THE SIXTY-STOREY CRISIS

THE STORY BEHIND BC HYDRO'S WORST NIGHTMARE: THE DISCOVERY OF A HOLE IN ITS MASSIVE BENNETT DAM AND THE BEHIND-THE-SCENES EFFORTS TO ENSURE THE UNTHINKABLE – A BREACH IN THE DAM – WOULD NEVER HAPPEN

by Anne Mullens

UP UNTIL 4 P.M. ON FRIDAY JUNE 14, 1996, THE DAY HAD BEEN like any other in the 30-year history of the W.A.C. Bennett Dam. As one of the world's largest embankment dams, for years it had quietly straddled the Peace River in the Northeast portion of the province, near Hudson's Hope. But then a tourist dropped into the tourist centre beside the dam, and nothing was to be the same again.

The tourist's name has been forgotten in the tumult of events that followed; nor is it known whether he had traveled by foot, car or bicycle over the road that runs along the embankment dam's crest. All that is known is that in the middle of the dam, he spied a hole in the asphalt and knew it ought to be reported. The tour guide thought so, too, and called the control building of the G.M. Shrum Generating Station nestled in the east shoulder of the dam.

Unless you've seen the Bennett Dam, it is hard to fathom its size. High as a 60-storey building and two kilometres wide, it's an enormous earth and gravel wedge that holds back 360 kilometres of Williston Lake, the largest reservoir in North America. In a word: massive – and with massive water pressure behind it.

And suddenly it had developed a small hole.

It was after office hours on a Friday; the control building was quiet. Peace River Generation manager Ron Fernandes, the regional boss for BC Hydro, had been in Vancouver on a business trip and was flying home. But operations manager Dennis Hunter was there and took the tour guide's call. He and another senior manager went to the crest to take a look, but not being civil engineers, they weren't sure what to make of it.

It was 4:30 p.m. when John Baker had the first inkling something was amiss. A civil engineer in BC Hydro's department of civil inspection, he was up from Vancouver for his yearly two-week check. So far, all the instruments seemed to show that everything was fine. He was in the office writing an e-mail when he picked up the tones of intense conversation.

"Pothole . . . " He looked up to see Hunter and a manager of finances in serious discussion. They saw him, and Hunter called over: "Hey, you're from civil, aren't you? Phew...

Come with us."

"I was thinking that the whole dam would breach," recalls BC Hydro's John Baker. "I really was. I was thinking the sides would continue collapsing to the point where the reservoir would enter the hole – and then it would be game over"

The hole was just 455 mm in diameter, about the size of a large pizza. Baker lay on his stomach and stuck his head into it. Through the dim light he could see a small cavern, the size of a doghouse, with the top of a badly corroded metal pipe exposed at its base. He recorded the dimensions, drawing a cross-sectional diagram, noting time of discovery, location and size, and the position of the corroded pipe. "I knew at the time it was something that we had to deal with right away," Baker recalls. "I was apprehensive."

In dam engineers' parlance, the term 'sinkhole' is akin to 'cancer'. So Baker told the others: "Right now, let's refer to it as a local surface depression."

As stipulated under the emergency preparedness plan, any event or incident which could potentially affect the integrity of the dam triggers a series of phone calls to about two dozen BC Hydro engineers, managers and government officials. One calls another, the word fans out. Hunter and his colleague returned to the control building to start phoning. Baker raced to the base of the dam to read the weirs – the drains that carry the natural seepage from the dam. "I was hoping against hope I didn't find dirty water or increased seepage or even worse, a crack opening up in the dam." He quickly walked the 'toe' of the dam, looking for danger signs in the wall of gravel towering above. He found nothing.

"As we say, 'The vital signs were still good'," says Baker. "It wasn't in imminent danger of collapse." But he didn't relax: "We didn't know how bad it was, but we knew we had a hole in the dam and that is not good."

