dam (the third such incident in three years, with costs averaging $90,000 each time); water spills through a breach in the dam causing significant damage to the railroad bed and trestle. Train traffic is stopped indefinitely</u>.

In this case, the Town would call an attorney, open the valves to drain the lake, and would look to the Community Development Block Grant Program for emergency funding.

The State would do the same as before, and so would the County.

The Army would declare it a disaster area and move on its contingency plan.

4. <u>Derailment which blocks and limits access. The access points are on 50 Lakes Drive, Boiling Springs Road and North Apache Road. One of these goes out to the York Plantation</u>.

In this case, the Town would call the Army and Highway Patrol (the lead agency) which would in turn contact the Department of Transportation (DOT).

The State would check to see that there is no damage done to the dam and contact DOT.

The County would contact its emergency management coordinator, highway department or the Sheriff, with the local coordinator in the lead.

The Army would assist the emergency management coordinator and the National Guard could airlift in or shuttle in help (Coast Guard).

5. <u>Explosion which would be large enough to burn out part of the Town</u>.

In this case, the Army would determine whose responsibility it was rather than act.

The State would lower the reservoir or maybe not lower it, since the water would be needed to help put the fire out.

The Town would resist lowering the lake until the fire was out.

The Forest Service would conduct water air drops.

The county coordinator would initiate action plans. The evacuation situation may similarly cause the Town Rescue Squad and Civil Defense people to react. (CP&L did a scenario of emergency situations at their power plant from which the Town can learn).

6. The Town's response to the Army's action, regardless of level of nature (sinkhole) catastrophe.

While scenarios 1 through 5 above were predicated upon responses to natural phenomena, the committee also realized that the Town is primarily in a responsive position with respect to the actions of the Army. Thus, the group discussed the Army's preparation of its own emergency plan which poses solutions as follows:

First, the Army has its own emergency contingency plan in which it may do one of several things. First, during an emergency the Army may want to construct a 4,000 foot bridge to replace the existing bridge and leave the existing dam intact. The first TAC work session revealed that in this situation, the Town would want to be assured that the vibrations would not cause damage to the dam. It would want assurance that this is, in fact, an improvement to the existing situation. It would want to prepare a statement of concern for the Army to consider during and after construction, and it might want to undertake parallel studies on vibration to the substructure or to the steel pilings. They may want to give the dam to the Corps of Engineers.

Second, during an emergency the Army may put the railroad on top of the existing dam. In this case, the Army would do considerable work; the Town would go immediately to court or perhaps hesitate to study the pros and cons of the issue; the Town could use the old railroad as a road in a swap. The Town could share the cost of repair through a grant. The State would take no responsibility. In this case, the Town would no longer be responsible for maintaining the water level.

CONCLUSIONS

Major themes exposed in the work session's six scenarios include the need to study the condition of the dam and the railroad regardless of the extent of catastrophe; concern for financing of repairs; concern for public safety and property values (rail property and individual resident property); legal responsibility; and interaction of parties in a timely and deliberate (planned) manner.

It is upon these scenarios and themes that Chapter IV (Alternative Courses of Action and Respective Costs and Benefits) is based.

CHAPTER IV

ALTERNATIVE COURSES OF ACTION AND RESPECTIVE COSTS AND BENEFITS

INTRODUCTION

The solutions (i.e., alternative courses of action) to stabilize the Boiling Spring Lakes dam and railroad, and reduce the hazards associated with sinkhole development, were identified through a review of existing studies and the scenario writing exercise. Once the alternative solutions were identified, engineering studies were initiated to determine the costs and benefits of each solution. The Technical Advisory Committee (TAC) also participated in the costs and benefits analysis phase.

METHODOLOGY

The alternatives list, which follows, was sent to the TAC, accompanied with the engineer's costs and benefits analysis report. The task of the TAC was to review the material and conduct their own assessments based upon the following instructions:

1) Given your area of expertise, please complete the selection grid (Exhibit A, See Appendix F) for each of the nine alternatives. Please rate each alternative as "high," "medium," or "low" on each selection criteria by placing an "H," "M," or "L" in each cell.

2) Having done #1 above, what are the particular advantages and disadvantages of each alternative? What is your most preferred and least preferred alternative? (Please complete on Exhibit B, See Appendix F).

3) Related to the array of alternatives, which lend themselves to short-term strategies for the Mayor's Committee and which for long-term? Given that the Mayor's Committee and the Army are both in a "wait and see" posture, what short-term and long-term steps do you see as advisable for the Town to undertake to place them (and the Army for that matter) in an appropriate state of readiness for renewed sinkhole activity of significant consequence? (Please list three short-term and three long-term steps in the space provided below).

In undertaking the three aforementioned steps, the TAC was reminded that in a very real sense, the situation before the Mayor's Committee is two pronged: 1) how to be best prepared and best respond to renewed sinkhole activity; and 2) how to be best prepared and best respond to the Army's action to repair the railroad.

The results of this process are presented in Chapter VI, Recommended Courses of Action.

FINDINGS

The following alternative courses of action were selected for a costs and benefits analysis (Note: not in priority order):

1. Lower the mean water level of the lake by one foot.
2. Construct a dam downstream of the existing dam.
3. Construct a set of terrace dams, either one or two in the middle of the lake.
4. Relocate the railroad onto the existing dam.
5. Construct a single grout curtain the entire length of the dam.
6. Construct a triple grout curtain along the existing curtain line for the entire length of the dam.
7. Install a non-porous membrance of considerable size on the bottom of the lake near the existing dam.
8. Establish alternative emergency access routes so that train derailment would not inhibit public egress from and access for emergency vehicles to the east side of the tracks.
9. Conduct a study of the vibration which the railroad contributes to the substructure through its trestle system.

The following is a technical review of the costs and benefits of the above alternative courses of action:

(1) Lowering the Water Level

At the present water elevation (30.3 ft. AMSL) in the lake the water seepage through the dam was calculated to be 1.26×10^{-4} cubic feet per second (See Figure 1, Appendix E). To reduce this seepage, the water elevation in the lake could be lowered to reduce the hydraulic gradient.

Lowering the water level one foot would reduce the seepage rate to 1.16×10^{-4} cubic feet per second or 8.1%, and lowering the water level 5 feet would reduce the seepage rate by 41% to 7.5×10^{-5} cubic feet per second. Although lowering the water level will reduce the water seepage, it is not know to what extent this would reduce the solution of the limestone and formation of sinkholes. In order to determine the exact result from this alternative, extensive geologic and engineerng analysis would be necessary. The loss of property value for the water front lots around the lake is expected if this alternative is adopted.

(2) Construction of a Dam Downstream from the Existing Dam.

Another dam construction alternative is to construct a new dam downstream from the existing dam. If the water is ponded around the existing dam so that the water elevation on both sides of the dam is the same, there will be no head difference between the two sides and minimum flow through the limestone under the existing dam will occur. If water is not flowing through the limestone, the formation of sinkholes could be reduced but the solution of limestone will continue because it is a chemical reaction.

Other factors of placing the dam downstream must also be considered; to keep the elevation of the water in the lake the same as it is presently, the construction of a higher dam downstream will be necessary. This could result in a higher construction cost. Other costs involved in this alternative is the cost of purchasing the land downstream for the future lake and the environmental impact study. The cost estimate for this alternative is $58,000 which includes: the selection of dam site including the geologic tests for two potential sites, feasibility of dam construction, preliminary design of the dam, preliminary cost estimate and environmental impact study.

(3) Construction of a Dam (or set of terraced dams) upstream from the Existing Dam.

The construction of a new dam on the upstream side of the existing dam is a possible way to mitigate the problems. Although there are advantages to this alternative, there are also some disadvantages. The placement of a new dam upstream of the existing dam will stop water from being ponded around the existing dam, lower the groundwater table, and reduce the formation rate of sinkholes.

Although this will protect the railroad, the feasibility of this solution will depend on whether an appropriate site upstream can be located. A geologic survey must be conducted to determine where the dam can be placed to eliminate the problem caused by the limestone. This alternative will also reduce the size of the lake and will result in the lowering of property value along the section of the lake between the two dams. The total cost of constructing a new dam cannot be estimated until the site is selected. It is estimated that the engineering study cost will be $50,000 which includes the geologic engineering tests for two predetermined sites.

(4) Relocate the Railroad onto the Existing Dam.

Cost. . .$255,430
(See U. S. Army Report, Appendix D).

(5) Construction of a Single Grout Curtain the Entire Length of the Dam.

