

Riverfront Redevelopment Flood Study



THE BANKS INTERMODAL TRANSIT FACILITY

THE BANKS INTERMODAL TRANSIT FACILITY
BUILD GRANT SUBMISSION OF JULY 19, 2018

THE BANKS PROJECT

OVERVIEW

The Banks Project is a 198-acre transit-oriented, mixed-use development that serves as a destination point and livable community for people across the region, providing a lively atmosphere full of attractions that promote public enjoyment of the riverfront and economic opportunity. The Banks Project spans the width of Cincinnati's Central Business District and encompasses real estate extending over eight city blocks from Third Street on the North to the Ohio River on the South. The Banks Project, which is being constructed in multiple phases, currently includes two major league sports stadia, the National Underground Railroad Freedom Center, the Cincinnati Reds Hall of Fame and Museum, a 17,500 seat arena, a 171 room AC Marriott "lifestyle" hotel, an award-winning 45-acre riverfront park, over 592 luxury apartment units, over 8,600 public parking spaces, access to multiple modes of transportation and transit, cultural events, GE's Global Operations Center, and numerous retail and dining options.



THE BANKS PROJECT

Flood mitigation is an essential component of The Banks, absolutely necessary to continue advancing private and public development within the project. The County of Hamilton, Ohio (the



THE PHASE III FACILITY

“County”) and the City of Cincinnati, Ohio (the “City”), in coordination with The Banks Public Partnership and with the support of the Cincinnati Reds, Cincinnati Bengals, the General Electric Company, the City of Cincinnati Park Board and the National Underground Railroad Freedom Center, are in the process of

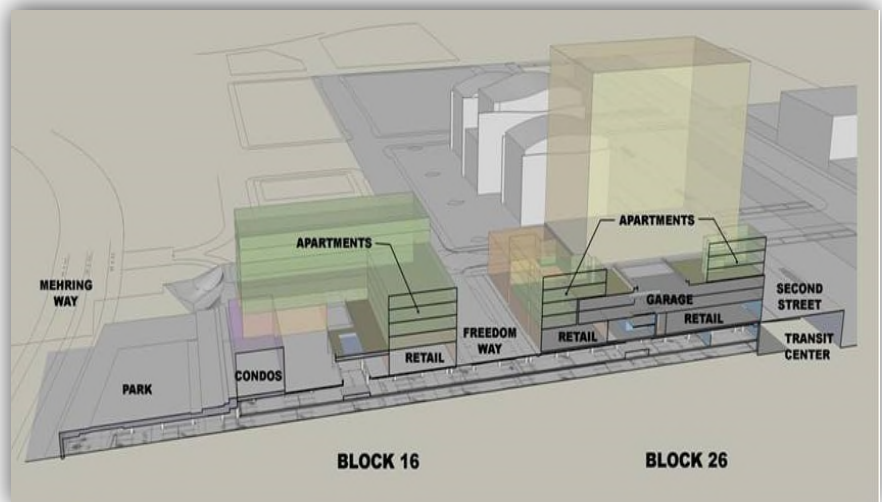
completing The Banks Intermodal Transit Facility associated with Phase IIIB, IIIC and IIID (collectively, the “Phase III Facility”), which consists of a multi-level public parking structure that provides flood mitigation, links the Cincinnati Riverfront Transit Center and will support the Phase III private and public development. The Phase III Facility has received an allocation from the previous State Capital Bill in the amount of \$10 million, which amounts have not yet been expended due to unforeseen delays in the previous Master Developer’s construction timeline. The City, the County and the Joint Banks Steering Committee have formulated, and are currently facilitating, a program to construct the Phase III Facility and related improvements in the very near term.

In addition, the City and the County have applied for \$5 million of additional funding for the Phase III Facility from the upcoming State Capital Bill. The County and City are now requesting that the previous \$10 million allocation and the upcoming \$5 million allocation be disbursed in accordance with an aggressive construction schedule pursuant to an agreement with the Ohio Department of Natural Resources



(“ODNR”). The County and the City have experience in working with ODNR for constructing Phase IIIA of the Phase III Facility, pursuant to a \$4 million state capital grant which was used to construct improvements along south Race Street. Such Phase IIIA improvements allowed for private development atop the parking podium and situated out of the flood plain, as described below.

Additional capital funding will allow transformative future development to be built on the Cincinnati riverfront and above the flood plain. Specifically, the Phase III Facility will include the completion of the next phase of a multi-level parking structure adjacent to the Cincinnati Central Business



District, that will provide general public parking, including parking for the General Electric employees at its U.S. Shared Services Center which was completed in October 2016, Central Business District employees, retail and commercial businesses located within The Banks Project, Paul Brown Stadium, Great American Ball Park, US Bank Arena, Smale Riverfront Park, and the National Underground Railroad Freedom Center. With respect to Phase IIIB and Phase IIIC, an additional 730 parking spaces will be fully integrated with The Banks Intermodal Transit Facility. Construction of Phase IIIB and Phase IIIC of The Banks Parking Garage Facility and Development Podium will also provide the structural support for the completion of the next phase of Smale Riverfront Park. The Phase IIIB and IIIC Facility will also be designed to provide structural support for additional mixed-use development immediately above, which could leverage an estimated \$250 million to \$300 million in additional private investment, including potential residential, retail, office and entertainment uses.

Phase IIID is designed to accommodate an alternative location for the development of a performance pavilion and event center. Such performance pavilion and event center would represent a private investment in excess of \$20 million and enable more than 150 events per year along the riverfront with more than 350,000 attendees annually.