If the Bennett Dam should ever fail, catastrophe would follow in the shape of an unstoppable burst of water 135 metres high. Like a titanic fist, it would roar down the canyon and take out the smaller Peace Canyon Dam, 22 kilometres downstream. The combined force of two ruptured dams would then descend on the town of Hudson's Hope, a giant fury obliterating buildings, uprooting trees, tossing cars and trucks like Dinky toys, and likely killing any of the 1,200 residents unable to get out of its way.

Unlike a tsunami, the destruction wouldn't simply peak and stop. The pent-up waters of Williston Lake would just keep coming, seeking to return to its natural elevation. The waters would flow for weeks, scouring away communities like Old Fort, Taylor, Peace River, Fort Smith and beyond. The onslaught would back up tributaries and inundate the entire Peace River Basin, flooding Lake Athabaska and Great Slave Lake. The floods could devastate northern Alberta, portions of Saskatchewan and the Northwest Territories all the way to the Arctic Ocean. The death toll could be high; the environmental and structural damage astronomical. Combined with the loss of generating power of the dam, the unprecedented disaster would cost billions of dollars and throw B.C.'s economy into turmoil.

Dam failure isn't some unrealistic threat. In the last century, more than 70 major dams have failed worldwide, causing loss of life and untold millions in damage. In 1976, a town was devastated and 11 people killed when the Teton Dam failed in Idaho. In 1972, the small Kelly Barnes Dam in Georgia let go, and 39 bible students died while sleeping in a residence. The most famous dam failure in North America occurred when the South Fork Dam collapsed on May 31, 1889, after a week of heavy rains. It sent 20 million tons of water, boiling with debris, crashing down on the community of 30,000 in Johnstown, Pennsylvania. The survivors reported hearing a roar like thunder as a 40-foot wall of water hit the town. More than 2,200 people were killed and almost the entire population left homeless.

Although the Johnstown flood remains one of the worst man-made disasters in North America, the collapse of the Bennett Dam would have unleashed a mountain of water 12 times larger.

"The failure of a large dam has the potential to cause more death and destruction than the failure of any other man-made structure," says Dr. Richard Woodward, an Australian dam engineer who maintains a Web page devoted to dam safety.

"The destructive power of water is phenomenal," agrees Jack Farrell. At the time of the Bennett Dam crisis, Farrell was comptroller of water rights for the Ministry of the Environment, a statutory position under the Water Act which gives him the legislative power to regulate and monitor dams in B.C.

That June 14, Farrell and his staff of dam safety officials and regional water managers were in the Lower Mainland for the department's annual golf tournament. They were having a beer at an outdoor patio when suddenly all their cell phones started ringing. A buzz quickly went around the table: "There's a pothole at Bennett Dam." Farrell and a few of his senior officials quickly retired to a quiet room to get more details.

"We said, 'Okay, it's a big dam and there's a little break in the asphalt and it dropped a couple of feet,' " recalls Farrell. "It could be nothing, but we'd better check it out." He decided to send a ministry dam safety engineer and engineering consultant up on the first flight to Fort St. John the next morning.

Meanwhile, a cadre of BC Hydro managers, engineers and executives had convened in a board room at BC Hydro's head office in Burnaby. The GM Shrum/Bennett Dam combo was BC Hydro's largest power-producer, generating 2,730 megawatt/hours, or 30 per cent of all the power in the province. A lot was at stake.

A conference call was made to the dam

The WAC Bennet Dam holds back the largest reservoir in North America.

Photo by Ray Stewart, reproduced courtesy of BC Hydro.

site, to where Ron Fernandes had returned from his trip and was back in command. In turn, Baker had faxed over the on-site measurements and drawings of the damage. The meeting was intense. Was this simply a small hole that signified nothing? Or was it the start of a larger problem such as internal erosion – a serious disease of an aging dam, one that could threaten its integrity, cost millions of dollars to repair, or perhaps even force the dam to be drained and decommissioned? If vital signs changed, how much time was there to alert the public? Although they agreed an actual dam breach was remote, the consequences would be horrendous. There was no question a full investigation must start immediately, and the repair undertaken as quickly as possible.