The following is only a cost estimate. The short and long term benefits (e.g., chances for success), are addressed later in this study.

DESCRIPTION	QUANTITY	UNIT PRICE	AMOUNT
Drilling Grout Holes	1,330 LF[1]	$38.70	$51,471
Portland Cement	14,763 LF[2]	6.46	95,369
Placing Grout	14,763 LF	16.55	244,328
Connection to Grout Holes	354[3]	25.50	9,027
Bentonite in Grout	590 lbs[4]	.31	183
Pressure Testing/Washing	160 hr[5]	100.00	16,000
			$416,378

(6) <u>Construction of a Triple Grout Curtain Along the Entire Length of the Dam.</u>

At the time of the 1978 repairs to the dam, a single grout curtain for the 230 ft. of the repair area (estimated) cost was $40,000. For a triple grout curtain, the cost was estimated at $750,000. This latter solution, (as proposed by the U. S. Army) was not proven to be "clearly superior" to the single grout curtain. Since the need for this level of repair (i.e., triple grout curtain) is excessive in the eyes of the court, a simple comparative cost estimate will suffice.

Based upon the 1978 cost estimates, triple grout curtain is 18.75 times the cost of a single grout curtain. This difference, when applied to the 1982 single grout curtain cost of $416,378 equates to a triple grout curtain cost of approximately $7.8 million. A simple tripling of the $416,378 cost would equate to $1.2 million.

(7) <u>Construct an Impervious Layer</u>

The feasibility of using an impervious layer on the upstream side of the dam was studied by the use of the flow net analysis method. Three flow nets were examined; one flow net was constructed for the existing dam, one with a 50 foot wide impervious layer and one for a 100 foot wide impervious layer. A flow net shows the path of water seepage under a dam, and the amount of seepage under the structure can be approximated.

Some assumptions were made for this analysis. The depth in the soil to which seepage would be minimal was assumed to be 40 feet from the base of the dam. The soil also was assumed to be a homogenous sandy clay and

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[1] Length of Dam in 1560; less area already grouted in April, 1978 (i.e., 230) equals 1330 lineal feet.
[2] The 1978 repair of 230' required 2555 cf of cement or 11.1 cf per lineal foot (i.e., 11.1 x 1330 = 14,763).
[3] Estimate based upon 240 ea./10,000 cf, Savannah report.
[4] Estimate based upon 400 less/10,000 cf, Savannah report.
[5] Estimate based upon 120 hrs/10,000 lf, Savannah report.

silty soil based on soil borings in a previous report. The permeability factor (k) of 3.28 x 10^{-5} cubic feet per second was therefore assumed. This permeability factor was obtained from An Introduction to Geotechnical Engineering by Robert Holtz and William Kovacs (Figure 7.6, page 210).

The flow net for the existing dam was developed and is shown in Figure 1 (see Appendix E). From analysis and calculations it was determined that the present rate of water seepage through the dam is 1.26 x 10^{-4} cubic feet per second per linear foot at the center of the creek. Appendix E, Figure 2 shows the flow net for the case when a 50 foot impervious layer is placed on the upstream slope of the dam. This layer causes the flow under the dam to start farther from the base of the dam, and the hydraulic gradient of the flow is reduced and consequently slower flow under the dam will be observed. The seepage rate was calculated to be 7.69 x 10^{-5} cubic feet per second. This is a reduction of 23% from the existing seepage rate.

The flow net with the 100 foot impervious layer is shown in Figure 3, Appendix E. It is conceivable that the flow must start even farther from the base of the dam. The hydraulic gradient of the water is decreased by the impervious layer causing the water to have less velocity and to erode less through the limestone. The seepage rate with the impervious layer was calculated to be 5.9 x 10^{-5} cubic feet per second, which is a reduction of 53% from the existing rate.

Two types of impervious layers, clay or plastic, are considered to be the best materials for this alternative. Each type of layer will be discussed on the pro's and con's and also estimates are given.

The use of a clay layer on the upstream slope of the dam would consist of a 1 foot deep layer of clay covered with the topsoil that had existed at the dam and a layer of type D Rip-Rap. The cover layer of top soil and Rip-Rap are added to protect the clay from drying, cracking, and wave protection. The advantage of clay material is that if the layer was cracked, the clay would have the ability to seal itself. The disadvantage of clay is that no soil material is total impermeable, thus some seepage through it can be expected although the amount of seepage is expected to be minimal. The cost of the clay material is estimated to be \$9.50/cubic yard. This includes the cost of the clay, transportation of the clay for 5 miles, removal of the top-soil, and the placement and compaction of the clay. The cost of the Rip-Rap is estimated to be \$15/square yard if the material is available nearby. The Rip-Rap should be placed 50 feet wide along the entire length of the dam to protect the clay against the lowering of the water level during the dry season.

For a 50 foot clay layer section the total cost of the clay is estimated to be \$26,000 and the cost of the Rip-Rap would be \$116,600. The total cost for this alternative would be \$142,600. The cost of the 100 foot clay layer section would be \$49,000 for the clay and \$232,000 for the Rip-Rap for a total cost of \$281,000.

The other alternative to this solution would be to use a plastic liner on the upstream slope of the dam. This liner is totally impermeable and will not allow any water seepage along the blanket. Although this will provide a totally impermeable blanket, it does not have the ability to seal itself if it is ruptured. If the blanket is ruptured, it would be necessary to lower the lake level below the fracture to repair it. The cost of this material is $1.05 per square foot including installation. (The price was quoted from Schlegel Lining Technology, Inc.). For a 50 foot plastic blanket the total cost would be $77,000 and the cost of the 100 foot blanket would be $145,000.

Before the placement of either the clay or the plastic layer, the area to be covered must be cleared and graded to remove the topsoil and to smooth out the area. Since the lake is not drained, the soil behind the dam would be very wet making grading of this area difficult. If the area is left alone to dry naturally, it would take quite some time before normal grading could start. The cost of efforts to grade the wet area could be expensive and could raise the construction cost of placing an impervious layer by 50%.

(8) Establish Alternative Emergency Access Route(s) Across the Railroad
The present access roads which cross the U. S. Army railroad are Fifty Lakes Drive, N. Apache Road and Boiling Springs Road. The railroad traverses the Town Limits for a distance of approximately 23,000 linear feet. The roads identified above cross the railroad right-of-way (beginning at the southern most point of the Town and heading north) at about 5,000 feet, 11,000 feet and 14,000 feet respectively. This means that 9,000 feet separate South Lakes Drive and Boiling Springs Road. As noted in the findings of this document, the average train length is about 480 to 600 feet with a maximum length of about 3,300 feet. While a train derailment which blocked all three access roads is unlikely, associated hazards (e.g., fire, ammunition or nuclear waste spill, etc.) may render all present access routes impassable. Further, just the delays at grade crossings by passing trains may necessitate medical, fire and police emergency responses to seek alternative routes. The alternate routes have been selected (see Appendix G). The costs are considered minimal—just the cost of maintaining equipment and soil to develop the roadway at the time of the emergency or develop it now with access limited to emergency vehicles.

(9) Conduct a Train Vibration Study Along the Trestle and Bridge Area
The anticipated "scope of work" for a vibration study of the trains traveling through Boiling Spring Lakes includes:

a. Conduct on-site vibration readings (before and during train travel) at the following locations:

(1) Train trestle
(2) Train bridge
(3) Train bed base (between railroad bed and BSL dam)

b. Analyze in terms of extent to which the vibration, identified above, accelerates the breakdown of limestone and overstory (i.e., sinkhole development). The detail of this analysis should be comparable to that of Harry La Grande's Hydrology Study(see bibliography, Appendix C).

c. A written report shall be the product of this study to include:

    (1) vibration study findings
    (2) analysis
    (3) conclusions (relative to sinkhole development).

The cost of the vibration study is estimated to be $5,000.

CONCLUSIONS

Although the least expensive short term solution to sinkhole development along and within the dam has been the single line grouting, the long term cumulative affect of this alternative is more than twice as expensive as developing an impervious layer on the upstream side of the dam ($416,000 for a single line grout curtain the entire length of dam versus $165,000 for a 50 foot clay layer or $145,000 for a 50 foot plastic blanket).

In Chapter V, these alternative courses of action were assessed against other criteria as a basis for prioritization and finally selection toward the expressed goal of mutual coexistence in Boiling Spring Lakes.