FLOOD MITIGATION

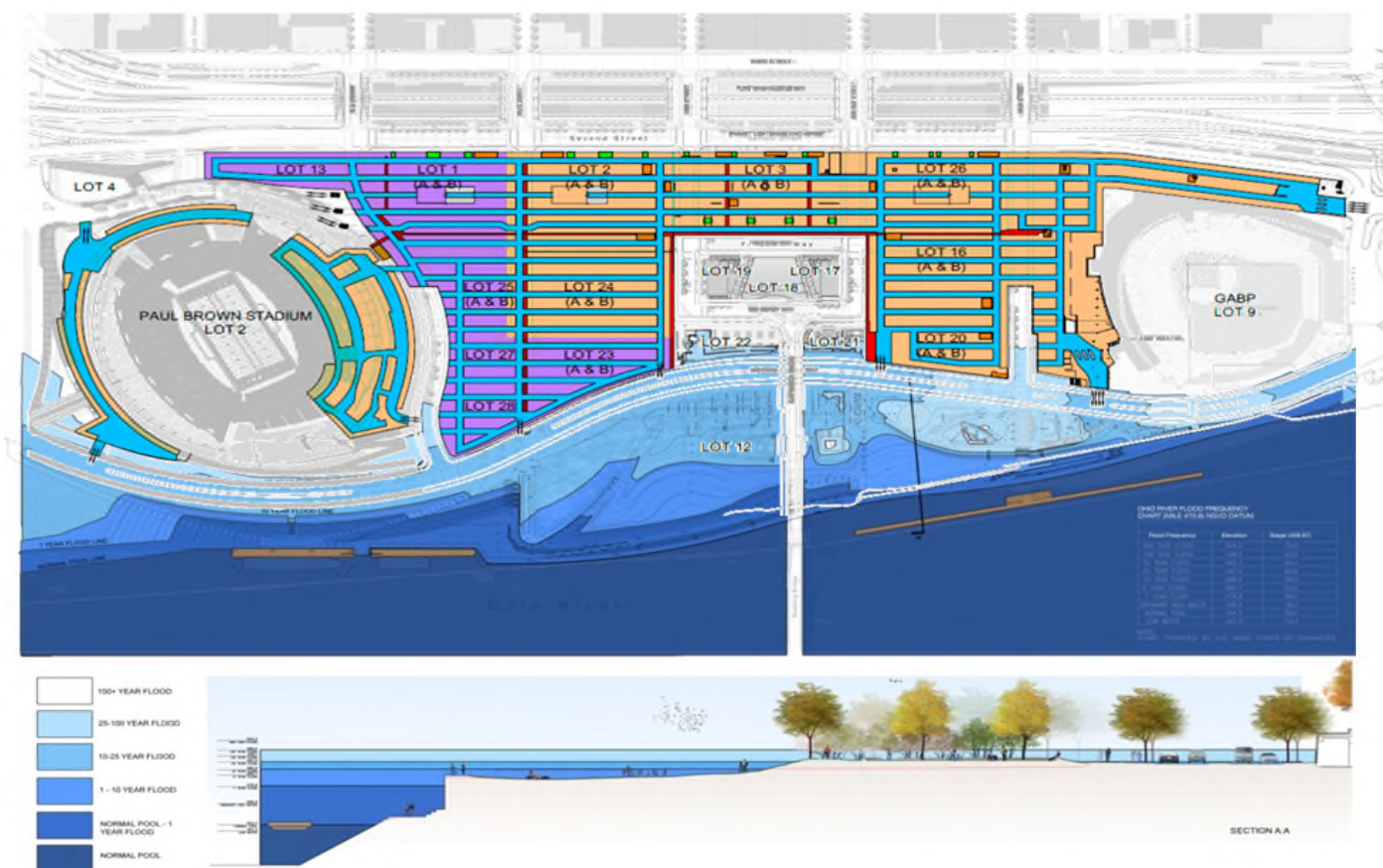
Prior to the construction of previous phases of Banks Intermodal Transit Facility and Development Podium, riverfront development had ceased due to the risk of flooding, as depicted below.



In March of 2000, the County commissioned a Parking Garage Flood Study (attached hereto as Exhibit A), which served as the plan for constructing The Banks Intermodal Transit Facility and Development Podium. Since the adoption of the recommendations set forth in the Parking Garage Flood Study, The Banks Project has experienced unprecedented economic growth as a result of the construction of The Banks Intermodal Transit Facility and Development Podium, and Phase II of The Banks Intermodal Transit Facility and Development Podium was awarded the International Parking Institute's 2013 Award for "Best Design of a Parking Facility with 800 or More Spaces." The award specifically touted The Banks Intermodal Transit Facility and Development Podium's work in lifting buildings, streets and utility infrastructure above the 500-year flood level.

The Banks Intermodal Transit Facility and Development Podium has enabled current and future residential, commercial and other private development of The Banks Project, because it has been constructed to allow such private development to be elevated above the 100 and 500-year flood plain. The Banks Intermodal Transit Facility and Development Podium has been designed as a floodable structure, as depicted on Exhibit B attached hereto and described below.

Based on the most FEMA panel, a portion of the Ohio River 100-year floodplain occurs within The Banks Project, as depicted in the image below.



Coordination with the local floodplain administrator has been completed prior to construction of all previous phases of The Banks Intermodal Transit Facility and Development Podium, and coordination will continue for future phases. The parking garages are designed to be protected from a 25-year flood event. For greater than 25-year flood events, award-winning design features (as depicted on Exhibit B attached hereto) have been developed, permitting them to flood, without material structural damage. Water will flow over the open-air windows of the garages and flow relatively unobstructed between Elm and Main Streets in the garages.

As the water begins to subside, water inside the garages will be collected in a nine by twelve-foot culvert that will discharge water into the Central Riverfront Park south of the garages. As the culvert drains, much of the flood debris and mud will be collected. Once the water subsides, the culvert will be accessed by a truck with a plow-type device, and the debris will be collected and disposed of in accordance with state and local regulations. The garages will be constructed of concrete, which will be washed, as needed, following any event that results in water collecting in the garages.

Utilities within the garages have been and will continue to be flood-proofed in accordance with Chapter 1109 of the Cincinnati Building Code, and electric conductors are located above the floodway to the 515 level.

The entire mixed-use development comprising The Banks would be impossible without construction of The Banks Intermodal Transit Facility and Development Podium as a flood mitigation element. Related benefits include direct transit connectivity (such as park-n-ride, carpool, vanpool, rideshare, bus, bicycle, future, light rail, streetcar and general public parking), flood mitigation and enabling of future economic development opportunities that are able to be flexibly tailored as the Phase III private development is constructed.

ECONOMIC IMPACT

To date, every \$1 dollar in public dollars expended on The Banks project attracts an average of \$5-\$7 dollars in private capital. In addition, as set forth in previously-commissioned Economic Impact Studies, completion of The Banks Project will yield an operating impact in excess of \$1 billion annually for the entire region. Construction of Phase IIIB and Phase IIIC of The Banks Intermodal Transit Facility and Development Podium will advance completion of a facility that will leverage additional investment in excess of \$250 million to \$300 million of private capital investment.

Construction of the public infrastructure portion of Phase IIIB, Phase IIIC and alternative Phase IIID will create an estimated 400 jobs during construction, yielding a \$70 million regional economic impact from 2018-2020. Construction of Phase IIIB and Phase IIIC of The Banks Intermodal Transit Facility and Development Podium will serve as the podium structure to support the construction of 400,000-550,000 square feet of additional private mixed-use development. Phase IIIB and Phase IIIC private capital investment is estimated to be approximately \$250 million to \$300 million, which will create an additional 1,500 jobs during construction and 1,200

permanent jobs upon completion in 2018-2020. An alternative Phase IIID which would include a music venue will also create additional jobs during and following construction, and will have an annual economic impact in excess of \$25 million upon opening in 2019.

