PA-AWWA 64th Annual Conference

SUSTAINABLE MUNICIPAL INFRASTRUCTURE PLANNING, MAINTENANCE, REPAIR, AND REPLACEMENT IN KARST SINKHOLE PRONE AREAS

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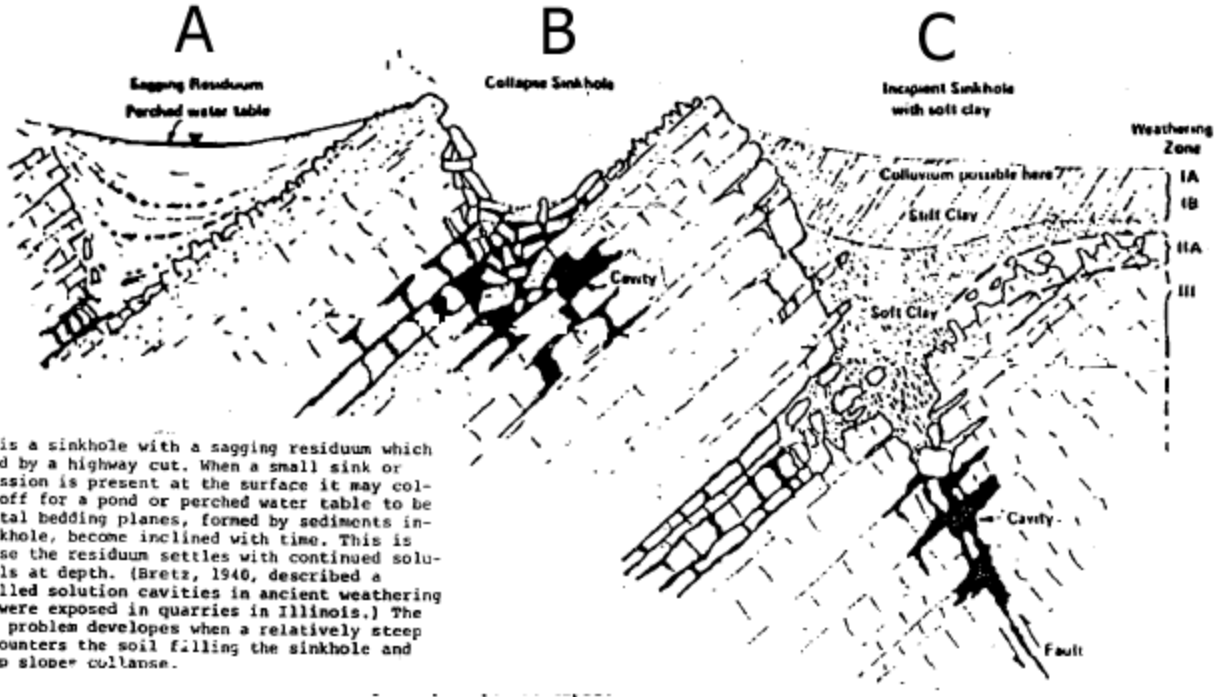
EKMLLC – Engineering & Infrastructure Help Desk

THE PROBLEM – AGING UTILITIES

THE PROBLEM – KARST GEOLOGY

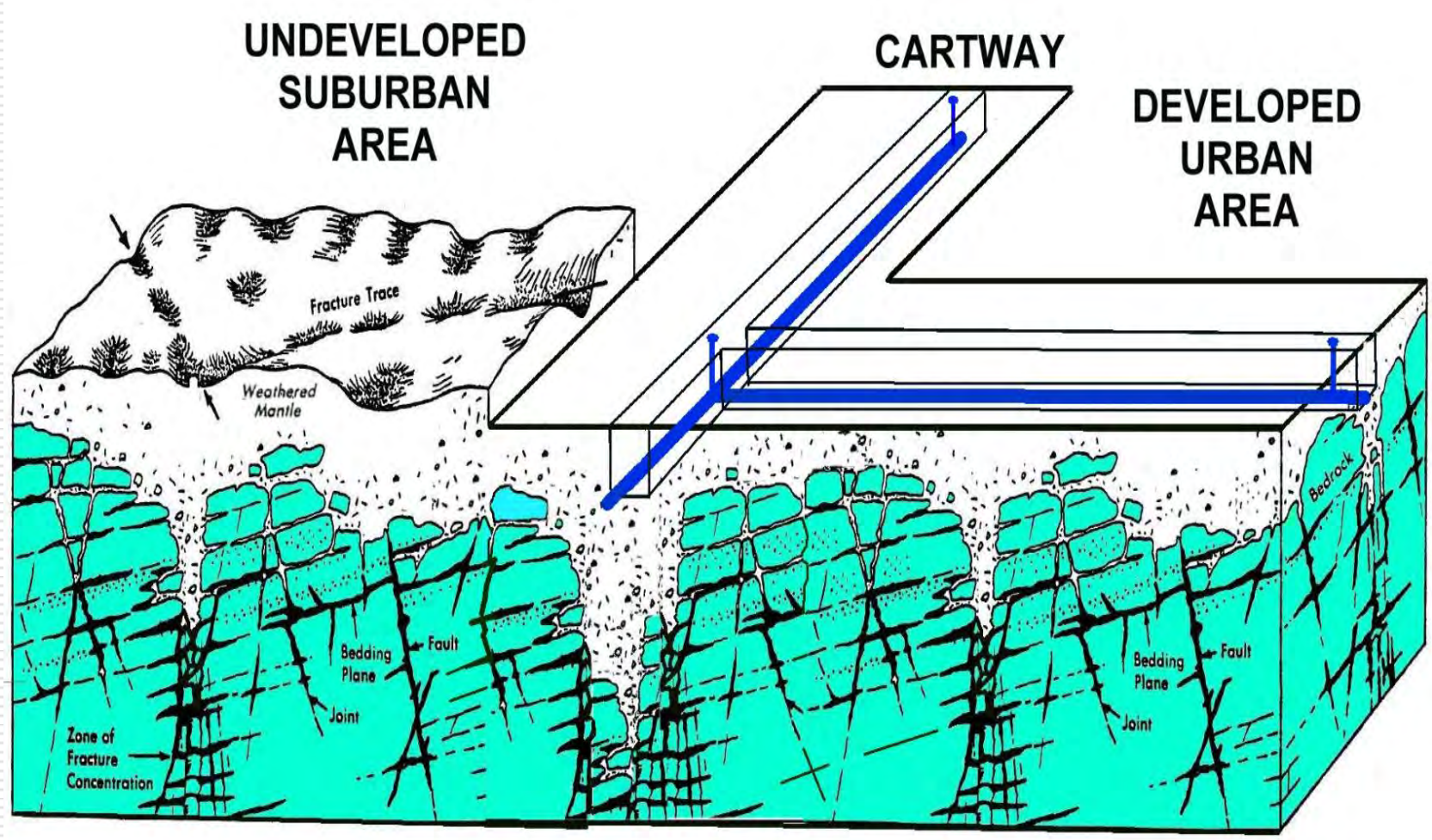


Feature A is a sinkhole with a sagging residuum which has been exposed by a highway cut. When a small sink or undrained depression is present at the surface it may collect enough runoff for a pond or perched water table to be formed. Horizontal bedding planes, formed by sediments infilling the sinkhole, become inclined with time. This is primarily because the residuum settles with continued solution of materials at depth. (Bretz, 1940, described a variety of infilled solution cavities in ancient weathering profiles which were exposed in quarries in Illinois.) The slope stability problem developes when a relatively steep bedrock cut encounters the soil filling the sinkhole and the overly steep slopes collapse.

Feature B, the collapse sinkhole, seldom causes a stability problem. Although the collapsed rock may be weaker than the surrounding rock, the nature of the material is apparent when the excavation begins. However, the collapsed debris may become mixed with clayey residual soil and a larger slope failure could develop.

Feature C is an incipient sinkhole in which the lower portion is filled with soft clay. This feature is likely to lead to a more serious slope failure than the others because the low strength of the soft clay may not be determined until the slide develops.

THE PROBLEM – URBAN LAND



THE PROBLEM - KARST SOILS

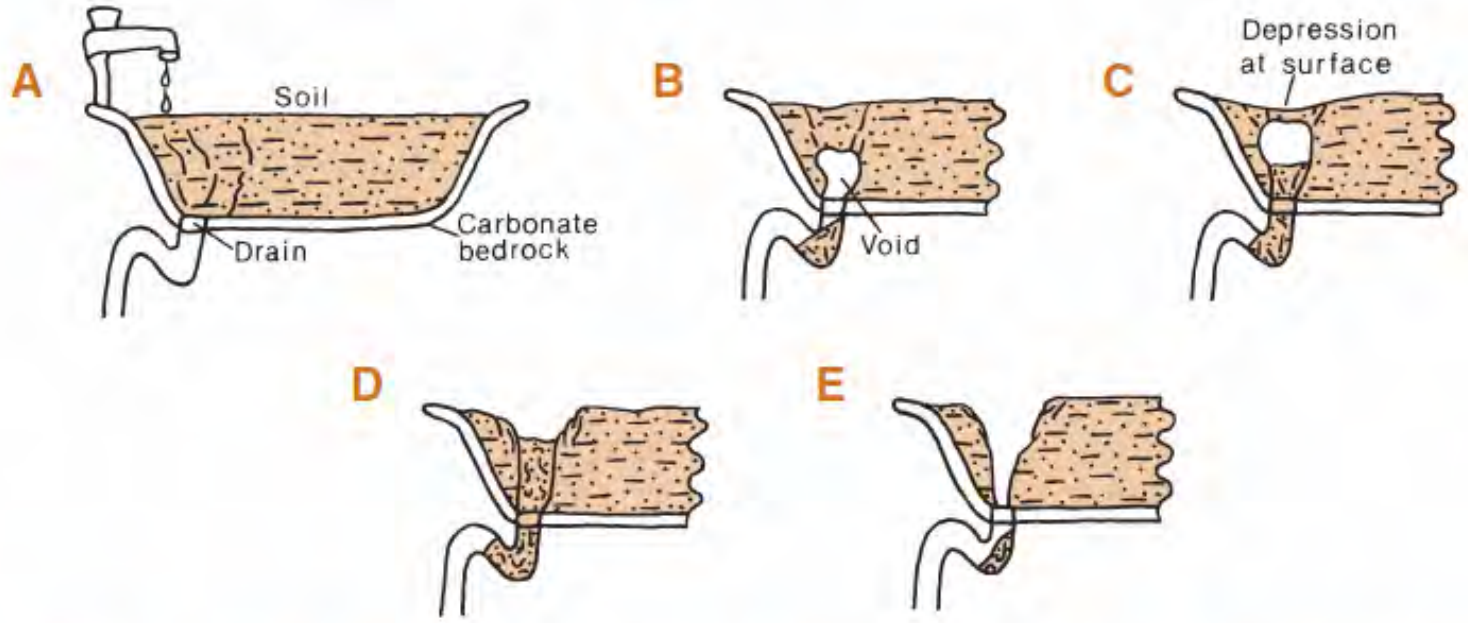
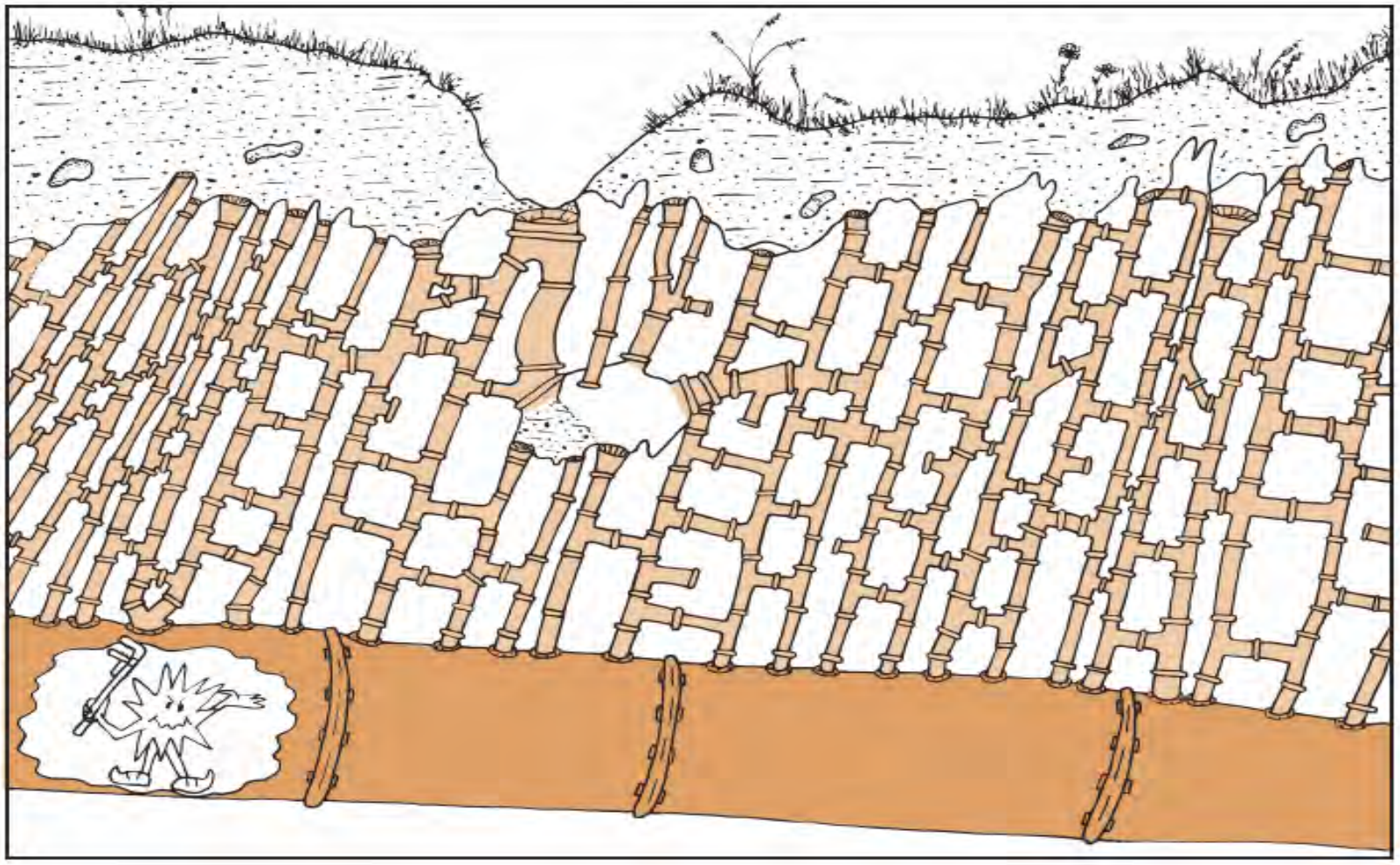


