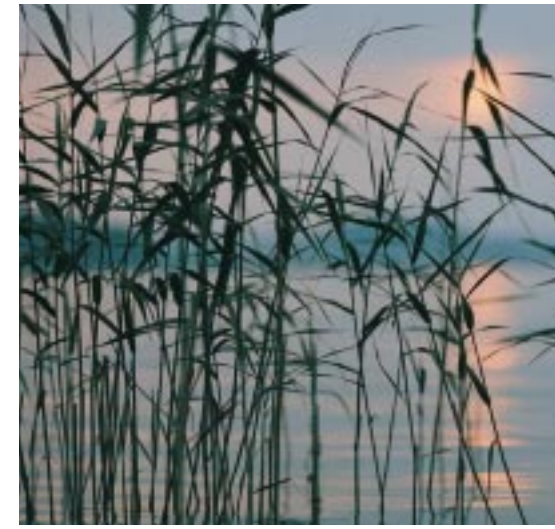
LAKE OKEECHOBEE
and
THE HERBERT HOOVER DIKE

A Summary of the Engineering Evaluation of Seepage and Stability Problems at the Herbert Hoover Dike.

The Good Life

Lake Okeechobee and the Herbert Hoover Dike Are Important to South Florida.



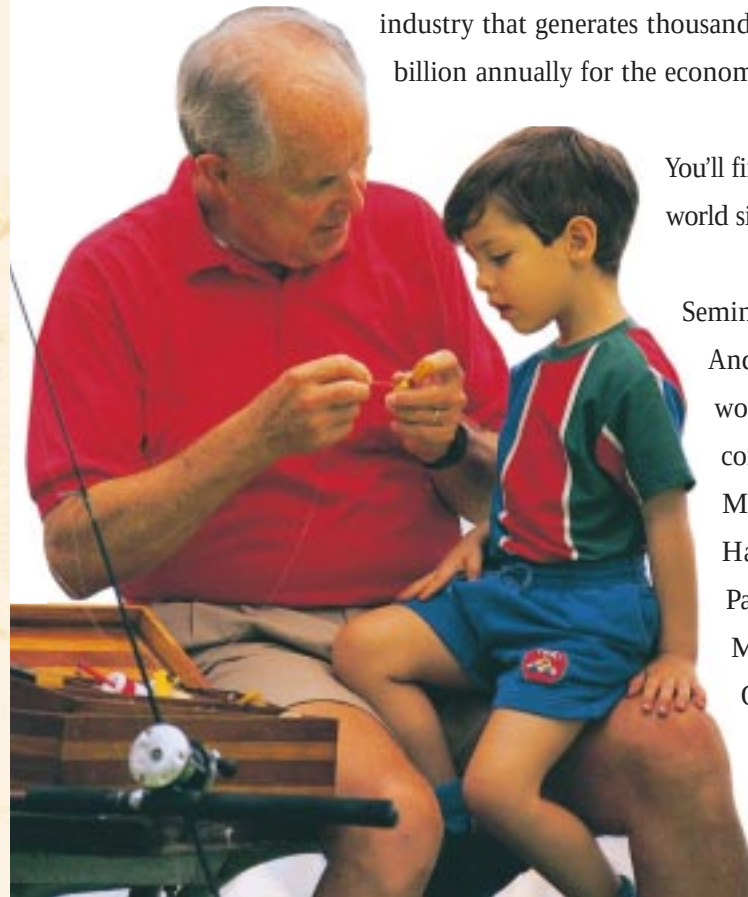
Here's Why:

It's the second largest freshwater lake that lies entirely within the United States.

To the north, cowboys on horseback raise cattle. To the east, vacationers in RVs make camp.

There are deer. Turkey. Wild boar. And scores of bird watchers seeking a peek at the rare Everglades Kite.

Miles and miles of citrus groves play neighbor to a sugarcane industry that generates thousands of jobs and more than $1.5 billion annually for the economy of the region.



You'll find tourists from around the world sightseeing and fishing for bass.