CHAPTER V

RECOMMENDED COURSES OF ACTION

INTRODUCTION

This plan identifies nine (9) alternative courses of action which could be taken to stabilize the Boiling Spring Lakes dam (and in turn, help stabilize the U. S. Army railroad) and provide emergency access to the east side of the railroad. These alternatives have been developed through a review of various studies and interviews, a scenario writing work session and a cost/benefit analysis work session. The alternatives have been analyzed through a technical cost/benefit study.

The evolution and ranking of these alternatives was based upon a set of criteria listed below. From this prioritization, contingency actions have been established.

METHODOLOGY

To establish a basis for evaluating the nine alternatives prior to the meeting of the TAC, members were asked fill-in the selection grids presented in Appendix F, Exhibits A and B, which featured the following criteria:

Positive Impact on the Problem
Durability Over Time
Unit Cost
Total Cost
Availability of Financing
Adverse Environmental Impacts
Complexity and cost of Maintenance and Management
Required Time for Completion

At the beginning of the Technical Advisory Committee (TAC) work session, the chairman, representing the Mayor's Committee, requested that alternative four (4) be amended to read, "Relocation of the Railroad," rather than "Relocation of the railroad onto the existing dam." Since relocating on the existing dam is a stated option of the Army, the group decided to add "Relocation of the Railroad" to the list (as option 10), while maintaining the original wording for option 4.

Next, discussion was held which (1) raised issues which participants had discovered during their homework; (2) the method of completing the form collectively; (3) determining mutually acceptable definitions for each criteria; (4) agreeing upon the rating scale; and (5) understanding that all criteria were assumed to be of equal importance (weight).

Regarding the latter, "total cost" was measured by estimated dollars for construction. "Unit cost" was determined incomparable across alternatives, and was deleted from the exercise. All other criteria were assigned ranges of "low," "medium," or "high" and rated nominally with "H," "M," or "L." No ratings were applied until each person had acknowledged that he understood the definition of the criteria and the limits of the rating ranges.

By collecting the ratings of each alternative on one criteria at a time, with discussion permitted for clarification only, a "concensus" method was used to record ratings.

As the group shifted to discussion of advantages and disadvantages of each alternative, the consultant assigned numbers to the ratings (H=7; M=5; L=3) and averaged scores within each cell of Exhibits 3 and 4 (Appendix F) to determine the "group score." These scores on each criteria were sumed to determine the total score for each of the 10 options, which were then ranked. Rankings were reported to the group during this work session to provide feedback and information for the remainder of the session.

FINDINGS

Based upon the aforementioned method, the alternatives were prioritized as follows:

Rank	Alternative
#1	Relocate the railroad upstream of the lake.
#2	Construct a triple grout curtain along the entire length of the dam.
#3 and #4 (tied)	Construct a dam downstream of the existing dam, and install a non-porous membrane or layer.
#5	Relocate the dam downstream (.5-1 mile) of the lake.
#6 and #7 (tied)	Construct a single grout curtain the entire length of the dam, and construction of a dam (or set of terraced dams) upstream from the existing dam.
#8 and #9 (tied)	Lower water level (one foot) of the lake. Relocate railroad onto existing dam.

The discussion on advantages and disadvantages of each alternative produced the following:

Alternative	Advantages	Disadvantages
Lower water	reduce hydraulic pressure	poor esthetics
New dam downstream	add more lake frontage, transfer active sinkholes below RR	displaces problem, expensive
New dam upstream	reduce hydraulic pressure	lower water-esthetics and use reduced.
Relocate railroad		
on existing dam	change ownership	creates a narrow road, could drain lake, vibration could damage dam.
downstream	safer-move RR from active area	dam failure still could cause damage, expensive.
upstream	safer-dam failure not damage RR	expensive
Single grout curtain	reduces some seepage	relatively inexpensive.
Triple grout curtain	reduces seepage	expensive.
Impervious layer	reduces seepage, easy to install	
Emergency access routes	N/A	N/A
Vibration study	N/A	N/A

CONCLUSIONS

There are a number of conclusions which can be drawn from the above exercise and findings. These include the following:

1) Many of the top priority options are beyond the control of the Mayor's Committee in terms of ownership and total costs.

2) There is still lack of agreement about whether the problem of crumbling limestone in Boiling Spring Lakes is primarily a chemical problem (the impoundment of water increases water-limestone contact causing the limestone to dissolve) or a physical problem (water circulating through the caverns within the subsurface, thereby eroding the limestone). Both in fact are operating.

3) Though the interaction between the Town and the Army has been cooperative at the information sharing level, there is still a clear delineation of legal and financial responsibility dividing the two. This part of the situation is not likely to change and should be considered in the design of any coordinated action.

4) Since the Town is limited in its control and budget, any strategy toward working down the priority list must consider short-range and long-range actions. Several fronts should be undertaken simultaneously, so as to prepare as best as the Town can for eventual recurrence of sinkholes.

On the latter point, the following set of actions is recommended as the course of action to be pursued by the Mayor's Committee.

Short-Term Actions

1. Develop and adopt an emergency access plan for implementation should derailment take place which restricts access to the east side of the U. S. Army railroad. This plan should be considered a contingency plan, to be initiated only when access is restricted. Alternative access routes, fill material, equipment needed, equipment operator and construction time should be identified.

2. Conduct a vibration study of the railroad trestle and land bridge areas. If the findings of this study reveals that significant levels of vibration are being transmitted to the limestone substructure (and hence, a possible contributor to the acceleration rate of the limestone breakdown and resulting sinkhole development), the Town of Boiling Spring Lakes will be placed on a more equal (legal) footing with the U. S. Army, should any future sinkholes develop.

3. Enlarge the BSL Lake Management Fund. While a number of fund raising activities should be undertaken, any action (e.g., tax increase, issuing of general obligation bonds, application for state and federal grants, etc.) will require the support of the community. To identify funding preferences, a Town-wide survey should be conducted. (Note: Town-wide survey costs are estimated at about $1,500).

Long-Term Actions

1. Do nothing - This approach is based upon the old adage, "If it isn't broken, don't fix it." (Additionally, time will judge the effectiveness of the existing grout curtain).

2. Undertake a single grout curtain method for repairs, up to a specified amount or percentage of cost before another alternative is selected.

3. Install a non-porous membrane or layer when the costs of a single line grout curtain repairs exceed a percentage specified of the non-porous membrane alternative.

Among the six options listed above, #3 (management fund for the lake) presents the most immediate and significant way in which the Town can prepare for the inevitable occurrence of renewed sinkholes.

The essence of this strategy is a fund-raising phased investment approach toward target thresholds. As funds reach the threshold of either an investment opportunity (higher interest rate, etc.) or a more long-term strategy (such as the impervious layer on the bottom of the lake), decisions are made, investments or purchases undertaken, or the strategy is renewed. The following describes in detail why it is recommended, and what funding levels are required.

The Boiling Spring Lakes Management Fund

Although the Town presently has a Lake Management Fund ($13,500), it is not sufficient to pay for anticipated repair costs, nor is it sufficient to avail the City to alternative measures which may have more long-term benefits.

Before the Town can identify what constitutes a "sufficient" Lake Management Fund (i.e., dollar amount), two questions must be answered: 1) What is the frequency at which sinkholes occur, and 2) What is the likely costs for dam repairs following sinkhole development. As indicated earlier, the state of the art and the brief recorded history of sinkhole development in Boiling Spring Lakes makes a statistically valid answer to the above questions impossible. Although such precision is lacking, a "ball park" figure is, nonetheless, needed. With this caveat in mind, the following analysis is presented.

Based upon dam repair costs of previous years and an interview with Bob Davis of Henry Von Oesen and Associates, cost estimates were established. The costs of future repairs could range between $10,000 to $500,000. Minor repairs (to the dam and lake only) could range between $10,000 and $50,000 with major repairs ranging between $100,000 and $500,000.

Inquiries were made with Planter's National Bank to determine at what investment thresholds (e.g., $50,000 or $100,000) special interest rates and terms become available. Currently (February, 1983), all such investments are paying about the same interest rates (around 8%), with no predictability in the future. Nevertheless, the larger the base amount, the better off the Town will be as investment opportunities arise. At any rate, earnings on large amounts are more than earnings on small ones.

Given the above estimates and assessment of investment opportunities, it is recommended that the Town of Boiling Spring Lakes establish a "Lake Management Fund" in the amount of $50,000 (to be adjusted annually by the inflation rate). This amount should cover the repair cost for any future minor sinkholes, and provide a base from which to earn interest toward the cost of any major sinkhole development.