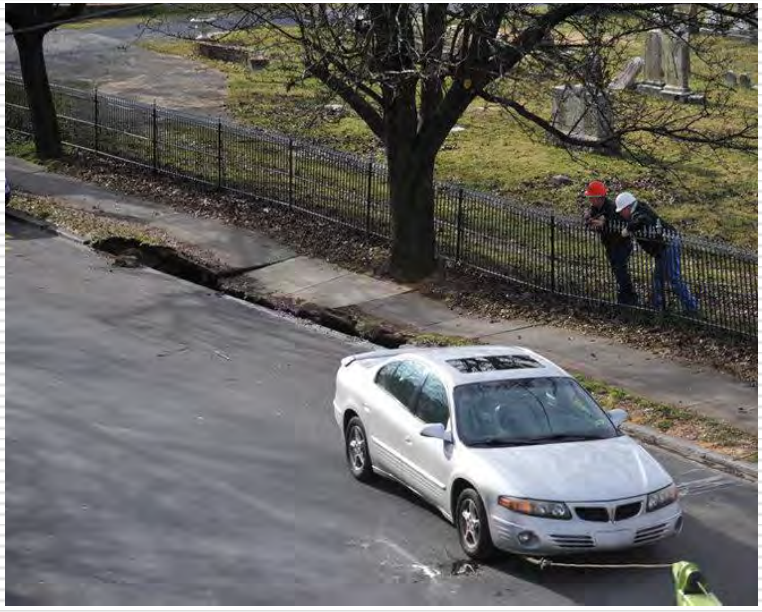
Figure 9. The bathtub model. A. Water infiltrates through the soil. B. As soil enters the drain, a void is left behind. C. Over time, the soil moves into the void and the void "migrates" toward the surface. D. Support is removed and collapse occurs. E. If enough water is supplied, an open connection to the drain results.

THE PROBLEM - KARST BEDROCK



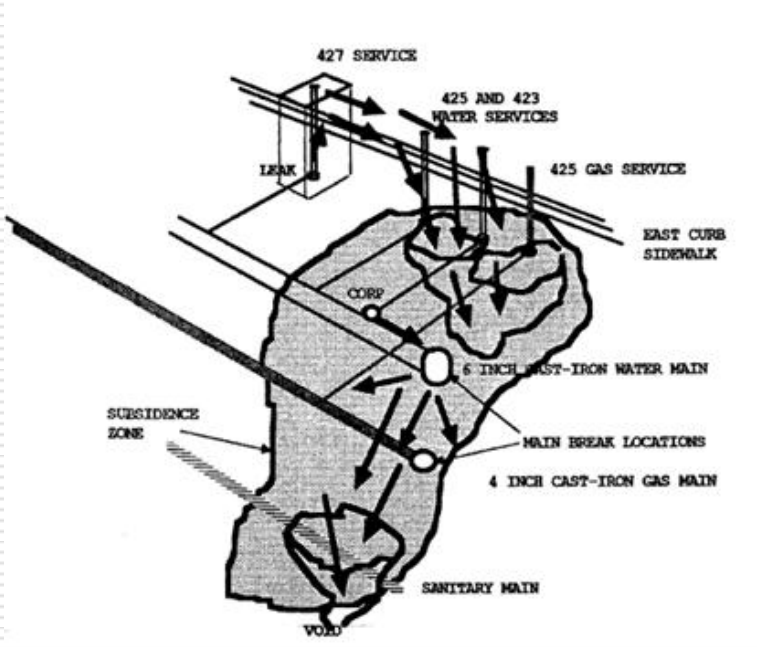
PROBLEM BACKGROUND

- **Migration of surface water from deteriorating pavements, sidewalks, and curbs into residual soils can result in slow subsurface erosion of soil into the underlying bedrock resulting in subsidence.**



PROBLEM BACKGROUND

- **Subsidence of soil supporting utilities can in turn result in leaks or even main breaks that can result in significant subsurface erosion and the formation of a sinkhole.**



MAJOR UTILITY REPAIR COSTS

Allentown water main break
(Donna Fisher/The Morning Call / December 30, 2011)

Officials gather as the sinkhole at 10th and Gordon Streets undergoes excavation. Old trolley tracks are evident at right.

RESULTING PROPERTY DAMAGE

Allentown water main break
(Donna Fisher/The Morning Call / December 29, 2011)

A new sign marks the home at 401 N. 10th Street as unfit for habitation in the wake of a water main break in the street's 300 block Thursday morning.

Allentown water main break
(Donna Fisher/The Morning Call / December 30, 2011)

Homes in the 300 block of N. 10th Street are affected by the sinkhole at 10th and Gordon Streets in Allentown.

DECLINE IN PROPERTY VALUES

WORST CASE – LOSS OF LIFE

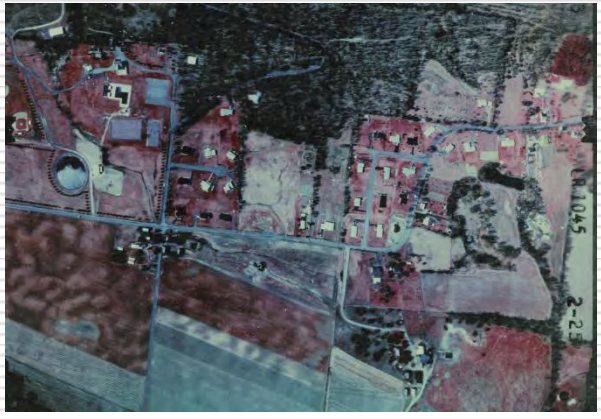
- **Failure of underground utilities in sinkhole prone karst areas can result in major property damage and even loss of life.**

MAJOR SINKHOLE – MAIN BREAKS

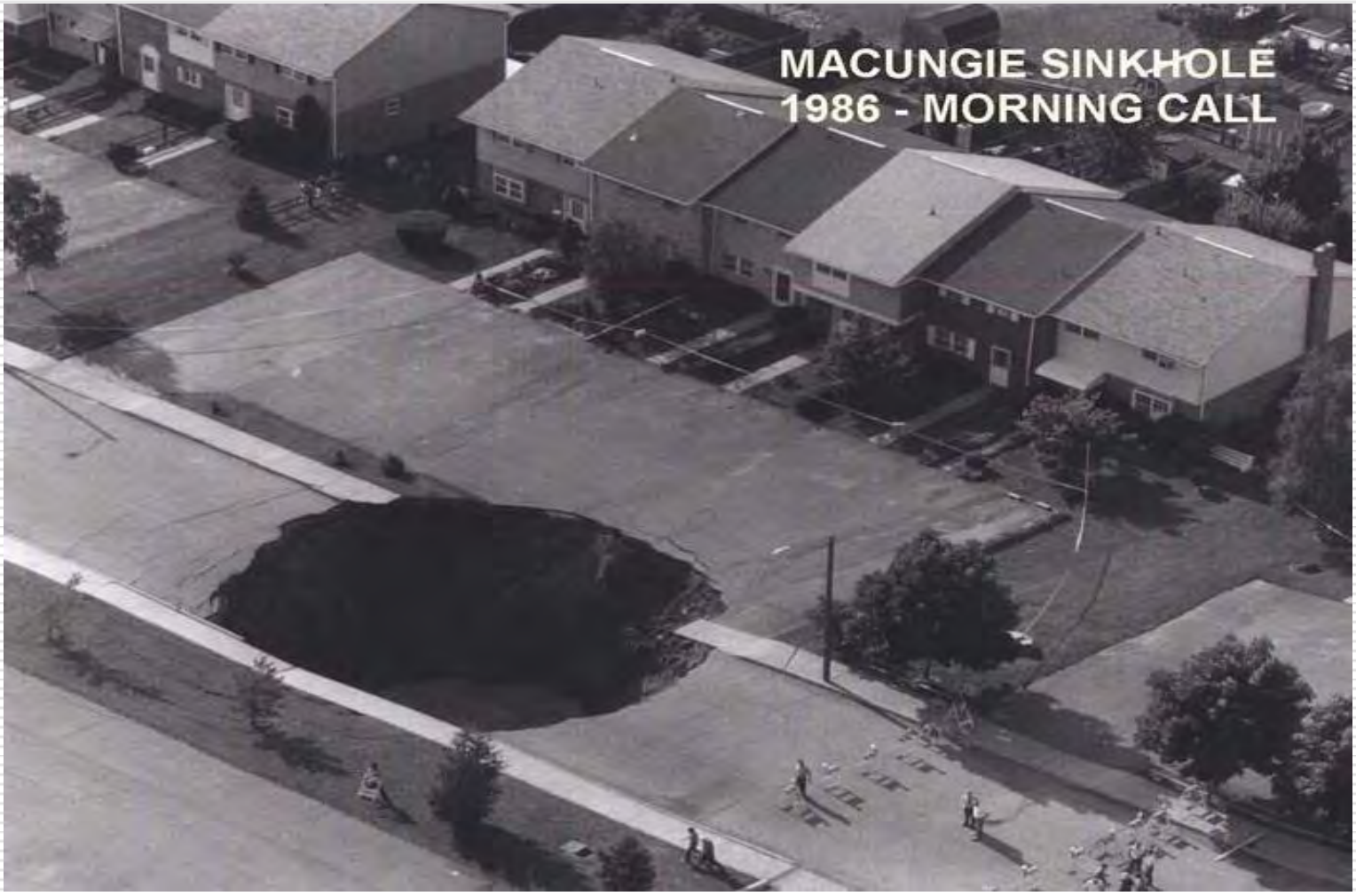
- VERA CRUZ RD SINKHOLE – SAUCON VALLEY
- MACUNGIE SINKHOLE – MACUNGIE PA
- LIBERTY & REFWAL STREET MAIN BREAK-SINKHOLE
- CORPORATE PLAZA COLLAPSE & DEMOLITION
- PENN STREET MAIN BREAK-SINKHOLE
- NORTH 5TH STREET MAIN BREAK – GAS EXPLOSION
- LEHIGH VALLEY COLLEGE MAIN BREAK-SINKHOLE