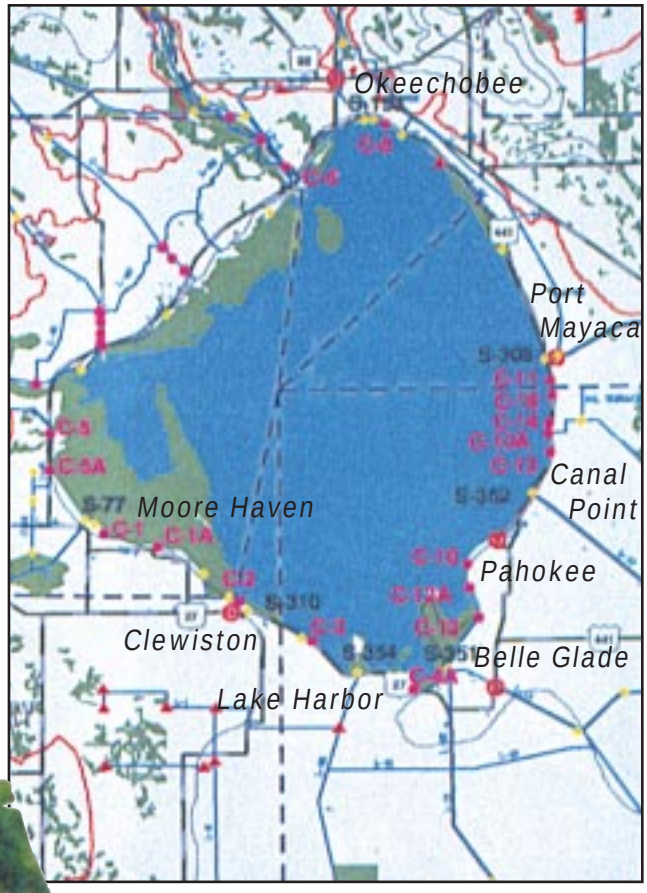
Seminoles named it "Big Water." And more than 40,000 men, women, and children living in communities like Lakeport, Moore Haven, Clewiston, Lake Harbor, South Bay, Belle Glade, Pahokee, Canal Point, Port Mayaca, Indiantown, and Okeechobee call it home.

Fact: *Sixteen species known to occur in the vicinity of the lake are currently listed as threatened or endangered by the U.S. Fish and Wildlife Service.*

The People.
The Land.
The Water.

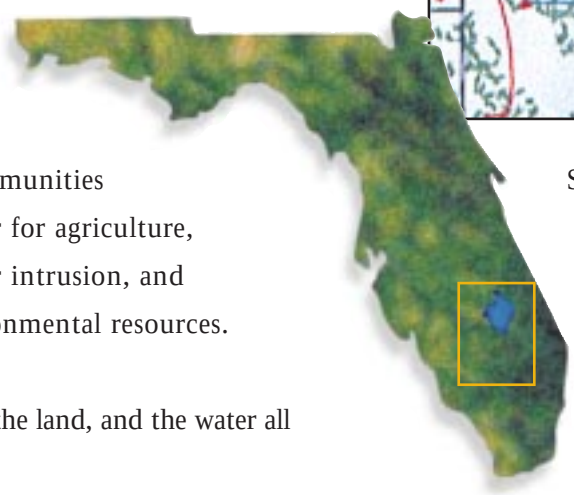
The good life is protected by the Herbert Hoover Dike.

The Herbert Hoover Dike is an earthen dike system that encircles Lake Okeechobee for 140 miles.



The dike system has numerous water control structures to provide flood protection, navigation, recreation, freshwater for the communities of south Florida, water for agriculture, prevention of saltwater intrusion, and enhancement of environmental resources.

In short — the people, the land, and the water all depend on each other.



Since 1984, the U.S. Army Corps of Engineers, Jacksonville District, has written several engineering reports documenting that areas of the dike are prone to water seepage and stability problems.

And these problems may put the good life at risk.

"Records covering the performance of the dike system during major flood events indicate that the embankment and foundation of the structure are susceptible to significant seepage and piping erosion when the reservoir reaches critical levels during these flood events."