That night, Ray Stewart, an experienced dam engineer who at the time was manager of the geotechnical department of BC Hydro, was selected as the technical manager to oversee the investigation and repair of the hole. Arrangements were made to get equipment and gravel to the crest of the dam should it collapse further. The mayor of Hudson's Hope was notified, but as every indicator showed the dam was still performing normally, the town wasn't put on evacuation alert. Meanwhile, Fernandes was to recall a crew of workers to start round-the-clock surveillance of the dam and its weirs. Any change in the dam's vital signs would trigger an evacuation.

Confident that all was safe, for now, the meeting adjourned. "I don't think any of us slept well that night," recalls Fernandes. Before returning to his hotel room, Baker checked the weirs one last time around midnight. Meanwhile, all night long, shifts of three walked the crest, the middle and the toe of the dam. That same night, Ray Stewart packed a small bag, thinking he would be at most three or four days at the dam. It would be a year before he was able to finally return home again.

Saturday, June 14 dawned cold and grey. Fernandes, Baker and a small crew watched as a backhoe peeled the asphalt off the top of the pothole. One of the crew took a long metal rebar rod and began probing the cavern's bottom. The rod slid easily through what should have been hard-packed dam. "The ease with which that rod went down – that gave me the willies," shudders Fernandes. "It just kept going and going and going. I knew there was something very, very wrong."

By noon, Stewart, Farrell's two men from the ministry and the mayor of Hudson's Hope, Lenora Harwood, had arrived. All afternoon they watched as the backhoe scooped out loose fill. Finally, the machine came to the end of its reach. The softness still stretched down, but it was feared any more digging would destabilize the top of the dam. Sand and gravel were pushed back into the hole and compacted, a marker placed to pinpoint the location of the corroded pipe.

They knew now that the pipe was a survey benchmark tube – a sighting marker used by surveyors as the dam went up. It consisted of a narrow steel rod, with a larger, hollow steel sheath surrounding it.

"The existence of the pipe was a surprise to us because it wasn't on the plans," explains Stewart. "But at the same time, it was good news, because we had a cavity forming around some physical object – not just internal erosion developing on its own. It gave us a hypothesis of why the cavity was there."

Stewart quickly calculated that the annular space of the corroded pipe extending 115 metres down to bedrock was roughly the same volume as the cavern at the top. Therefore, the cavity could be caused by silt and soil migrating to fill the space in the rotted pipe. But was that the only explanation? Did the softness go deeper? How many more unmarked survey pipes were in the dam? Would the earth be soft around them as well? Or was this internal erosion?