VERA CRUZ ROAD SINK - 1984

VERA CRUZ ROAD - SAUCON VALLEY

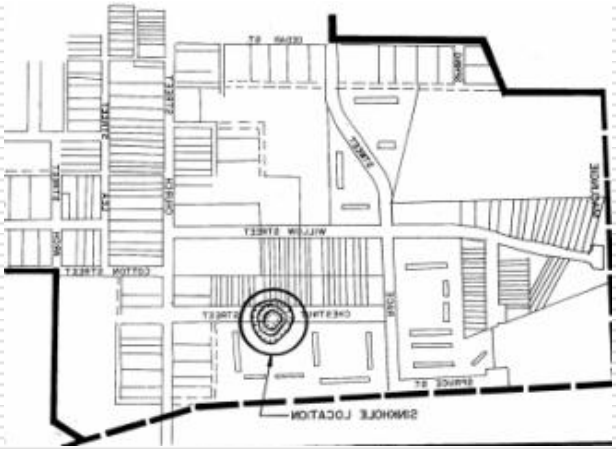


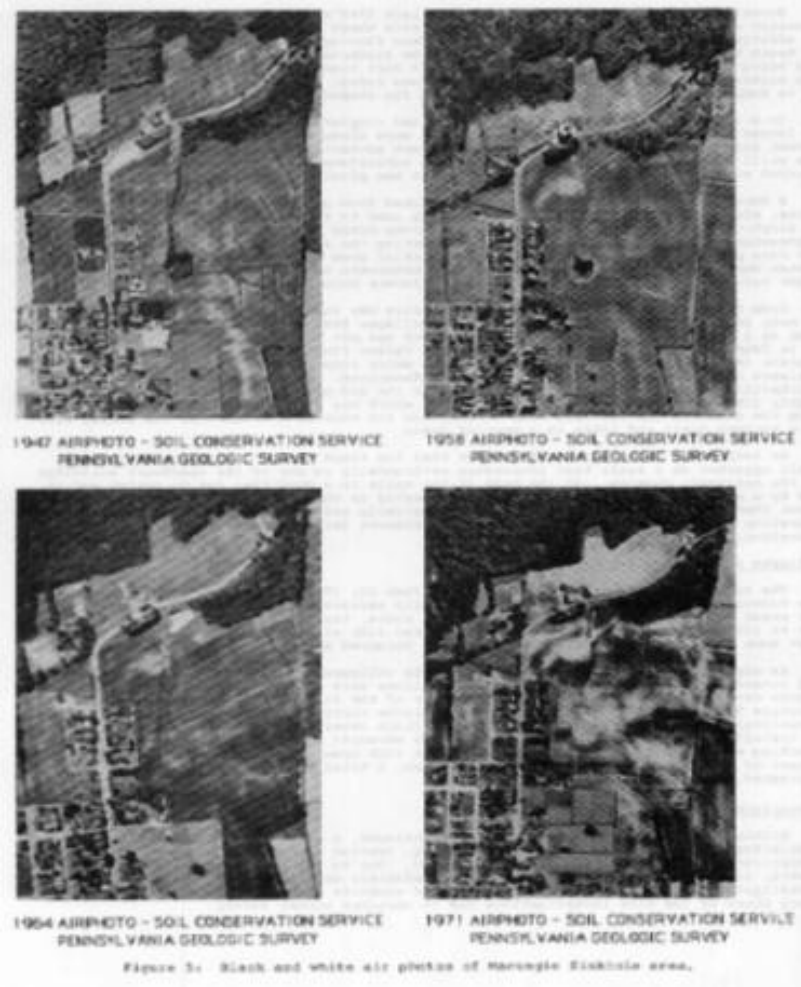
MACUNGIE SINKHOLE - 1986



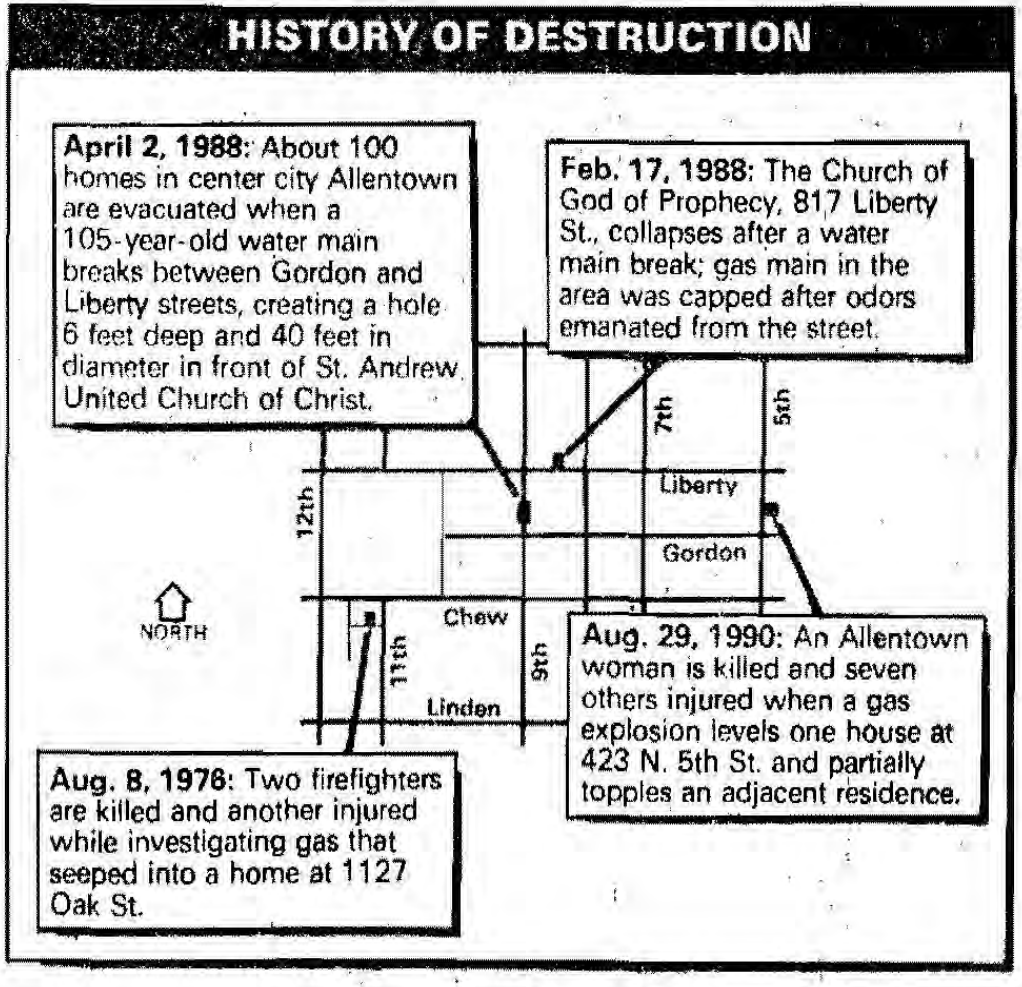
MACUNGIE SINK – MAIN BREAK

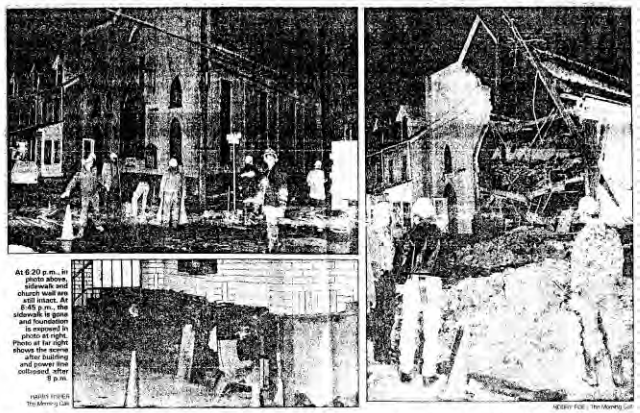
MACUNGIE SINK - HISTORY





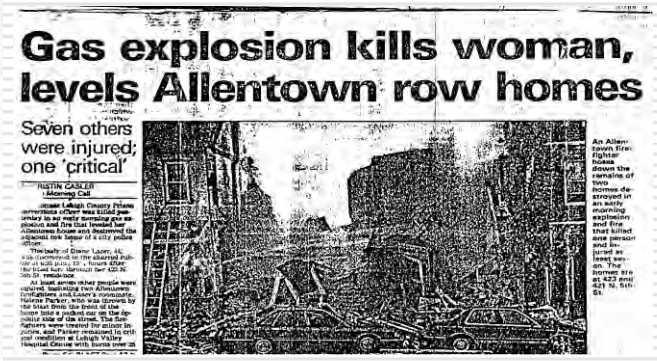
ALLENTOWN – 1976 TO 1990





City church collapses into sinkhole

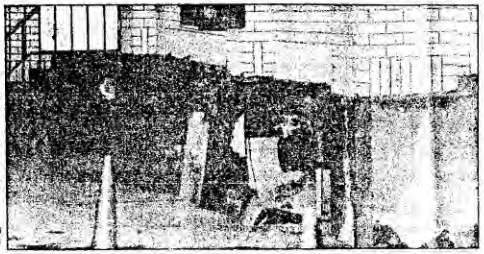
Area still unstable; residents evacuated



Gas explosion kills woman, levels Allentown row homes

Seven others were injured; one 'critical'

LIBERTY & REFWAL ALLENTOWN



At 6:20 p.m., in photo above, sidewalk and church wall are still intact. At 6:45 p.m., the sidewalk is gone and foundation is exposed in photo at right. Photo at far right shows the scene after building and power line collapsed, after 8 p.m.

HARRY FISHER
The Morning Call

BOBBY ROE / The Morning Call

City church collapses into sinkhole

Area still unstable; residents evacuated

By JOHN [illegible]
and [illegible] SCAMAN
Of The Morning Call

A major portion of a 100-year-old center city Allentown church building collapsed early last night after its foundation apparently was destabilized by water pouring from a broken city water main.

Assistant Fire Chief Melvin Keyser said families in the immediate area of the church were evacuated from their homes between 6 and 7:45 p.m. It could not be immediately determined how many people or families were asked to leave.

Around 7:55 p.m., when it became apparent that the collapse of the church was imminent, a city inspector condemned it and said it would have to be razed. The building, a barn-like, 2½-story structure with an arti-

[illegible] house the Church of God of Prophecy.

The building collapsed 8 minutes later.

When the building began to crumble, emergency crews from the city water department and the UGI Corp. had to scamper to safety. No injuries were reported.

Although the Rev. Norman Scott of Philadelphia, the pastor of record for the church, could not be reached, a church member, Barbara Johnson, said the building was substantially renovated within the last five years.

Keyser said preliminary indications are that the problem was caused by a 6-inch water main that fractured near Liberty and Refwal streets, causing a huge sinkhole to

[illegible] portion of the street and the church's foundation. The church is at 617 Liberty St. and sits on the northwest corner of that intersection.

About 15 minutes before the building began to collapse, Keyser said a construction firm had been called to the scene in an attempt to stabilize the foundation. "It's possible the church can be saved . . . or it can go at anytime."

The firm was identified as Alvin H. Butz Inc., a contracting firm. But officials of the company determined they couldn't save the structure.

Soon after Keyser speculated that there was a slight chance the building could be saved, he was notified that the ceiling col-

lapsed. [illegible] broke along the exterior wall on the east side and expanding. With that new information, Keyser quickly ordered that spectators close to the scene be moved back.

That action possibly kept some onlookers from being injured because the falling brick and debris and the power lines that were torn by the falling material scattered over a 100-foot area.

The debris also filled the huge sinkhole that had been created in front of the church.

"The sinkhole was caused due to the flow of water," said Deputy Fire Chief Kenneth Dottery. "It was a major washout. It destroyed the foundation of the church."

Dottery said the water flow also damaged a gas [illegible] at 615 Liberty St., and the walls beginning to open up. But the house was in no immediate danger last night.

"There is no hazard from the gas, and the wires were de-energized," he said. Six trucks, two assistant chiefs, a deputy chief and seven firefighters from the city's fire company were on the scene.

Dottery said the fire company was called to the scene at 5:23 p.m. because of a gas odor. When firefighters arrived on the scene, UGI was there. A strong gas odor was present, with water flowing from a hole in the street.

"The street and a telephone pole began to collapse right into the ground," he said. "The foundation then began to collapse, and cracks appeared at the sides of the building."

Choose Size CHURCH Page B6 ▸

Church collapses after main breaks, street caves in

▸Continued From Page B1

Fire Chief Ernest E. Toth was worried the remaining part of the structure would not stay up through last night.

"I'm afraid the building is going to collapse some more through the night," he said. "But we're very fortunate that at this time there are no injuries."

Toth said he was grateful there was no gas explosion, but by last night a chance still remained that there could be.

He credited the combined efforts of city employees and volunteers for the handling of the situation.

"I would like to commend our firefighters, the city police, the fire police, Red Cross, the water department and the inspection bureau for their cooperation at the scene," he said.

Art Kline, a volunteer for the Red Cross Disaster Service, said five volunteers would work through the night if necessary. As of last night, none of the people evacuated from their homes needed Red Cross assistance.

Around 20 fire police volunteers assisted at the scene, said Fire Police Capt. Jim Redline. A second crew was brought in last night and several of the men would be working through the night, only to go to their other jobs in the morning.