— Excerpt from *Expert Review Panel Report of Findings and Recommendations*, October 1, 1998

The Problem

Breach of Florida Power and Light Cooling Reservoir, 1979. Failed due to piping of material from the foundation of the dike.

Here's What We Have Found:

For the layman, the problem with the Herbert Hoover Dike when the lake reaches high water levels can be summed up in two words:

"It leaks."

An overly simplified description of the problem? Perhaps. Yet, it's true. When the lake is high, water finds its way through the dike from lakeside to landside – sometimes eroding soil from within or beneath the dike.

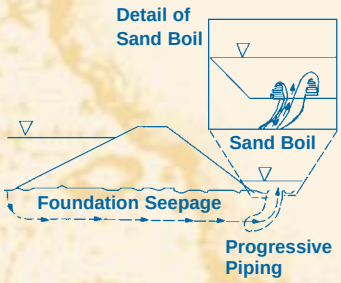
This erosion of soil is technically known as *piping*. The piping of the soil creates a continuous open path through which water can erode even more soil. If this soil erosion is allowed to continue, it will eventually create large cavities in the dike.

And those large cavities — with water from the lake running through them unimpeded — create a serious risk that the dike will breach, with large releases of water from Lake Okeechobee flooding the surrounding lands.

Building the Dike

Throughout its history, the dike was designed, built, and maintained within the accepted

FOUNDATION PIPING



Piping — *the erosion of soil caused by water. As the soil erodes, it creates an open path (a "pipe") through which water can pass. As more and more soil erodes, the pipe gets larger.*

Sandbagging and piping at Lake Harbor showing mound of piped material that is flowing from the dike.

standards existing at the time — beginning in the 1930s.

The dike was originally constructed using hydraulic dredge and dragline techniques which concentrated deposits of pervious shell, rock, and gravel within the dike.

The hydraulic dredging methods used to construct the first levees were state-of-the-art and fully acceptable in the 1930s; however, due to an improved understanding of material properties and seepage mechanisms, those same methods would not be acceptable today.

In addition, the foundation beneath the dike has pervious layers of limestone, sand, gravel, and shell.

As a result of the pervious zones described above, some areas of the dike are prone to excessive seepage.

Sinkhole on levee crest at Lake Harbor site.

"The causes of the seepage and piping are related to the geometry, materials, and methods used in the construction of the dike and in the complex and variable geology comprising the foundation of the dike system."

— Excerpt from *Expert Review Panel Report of Findings and Recommendations*, October 1, 1998

"Our seepage analysis indicates that dike seepage gradients increase non-linearly as the lake elevation rises above +20 feet. In its present geometry, condition, and without extensive maintenance activity, it is our opinion that seepage and piping related dike breach is likely as the lake elevation rises above +20 feet."

— Excerpt from the conclusions of URS Greiner Woodward-Clyde, an engineering consultant firm hired to perform an independent analysis of dike conditions

What is a Dike Failure?

When we say dike failure, we mean a breach or open gap in the dike. Waters from Lake Okeechobee would pass through the breach — uncontrollably — and flood adjacent land.

Some dike problems may be harmless – such as the formation of springs and wet areas along the landward toe of the dike. These conditions are undesirable but do not pose immediate safety hazards.

We have found, during recent high water events, that numerous areas of the dike have seepage and piping problems when the lake elevation reaches 18.5 feet.

THE DANGER: Flooding would be severe and warning time would be limited. And with 40,000 people living in the communities protected by the Herbert Hoover Dike, the potential for human suffering and loss of life is significant.

It's a risk we can't afford to take.

How Bad is It?

There is limited potential for dike failure with lake elevations lower than 18.5 feet. But as the lake level rises, so does the risk of dike failure.

Our analytical studies show a dike failure would be likely at one or more locations if the water elevation in Lake Okeechobee reached elevation 21 feet.

The lake would reach elevation 21 feet during a 100-year flood event.

Statistically, a 100-year flood event would be expected to happen on average once every 100 years. But in reality, a 100-year flood event can happen during any given year.