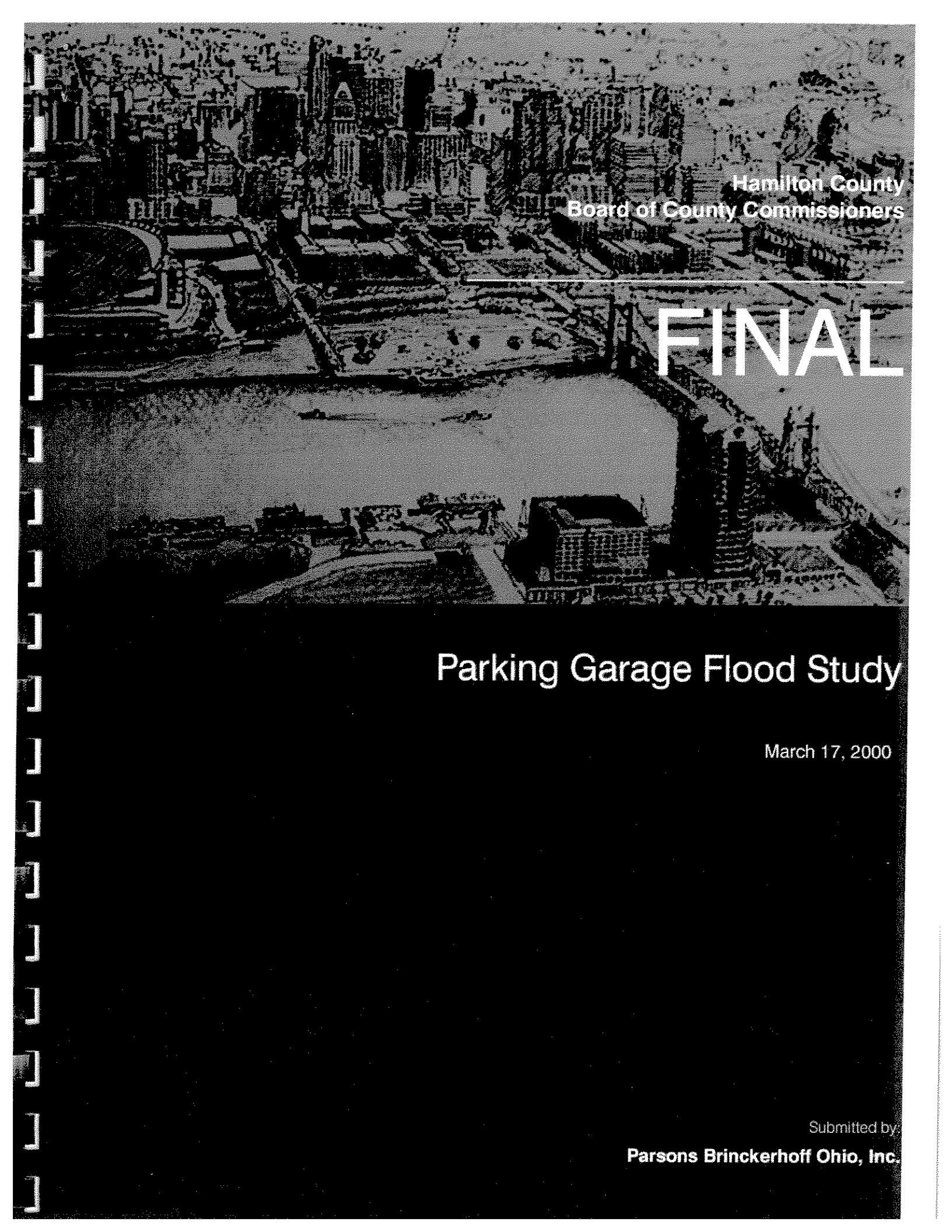
Completion of Phase IIIB and Phase IIIC will also enable the development of the next phase of the Smale Riverfront Park, which will result in a capital investment in excess of \$25-\$30 million and create an additional 300-350 jobs during construction. The estimated economic impact of the Smale Riverfront Park is \$330 million per year.

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EXHIBIT A

2000 BANKS PARKING GARAGE FLOOD STUDY



Hamilton County
Board of County Commissioners

FINAL

Parking Garage Flood Study

March 17, 2000

Submitted by:
Parsons Brinckerhoff Ohio, Inc.

**HAMILTON COUNTY
PARKING GARAGE FLOOD STUDY**

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Parking Garage Flood Study

1.0 Introduction

A parking garage is proposed to serve stadium facilities and related development on the Cincinnati Riverfront. The garage is located immediately north of proposed Theodore M. Berry Way (TBW), which will be constructed on approximately 20 feet of embankment and supported by two retaining structures. The embankment and the parking garage will be located in the 100-year floodplain of the Ohio River. The embankment height is above the 500-year floodplain elevation. However, floodwaters will enter the parking garage from its west, east, and north sides above a flood-protected elevation.

The TBW embankment will restrict floodwaters entering the garage from the west, east and north sides from exiting to the river. The bottom floor elevation of the parking garage is 489 feet. When the floodwaters recede, water above approximately 490.6, which is the entrance elevation to the eastern parking garage of Paul Brown stadium, can escape and return to the river. All water below 490.6 will remain in the garage and will need to be drained through a drainage system that will connect the low-lying area of the garage to the river. This drainage system must also prevent the garage from flooding due to water backing up through the system due to high river elevations.

The east and west entrances to the garage will be flood-protected. According to THP Limited, Inc. (THP), who is responsible for design of the garages, a flood-protected elevation of 493 feet will be incorporated into the design. The hydrostatic pressures resulting from flood protection to 493 would significantly impact the design of the parking garage floor slab. An elevation of 491 was discussed as an alternative elevation that would not significantly impact the design of the garage floor slab. Floodwaters would enter the parking garage from the north side from the transit center above an elevation of 491.8. Modifications to the roadway design of the transit center could increase this flood-protected elevation of the transit center to approximately 495. This report will evaluate drainage systems based on garage flood-protected elevations of 493 and 491 feet for comparison.

Experience has shown that when flooding has occurred, a large amount of sediment is deposited on the ground. This sedimentation has typically resulted in blockage of drainage systems. Therefore, for the garage drainage system to be effective, facilities must be provided to allow the system to remain functional in spite of the potential for plugging due to sedimentation.

This study presents two alternatives for effectively draining the garage. Sedimentation calculations and hydraulic analyses of both systems, a cost analysis, descriptions of the advantages and disadvantages of each alternative, and conclusions are outlined below.

2.0 Sedimentation

The sedimentation problems that occur due to a flood can be substantial. During flood events, records have shown that as the discharge of the Ohio River increases, the amount of sediment it carries increases. When the floodwater stands for a period of time the sediment held in suspension will settle causing a layer of sediment to be deposited on the ground.