Efforts to [illegible] crew [illegible] were working for the water department and UGI at the scene were unproductive. However, residents living near the church said the water department was in the area on Tuesday and that a UGI crew had been working in the area most of yesterday afternoon.

Randall Leonard of 821½ Liberty St., one of the first residents to be told to leave his home, said the UGI workmen were drilling or jackhammering near the front of the church. He said he didn't think much of it until he discovered he had no running water around 5:30 p.m.

"About a half hour later, we were told to leave the house by my father-in-law," he said, identifying his father-in-law as Elwood Vogel, a volunteer fire policeman. Leonard said his neighbors, the Richard Rabenold family, apparently were not home when the evacuation was ordered.

Keyser said those who were asked to evacuate will not be permitted back into their homes until the area is secure. He said he could not say when that would be. "It definitely will not be tonight," he said.

Residents were evacuated from their homes on N. Refwal Street, from 8th to Lumber streets, and from two homes behind the church, on Pratt Street.

Electricity and gas services were shut off to residents in the vicinity of the church, on Liberty Street from 8th to Lumber streets, said Dottery. Cable TV service also was disconnected to some residents.

Johnson said she first became aware that something was amiss at the church when she was contacted by the Allentown Communication Center between 1:30 and 2 p.m. "They asked for my husband Benny because they had to get into the church," Johnson said, noting that her husband was one of several people who has access to the church. Johnson, however, said her husband did not have the keys to the church and suggested that another member of the church be contacted.

"I got saved in that church," said Johnson, clutching the hand of her 9-year-old daughter. "I prayed for my first child in that church and here she is now. I thought I couldn't get pregnant or have children until I got involved with that church. . . . If something happens to that church it will destroy a part of me."

Minutes later, when the front wall of the church collapsed, Johnson's daughter Tanda began to cry loudly. Her mother attempted to comfort her with the assurance that there would be another church building to replaced this one.

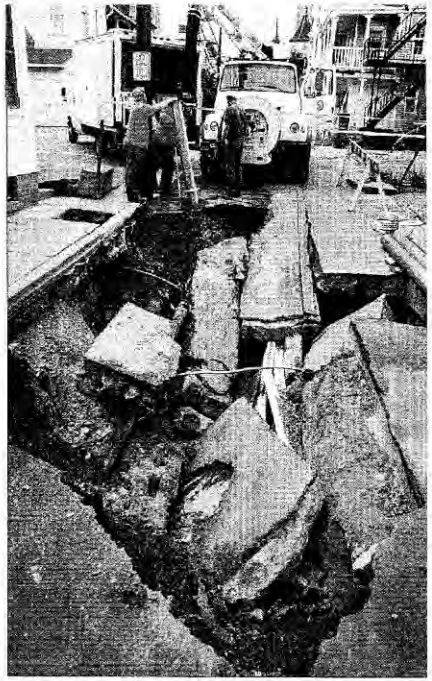
Johnson said she was not sure who would be responsible for the damage to the church or whether the church was covered by insurance.

CORPORATE PLAZA –1994

NORTH PENN STREET ALLENTOWN

N. Penn St. in Allentown is cracked after a sinkhole opened up early Tuesday. Right, city Water Resources employees work on the sinkhole. Eleven homes were evacuated about 3 a.m. Residents were allowed to go back later to get their belongings.

DOUGLAS BENEDICT
The Morning Call



Sinkhole damages Allentown homes

■ Eleven buildings were evacuated. Official says two may have to be demolished.

By KIRK BELDON JACKSON
Of The Morning Call

A 20-by-10-foot sinkhole opened on an Allentown block Tuesday morning, damaging homes and causing evacuations, fire officials said.

Several residents of the 100 block of N. Penn Street were scrambling Tuesday afternoon to retrieve belongings from their homes after the sinkhole left walls cracked and floors uneven.

"This is my birthday gift," said Omayra Rosario, 29, as she showed cracks in the wall of the home she shared at 116 N. Penn Soto, 37, and her two children. Rosario, whose birthday was Tuesday, said the Red Cross will provide her and her family with three days' lodging. "After that, I don't have anywhere to go," she said.

Lou Stalisitz, bureau manager of Water Resources/Distribution for Allentown, said 11 homes were evacuated after the 5-foot-deep hole formed about 2 a.m.

Code enforcement inspector Tom Rizzotto said Tuesday evening that four homes on the west side of Penn Street were damaged, two of which will likely need to be demolished.

Rosario said she was evacuated about 3 a.m. City engineers later allowed her to retrieve belongings from the home, she said.

"They told us we have to get out quickly because it's getting worse by the minute," she said as Jim Duong, who lives at 114 N. Penn St., noted that there is now a dip in his roof. There were cracks in his walls, he said.

"We're taking a chance" by being in the building, he said as he moved items out. "We know it's going to be a total loss."

Stalisitz said workers found that a century-old water main that the city is replacing had cracked. The old pipe was still in partial use because a handful of properties in the area had not been transferred to the new main, he said.

Stalisitz said workers couldn't tell whether the sinkhole caused the pipe to break or vice versa. you're underground when it happens, to see what happens," he said.

But Rosario said she felt that work on the new main is what caused the sinkhole. She recalled that her house would start shaking whenever a car drove down her street.

Rosario, who rents her home, said there is no sinkhole insurance on it. And Duong said the insurance policy he bought for hi home doesn't include sinkhole coverage.

"They didn't tell me," he said.

■ *Reporter Kirk Jackson 610-820-6790*

NORTH 5TH STREET - ALLENTOWN

Gas explosion kills woman, levels Allentown row homes

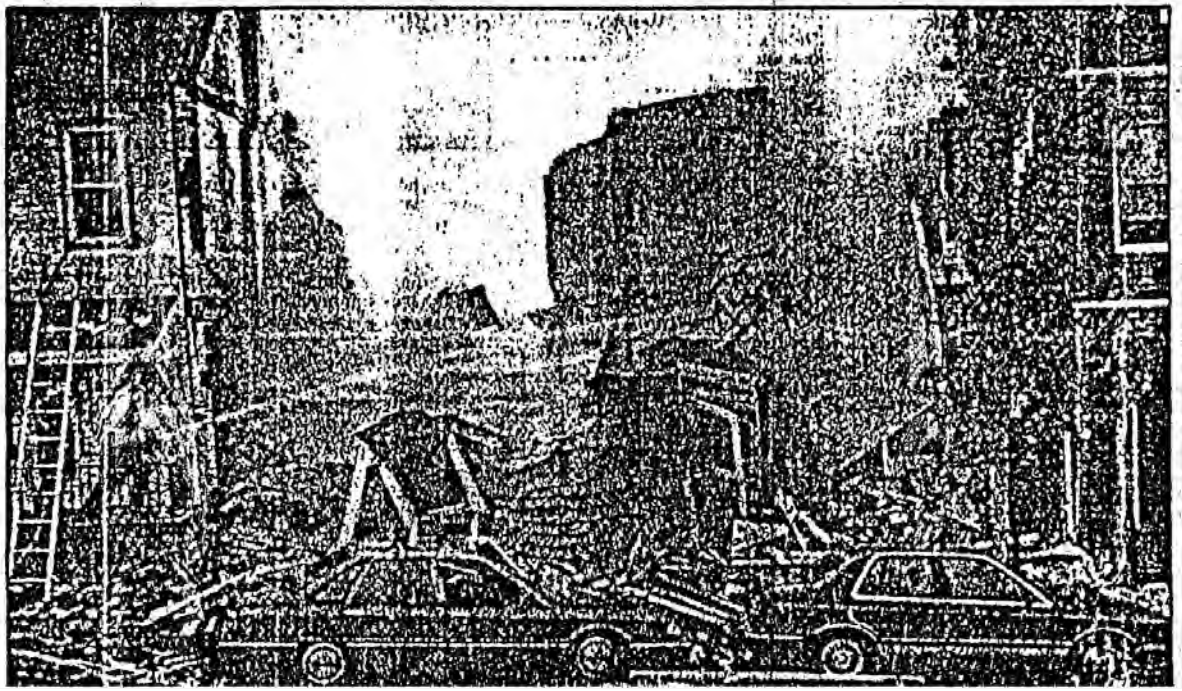
Seven others were injured; one 'critical'

RISTIN CASLER
Morning Call

former Lehigh County Prison corrections officer was killed yesterday in an early morning gas explosion and fire that leveled her Allentown house and destroyed the adjacent row home of a city police officer.

The body of Diane Lazer, 44, was discovered in the charred rubble at 6:35 p.m., 13½ hours after the blast tore through her 423 N. 5th St. residence.

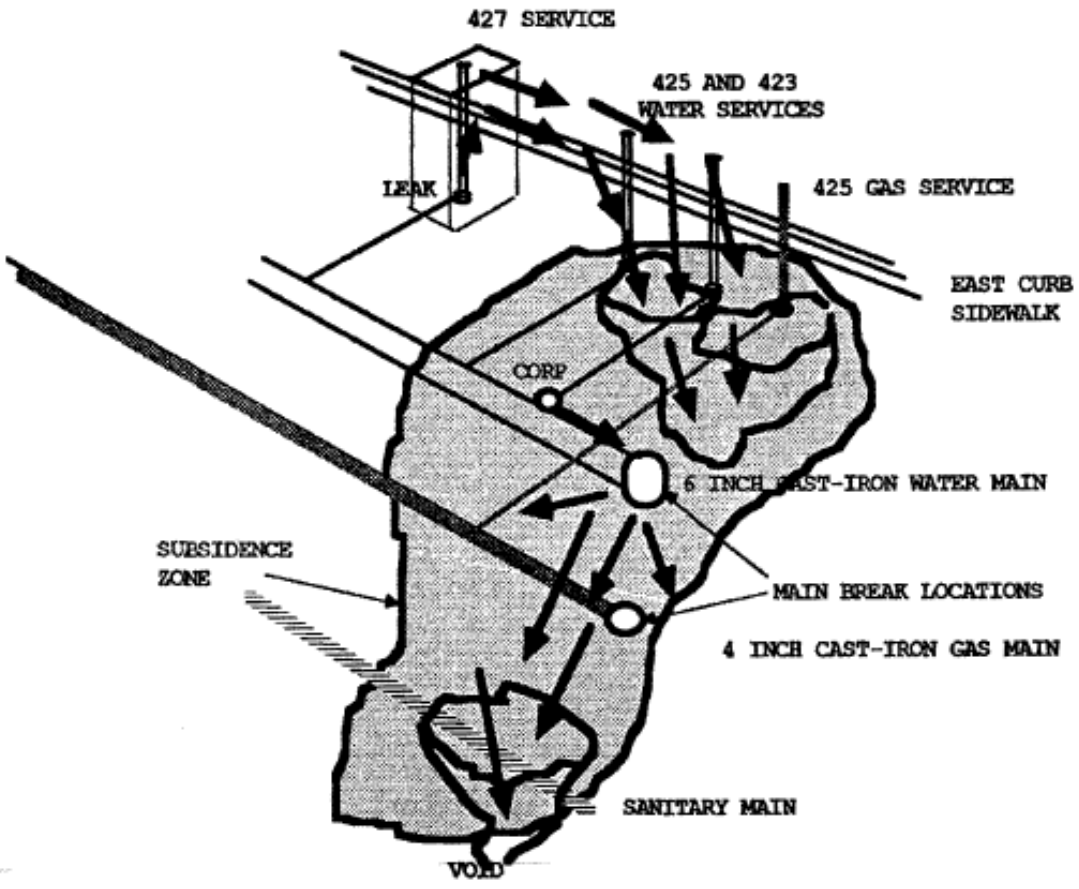
At least seven other people were injured, including two Allentown firefighters and Lazer's roommate, Helene Parker, who was thrown by the blast from the front of the home into a parked car on the opposite side of the street. The firefighters were treated for minor injuries, and Parker remained in critical condition at Lehigh Valley Hospital Center with burns over 25



An Allentown firefighter hoses down the remains of two homes destroyed in an early morning explosion and fire that killed one person and injured at least seven. The homes are at 423 and 421 N. 5th St.