As indicated below, the "Lake Management Fund" should be generated at an annual rate of from $10,000 to $13,000, depending upon the annual inflation rate and interest rate:

Using the following formula, we find that the future value of $61,500 at a 4% inflation rate and $76,000 at an 8% inflation rate is approximately $50,000 (the present value of the target amount).

$$P = F(1-i)^N$$

where P = present value

F = future value of a sum of money

i = expected inflation rate

N = number of years at a given i[1]

Calculations:

<u>at 4% inflation rate:</u>

$$\$50,000 = F(1-.04)^5 = \$61,322 \text{ or about } \$61,500$$

<u>at 8% inflation rate:</u>

$$\$50,000 = F(1-.08)^5 = \$75,863 \text{ or about } \$76,000$$

To determine the annual end-of-year payment needed to reach the targeted $61,500 or $76,000 within five years, the following formula is used:

$$A = F \frac{i}{(1 + i)^N - 1}$$

where A = size of annual payment

F = targeted amount

i = expected interest rate

N = number of years at a given.[2]

---

[1] & [2] "Introduction to Planning Techniques," Keber, Robert, Pembroke State University, 1981.

Calculation:

at 8% interest rate:

$$A = \$61,500 \frac{.08}{(1 + .08)^5 - 1} = \$10,483$$

$$A = \$76,000 \frac{.08}{(1 + .08)^5 - 1} = \$12,955$$

at 10% interest rate:

$$A = \$61,500 \frac{.10}{(1 + .10)^5 - 1} = \$10,074$$

$$A = \$76,000 \frac{.10}{(1 + .10)^5 - 1} = \$12,449$$

at 12% interest rate:

$$A = \$61,500 \frac{.12}{(1 + .12)^5 - 1} = \$9,681$$

$$A = \$76,000 \frac{.12}{(1 + .12)^5 - 1} = \$11,963$$

Once the $50,000 mark is reached (i.e., $61,500 or $76,000 or as adjusted for inflation), the Town should reassess their situation (as history establishes a more accurate sinkhole occurrence rate and repair cost rate), and work down the prioritized list of actions (1 - 10) as the situation dictates.

In this manner, the Town will have a systematic program of enhancing security for the future.

CHAPTER VI

DEMONSTRATION VALUE FOR OTHER COASTAL COMMUNITIES

INTRODUCTION

This year, the Office of Coastal Management of the Department of Natural Resources and Community Development funded five coastal demonstration projects. The Boiling Spring Lakes project is one of them.

This chapter is an epilogue which reflects upon the situation in Boiling Spring Lakes and the analytical and technical work undertaken to address that situation. It highlights the strengths which other communities may wish to replicate, and exposes points upon which other communities may wish to improve as they apply methods used in Boiling Spring Lakes.

As has already become apparent to the reader, the demonstration value of the Boiling Spring Lakes project lies within its analysis of the situation, its selection of planning methods and its techniques for carrying out those methods.

This chapter examines each preceding chapter primarily from a methodological standpoint, with assessment of strengths and recommendations for improvements in subsequent applications. To get the most out of this chapter, it is best to have read the document itself and to refer to it while working through this chapter.

ARTICULATION AND ASSESSMENT OF DEMONSTRATION VALUE

Chapter I--Purpose and Overview

The situation at Boiling Spring Lakes presents a typical coastal area dilemma in which fragile natural resources and community development needs confront each other. Other similar cases include pressures for new development on cherished and even unstable oceanfronts and the development of intensive waterbased uses in primary nursery areas.

On the other hand, the situation in Boiling Spring Lakes is unique in that the natural resources are particularly vulnerable (the limestone substructure is incompatible with any form of intense development and apparently will remain so for all of geological time) and the uses there are particuarly intense (the City of Boiling Spring Lakes is committed to being there as a lake-based, predominantly retirement community, and the U. S. Army is intent on using the railroad for national defense purposes).

Before the Mayor's Committee and its consultants began seeking solutions, they articulated the following questions to help focus their mission and scope of work.

1. What is the real problem? How do we define the problem when all options, studies, court cases and scientific studies to date appear inclined toward one viewpoint or another?

2. Who are the parties involved and what are their strengths and weaknesses (i.e., jurisdictions, authorities, financial capacities, political postures, commitments to their viewpoint, and stakes in the process)? Who has the power to act and who is merely responsive?

3. How does #2 above compound our understanding of #1?

4. How can planning be of meaningful assistance in resolving the problem as recognized?

5. What type of planning instruments should be developed, what areas of expertise will be required to help develop them, what commitments are required, and who will be responsible for funding the proposed short and long-term actions?

Other communities will find such pre-planning essential for clarity of purpose and vision, even before data collection begins. At Boiling Spring Lakes, it was important to reflect upon these questions throughout the development of the project.

<u>Chapter II--A Review of the Problem.</u>

As explained in detail in Chapters II and III respectively, the situation in Boiling Spring Lakes is complex, from a physical (i.e., engineering) and political perspective.

Examination of the physical aspects preceded examination of the political because the problem was initially conceived as a physical one--one which could be clearly perceived, studied and remedied with engineering solutions. This conventional wisdom led to a detailed research effort into the earlier studies, court cases and a collection of any technical pieces on sinkhole problems elsewhere. Additionally, intensive interviews were conducted with technical experts and other persons who had previously been involved with the Boiling Spring Lakes situation. The interviews became the base upon which candidates for the Technical Advisory Committee (TAC) were identified. The TAC served to review alternative solutions and the cost-benefit findings, and set priorities for recommendation to the Mayor's Committee.

During the process of interviewing the various parties involved (the Army, the town, county, state and citizens), it became apparent that all technical solutions would be heavily influenced by the politics of the situation.

Additionally, it was apparent that the viewpoints of the participants were adverse (the Army seriously wanted to maintain its railroad in Boiling Spring Lakes and the Town seriously wanted to maintain the Lake and sustain property values).

Understanding this situation gave the Chairman of the Mayor's Committee a second reason to establish the Technical Advisory Committee—to get a well-rounded political perspective on the values at play within and around the situation at Boiling Spring Lakes.

A third reason for appointing the TAC was that the planning process needed to be accountable within itself, and the product needed to be viewed as credible and legitimate. The TAC along with the Mayor's Committee provided a two-tiered approach to checks and balances, and it spread the working body to include other than community residents.

Once the TAC was established, the next step was to establish a process through which the TAC and Mayor's Committee would become involved in the project. Each group was given a series of working papers throughout the planning process. The TAC would meet first in a work session format, with their conclusions and findings recorded and sent to the Mayor's Committee. Subsequent to the TAC work sessions, the Committee held their own work session. It was through this process that the broad based technical and political critique preceeded the Town's critique, and, hence, maximized the use of the TAC.

Having established the process, the first step was problem definition. While conscious of the five questions presented above, the Mayor's Committee and the TAC reflected upon the following guidelines, which are recommended to other communities at the problem definition stage.

1. Articulate clearly at the outset what aspects of the problem you are going to focus upon. All analytical methods are laced with values, usually those held by the examiner, the audience/client or the technician who developed the method. False objectivity is often a downfall in problem definition and needs assessment. Be prepared to recognize these aspects and be prepared to make adjustments during the study.

2. Take risks in challenging the conventional wisdom related to the problem. Take nothing for granted and learn to disect viewpoints according to interest and stakes in a situation.

3. Build in checkpoints along the course of the study, such as the two-tiered approach at Boiling Spring Lakes, based upon specific criteria of how balanced or how in-depth your information needs are.

4. Identify early what your product is. In the Boiling Spring Lakes case, it was important to not "re-study the already overstudied" technical aspects of the situation for which thousands of dollars had already been spent. Our product was to be an action plan—not solely a new understanding of the problem from which some other group would then develop a plan of action.

5. Be prepared for conflicting expert opinion at every level. Working papers, testimony and work sessions findings will invariably conflict, rendering creative consensus building a requirement.

6. Use a participatory process. While this principle is well stressed in CAMA projects (such as in its guidelines for land use planing (15 NCAC 7B)), it stands repeating as an important element of projects where intial consensus is not apparent.

7. Expect the unexpected. In the Boiling Spring Lakes case, the lack of emergency access to the east side of the tracks, while cited as a reason for concern, emerged as a real problem in its own right. This led to an unexpected assessment of emergency readiness and cast a different light upon the preoccupations with dam stabilization and continuous operation of the railroad.