To estimate the sedimentation that could occur due to flooding in the Cincinnati area, research was done to find site-specific data that could be applied to the Cincinnati area. The United States Geological Survey (USGS) has collected sedimentation values for the Ohio River in Louisville, Kentucky in the past. These values for the period of 1989 to 1993 are presented in Appendix A. A graph was developed to compare the Ohio River discharge versus the suspended sediment concentration as shown in Figure 1. This figure shows that the sediment concentration increases with the increases in discharge.

The Army Corps of Engineers provided stage and discharge values at Ohio River Mile 470.5, which is the Cincinnati gage station. This information is presented below in Table 1 and in Appendix B. With a low elevation of 489 in the garage, flooding through backing up of the drainage system could occur with an 18-year frequency with no flood protection. With the construction of flood protection to 491 and 493, flooding directly from the river would occur at a frequency of 25 and 34-years, respectively. The limits of flooding in the proposed condition for each frequency event are shown in Figure 2.

TABLE 1
Stage, Frequency, Discharge Relationship
Ohio River Mile 470.5

Frequency (Years)	Discharge (cfs)	River Stage (ft)
1	394,000	470.67
2	437,000	476.07
5	488,000	482.37
10	532,000	486.57
25	608,000	491.67
50	663,000	495.27
100	718,000	498.47
500	842,000	505.07

When the Ohio River has reached a stage above the flood-protected elevation of the garages, the water in the overbank areas is still flowing along with the river. When the floodwater in the Ohio River begins to recede, the floodwaters will be trapped in the garage and deposition will occur. A review of Figure 1 indicates that the concentration of suspended sediment in a flooding condition will vary depending on the frequency of the flood event.

FIGURE 1
Suspended Sediment in the Ohio River Louisville KY

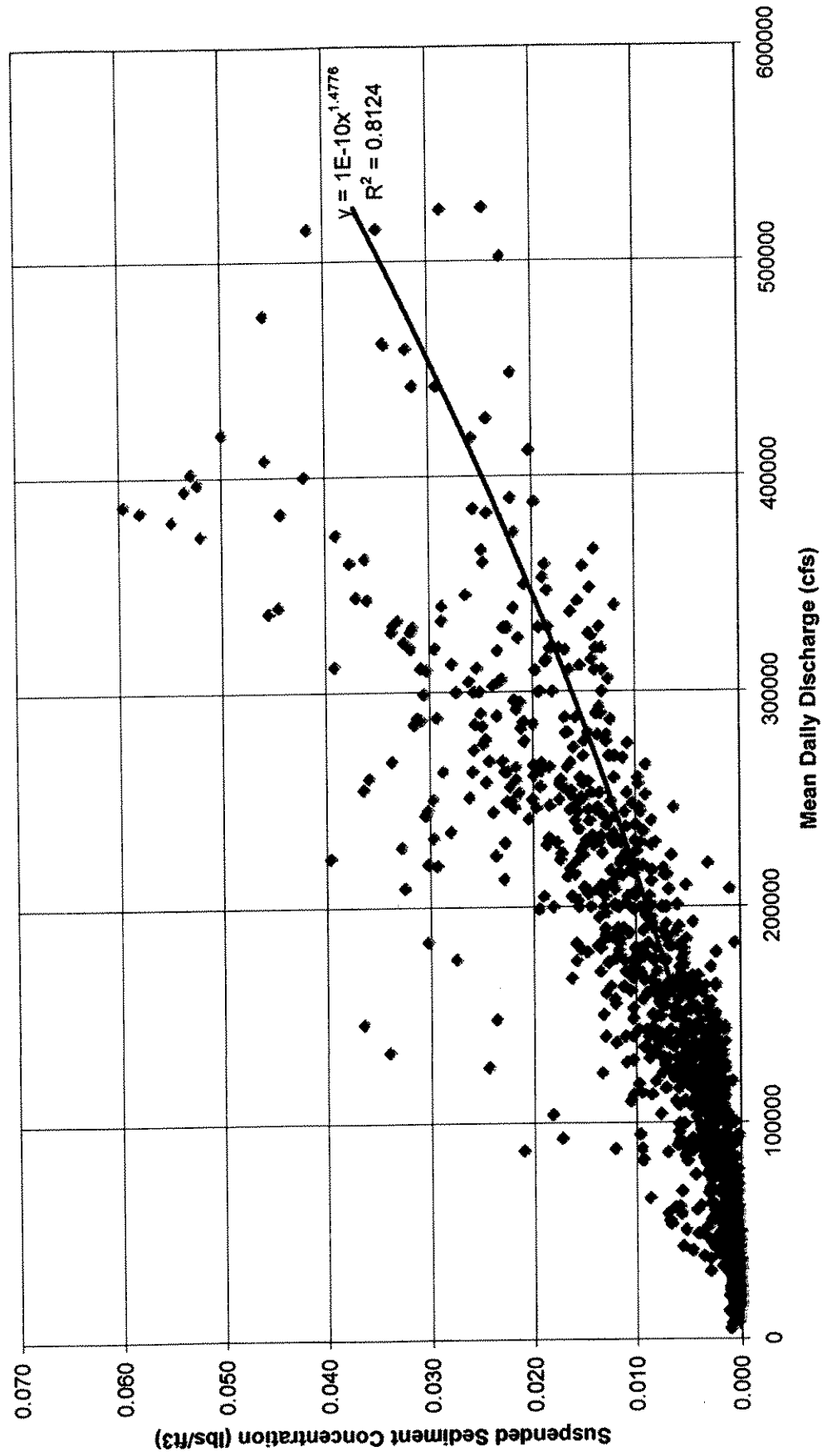
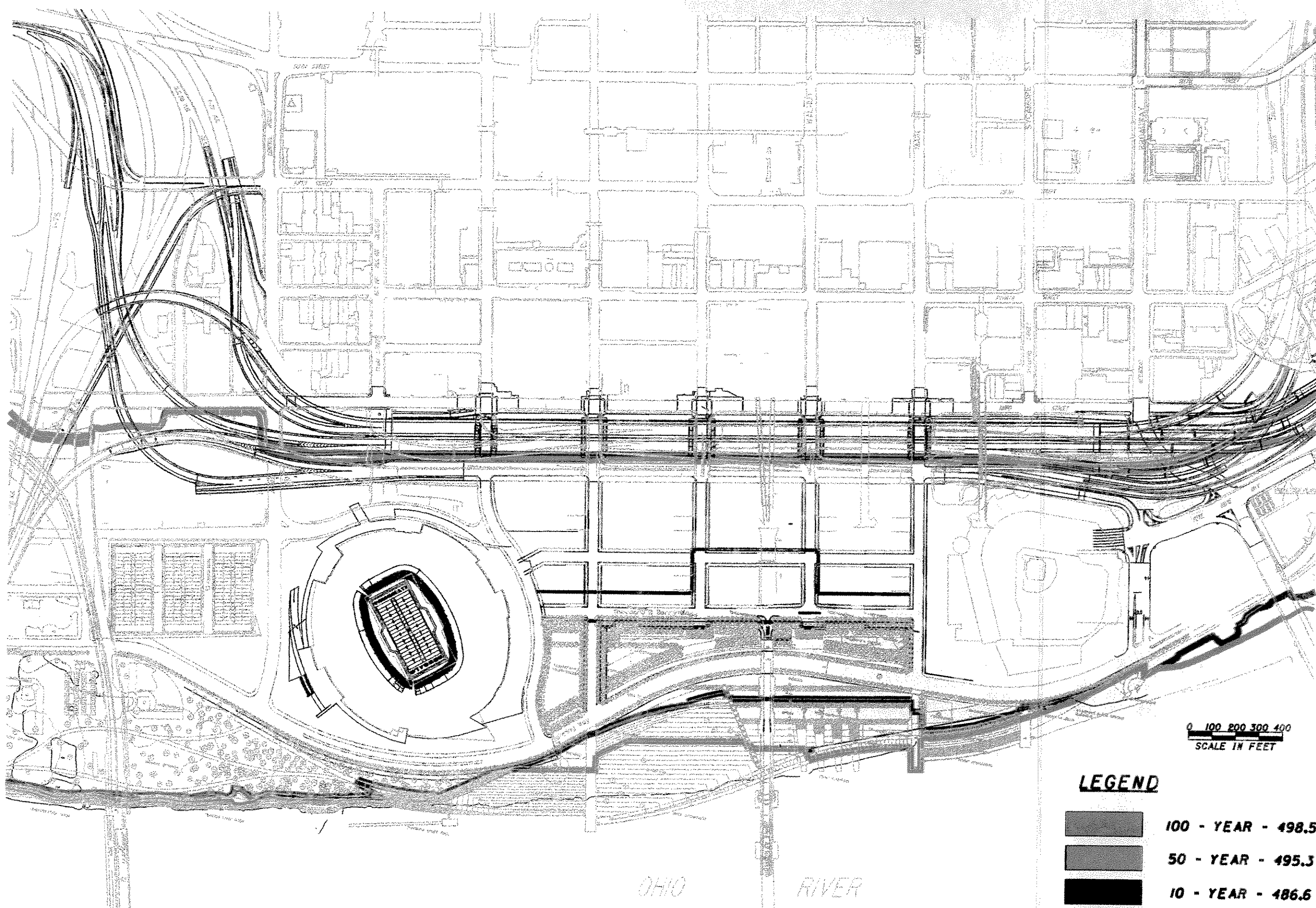