NORTH 5TH STREET - ALLENTOWN

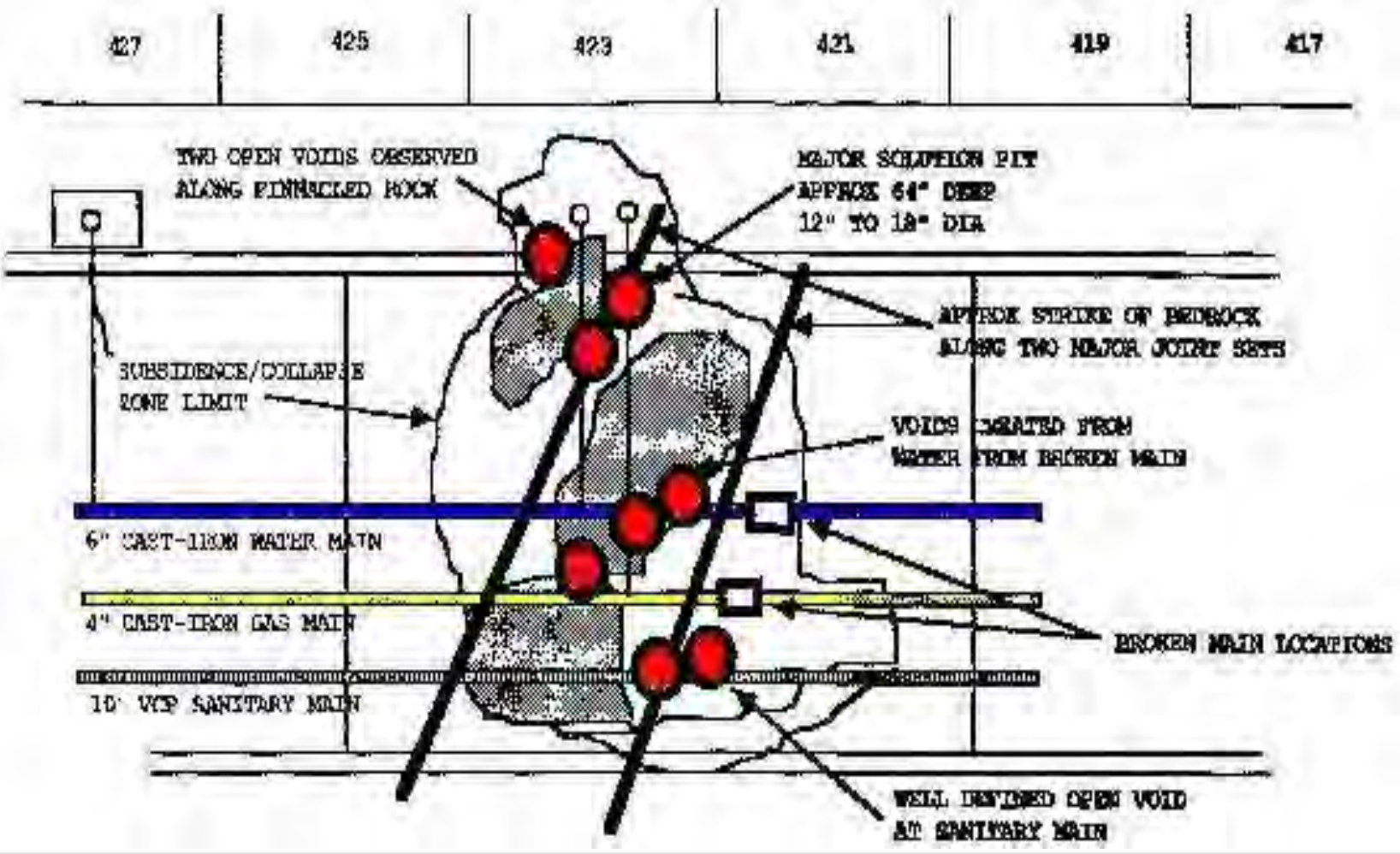
NORTH 5TH STREET - ALLENTOWN



POSTULATED MAINBREAK CAUSE

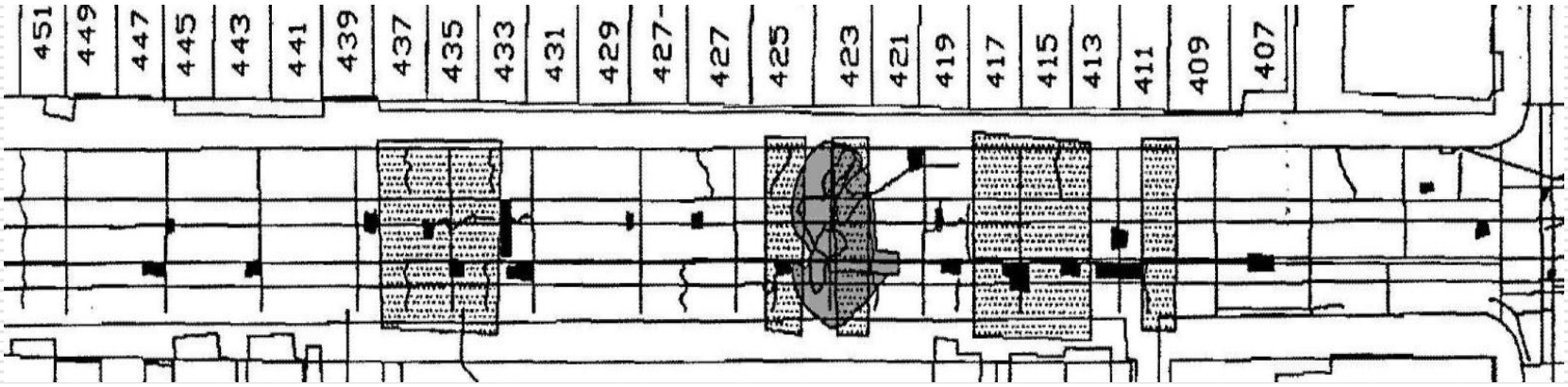
1. HARD/SOFT PAVEMENT SUBGRADE SUPPORT RESULTS IN CRACKING OF CONCRETE PAVEMENT
2. SURFACE WATER BEGINS TO MIGRATE OVER TIME INTO CRACKS SOFTENING RESIDUAL SOILS
3. SLIGHT SUBSIDENCE OCCURS IN SOLUTION ZONES
4. SUBSIDENCE AT LEAD JOINT AT CURB BOX/CORP RESULTS IN LEAK/BREAK OF WATER SERVICES OVER THE PAST 35YEARS WHICH FURTHER DESTABILIZE SUPPORTING SOILS IN PINNACLED ROCK AREAS
5. WATER SERVICE LEAK OCCURS AT 427 ON 1/28/90 MIGRATING WATER FOLLOWS SIDEWALK/CURB
6. RELEASED WATER ENTERS BEDROCK SOLUTION ZONE RESULTING IN SUBSIDENCE OF SUPPORTING SOILS FOR 425 & 423 GAS/WATER LATERALS
7. FURTHER LEAKS OCCUR IN 423 LATERALS ON 8/29 RESULTING IN A MAJOR LEAK OF GAS AND WATER
8. GAS EXPLOSION OCCURS BREAKING LATERALS/MAIN
9. ONCE WATER MAIN BREAKS, SUBSURFACE EROSION OF SUPPORTING SOILS OCCURS BY ENTRY OF RELEASED WATER INTO UNDERLYING SOIL AND ROCK VOIDS
10. SANITARY MAIN SUBSIDES/GAS MAIN IS BROKEN
11. SUBSURFACE EROSION CONTINUES UNTIL MAIN IS SHUT OFF RESULTING IN MAJOR GROUND LOSS AND SUBSIDENCE

NORTH 5TH STREET - ALLENTOWN

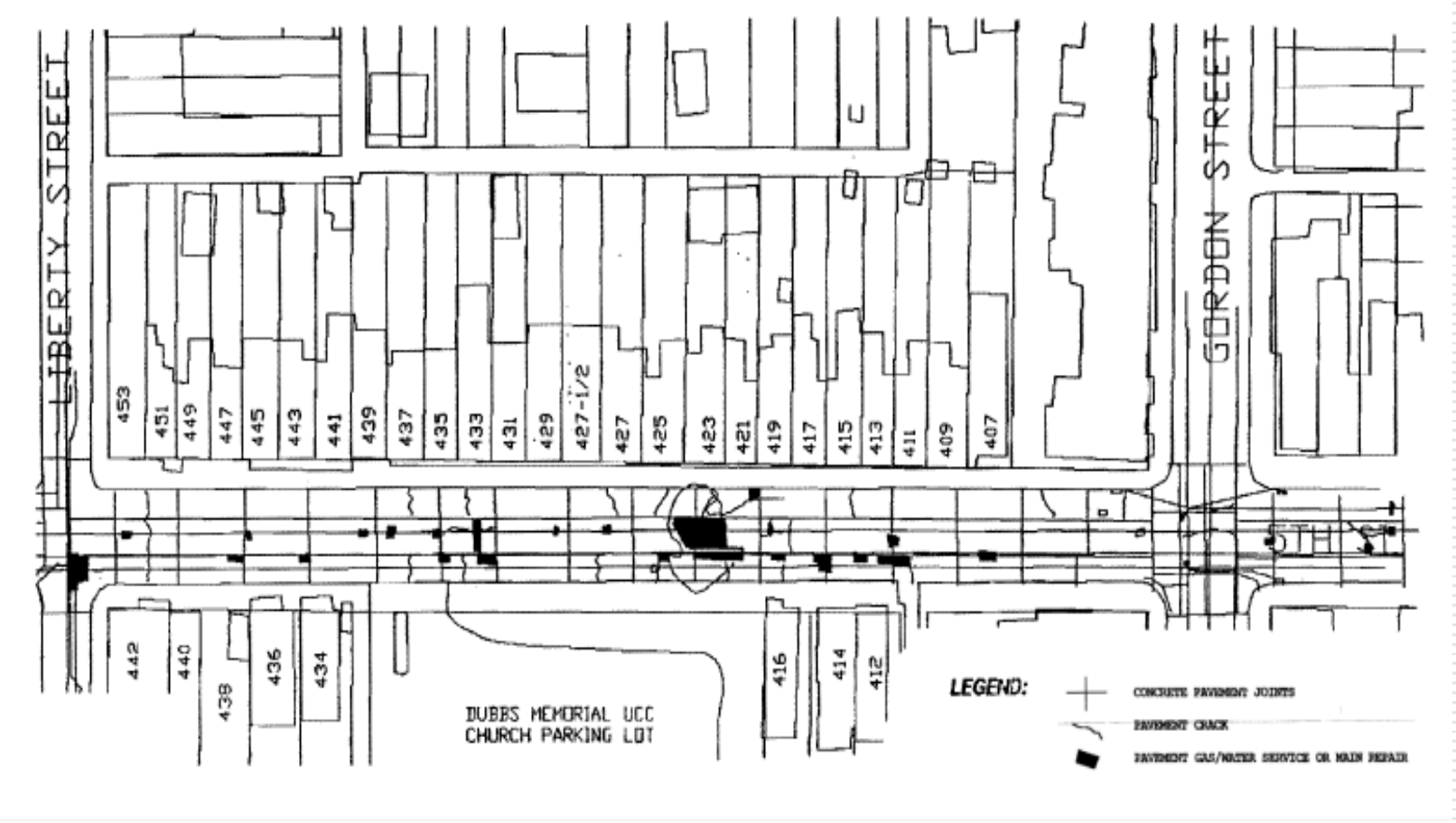


UTILITY HAZARD INDICATORS

- Pavement cracking was an early indicator of subsurface erosion and subsidence
- The increasing number of water service leak-break frequency was a secondary warning
- The presence of suspected solution weathering zones identified where a failure could occur