Record water level tests dike holding Okeechobee

High water strains Okeechobee

ASSOCIATED PRESS

CLEWISTON — The massive levee that contains Lake Okeechobee hasn't faced a test like this in nearly 50 years. With the lake's water 18.61

levee, worrying residents and authorities with the Army Corps of Engineers, which manages the lake.

Inspectors have found 25 seepages, or small water leaks, in the dike and in the trench at the foot of the levee. What worries engineers

City of Pahokee, on the east side of Lake Okeechobee.

In fact, Lake Okeechobee reached an elevation of 18.6 and 18.5 — both 30-year events — in 1995 and 1998. That's two 30-year events in only four years.

Note: The lake elevations referred to in this report are static lake levels that last for weeks, not a hurricane wind driven storm surge that lasts for only a few hours.

When Will the Dike Fail?

There is limited potential for a dike failure with lake levels as low as 18.5 feet. The likelihood of a failure increases at higher lake levels. At a lake level of 21 feet, a dike failure would be likely at one or more locations.

What the World Experts Say:

The U.S. Army Corps of Engineers, Jacksonville District, convened an expert panel of five of the world's foremost authorities in Geotechnical Engineering. Here is a portion of their conclusions:

"We believe the deterministic and probabilistic models developed by URSGWC and the (Jacksonville) District are based on the best information available. Further, we believe the conclusion they have drawn from their analyses — that there is a very serious risk of catastrophic failure and loss of the reservoir due to piping — is reasonable.

"Considering the past performance of the dike system and our assessment of the probable performance of the dike under the more critical 100-year flood event, as well as the high potential for downstream catastrophic loss of life and damage due to dike failure, the Panel considers the dike to be unsafe from a piping and erosion point of view, and recommends that actions be taken without further delay to initiate remedial design and construction of repairs to bring the dike up to satisfactory condition."

Members of the Expert Review Panel for the Herbert Hoover Dike:

John A. Bischoff, P.E.
Senior Managing Principal and Vice President for Woodward-Clyde Consultants

J. Michael Duncan, Ph.D., P.E.
University Distinguished Professor, Department of Civil Engineering, Virginia Polytechnic Institute and State University

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Associate Professor of Civil Engineering
Massachusetts Institute of Technology (Retired)

Dr. J.B. (Hans) Sellmeijer
Scientific Specialist, Delft Geotechnics,
The Netherlands

Thomas F. Wolff, Ph.D., P.E.
Associate Professor and Associate Dean,
Department of Civil and Environmental Engineering, Michigan State University

The Precedence

Disaster Led to the Building of the Dike

View from Pahokee water tower before the dike was built, circa 1935.

The ravages of nature struck Lake Okeechobee in September of 1926.

There was no Herbert Hoover Dike. Just a small muck dike that had been made to keep the lake from drowning crops.

Hurricane winds thrashed the town of Moore Haven with a wall of water that killed nearly 400 people.

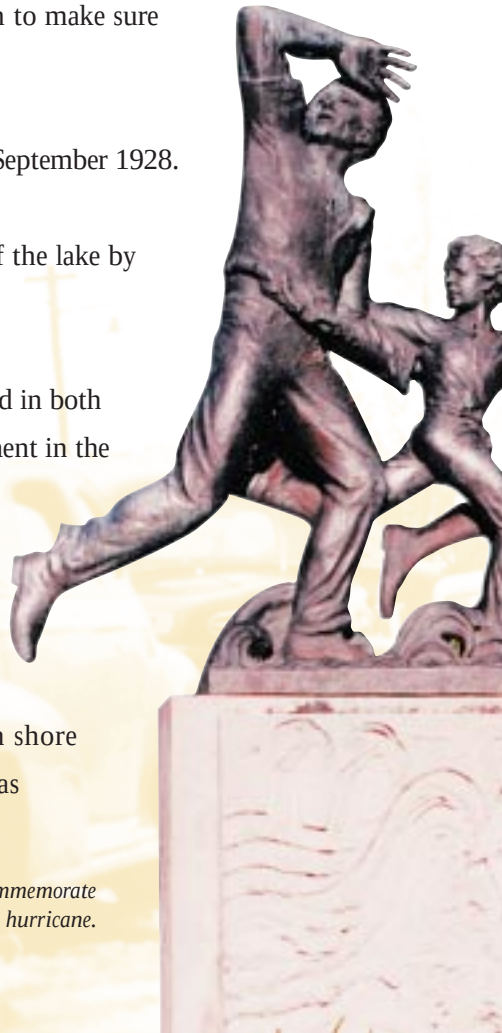
Engineers, lawyers, and politicians looked for a solution to make sure that kind of tragedy never happened again.