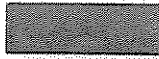
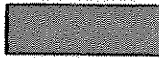
FIGURE 2

\$\$\$date\$\$\$
\$\$\$time\$\$\$
\$\$\$prfspec\$\$\$
\$\$\$dgnspec\$\$\$



0 100 200 300 400
SCALE IN FEET

LEGEND

	100 - YEAR - 498.5
	50 - YEAR - 495.3
	10 - YEAR - 486.6
	2 - YEAR - 476.1

To assess the impact of a 100-year event, a suspended sediment concentration could be as high as 0.045 lbs./ft³. Based on an estimate of the area of the garage, the depth of sediment in the garage resulting from this event assuming complete deposition would be less than one inch. The calculations for this depth are presented in Appendix C.

During events of this nature, it has been local practice to get as much sediment as possible back to the Ohio River. In an attempt to re-suspend this material, trucks with snowplows have been deployed to stir up the previously settled material. This will allow the floodwater to carry a substantial portion of the sediments back to the Ohio River as the river recedes. Sediments that cannot be removed in this manner will remain on the ground. It has been assumed that this practice would continue within the area of the parking garage in the future.

Therefore, there are two goals that must be achieved to ensure that the garage drainage system remains functional during such an event.

- The drainage system must not become plugged with sediments during the period of flooding.
- The drainage system must be able to return the re-suspended sediments to the river without becoming plugged.

3.0 Alternative Methods of Draining the Parking Garage

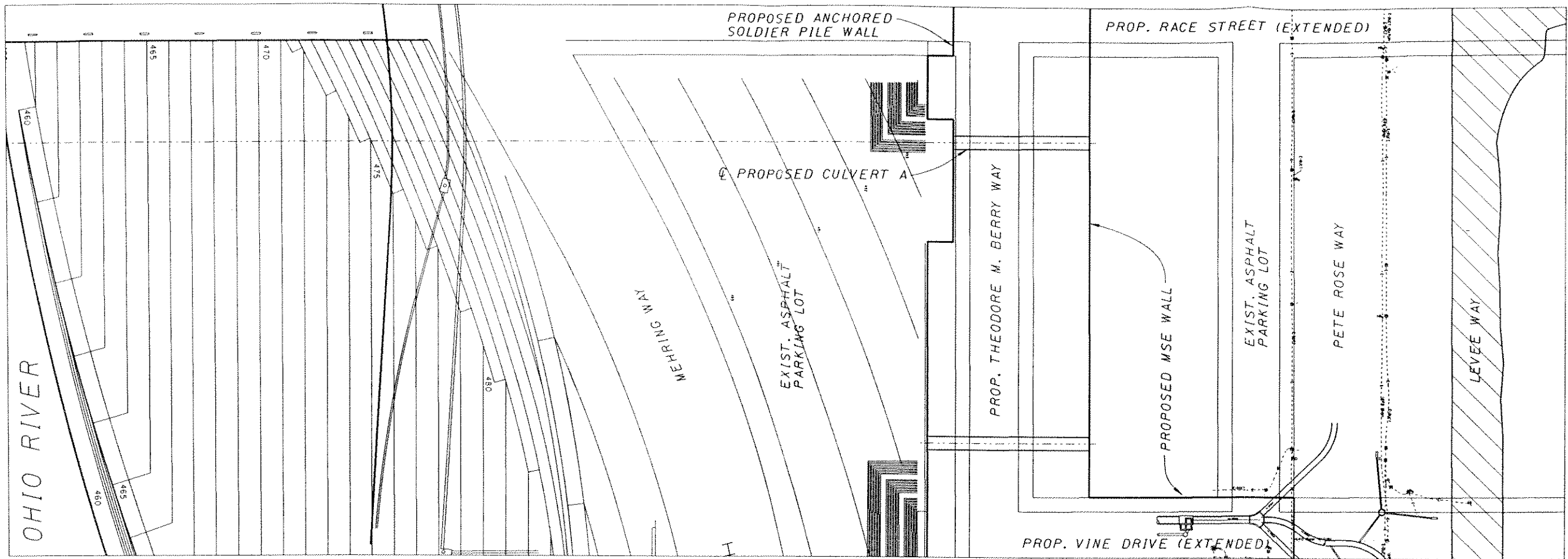
Two alternative methods have been developed and assessed to determine their suitability to achieving the two operational goals for the parking garage drainage system. These are as follows:

Alternative 1

Alternative 1 includes the construction of two, 9'x12' box culverts (A1 and A2) within the TBW embankment. The top of the culverts are approximately 5 feet above, and the inverts of the culverts are approximately 4 feet below the proposed grade of the park. The ground (fill) above the invert of the culverts will be removed in a flooding condition to provide positive drainage via a concrete channel to Mehring Way. After the recession of a flood, maintenance vehicles would need to remove the fill from Mehring Way to the downstream end of the culverts to open the floodgates to allow the garage to drain. The parking garages have been proposed to be flood-protected to an elevation of 491 or 493 by the use of floodgates or other means. Illustrations of Alternatives 1A and 1B for the western side of TBW are presented in Figures 3 and 4.