By addressing these points early, many hidden agendas, misconceptions, miscommunications and future stumbling-blocks can be eliminated at the problem definition stage.

Chapter III—Scenario Development

Chapter III demonstrates how the Boiling Spring Lakes project met the seven guidelines presented immediately above.

The findings from the technical assessment in Chapter II indicated that creative methods were required to challenge assumptions underlying earlier findings and to expose aspects of the problem not heretofore recognized or emphasized.

One of the principal attractions of the scenario writing exercise is its ability to activate creative processes. Namely, to adjust perspectives and expose the participants to a wide range of consequences of given actions through a set of "what if" situations. In Boiling Spring Lakes, the interests were clearly drawn and the respective opinions of "what the problem is" and "what should be done about it" were well known. Politically, the situation seemed stalemated and the entire problem solving process appeared high-centered. The need existed to "shake-up" the situation, to re-activate creative problem solving processes. The scenario writing exercise provided this necessary "shake-up."

Scenario writing (see the particular reference in Chapter III) was chosen as the main planning method because the Boiling Spring Lakes problem is so dominated with the passage of time (geologic time). Most appealing in the context of the Boiling Spring Lakes situation was the beginning-state scenario rather than the end-state scenario. This allowed the group to look at the world in terms of "opportunities" rather than "problems," and allowed the group more latitude to respond to changes in the situation as it proceeded.

Additionally, scenario writing lent itself to a participatory process, providing a structure through which to give participants the permission to lay out values, opinions and assumptions in front of others. In otherwords, it provided a sense of "creative security" that set the stage for thoughtful discussion. This, plus the fact that the TAC was comprised of such different technical and political persuasions, and equally different professional and personal opinions, produced a meaningful group exercise.

In fact, it is from the scenario writing session that it became clear that a consensus model was desired—that the Army and the Town both had firm convictions toward staying in Boiling Spring Lakes and that the task at hand was one of seeking peaceful co-existence.

One of the learnings from the scenario exercise comes from the technique of themes-extraction. That is, once the scenarios were developed, the consultant attempted to extract and analyze themes from the scenarios--looking for opportunities for natural coordination and compatability, as well as points of obvious contention.

From these themes came the concept of gestalt--that the whole of the Boiling Spring Lakes solution may be larger than the sum of its parts. Simply put, in the event of renewed sinkhole activity, each party could act in a separatist manner, taking steps to bolster its own position at the expense of the position of the other. Or, it could take steps toward a commonly held objective which would better not only its position, but the position of the other. With all parties doing so simultaneously, presumably a situation of betterment would be created.

Thus, the concept of gestalt and the scenario writing exercise produced the goal statement presented in Chapter I, repeated here:

> GOAL: To maintain the stability of the main lake at Boiling Spring Lakes, to continue to operate the railroad safely, and to provide emergency access to the east side of the tracks, all in a manner which: 1) improves the long-term mutual compatability of the lake and the railroad, 2) serves the interests of community pride, and 3) is consistent with the adopted Land Use Plan.

It was upon this Goal and a recall of the problem definition in Chapter II, that alternative solutions were designed.

Chapter IV--Alternative Courses of Action and Respective Costs and Benefits

Chapter IV presents an array of nine (which later become ten) alternative solutions.

First, a description of each alternative was developed and each solution was assessed for its costs and benefits (See Chapter IV).

It was during this stage of the project that the need for additional technical studies became apparent. Subsequently, engineering studies were undertaken and more detailed cost estimates established (See Chapter IV). Additionally, the early request for information from the Army's technical personnel paid off in a timely fashion for consideration with the alternatives generated by other members of the TAC.

Thus, two of the learnings for replication to other communities in this chapter are: 1) anticipate greater technical detail for cost-benefit studies than may be apparent at the outset, and 2) ask for outside technical information at the earliest possible time, especially where large bureaucracies are involved.

The next step was to decide how the TAC could use the technical studies and cost/benefit findings to set priorities for recommendation to the Mayor's Committee. Chapter IV (and the referenced Appendix F) presents details of the selection grid procedure that the consultant and the TAC worked through to digest and assemble information relative to the alternatives. That process was undertaken in two distinct steps: 1) a homework step, in which each member of the TAC was sent the selection grids and the cost benefit information beforehand and asked for response, and 2) the on-site group session in which the group collectively reconciled questions from the homework step and articulated new assumptions and held discussion.

In retrospect, the homework step was useful only for introductory or familiarization purposes. There was too much material and too many definitions and assumptions involved (not to mention that the TAC members were volunteers) to expect much before coming to the meeting. On the otherhand, the work session was much more useful since the group had had the material to reflect upon before the session. Another key to the success of the work session was a strict time allotment to each step in the grid-completion exercise. Additionally, agreement was obtained from the group members at the outset about the need to streamline the process, to fully understand definitions, etc., rapidly complete the grid (permitting questions for clarity only), and then holding brief discussions as needed to enrich the record. It also helped to have two facilitators present, one to drive the exercise and the other to watch the clock and ask probing questions of the group as needed.

This process worked as well as it did because the group had a wide range of alternatives to consider. The alternatives were well researched with detailed design and cost/benefit estimates, and a systematic process for comparison and contrast was instituted.

Chapter V--Recommended Courses of Action

The results and methodology applied to rank the alternatives developed in Chapter IV is explained in detail in Chapter V. As mentioned in Chapter V, the application of nominal scores (High, Medium and Low) and later the application of numerical scores, allowed the ranking to be developed to the point that it could be massaged by the group.

This latter point is important, in that such methodologies are useful to a specified degree. Often, such are over-emphasized and relied upon too heavily, especially in situations which are as politically and finacially constrained as Boiling Spring Lakes'.

For these reasons, as the scores were being tabulated by one facilitator, the other led a question-and-answer period on the advantages and disadvantages of each option, to later be taken into account in selecting the recommended course of action.

Often in such priority setting work, it is easy to forget that the list of options is not homogeneous on any aspect. In this case, the list of rankings separates into short-term and long-term actions, as indicated in Chapter V. From such disection often comes insight into immediate steps for fund raising, etc. which, in the Boiling Spring Lakes case, led the consultant to consider alternative investment strategies to help put the community in a position to better pay for priority solutions in the event of renewed sinkhole activity.