But before one was reached, another hurricane struck in September 1928.

Nearly 2,000 people were killed by waters driven out of the lake by hurricane winds.

These tragedies — commemorated by monuments erected in both Clewiston and Belle Glade — prompted federal involvement in the provision of flood protection to lakeside communities.

The result was the Corps of Engineers construction of the Herbert Hoover Dike, which began in 1932. The 68-mile south shore was completed in 1936, and an additional 16-mile north shore was completed in 1938. Subsequent construction has increased the dike length to 140 miles.



Monument in Belle Glade to commemorate the 2,000 victims of the 1928 hurricane.

100-Year Event — *an event that happens an average of once every 100 years. (For example: Every year Lake Okeechobee has a 1 in 100 chance of reaching a level of 21 feet.)*

The Corps has maintained a diligent schedule of maintenance and repair ever since. Yet, even so, time has taken its toll.

May 1974 – North Shore Dike Breach

A section of the north shore dike extends for about 6.5 miles from Lake Okeechobee along the north bank of the Kissimmee River.

In 1974, a portion of this dike at the intersection of a drainage canal breached due to piping.

Fortunately, due to low lake levels at the time, the breach of the dike resulted in a flood release from the canal that flowed into Lake Okeechobee rather than out of the lake.

As a result, only the dike and a water control structure were damaged, and there were no other flood-related damages.

1979 Florida Power & Light Dike Failure

The nearby Florida Power and Light Cooling Reservoir Dike failed in 1979 causing considerable flooding damages. It failed as a result of piping through its foundation.

Similar foundation conditions and piping potential would exist for the portions of Herbert Hoover Dike north of Port Mayaca.

Flooded Main Street in Clewiston due to hurricane rains, circa 1948.

"There are numerous case histories of piping failure where seepage-control measures were not present, as is the case at Herbert Hoover Dike. Two piping failures have occurred in the immediate vicinity (northwest corner of Herbert Hoover Dike and Florida P&L) with differential heads of approximately 14 feet. Seepage and piping failures may occur without warning. They may result, in part, from accumulated damage from previous high water events and/or high water duration, in addition to differential head."

— Excerpt from *Expert Review Panel Report of Findings and Recommendations*, October 1, 1998

The Threat

High Lake Levels Create an Unacceptable Risk

The subtropical climate of the Lake Okeechobee area produces steamy summers and dry winters.

And it rains a lot — between 55 and 60 inches every year.

Any excessive rainfall would result in higher lake levels if it falls directly on the lake or within its drainage basin.

There is no reason to be afraid of a spring shower. But if it rains . . . and rains . . . and keeps raining — like it often does in South Florida — stress is placed on the dike as the rain causes lake levels to rise.

And Then There's Hurricane Season

It happens — without fail — every year.

From June 1 to November 30, the people who live in the communities around Lake Okeechobee stay prepared. They stock up with extra food, drinking water, batteries — all the essentials, just in case a storm hits. And they trust in the Herbert Hoover Dike to help protect them.

The effects of a hurricane — with its strong winds, heavy rains, and storm surges on the lake — could contribute to loss of life and property.

But the dike has been stressed during recent high water events — even without a hurricane.

High Water Event — 1995

In the late summer and early fall of 1995, the lake rose to elevation 18.6 feet. The dike showed substantial distress, but it did not breach.

However, several significant problem areas were identified.

Cane field in Clewiston, 1998.