Two methods of hydraulic analysis were used to evaluate the behavior of the water surface elevation in the culverts as the water recedes during a flood event.

One method of evaluating the water surface elevation in the culverts included the comparison of culvert capacity (Q) to the discharge resulting from a drop in the river



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SCALE IN FEET

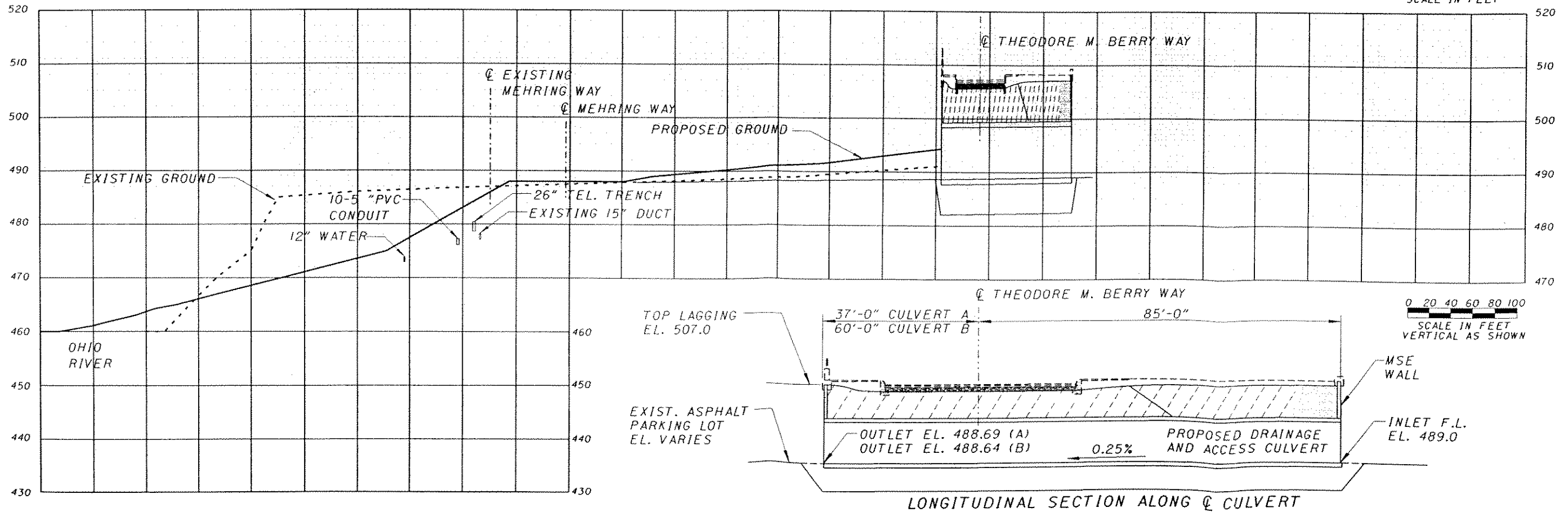
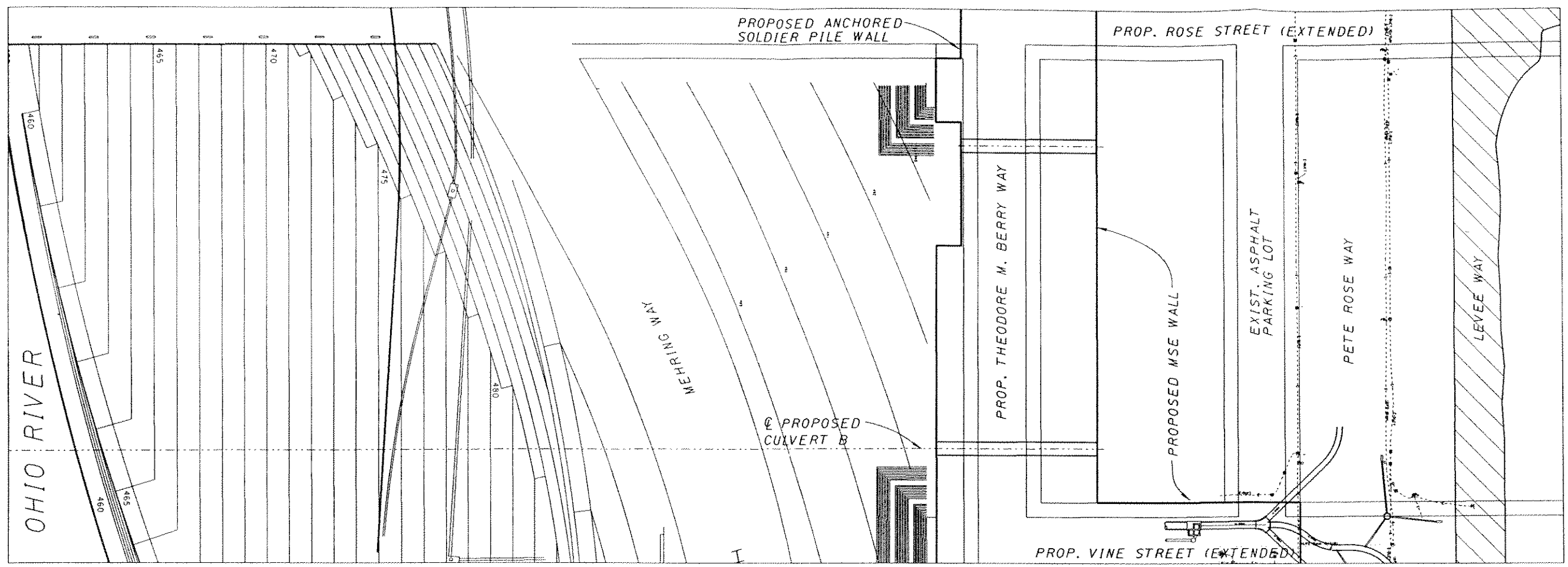