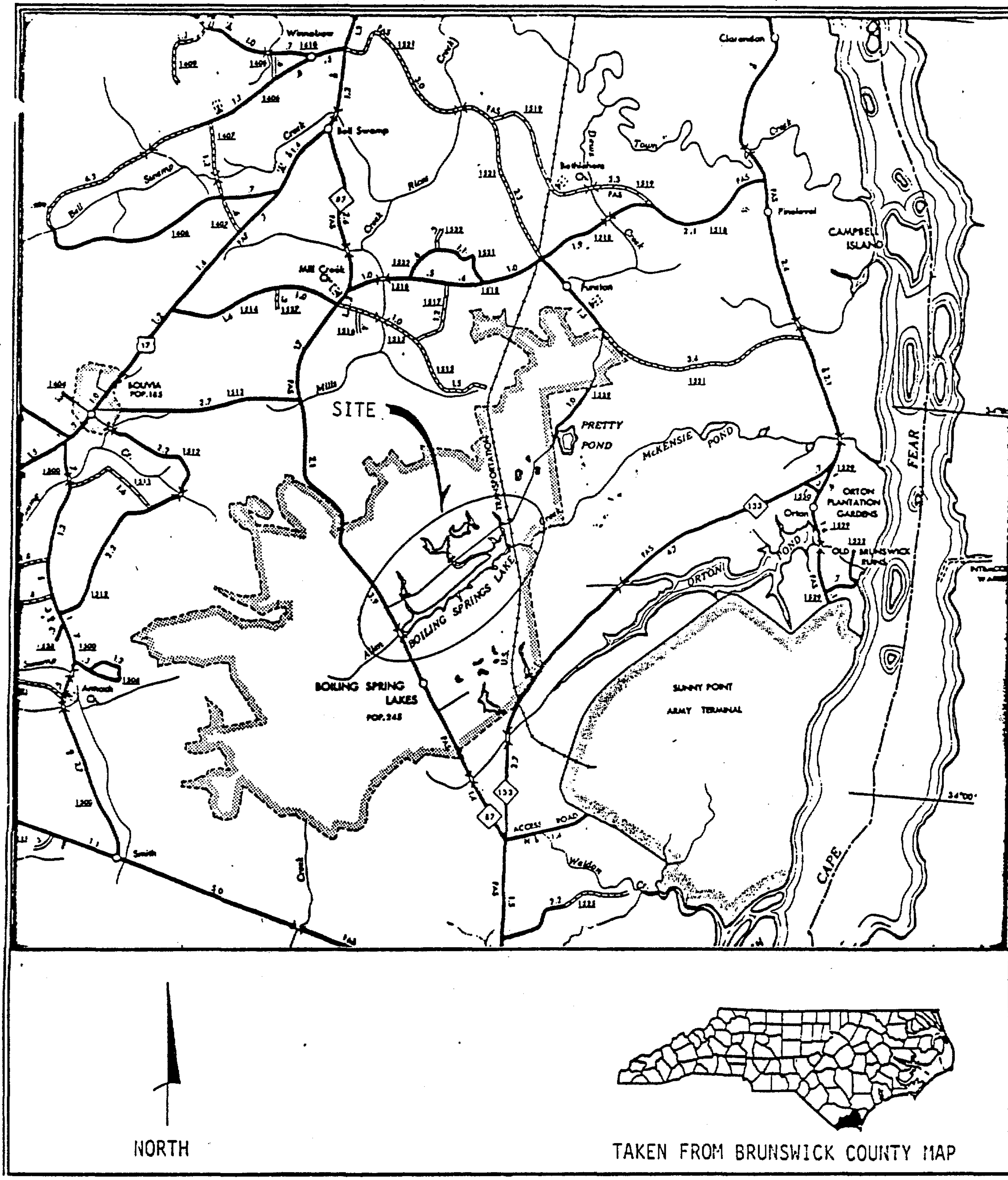
CONCLUSION

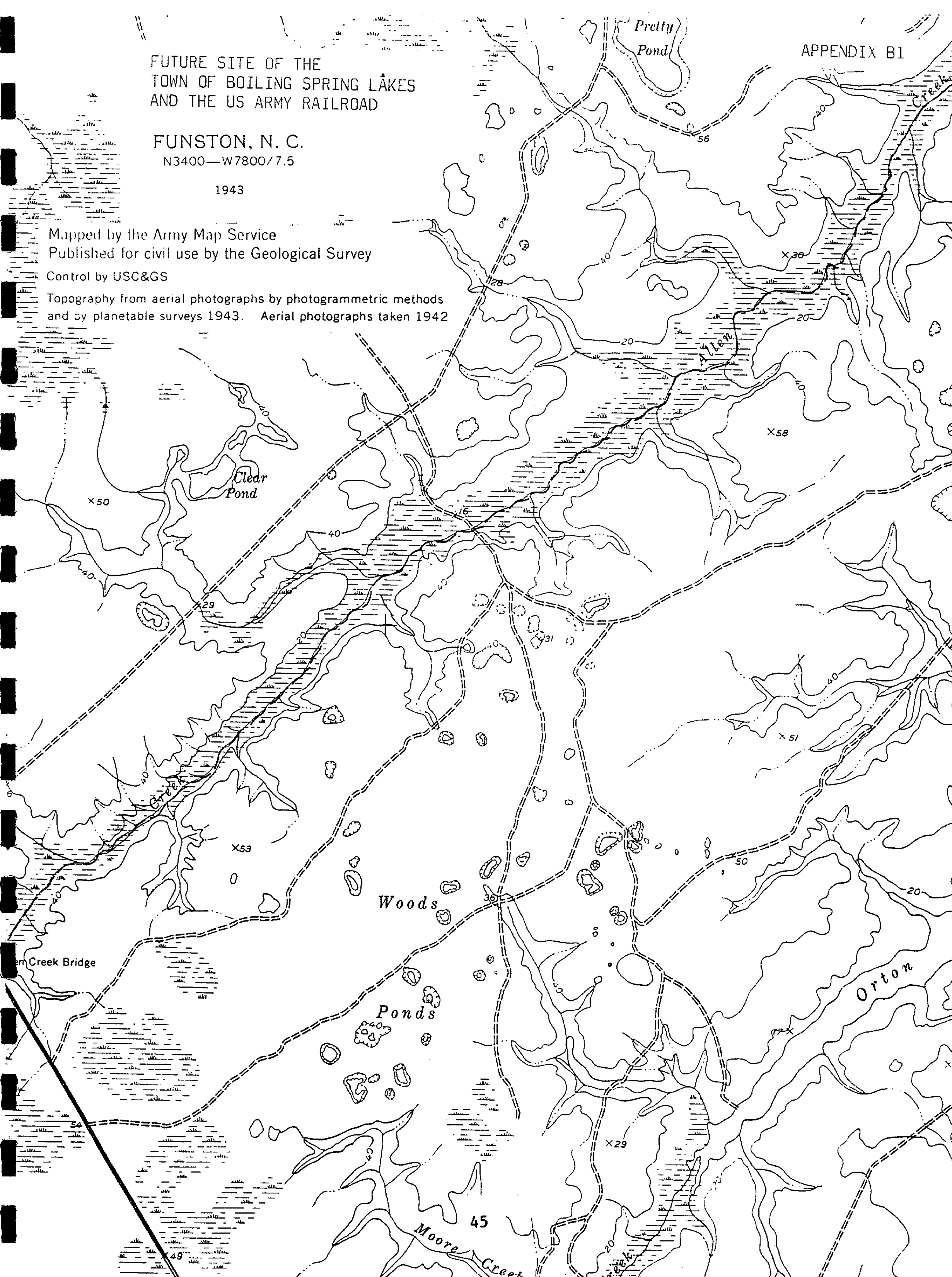
In a nutshell, the Boiling Spring Lakes project indicates that successful analysis of complex natural resource and political problems stretches planning methods beyond their technical limits. Planners and community members who are prepared to shift gears and re-think assumptions, intentions and their own values during the course of the study are more likely than others to be successful.

The Mayor's Committee, the TAC and the consultants will be happy to answer any questions from other coastal communities about particular aspects of the Boiling Spring Lakes Coastal Demonstration Project.

APPENDIX

BOILING SPRING LAKES VICINITY MAP




FUTURE SITE OF THE
TOWN OF BOILING SPRING LAKES
AND THE US ARMY RAILROAD
FUNSTON, N. C.
N3400—W7800/7.5
1943
Mapped by the Army Map Service
Published for civil use by the Geological Survey
Control by USC&GS
Topography from aerial photographs by photogrammetric methods and by planetable surveys 1943. Aerial photographs taken 1942
Pretty Pond
Clear Pond
Allen Creek
Creek
Woods
Ponds
Orton
Moore Creek
Creek Bridge

APPENDIX B1
(continued)

TOPOGRAPHIC MAP SYMBOLS

VARIATIONS WILL BE FOUND ON OLDER MAPS

Primary highway, hard surface
Secondary highway, hard surface
Light-duty road, hard or improved surface
Unimproved road
Road under construction, alinement known
Proposed road
Dual highway, dividing strip 25 feet or less
Dual highway, dividing strip exceeding 25 feet
Trail

Railroad: single track and multiple track
Railroads in juxtaposition
Narrow gage: single track and multiple track
Railroad in street and carline
Bridge: road and railroad
Drawbridge: road and railroad
Footbridge
Tunnel: road and railroad
Overpass and underpass
Small masonry or concrete dam
Dam with lock
Dam with road
Canal with lock

Buildings (dwelling, place of employment, etc.)
School, church, and cemetery — Cem
Buildings (barn, warehouse, etc.)
Power transmission line with located metal tower
Telephone line, pipeline, etc. (labeled as to type)
Wells other than water (labeled as to type) — Oil ..... Gas
Tanks: oil, water, etc. (labeled only if water) — Water
Located or landmark object; windmill
Open pit, mine, or quarry; prospect
Shaft and tunnel entrance

Horizontal and vertical control station:

- Tablet, spirit level elevation — BM Δ5653
- Other recoverable mark, spirit level elevation — Δ5455

Horizontal control station: tablet, vertical angle elevation — VABM Δ9519

- Any recoverable mark, vertical angle or checked elevation — Δ3775

Vertical control station: tablet, spirit level elevation — BM X957

- Other recoverable mark, spirit level elevation — X954

Spot elevation — x 7369 x 7369
Water elevation — 670 670

Boundaries: National
State
County, parish, municipio
Civil township, precinct, town, barrio
Incorporated city, village, town, hamlet
Reservation, National or State
Small park, cemetery, airport, etc.
Land grant
Township or range line, United States land survey
Township or range line, approximate location
Section line, United States land survey
Section line, approximate location
Township line, not United States land survey
Section line, not United States land survey
Found corner: section and closing
Boundary monument: land grant and other
Fence or field line