Seepage — *the movement of water through soil or rock.*

Inspection teams discovered excessive seepage, piping, and sinkhole formation on the dike crest. Cloudy water exiting the landward toe of the dike and the accummulation of fine sands indicated that internal erosion of the dike was occurring.

Emergency repairs (construction of "seepage berms") were completed in time for the 1996 hurricane season, but these repairs were not intended or designed to be a permanent solution to the seepage and stability problems.

High Water Event — 1998

In March of 1998 the lake rose to elevation 18.5 feet. Again, it did not fail.

But overall conditions continued to worsen. Areas not repaired from the 1995 high water event exhibited additional boil formation and seepage — presumably due to cumulative damage that occurs with each successive high water event.

The Risk is Unacceptable

It could be a hurricane, a tropical storm, or just lots of heavy rain. The risk increases significantly anytime the lake reaches an elevation above 18.5 feet.

Major Rehabilitation Evaluation Approach

The Army Corps of Engineers' goal is to ensure that a reliable dike system is provided along the perimeter of Lake Okeechobee. That's why we have conducted a Major Rehabilitation Evaluation of the Herbert Hoover Dike.

For the Major Rehabilitation Evaluation, we performed engineering, economic, and environmental analyses for the entire Herbert Hoover Dike system. This approach has allowed the Army Corps of Engineers to:

- Determine that rehabilitation measures related to seepage and stability problems are warranted
- Provide economic justification for the rehabilitation measures
- Address environmental issues related to the proposed rehabilitation
- Provide a technical supporting document for a comprehensive Project Cooperation Agreement
- Allow direct progression into preparation of Plans and Specifications for rehabilitation of Reach 1

The evaluation has indeed indicated that rehabilitation efforts are warranted; therefore, upon approval of the Major Rehabilitation Evaluation Report, a series of additional efforts will be initiated if appropriate funding is available.

The Plain Truth

What Are Our Options? And What Happens if We Do Not Fix the Dike?

If the problems with the dike are not corrected, we would continue to inspect the dike during high water events. And we would do whatever was humanly possible to prevent a dike breach.

We would continue to perform maintenance and operate the dike as we have done historically.

But that means the people and property protected by the Herbert Hoover Dike would continue to be subjected to an unacceptable risk of dike failure. Also, the best efforts of the Corps of Engineers, the South Florida Water Management District, and the local emergency management agencies may not be enough to avert a dike failure if the lake rises above 19 feet.

So what are our options?

We Could Keep the Lake Below Elevation 18.5 Feet

This may seem like an easy answer; however, our ability to remove water from the lake is limited by the capacity of available outlet facilities.

In short, we can only lower the lake at a rate of about 0.4 of an inch per day under ideal conditions. But during extreme rainfall events, this would not be enough. The amount of water entering Lake Okeechobee would be much greater than the amount of water we could discharge.

The lake elevation would actually rise even if we were discharging water from the lake at the maximum possible rate.

We could increase our outlet capacity by building a new outlet channel, but the costs would be much greater than our proposed rehabilitation of the dike.

We Could Permanently Lower the Lake

Unfortunately, even if we were to substantially lower the lake, during a 100-year flood event, the water comes into the lake much faster than we could remove it. The lake level could still rise to an elevation that could result in a dike failure.

Besides, maintaining unusually low lake levels — or draining the lake entirely — would have significant socioeconomic and environmental consequences.

During high lake stages, large regulatory discharges are sometimes made from the lake to the estuaries to avoid loss of life and property associated with high stages and hurricane-generated waves and tides. Any prolonged releases of large freshwater discharges, including urban and agriculture basin runoff, can cause adverse effects to the estuarine system.

Therefore, lake levels must be maintained within reasonable levels.

We Could Build Relief Wells

Relief wells are specialized water wells that would be constructed to drain seepage water from within the dike or from the foundation of the dike before the seepage water can exit on the surface.

When seepage water is prevented from exiting on the surface, no piping of dike materials is possible.

The problem with this solution is that it will only work for certain portions of the dike.

We Could Build Ring-Dikes and Increase the Tailwater

We could build a second smaller dike parallel to and landward of the Herbert Hoover Dike. We would then raise the water level between the two dikes (tailwater). This would decrease the differential seepage pressure across the big dike. Decreasing the seepage pressure would prevent the piping of materials from the Herbert Hoover Dike.