FIGURE 3
ALTERNATIVE 1A

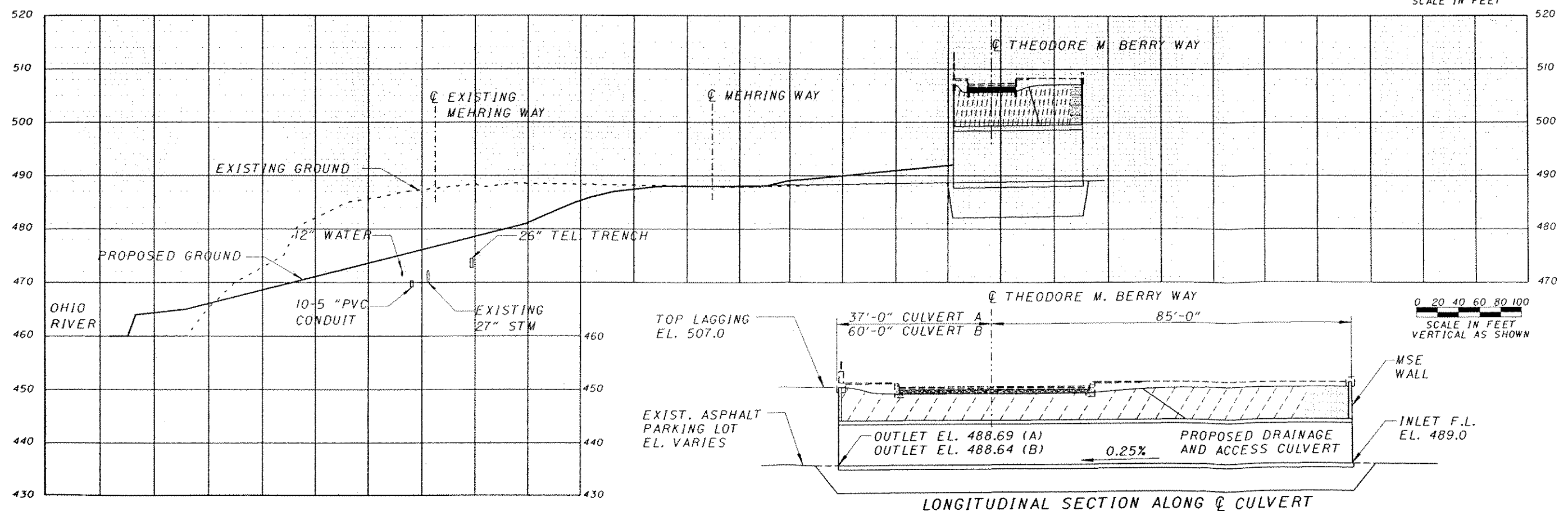
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0 20 40 60 80 100
SCALE IN FEET



0 20 40 60 80 100
SCALE IN FEET
VERTICAL AS SHOWN



FIGURE 4
ALTERNATIVE 1B

DESIGNED	CHECKED	DRAWN	REVIEWED	DATE

DESIGN AGENCY
PARSONS BRINCKERHOFF, INC.
312 ELM STREET, SUITE 2500
CINCINNATI, OH 45202-2720

elevation by time step. The culvert capacity was calculated using the Manning equation at varying depths as the river recedes. The reduction in volume of water in the garage resulting from a drop in the river was calculated by multiplying the stage change in the river by the garage area. This volume was divided by the length of time between measurements (time steps) to calculate an average discharge. Comparison of these discharges indicates that the culvert will always have the capacity to pass the volume of water as the river recedes. In other words, the water can leave the garage at a rate that is only limited by the depth of water at the culvert upstream entrance. The depth of water in the garage would be equal to the depth of water in the Ohio River, and would simply operate as equalization culverts without the use of a flood control system.

With the use of a flood control system, the water would be trapped inside the garage until the river elevation reaches 485, the elevation of Mehring Way. At this elevation, vehicles could drive on Mehring Way, expose the underlying trench, remove the floatable fill, and open the flood control system. The calculations with flood protection to 493 and 491 are presented in Table 2 and Table 3 respectively.

TABLE 2
Alternative 1 Analysis
Flood Protection to 493

Time Day	River Stage (ft)	Garage Stage (ft)	Comments	Area (ft ²)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	Discharge from Garage $Q = 1.49/n(AR^{2/3}S^{1/2})$ (ft ³)	Volume Removed based on discharge (ft ³)	new depth in garage (ft)
35.50	490.65	493.00	culvert gate closed						
36.00	487.80	493.00	culvert gate closed						
36.50	484.30	493.00	open	48.00	20.00	2.40	531.07	4588486	490.81
36.60	483.60	490.81	open	21.71	15.62	1.39	167.52	1447354	490.12
36.70	482.90	490.12	open	13.42	14.24	0.94	80.12	692209	489.79
36.80	482.20	489.79	open	9.45	13.58	0.70	46.21	399294	489.60
36.90	481.50	489.60	open	7.16	13.19	0.54	29.73	256859	489.47
37.00	480.80	493.00	open	48.00	20.00	2.40	531.07	4588486	490.81
37.10		490.81	open	21.71	15.62	1.39	167.52	1447354	490.12
37.20		490.12	open	13.42	14.24	0.94	80.12	692209	489.79
37.30		489.79	open	9.45	13.58	0.70	46.21	399294	489.60
37.40		489.60	open	7.16	13.19	0.54	29.73	256859	489.47
37.50		489.47	open	5.69	12.95	0.44	20.55	177553	489.39
37.60		489.39	open	4.68	12.78	0.37	14.95	129181	489.33
37.70		489.33	open	3.94	12.66	0.31	11.30	97670	489.28
37.80		489.28	open	3.38	12.56	0.27	8.81	76089	489.25
37.90		489.25	open	2.94	12.49	0.24	7.03	60719	489.22
38.00		489.22	open	2.59	12.43	0.21	5.72	49418	489.19
38.10		489.19	open	2.31	12.38	0.19	4.73	40888	489.17
38.20		489.17	open	2.08	12.35	0.17	3.97	34308	489.16
38.30		489.16	open	1.88	12.31	0.15	3.37	29135	489.14
38.40		489.14	open	1.71	12.29	0.14	2.89	25002	489.13
38.50		489.13	open	1.57	12.26	0.13	2.51	21654	489.12
38.60		489.12	open	1.44	12.24	0.12	2.19	18906	489.11
38.70		489.11	open	1.34	12.22	0.11	1.92	16628	489.10