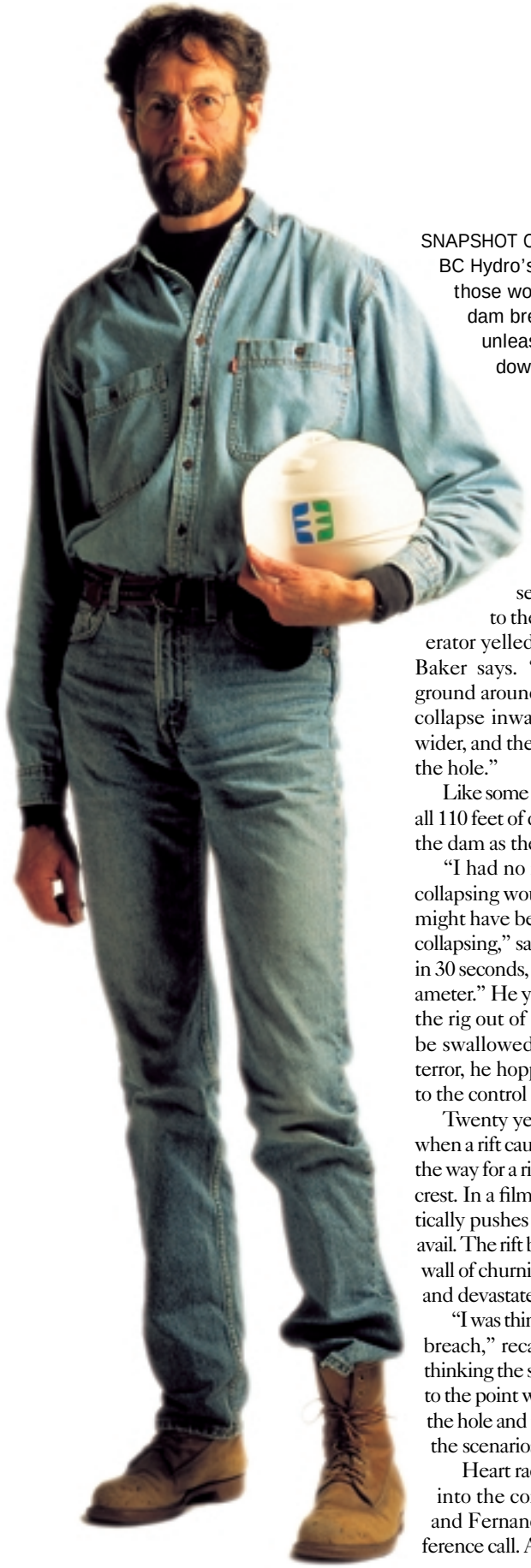
Getting the answers meant drilling into the dam's core. Like slipping a needle into a living heart, it involved risk. "No dam engineer takes drilling into an operating dam lightly," says Stewart. "It was very much exploratory. We knew we had to disturb ground and we knew we had to go ahead, but it was serious."

The Vancouver office scoured B.C. and Alberta for an available drill rig. A Becker drill was located in Calgary. It and a crew set out on Sunday afternoon by truck, arriving at the dam site just before noon on Monday, June 17.

A Becker drill is a large diesel-operated pile driver, or hammer. For this exploration, it was equipped with a closed sectional pipe and a computer to measure the number and back pressure of the blows needed to drive the pipe. "If it is very dense material, it will be a high number of blows per foot and the pressure will be higher," explains Baker. "We thought this would give us a good idea of how tightly packed the dam was."

The drilling began just after 1 p.m. At the surface, the dam was fairly dense from the new gravel compacted into the hole. But once the drill hit 18 to 20 feet, the ground began to lose density. The weight of the rig alone was enough to push the drill through the soil. For its hammer to fire, a Becker drill requires resistance; at 20 to 30 feet the ground was so soft the drill would not hammer. From 30 to 40 feet, some ground resistance was encountered, but the blows were low.

Every 10 feet, the crew added a new section of heavy, double-walled steel drill pipe. The drill string was becoming heavier and heavier. At 50 feet, the ground suddenly became so soft the hammer quit; its weight simply pushed through the soil. Baker's notebook attests to the alarming figures – from 50 to 100 feet, line after line of zeros. There was virtually no resistance in a portion of the core. As the drill neared 100 feet, Stewart returned to the control building for a pre-arranged con-



SNAPSHOT OF A CRISIS: BC Hydro's Ray Stewart was among those working feverishly to prevent a dam breach that would have unleashed a wall of water on downstream communities.

ference call to head office. Baker stayed at the crest.

And then at 110 feet, it happened.

"I had turned away for a second, to do some adjustments to the computer, when the drill operator yelled: 'The hole is opening up!' " Baker says. "I turned and looked. The ground around the drill pipe was starting to collapse inward, and the hole was getting wider, and the drill pipe being sucked down the hole."

Like some ghastly slow-motion nightmare, all 110 feet of drill pipe was disappearing into the dam as the walls caved in around it.