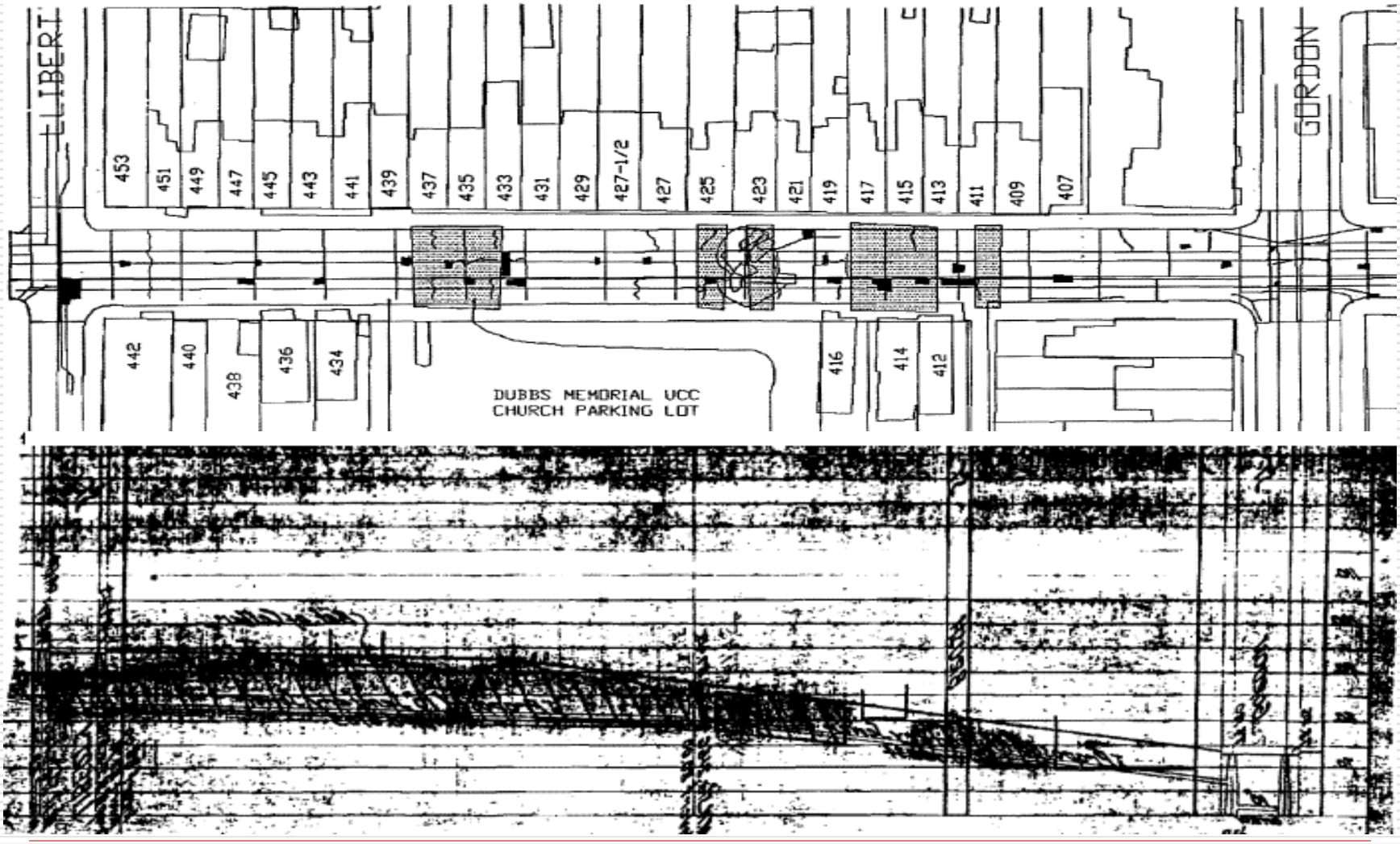


PAVEMENT CRACKING INDICATORS

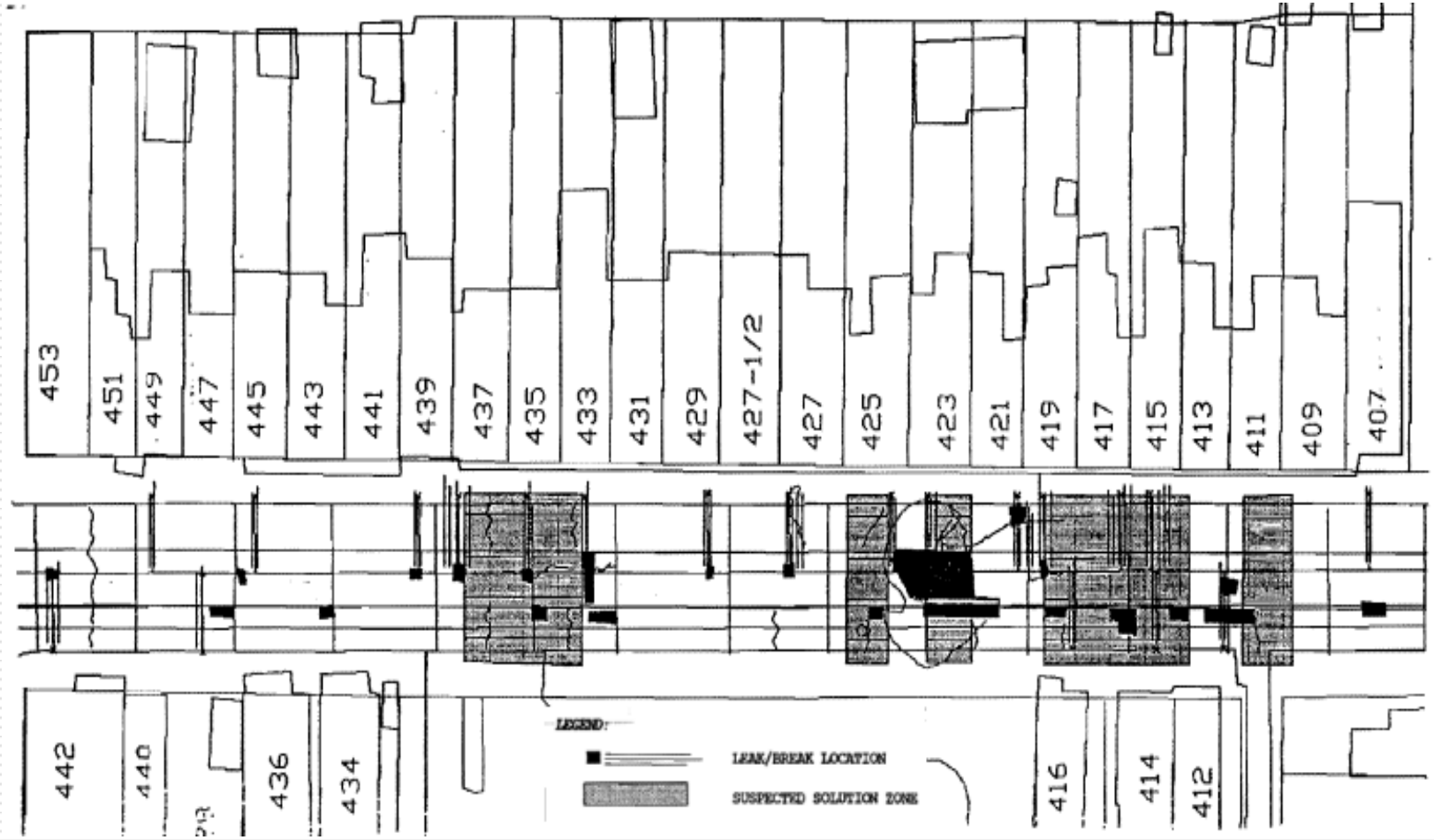


PAVEMENT CRACKING INDICATORS

SANITARY LIMESTONE BEDROCK PROFILE



UTILITY-LEAK BREAK INDICATORS



UTILITY LEAK-BREAK DATA

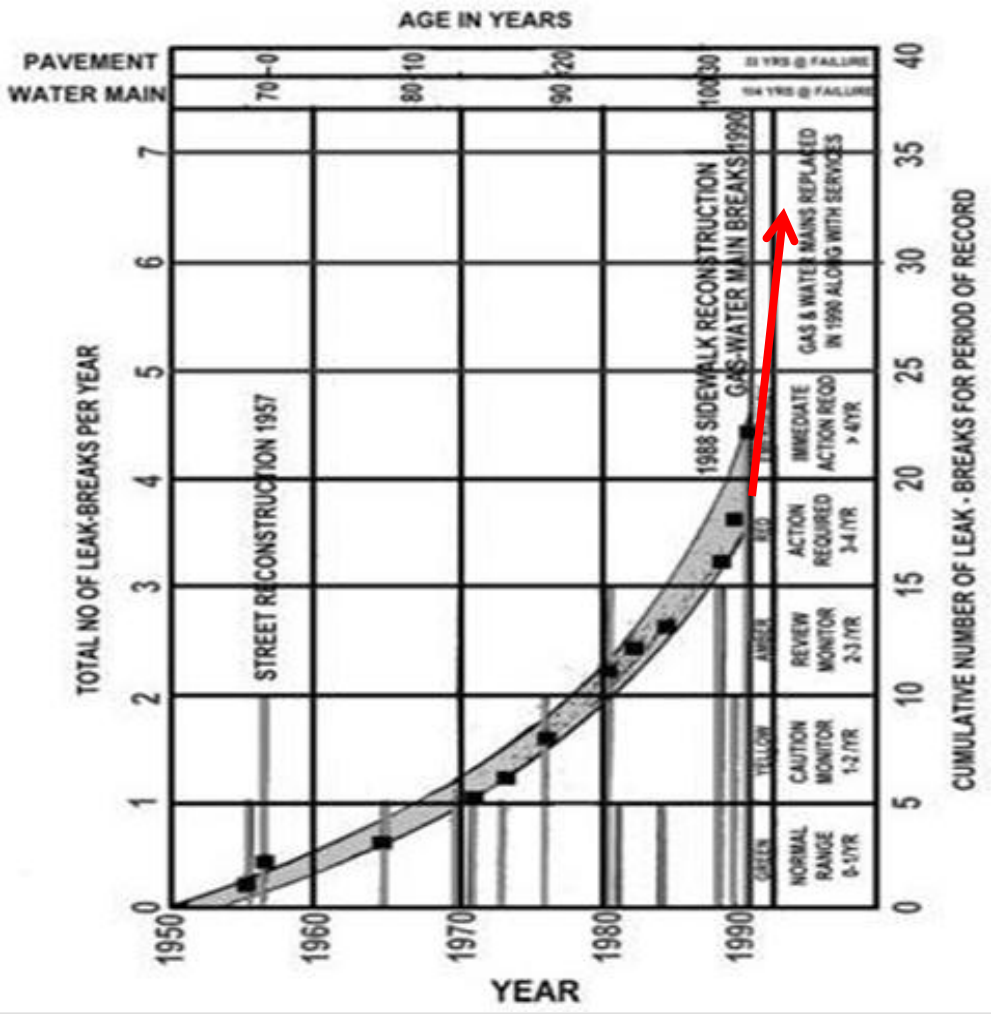
Table 1. Leak-Break Chronology

Year	Location	Date	Component	Cumulative Leak-Breaks
1956	416	6/28/56	Corp	1
1957	414	7/16/57	Corp, pipe	2
	Street Reconstructed			
1965	412	9/17/65	Curb Box	3
1970	445	3/04/70	Corp	4
1971	429	10/13/70	Curb Box, pipe	5
1973	427	5/04/73	Corp	6
1976	425	2/09/76	Curb Box	7
	433	3/19/76	Corp	8
1980	435	5/28/80	Corp	9
	419	11/10/80	Corp – Joint	10
	449	11/15/80	Curb Box	11
1982	407	4/05/82	Corp	12
1984	442	9/26/84	Corp	13
1988	5th & Liberty West	8/18/88	Valve	14
	421	11/15/88	Curb Box	15
	437	11/30/88	Corp	16
1989	415	2/14/89	Corp	17
	417	2/14/89	Corp	18
1990	427	8/28/90	Curb Box	19
	423	8/29/90	Curb Box, Corp	20, 21
	Water-Gas Main Break	8/29/90	Main	22
	StreetCollapse-Explosion	8/29/90	Street	
	421, 423, 425 Damage	8/29/90	Property	
	Summary	Corp Joint	Curb Box	Main-Valve
15	Solution Zones – 170lf	9	5	1
7	Shallow Rock – 330 lf	4	2	1
22	Total	13	7	2

Table 2. Leak-Break Analyses

Item	Leak-Break Comparison	Analyses	Breaks Per Block Per YR
1.	Overall Break Rate	Services	
	Total Per Block	20	
	Total Per Block Per YR	20/1/33	0.60
	Total – Solution Zones	13	
	Total Per Block	13/170/lf = 38 per blk	38* (4 Times)
	Total Per Block Per YR	38/blk/33 =	1.2
	Total – Shallow Rock	6	
	Total per Block	6/330 lf = 9 per blk	9*
	Total Per Block Per YR	9/blk/33 =	0.3
2.	Main-Valve Breaks	2	
	Total per Block	2/33 =	0.1
3.	Service Breaks	20	
		Corporations = 13	
		Curb Boxes = 7	
4.	Rate of Growth	Age of Pipe	
	1959 - 1969	80 yrs	0.10
	1970 - 1979	90 yrs	0.50
	1980 – 1989	100 yrs	1.0
	1990 – 1999 (projected)	> 100 yrs	4.0
5.	Estimated Useful Life	80 to 90 years	
		100 Years	Increase 5 fold
			In Leak-Break
			Rate after 90yrs
NOTE:	(*) Solution Zone		