This alternative was investigated in significant detail; however, the estimated level of protection it would provide is not adequate.

Or We Could Build a Cutoff Wall to Hold Back the Lake Waters

A cutoff wall would require digging a trench through the dike and into the dike foundation. This trench would then be filled with clay. The clay would not allow the passage of seepage water from the lake through the dike.

With this seepage water cut off, piping of materials from the dike would not be possible.

Although this alternative may be very effective, it is expensive. The estimated cost is $16 million per mile.

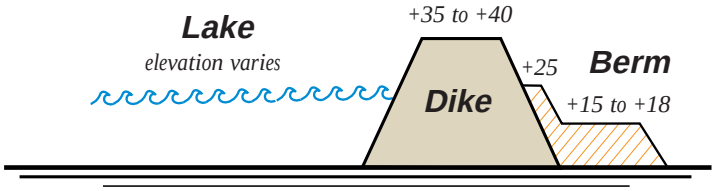
Also, this alternative could have detrimental impacts on groundwater flows immediately adjacent to the dike.

"The [Jacksonville] District's vigilance in taking emergency action in 1995 may have prevented a breach. After the 1995 event, they made very diligent efforts to staff and train a surveillance team and to react to observed distress.
They also constructed effective seepage control berms, filters, and drains after the event. These measures performed well in the 1998 high water event. The importance of this effort cannot be overemphasized."

— Excerpt from *Expert Review Panel Report of Findings and Recommendations*, October 1, 1998

The Recommended Solution

Cross Section of Dike



Typical dike section for southeast portion of the lake, not to scale, elevations shown are in feet.

This is It:

We are currently proposing for approval a solution which involves the construction of a seepage berm, with relief trench and drainage system, along the landside toe of the dike.

In other words, we would build a filter that lets the water through without allowing the dike material to pass through with it.

It's cost-effective, provides good flood protection, and doesn't harm the environment.

We are pursuing this solution for the first phase of construction along 22 miles of the southeast shore. This first phase — one of eight segments we have prioritized due to the great length of the dike — is where the most severe seepage and stability problems occur.

Here's the Technical Stuff:

The five-foot thick berm will consist of filter sand

Construction site at culvert No. 3 east of Clewiston - An example of part of the 10 million dollars of construction work already completed.

Fishing pier on Lake Okeechobee.

and gravel and will contain a perforated culvert for the collection and transfer of seepage waters.

The berm will prevent piping of soil from the embankment and foundation. A relief trench below the berm will control uplift pressures and prevent heaving at the landward toe of the embankment. It will also intercept and transport seepage which would otherwise emerge uncontrolled landward of the embankment.

Sound complicated?

Think of it this way: It's like making coffee. The water passes through, but the grounds are retained by the filter.

And the people living around Lake Okeechobee stay protected.

"We recommend that the Corps of Engineers stockpile repair materials at strategic locations to control piping that may develop along those stretches of the dike that showed signs of distress during the high-water period in 1998. Such repair materials would include, but not be limited to, filled sandbags and soils that satisfy filter criteria and that could be used to build weighted filters over areas where springs discharge soil."

— Excerpt from *Expert Review Panel Report of Findings and Recommendations*, October 1, 1998

The Need

Time. Money. Dedication.

Here's the bottom line:

For the first phase of construction — 22 miles along the southeast shore of the lake from Belle Glade to Port Mayaca —the estimated cost is $67 million.

The rehabilitation of other portions of the dike will be addressed in subsequent engineering reports.

It Will Take Time

The first phase of construction will take about four years.

If rehabilitation is required along all of the south and east shores, we estimate the total construction time will be 12 years.

We could construct the needed improvements more quickly if funds were available to support simultaneous construction efforts.

The Happy Ending

For the People, the Water, and the Land

The Herbert Hoover Dike was built to protect the people who live around Lake Okeechobee.

The dike has provided significant benefits to the people and economy of South Florida for 60 years.