"I had no idea how long this process of collapsing would continue – for all I knew it might have been the start of the whole crest collapsing," says Baker. "The hole had gone, in 30 seconds, from nothing to four feet in diameter." He yelled to the drill operator, "Get the rig out of here!" fearing it was about to be swallowed. Then, in what was close to terror, he hopped in his rental car and raced to the control building.

Twenty years ago, the Teton Dam failed when a rift caused by internal erosion opened the way for a rivulet of water through the dam crest. In a film of the event, a bulldozer frantically pushes soil into the wound, but to no avail. The rift becomes a canyon. Then a huge wall of churning muddy water bursts free . . . and devastates a small town downstream.

"I was thinking that the whole dam would breach," recalls Baker. "I really was. I was thinking the sides would continue collapsing to the point where the reservoir would enter the hole and then it would be game over. All the scenarios go through your head."

Heart racing, pale as a ghost, Baker ran into the control building where Stewart and Fernandes were conducting the conference call. As the two men spun around in alarm, Baker's face said it all.

"John is a pretty calm, collected guy and just to see him – it rattled us," says Fernandes. "We said to Vancouver: 'Something is happening, we'll call you back,' and slammed down the phone." Adds Stewart: "And all these senior managers in Vancouver are sitting there thinking: 'What the hell is going on?!' "

It takes time for a dam to fail. At the first signs of increased flow into the dam, it would be at least four hours before the Bennett Dam might give way. Even with a catastrophic collapse of the dam core, it would still take 20 minutes for the wall of water to reach the Peace Canyon Dam and 30 minutes to reach Hudson's Hope. The men knew they still had time to assess the situation.

When they arrived back at the crest, the collapse had come to a halt. The vital signs remained healthy – no increased flow, no dirty water. One observation well did show a sudden increase in flow, but over the next two hours it returned to normal. What did it mean? One thing was certain: the little pothole was now a gaping maw 23 feet deep and eight feet across. They also knew the softness continued down for at least 100 feet, if not all the way to bedrock.

This was no longer a 'localized surface depression' – this was dam cancer, a sinkhole.

"From that incident on, the safety status of the dam was uncertain," says Stewart.

In the minds of BC Hydro officials, the unexpected collapse and the coinciding response of the observation well marked the beginning of the sinkhole crisis at Bennett Dam. From that moment on, there would be no holding back. Whatever had to be done, would be done, no matter what the cost.

Jack Farrell, the comptroller of water rights, was at home in Victoria that Monday night when the telephone rang.

"It was a shocker," Farrell recalls. "My

Photo by Lionel Trudel (http://www.trudelphoto.com)

"It's easy to look back at it now, but at times I can recall the intense emotion and stress around the enormity of what we were dealing with," says BC Hydro's Ray Stewart. "It was like a war"

first concern was for public safety. I knew that the snow pack was extremely high, one of the highest snow packs on record. And that time in June is when the melt really starts to flow into the reservoir. The water would be coming up very quickly. And here, the top of the dam is soft. We couldn't let the water get up there, because that's how dams fail."

As his staff gathered data about the rate of flow into the reservoir, Farrell knew he would soon have to order BC Hydro to spill water in unprecedented levels from the reservoir – a move that would have a huge cost to BC Hydro's bottom line and could even cause flooding and environmental damage downstream. However, he felt there would be no choice.

Meanwhile, down in Hudson's Hope, word of the collapse traveled fast – especially as almost one-third of the community had a family member who worked at the dam or generating station. That afternoon, some parents took their children out of school. Some even prepared to flee. The mayor and council held an emergency meeting that Monday night, and residents of the town's only nursing home were told to get ready for possible evacuation.

But still, the dam's vital signs remained good.

"It was such an anxious time. I think the worst part for us was the uncertainty," says Ron Fernandes. "We wanted to be sure we did the right thing. We didn't want to create havoc and panic everybody by ordering evacuation when it wasn't necessary, but we sure didn't want to wait too long, either. Part of me just wanted to say, 'What the heck, let's go to alert.' The responsibility I felt was enormous."