UTILITY FAILURE MODEL



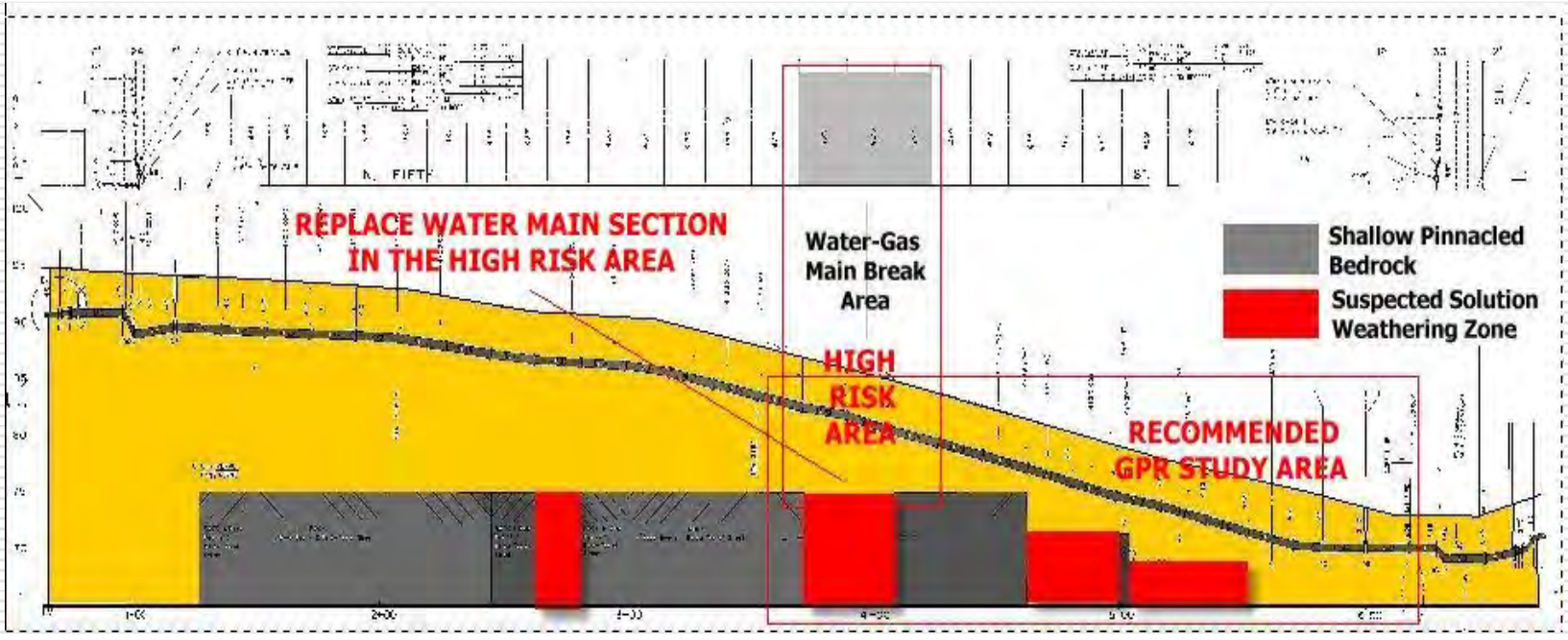
LEAK-BREAK PER BLOCK

- **Urgent Action**
- **Action Required**
- **Monitor**
- **Caution**
- **Normal**

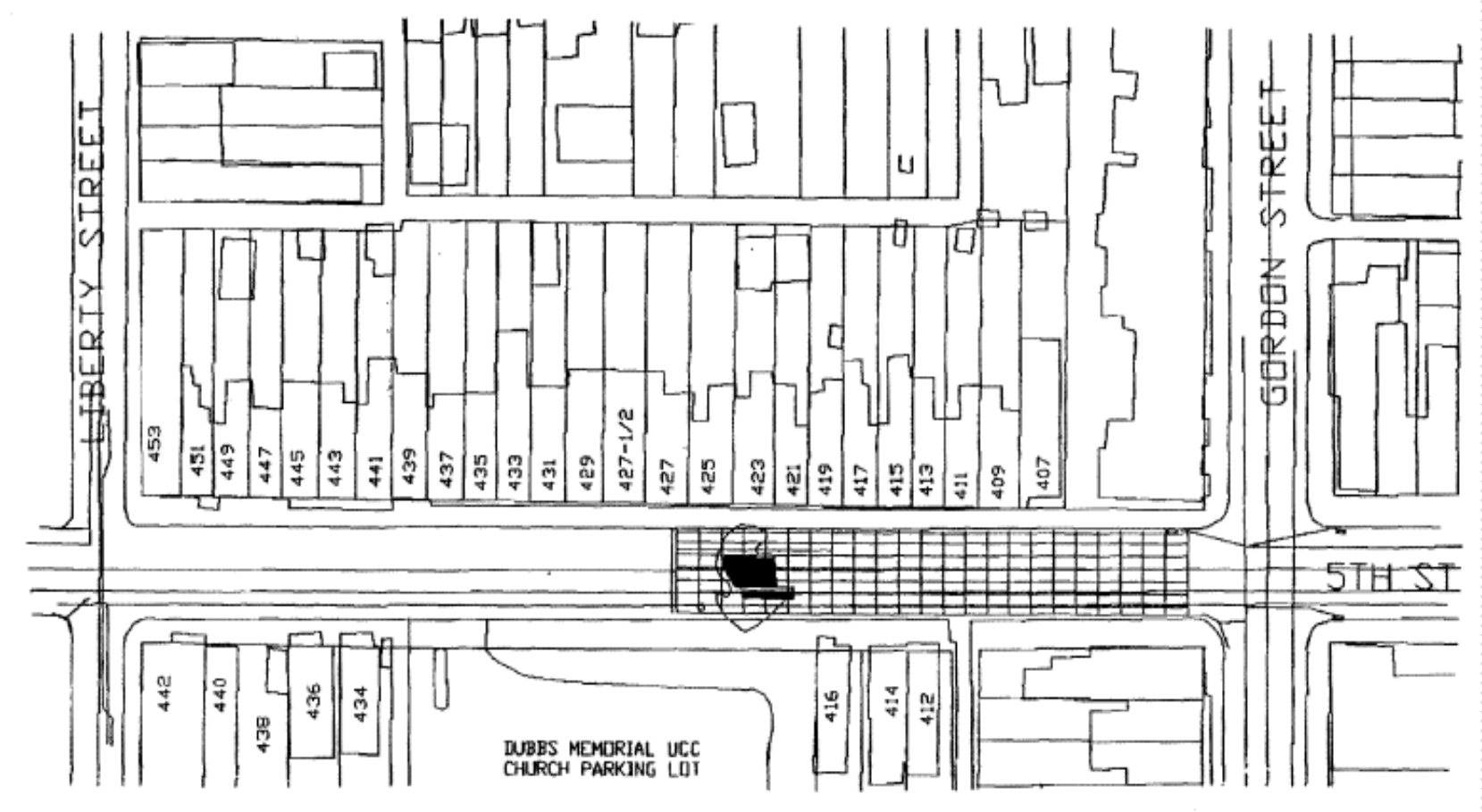
ACTION LEVEL

RECOMMENDED REMEDIAL ACTION

- Conduct a GPR Survey to confirm the location of solution weathered high risk areas
- Replace the water main in the high risk areas



GROUND PROBING RADAR SURVEY



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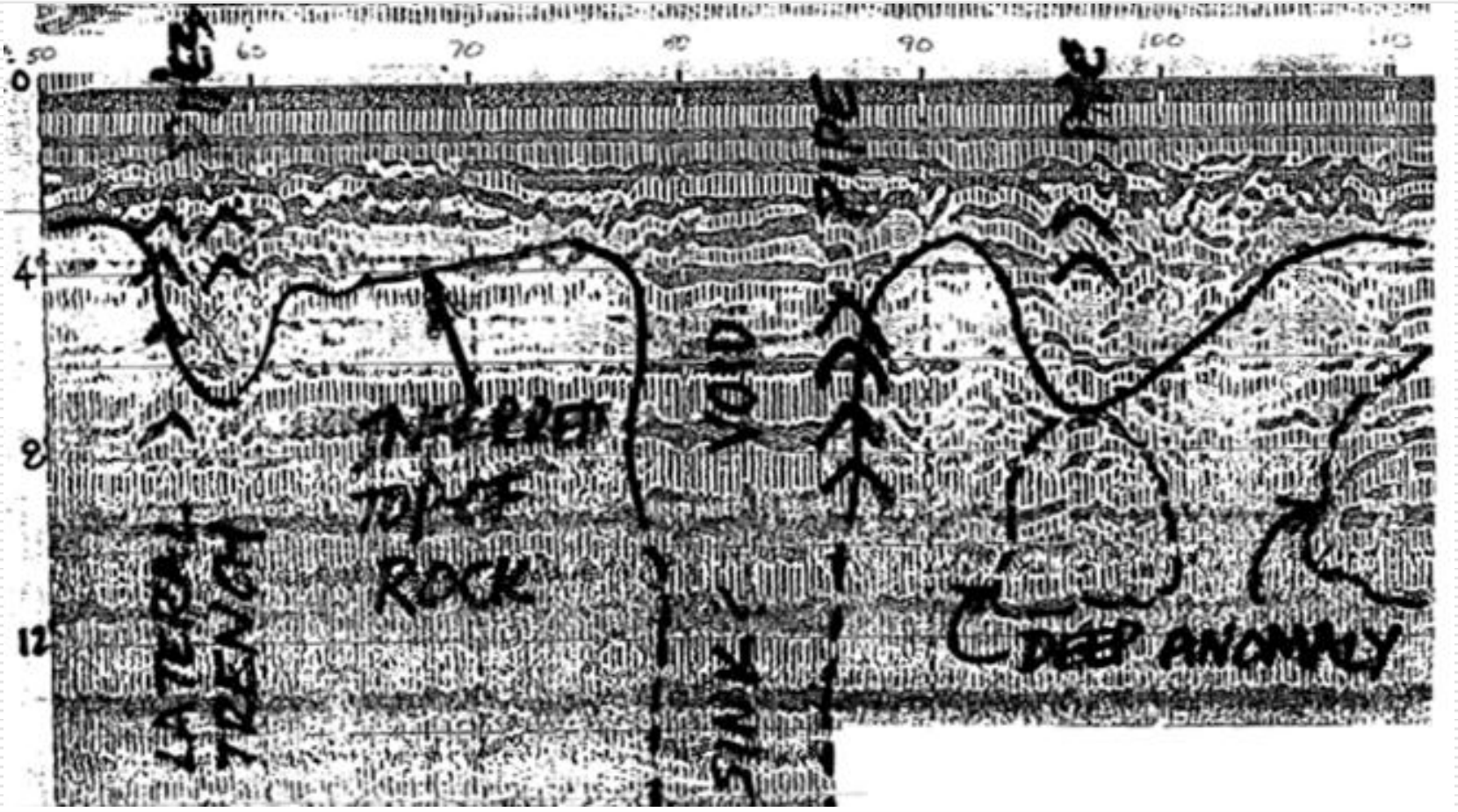