Index contour — Intermediate contour
Supplementary contour — Depression contours
Fill — Cut
Levee — Levee with road
Mine dump — Wash
Tailings — Tailings pond
Shifting sand or dunes — Intricate surface
Sand area — Gravel beach

Perennial streams — Intermittent streams
Elevated aqueduct — Aqueduct tunnel
Water well and spring — Glacier
Small rapids — Small falls
Large rapids — Large falls
Intermittent lake — Dry lake bed
Foreshore flat — Rock or coral reef
Sounding, depth curve — 10 — Piling or dolphin
Exposed wreck — Sunken wreck
Rock, bare or awash; dangerous to navigation

Marsh (swamp) — Submerged marsh
Wooded marsh — Mangrove
Woods or brushwood — Orchard
Vineyard — Scrub
Land subject to controlled inundation — Urban area

CURRENT SITE OF THE
TOWN OF BOILING SPRING LAKES
AND THE US ARMY RAILROAD

APPENDIX C

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STUDY OF THE ACCESS RAILROAD SINKHOLE PROBLEM

MILITARY OCEAN TERMINAL
SUNNY POINT, NC

Prepared by:
U. S. Army Engineer District,
Savannah
Corps of Engineers

Date: 20 Nov 81

Principal Action Officer:

B. G. Williams
SASEN-MP
912/944-5362

TABLE OF CONTENTS

INTRODUCTION:

This study presents a recommendation for a solution to deal with the occurrence of sinkholes in the Sunny Point access railroad bed. The solution selected should provide the least Risk of Loss of the railroad with the greatest Confidence of Success for the lowest cost. It is the result of a November 1980 review by MTMC of a previous report entitled, "Technical Report on the Sinkhole Development Along the Sunny Point Access Railroad At Boiling Springs, 1978," prepared by Savannah District. Funds for this study were provided by MTMC in March 1981.

Five alternative solutions were considered in the final analysis and will be discussed below. In addition consideration was given to inducing failure along the rail line, constructing a floating or mat foundation, and constructing two additional parallel sets of track through the areas under study. Risk of liability from potential damage to adjacent properties was judged too great to warrant further study of the "induce failure" alternative. The floating or mat foundation was judged not practical from an engineering standpoint. Constructing two additional parallel sets of track may reduce the probability of loss of a line at the same time but is no less vulnerable to failure than other less costly alternatives.

EVALUATION OF ALTERNATIVES:

In the evaluation of alternatives, the following measures were used: Cost, Construction Time, Restriction on Operation During Construction, Restriction on Operation, Environmental Impact, Confidence of Success, and Risk of Loss. No Restriction on Operation During Construction was a criterion used in selection of alternatives. Currently, the mission is not adversely affected by the physical inspection prior to use of the rail line and the 5 mile per hour slow order in effect. Confidence of Success was rated good, fair, or poor. Risk of Loss was rated none, low, moderate, or high. All cost estimates are on the same basis, November 1981.

None of the alternatives would impact significant amounts of woodlands or areas used as habitat by threatened or endangered animal species. The alternatives would not result in significant alteration of the existing environment. Therefore, a finding of no significant impacts could be prepared for the work if the final plans are not significantly different from the preliminary plans. A Memorandum For Record dated 11 June 1981 addressing the environmental inspection is in the appendix.

ALTERNATIVE I. Operate as you are with physical inspection prior to travel and a 5 mile per hour slow order in effect during travel. Risk of Loss is low and Confidence of Success is good. The following contingency actions are recommended with this alternative:

1. Maintain a stockpile of rail and ties for a detour in case of the occurrence of a sinkhole and have a plan for plugging the sinkhole.

a. Cost ....$78,320.

b. Storage area: North Rail Holding Yard

c. Borrow material from onsite within the existing right-of-way.

d. Time to respond with government forces and equipment ......1 - 3 weeks

(Stockpiling a prefab bridge, though practical, is estimated to cost about $231,040 and is not recommended in this alternative.)

2. In the case of a national emergency reroute the railroad over the dam at the time of mobilization and maintain this as a standby in case of a problem in the main line.

a. Cost $255,430

b. Storage area for rail and ties.........North Rail Holding Yard.

c. Construction time (government forces) ... Two weeks from obtaining right-of-entry for construction purposes.

ALTERNATIVE II. Grout Area 1 (Station 805+00 to Station 808+00)and Area 2 (Station 824+00 to Station 825+50). This involves pumping a cement type mixture underground to strengthen the subsurface. The Risk of Loss is moderate, and the Confidence of Success is fair.

a. Cost $1,526,600

b. Construction Time ....6 months

In addition the slow order should remain in effect and contingency in case of the occurrence of a sinkhole should be maintained increasing the cost of this alternative to $1,604,920.

ALTERNATIVE III. Construct two new bridges, one in area 1 and one in area 2 and replace the wooden trestle over Allen Creek with a bridge. This is referred to as the "Incremental Bridge" Alternative. The Risk of Loss is low, and the Confidence of Success is good.

a. Cost $1,031,490

b. Construction Time ....18 months

In addition the slow order should remain in effect and contingency in case of the occurrence of a sinkhole should be maintained increasing the cost of this alternative to $1,109,810.

ALTERNATIVE IV. Construct a total bridge over the area from Station 792+00 to Station 832+00, 4,000 feet. The Risk of Loss is none, and the Confidence of Success is good.

a. Cost $7,440,210

b. Construction Time.........24 months

ALTERNATIVE V. Replace the wood trestle over Allen Creek with a permanent bridge. The Risk of Loss is low and Confidence of Success is good.

a. Cost $436,650

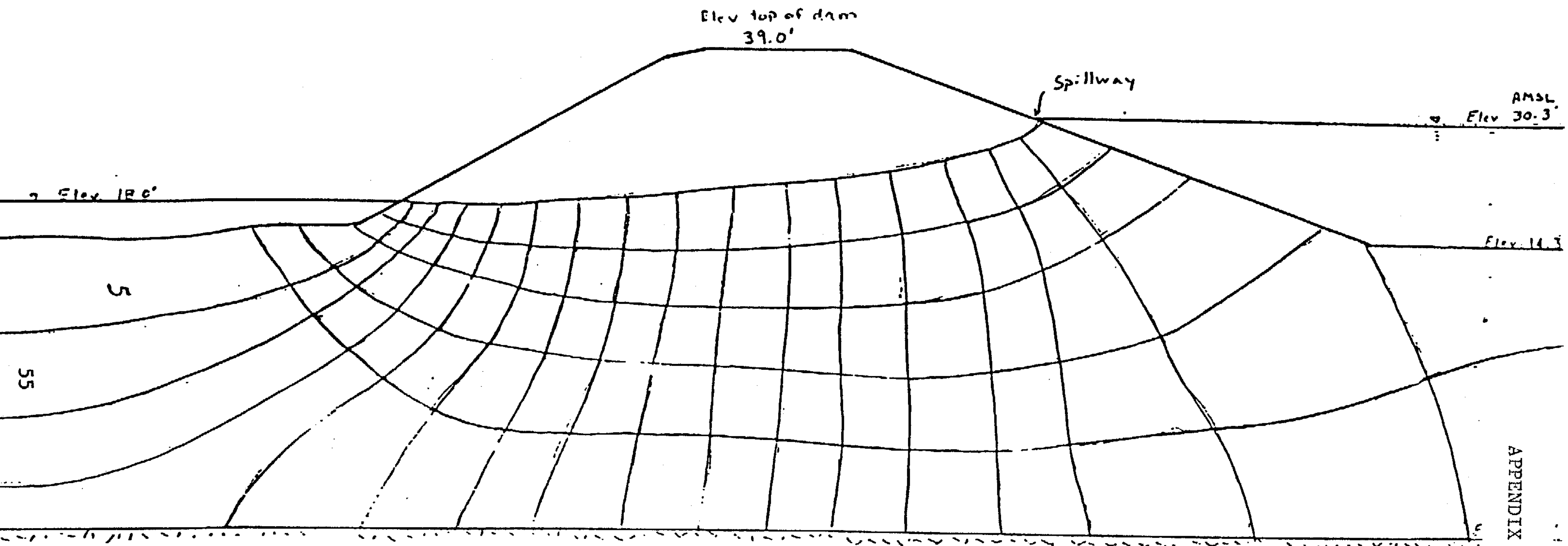
b. Construction Time...........12 months

In addition the slow order should remain in effect and contingency in case of the occurrence of a sinkhole should be maintained increasing the cost of this alternative to $514,970.