Ray Stewart and others started marshaling dam experts from all across Western Canada and beyond. Over the next six months, there were at times more than 60 experts, some from as far away as Sweden, working at the dam.

The teams doing 24-hour surveillance were immediately boosted to three inspectors and a shift supervisor. For the next 10 months, they walked the dam doing visual and instrument inspection. Nicknamed "Cresty", "Middleman" and "Toeboy", the men logged up to 20 kilometres a shift, even in the dead of night and the dead of winter when temperatures plunge below - 40 degrees Celsius.

Wednesday June 19. More than 400 people crammed into the Hudson's Hope school gym to hear Stewart, Fernandes and officials from the provincial emergency preparedness program speak about the dam.

"The meeting was intense," says Fernandes. "Some people were close to panic, but most were just really, really concerned and ready to do something like move. We did not tell them there was no problem. We told them we were concerned, too. We told them what we were monitoring and what vital signs we were looking for. I think there was acceptance that we were doing what we could and that there was no immediate danger."

In the months that followed, only one family moved out of the downstream area because of worries about a breach. As it was the family of one of the Hydro employees doing 24-hour surveillance on the dam, it sparked a flurry of worry among the downstream residents who heard of it. But Fernandes and others kept their families in the downstream path. Ray Stewart even moved his young family from New Westminster up to Hudson's Hope.

"When my wife was picking up the kids from school, moms would come and ask her what was going on at the dam," says Stewart. "I think they were quite reassured that I would move my family up there and we would rent a home in the downstream area."

Along with all the experts in dam safety and repair brought in to the site that first week, a BC Hydro communications team was dispatched from head office. It stayed for 10 months, commandeering the public relations and media relations arm of the crisis. The strategy was straightforward: be proactive and give facts so that rumors don't proliferate; communicate immediately, even if tempted to wait for more or better information; be open and honest because people can handle bad news better than the feeling something is being withheld.

The policy of openness resulted in scores of news releases, daily fax bulletins, Internet updates, a toll-free line, site tours and briefings to any interested public, and even an explanatory video. The communiqués were rather technical and devoid of any emotion or drama, but they were accurate and correct.

Ironically, this openness not only increased the downstream residents' confidence and comfort with BC Hydro, it had another unexpected result: the major media, perhaps realizing there was nothing to hide, lost interest and over time ignored the story.

But the story was far from over.

Jack Farrell flew up from Victoria to attend the first on-site advisory board meetings June 21 and 22. Ray Stewart, who for the last week had barely slept or eaten, was so exhausted and stressed that when he tried to sum up the week's events, he was unable to speak. He had to leave the room to compose himself while a colleague briefly took over.

The two days of discussion centered on what could realistically be done to investigate the dam without further undermining the core. How much freeboard is needed to safely work on the dam, and therefore how much water must be spilled from the reservoir? Farrell was adamant no further drilling and investigation could take place until the level was dropped by at least two metres. BC Hydro was worried that spilling that much water would not only risk flooding some downstream communities

At the sinkhole, prompt action prevented any chance of a dam breach that would have unleashed a wall of water on downstream communities.

Photo by Ray Stewart, reproduced courtesy of BC Hydro.

and farmland, but it could undermine the stability of bedrock on the downstream side of the Peace Canyon Dam.

"We were worried about something called the 'plunge pool'," explains Fernandes. "When water is spilled from a dam, the force carves a pool in the bedrock. We were worried the Peace Canyon Dam's plunge pool hadn't stabilized yet. With the volume of water being spilled, the pool could carve itself either downstream or upstream. If it carved upstream it could weaken the foundation of the dam and threaten its stability."

A compromise was reached. The spill would be commenced, then briefly stopped so engineers could test the bedrock below both dams to ensure the plunge pools weren't carving upstream. Then the spill would be restarted.