But our engineering studies and the recent two high water events have demonstrated that the dike does not provide the required level of flood protection when lake levels exceed 18.5 feet.

But it can. We have the solution.

We can protect the good life — the heart-stopping beauty of Lake Okeechobee — for the people who live here . . . work here . . . play here.

For their children. And for future generations.

"We recommend that the Jacksonville District, U.S. Army Corps of Engineers review their Emergency Action Plans to ensure that timely warnings can be issued and emergency actions taken in case of a breach or imminent breach anywhere along the dike. The District should review their plans for stockpiling materials and for mobilizing earthmoving equipment and operators to plug any breaches that may develop."

— Excerpt from *Expert Review Panel Report of Findings and Recommendations*, October 1, 1998

Questions & Answers

1. Is the dike going to fail?

There is limited potential for dike failure with lake levels as low as 18.5 feet. The likelihood of a failure increases at higher lake levels. At a lake level of 21 feet, a dike failure would be likely at one or more locations.

2. Wasn't the dike fixed in 1995?

In the past five years, we have completed $10 million worth of construction that was directed toward problem areas. Those critical repairs were only a partial solution to the seepage and stability problems — more work is needed.

3. What is being done about the problem now?

Our plan is to diligently inspect the dike during high water events. In a joint effort with the South Florida Water Management District and local authorities, we will inspect the dike system daily when lake levels meet or exceed elevation 18.5 feet. We will direct all available resources toward the early identification and rapid repair of any problem areas.

If conditions began deteriorating in spite of our efforts to control the seepage, we would recommend evacuation of the threatened areas.

4. How long have you known about this condition?

There have been some questions about the reliability of the dike since 1984. Our engineering studies, along with our observations of the dike during the 1995 and 1998 high water events, have demonstrated that those concerns were warranted.

5. Why was an unsafe dike built in the first place?

The Corps would not intentionally build an unsafe dike. The dike was built in compliance with the construction standards that existed in the 1930s. Recent engineering analysis, along with the observed high water damage to the dike, demonstrate that the levee will not withstand sustained high lake levels.

6. If the dike fails, where would it fail?
Our engineering studies indicate the southern and eastern portions of the dike system are more likely to fail than the northern and western portions of the dike.

7. Is my community at risk of flooding?
The Corps of Engineers have developed flood maps that show the areas that would be flooded if the dike were to break. If a dike break occurred near a population center, that area would be flooded.

8. How much warning would there be?
In general, we would expect a warning time of 24 to 48 hours prior to a dike failure that releases water from the lake; however, under some conditions the warning time might be longer, and under others, a dike failure could occur with no warning.

Should an emergency occur, instructions for public saftey will be issued through the local Emergency Management Agency.

The primary objective of our high water inspection procedures is to identify any problems as quickly as possible. If problems are detected soon enough, remedial measures can be taken in an effort to prevent a dike failure. However, there are over 140 miles of levee within the dike system, and inspection resources and manpower are finite. Also, there exist some possible failure scenarios which would be difficult, or impossible, to detect prior to failure. If a dike failure occurred, the warning time would depend on factors such as the nature and mechanism of the failure, where it occurs, and at what stage the problem was detected.

9. How could such a massive structure fail?
The massiveness of the structure would argue for the inherent safety of the dike, but there are specific features within the dike that could contribute to a failure.

For example, substantial portions of the levee were constructed out of shelly material that is highly pervious to water. Water seeping through these shelly materials during the 1995 and 1998 high water events caused erosion of the dike material. This type of erosion creates cavities within the dike which increase the potential of a dike failure.

10. How will the public be informed about potential failures of the dike?
The Corps will keep all interested parties informed about seepage problems along Herbert Hoover Dike and efforts to remedy those problems. If high water conditions arise in the future, prior to construction of the remedial measures, the Corps will coordinate with local emergency management agencies and issue press releases to inform the public of our concerns and proposed actions. Individuals seeking information about any Corps activities can contact the Jacksonville Corps of Engineers' Public Affairs Office. The phone number is (904) 232-1650.

This publication is furnished by:

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