RECOMMENDATION:

Alternative I, operate as you are with a contingency plan, is recommended. It is judged as having low risk, good confidence of success, and a cost of $78,320.

Figure 1 EXISTING DAM



$K = 10^{-3}$ cm/sec : 3.28×10^{-5} ft/sec

$n_c = 5$

$n_d = 16$

$h_L = 30.3 - 16 = 12.3'$

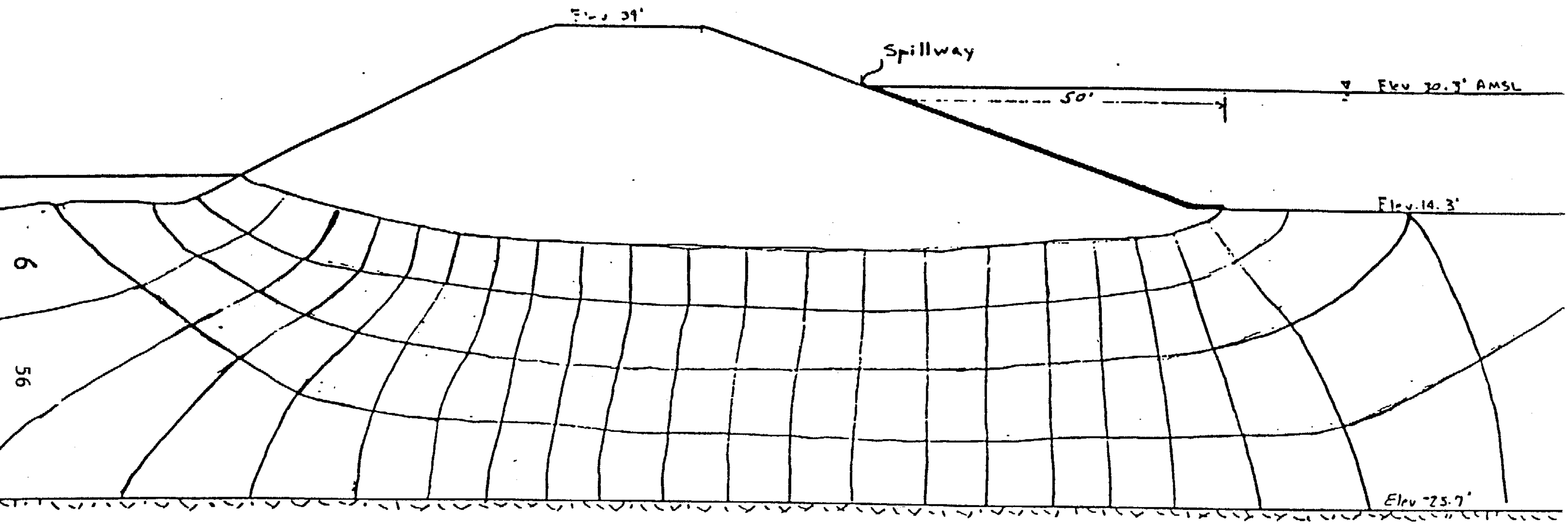
$q \text{(seepage)} = K h_L \frac{n_c}{n_d}$

$q = 3.28 \times 10^{-5}$ ft/sec $(12.3')\left(\frac{5}{16}\right)(1\text{ft}) = 1.26 \times 10^{-4}$ ft³/sec for a (1ft deep section)

Assumptions

1) at Elev − 25.7 MSL impervious laye
2) $K = 1 \times 10^{-3}$ cm/sec = 3.28×10^{-5} ft/sec for sandy clay + silt
3) homogenous soil throughout the dam.

Figure 2 DAM WITH 50 Ft. IMPERVIOUS LAYER



q(seepage) = 3.28×10^{-5} ft/sec (12.3 ft)(4/21)(1 ft) = 7.69×10^{-5} ft³/sec

Reduction of seepage from existing dam: 23%

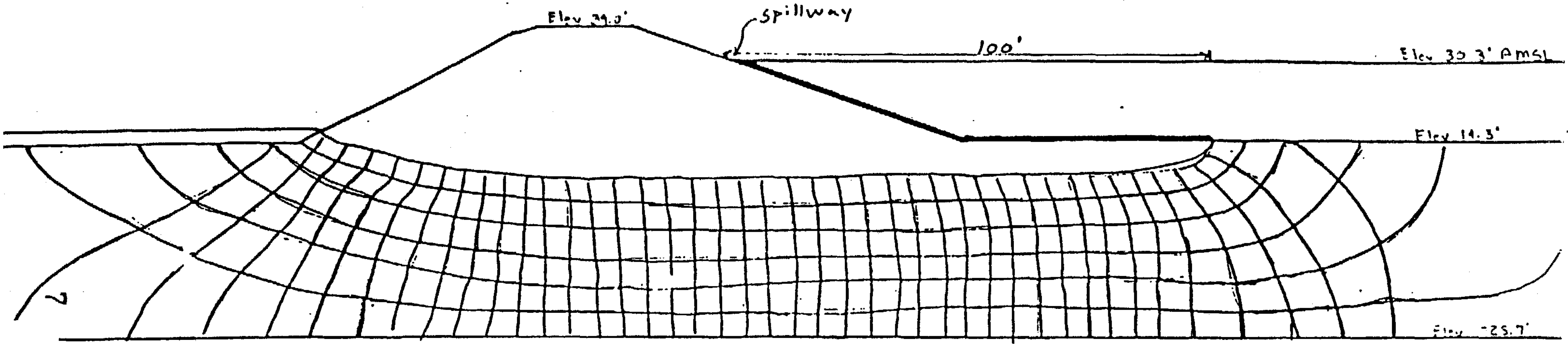
Amount of area to be covered
56' back from dam, 1/4 mile long dam } ~74,000 ft²

1' deep clay
require 74,000 ft³, 2700 yd³
Cost for clay, transportation, and compaction: $ 23,650

Plastic liner
$ 1.05/ft²
74,000 × 1.05 = $ 77,700

Figure 3

DAM WITH 100 Ft. IMPERVIOUS LAYER



q seepage: 3.28×10^{-5} ft/sec $(12.3\text{ ft})\left(\frac{6}{41}\right)(1\text{ ft}) = 5.9 \times 10^{-5}$ ft^3/sec

Reduction of seepage from existing dam: 53%

Amount of area to be covered

105' back from dam
1/4 mile long dam } 138,600 ft^2

1' deep clay

require 138,600 ft^2 = 5100 yd^3

cost for clay, transportation, and compaction = $ 48,767

Plastic liner

$ 1.05/ft^2

138,600 × 1.05 = $ 145,530

EXHIBIT A: SELECTION GRID

ALTERNATIVE COURSES OF ACTION	POSITIVE IMPACT ON THE PROBLEM	DURABILITY OVER TIME	UNIT COST	TOTAL COST	AVAILABILITY OF FINANCING	ADVERSE ENVIRONMENTAL IMPACTS	COMPLEXITY & COST OF MAINTENANCE & MANAGEMENT	REQUIRED TIME FOR COMPLETION
1) Construction of a dam upstream from existing dam.								
2) Construction of a dam downstream from the existing dam.								
3) Impervious layer								
4) Lowering the water level								
5) Relocation of the railroad onto the existing dam.								
6) Construction of single grout curtain the entire length of the dam.								
7) Construct a triple grout curtain along the entire length of the dam.								
8) Conduct a train vibration study along the trestle and bridge area.								
9) Establish alternative emergency access route across railroad.								

Please rate each alternative "high", "medium", or "low" by putting "H", "M", or "L" in each cell.

EXHIBIT B

ALTERNATIVE COURSES OF ACTION	ADVANTAGES	DISADVANTAGES
1) Construction of a dam upstream from existing dam.		
2) Construction of a dam downstream from the existing dam.		
3) Impervious layer		
4) Lowering the water level		
5) Relocation of the railroad onto the existing dam.		
6) Construction of single grout curtain the entire length of the dam.		
7) Construct a triple grout curtain along the entire length of the dam.		
8) Conduct a train vibration study along the trestle and bridge area.		
9) Establish alternative emergency access route across railroad.		
10a) Relocate railroad system.		
10b) Relocate railroad downstream.		

APPENDIX F Exhibit B