On June 24, under order from the comptroller of water rights, BC Hydro began to spill 180,000 cubic feet per second; 70,000 through the generators and the rest down the concrete spillway. It was the biggest spill in the history of BC Hydro. Equal to the flow over the Canadian side of Niagara Falls, the spill plumed high into the sky and soon became a local tourist attraction. To BC Hydro, it represented an estimated $2 million a day in future lost power production.

While the spill created much-needed freeboard for repair work to begin, it also created problems downstream. Fish eggs and all that year's juvenile fish stock were wiped out. The rising waters cut off 200 deer fawning on one of the islands in the river. The does could swim through the current, but the newborn fawns were at risk of drowning. Knowing that news photos of dead, bloated fawns would be a public relations nightmare, BC Hydro orchestrated a helicopter rescue with help from the Ministry of the Environment.

Of greater concern was the risk of flooding in communities downstream, particularly a subdivision built on a flood plain in Taylor, a community of 1,200 people about 123 kilometres east of the Bennett Dam.

"We had to be on a continuous vigil, watching weather forecasts, seeing if any storms are coming in, to adjust the spill level so we wouldn't flood Taylor," says Fernandes. Since the water from the Bennett Dam took about eight hours to reach Taylor, all adjustments to the spill volume had to be anticipated. Sure enough, in mid-July, a record-breaking rain storm hit the region.

"It was very tense. We came not quite six inches from flooding the bank at Taylor," says Fernandes. (Last year BC Hydro bought all 40 houses in that particular Taylor subdivision and is removing them to eliminate future headaches.)

Seven weeks later, in the first week of August, the reservoir was down two metres. Crews began to use a number of new drilling methods to map the extent of the sinkhole and assess the health of the dam. Work continued night and day for months.

Then in early September, to BC Hydro's surprise and frustration, exploratory drilling revealed a second spot of major weakness in the core, smaller than the first, on the east side of the dam around another survey benchmark tube. "It seems that from that first day in June, everything just got worse and worse for months," sighs Fernandes.

Now the question, how to fix the weaknesses? Concrete wasn't an option: the material used must match the density and texture of the dam so as to distribute the water pressure evenly across the structure. But how to funnel rock, sand and gravel at high pressure to that depth? It had never been done before.

Through extensive research and modeling, 'compaction grouting' was chosen as the best method to fill the holes. Widely used in North America in other construction, it had never been used to this depth in a dam. In mid-fall BC Hydro asked for bids from North America contractors. In a rare move for a Crown corporation, it would be a two-envelope bid system; technical details in one envelope, the price in a second. Once the best technical bid was selected, only then would its price envelope be opened. "We didn't want the price to influence our decision at all, only the technical merit," says Stewart.

For a month the successful team, Hayward Baker of Santa Paula, California and Foundex of B.C., practised on the Fraser delta at a spot where the soil consistency was similar to the dam core. Day after day they practised shooting the grouting material – a mixture of 20 per cent pea gravel, 50 per cent gravel and 30 per cent silt – to deep levels. Only when the kinks were worked out did they finally, in March 1997, go up to the dam. By June, the repairs were finished.

The investigation and repair cost BC Hydro almost $40 million, not including lost power potential from the spill. By the end of the ordeal, Ray Stewart was appointed director of dam safety for all of BC Hydro's 61 dams. As well, the government ordered continued monitoring and surveillance of the Bennett Dam, status reports every six months and reinforcement of the structure's toe.

"It is easy to look back at it now, but at times I can recall the intense emotion and stress around the enormity of what we were dealing with," says Stewart. "It was like a war."

"We can be thankful that everybody did the right thing to avert a potential catastrophe," says Farrell, now a private consultant. "It worked out well. But I don't think any of us will ever feel completely comfortable with the Bennett Dam again. It must be watched very closely for the rest of its life." ■

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