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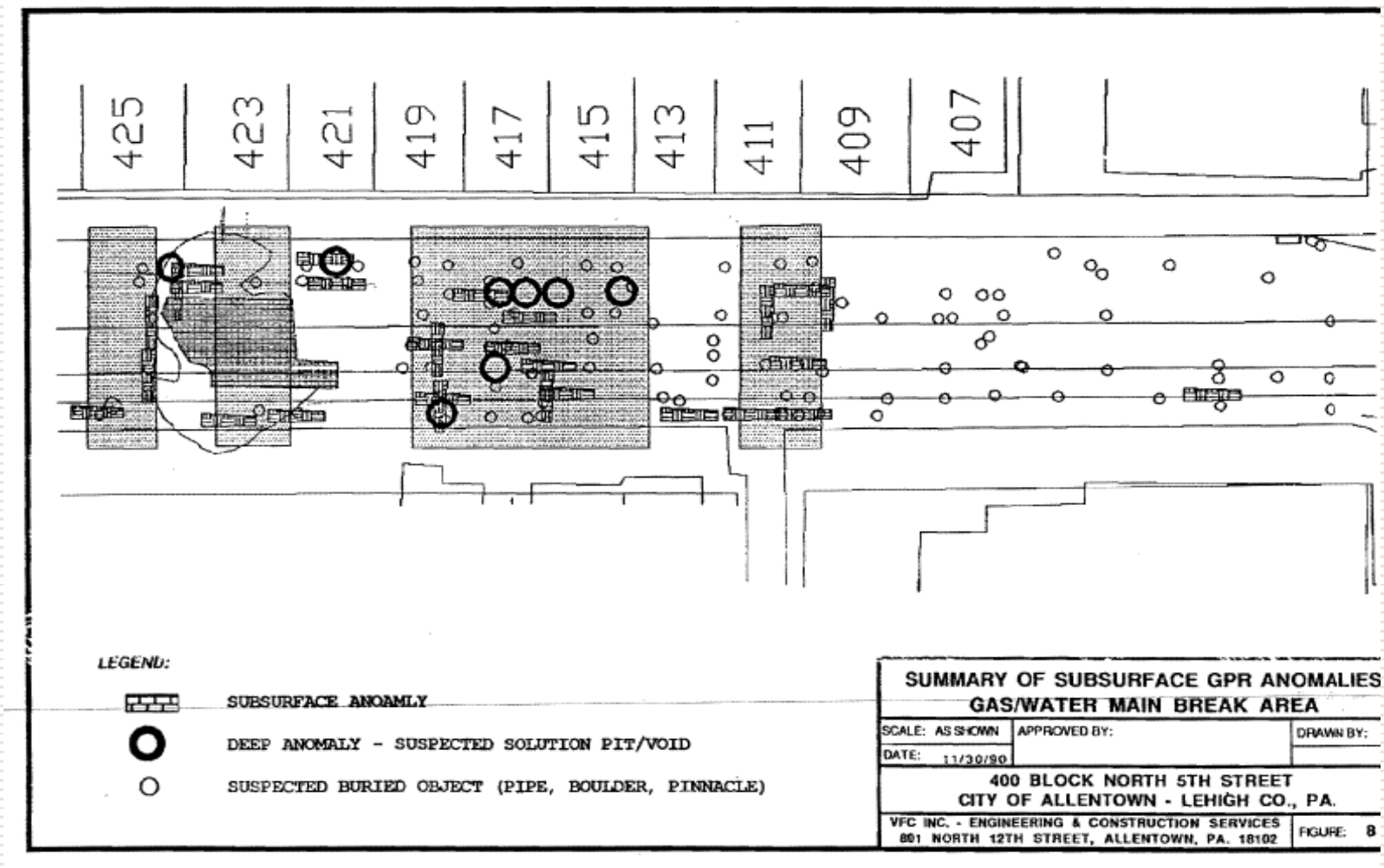
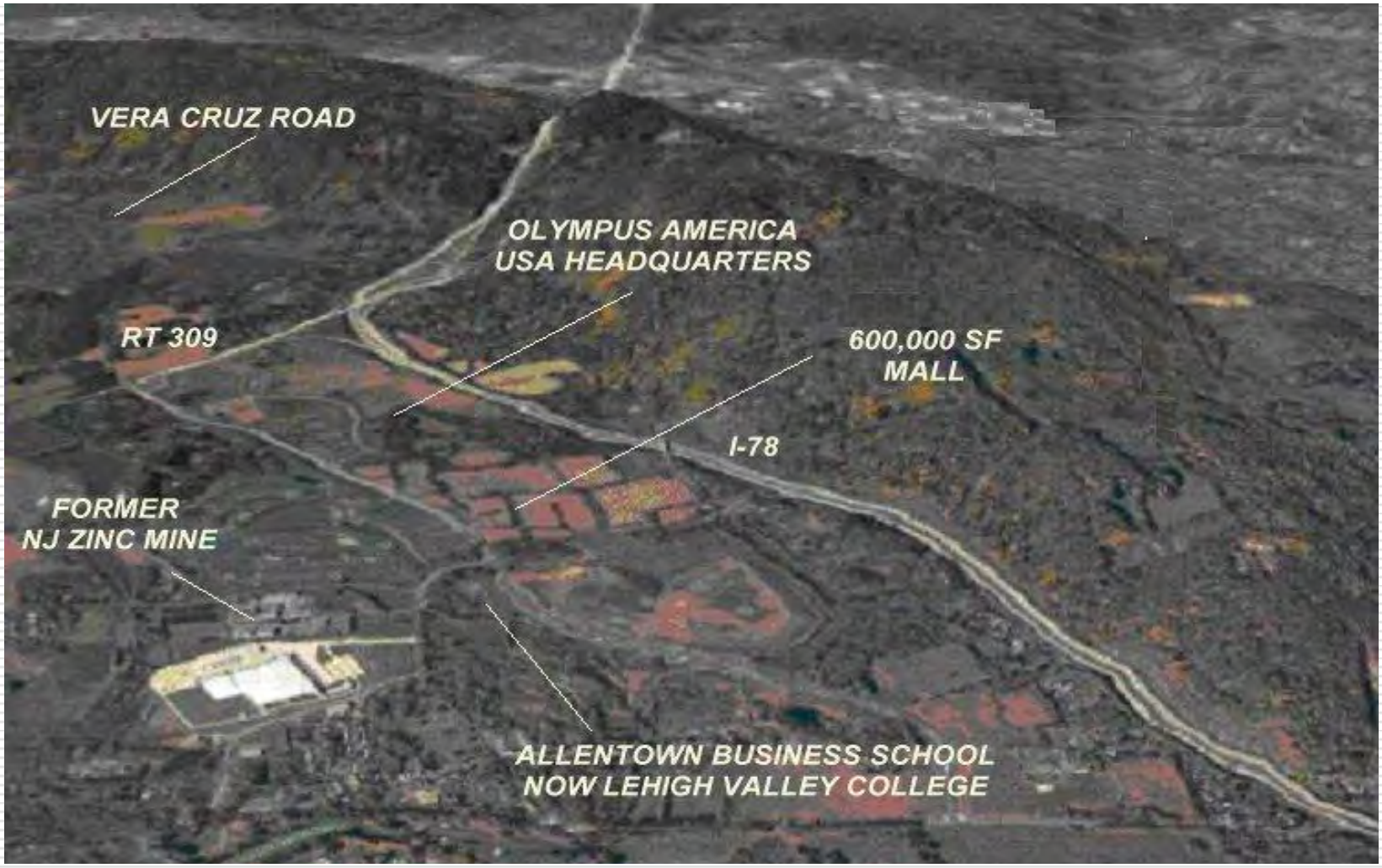
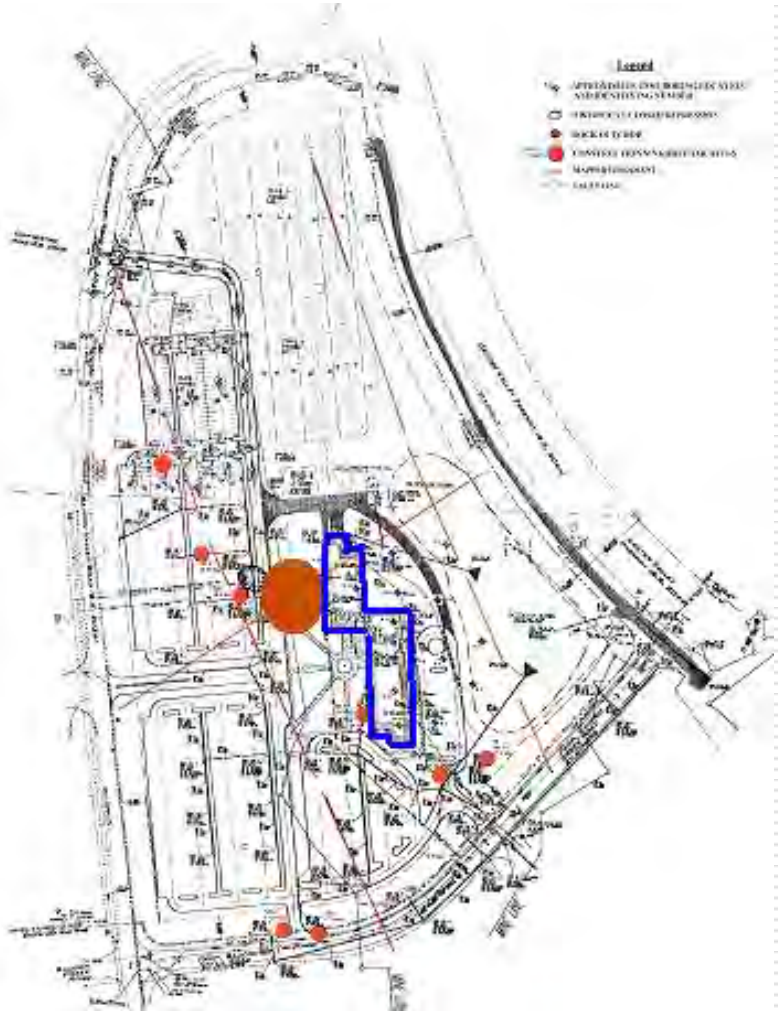


STABLER CENTER SAUCON VALLEY



ABS - ALLENTOWN BUSINESS SCHOOL



ABS - ALLENTOWN BUSINESS SCHOOL

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SUMMARY & CONCLUSIONS

- **Migration of surface water from deteriorating pavements, sidewalks, and curbs into residual soils can result in slow subsurface erosion of soil into the underlying bedrock resulting in subsidence**

- **Subsidence of soil supporting utilities can cause utility leaks or even main breaks that can result in rapid subsurface erosion, significant ground loss, and the formation of a sinkhole**

- **Extreme Precipitation Events will greatly increase sinkhole risk, utility breaks & property damage**

HOW DO WE SOLVE THE PROBLEM

- **Conduct a Comprehensive Inventory, Condition Assessment, Useful Life Determination**
- **Evaluate Life Cycle Costs & Replacement Fees**
- **Identify, Prioritize and Determine Costs for Critical Infrastructure Replacement Projects**
- **Establish a Long-Term Funding Source through Infrastructure Replacement Fees deposited into a Dedicated Reserve Account similar to that used by Condo Associations to Fund Infrastructure Repair, Reconstruction, and Replacement**

FEDERAL RESERVE LOAN DESK

Infrastructure Reserve Accounts would be used to obtain "zero" interest loans from Regional Federal Reserve Banks similar to the $ 8-Trillion made available to Wall Street Banks since 2008.

a) **By Law the Federal Reserve is responsible for monetary policy which is to accomplish manageable inflation, full employment, and steady growth in the economy**

b) **Investment of $3 to $4 Trillion in the Guarantee of Infrastructure Replacement Fee Account Loans would Lead to Increased Employment, Improvement of Local Economies, Increase in Tax and User Fee Revenues as well as Replacement of Critical Municipal Infrastructure that Sustains our Regional Economy and Quality of Life**

QUALIFICATION FOR LOANS

Qualification for Reserve Account Loans would come from the Submittal and Approval of Infrastructure Replacement Project Funding Requests by the Regional Municipal Planning (MPO) or Rural Planning Organization (RPO) which have been used for Federal Highway Transportation Infrastructure Funding Planning since 1962.

a. **A Municipal Infrastructure Committee would be established for each MPO and RPO to review and approve infrastructure project requests and loans**

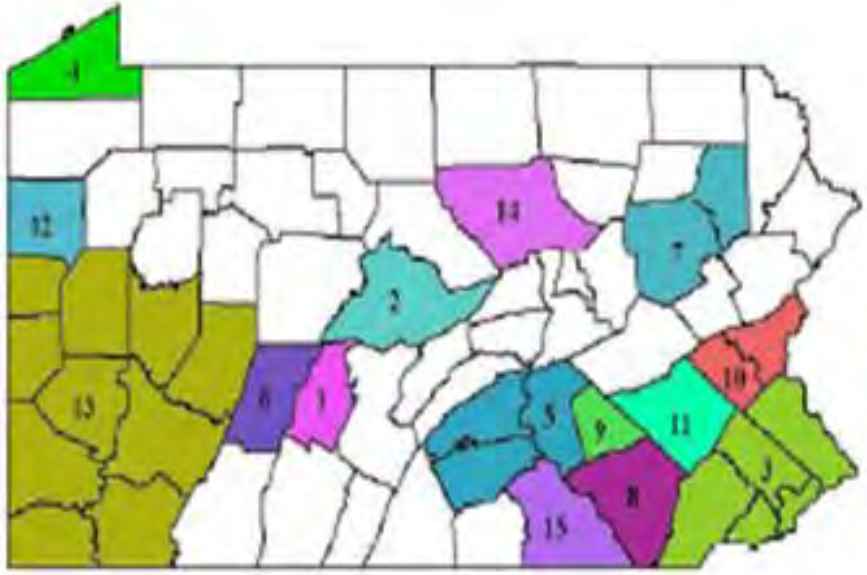
b. **A Sustainability & Resilience Review would be conducted for each Infrastructure Replacement Project by Regional MPO or RPO Planning Organizations**

PENNSYLVANIA MPO & RPO'S

MPOs are required to develop and maintain a Long Range Transportation Plan of at least 20 years and a Transportation Improvement Program that covers four years. MPOs are supported by Federal and State Planning Funds.

MPOs in Pennsylvania are (See Map 1)

1. Altoona
2. Centre Region
3. Delaware Valley
4. Erie
5. Harrisburg
6. Johnstown
7. Lackawanna/Luzerne
8. Lancaster
9. Lebanon
10. Lehigh Valley
11. Reading
12. Shenango Valley
13. Southwestern Pennsylvania
14. Williamsport
15. York



PA RPO's
Rural Planning
Organizations

THANK YOU – ANY QUESTIONS ?