TABLE 3
Alternative 1 Analysis
Flood Protection to 491

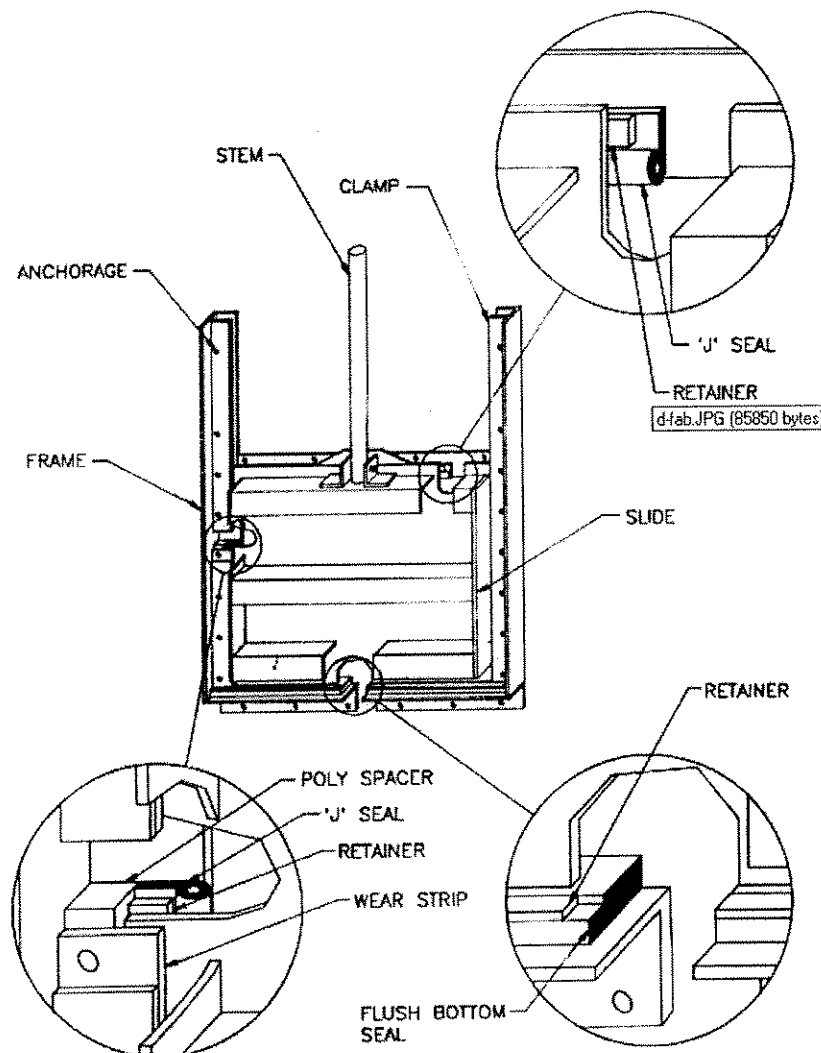
Time Day	River Pool Depth	Garage Stage (ft)	Comments	Area (ft ²)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	Discharge from Garage $Q = 1.49/n(AR^{2/3}S^{1/2})$ (ft ³)	Volume Removed based on discharge (ft ³)	new depth in garage (ft)
35.50	58.20	492.60	culvert gate closed						
36.00		492.60	culvert gate closed						
36.50		492.60	open	43.20	19.20	2.25	458.04	395743	492.41
36.51		492.41	open	40.93	18.82	2.17	424.36	366643	492.24
36.52		492.24	open	38.83	18.47	2.10	393.67	340130	492.07
36.53		492.07	open	36.88	18.15	2.03	365.68	315945	491.92
36.54		491.92	open	35.07	17.85	1.97	340.11	293858	491.78
36.55		491.78	open	33.39	17.56	1.90	316.74	273663	491.65
36.56		491.65	open	31.82	17.30	1.84	295.34	255175	491.53
36.57		491.53	open	30.36	17.06	1.78	275.73	238230	491.42
36.58		491.42	open	28.99	16.83	1.72	257.73	222680	491.31
36.59		491.31	open	27.72	16.62	1.67	241.20	208394	491.21
36.60		491.21	open	26.52	16.42	1.62	225.99	1952518	490.28
36.70		490.28	open	15.34	14.56	1.05	98.57	851656	489.87
36.80		489.87	open	10.46	13.74	0.76	54.22	468487	489.65
36.90		489.65	open	7.77	13.30	0.58	33.87	292670	489.51
37.00		489.51	open	6.10	13.02	0.47	22.95	198304	489.41
37.10		489.41	open	4.96	12.83	0.39	16.46	142196	489.35
37.20		489.35	open	4.15	12.69	0.33	12.31	106325	489.29
37.30		489.29	open	3.54	12.59	0.28	9.50	82112	489.26
37.40	51.20	489.26	open	3.07	12.51	0.25	7.53	65062	489.22
37.50		489.22	open	2.69	12.45	0.22	6.09	52644	489.20
37.60		489.20	open	2.39	12.40	0.19	5.02	43345	489.18
37.70		489.18	open	2.14	12.36	0.17	4.19	36217	489.16
37.80		489.16	open	1.94	12.32	0.16	3.55	30645	489.15
37.90		489.15	open	1.76	12.29	0.14	3.03	26215	489.13
38.00		489.13	open	1.61	12.27	0.13	2.62	22641	489.12
38.10		489.12	open	1.48	12.25	0.12	2.28	19719	489.11
38.20		489.11	open	1.37	12.23	0.11	2.00	17305	489.11
38.30		489.11	open	1.27	12.21	0.10	1.77		489.11

The results of the analysis indicate that initially, the water would travel through the culverts at a discharge over 450 cfs and velocity over 10 ft/s. The garage would be empty within approximately 2.2 days with flood protection to 493 and less than 2 days with flood protection to 491 after the flood control system is opened.

The second method used to evaluate the water surface elevation in the culverts included running the Environmental Protection Agency (EPA) Stormwater Management Model (SWMM). In the model, it was assumed that the culvert tailwater depth is equal to minimum of the critical or normal depth. Results indicated that the culverts have the capacity to empty the garage at the same rate as the river recedes. The culverts have the capacity to pass the water and are again controlled by the proposed gates and/or water control structure proposed to reduce flooding frequency. Resulting figures for this modeling are included in Appendix D.

Alternative 2

Alternative 2 includes the construction of a water control structure on the upstream side of the TBW embankment. Figure 5 shows the proposed layout of Alternative 2. This water control structure is comprised of stop logs that could be removed, from the second level parking elevation above, intermittently during the recession of a flood. As the water passes over the top of the stop blocks it is collected in a chamber below. A concrete pipe located in the invert of the chamber conveys the floodwaters to the Ohio River. A backflow preventor on the end of the pipe will not allow river water to back into the garage when its depth is above the outlet pipe. This backflow preventor also minimizes the opportunity for the drainage pipe to become filled with sediment during the flooding period. An illustration of a system similar to a stop log system is presented below.



It is envisioned that the stop logs would remain in place until the flood recedes. Due to the presence of a backflow preventor, the pipe to the river would remain relatively dry in a flooding event. When the height of water in the river recedes, the stop logs would be

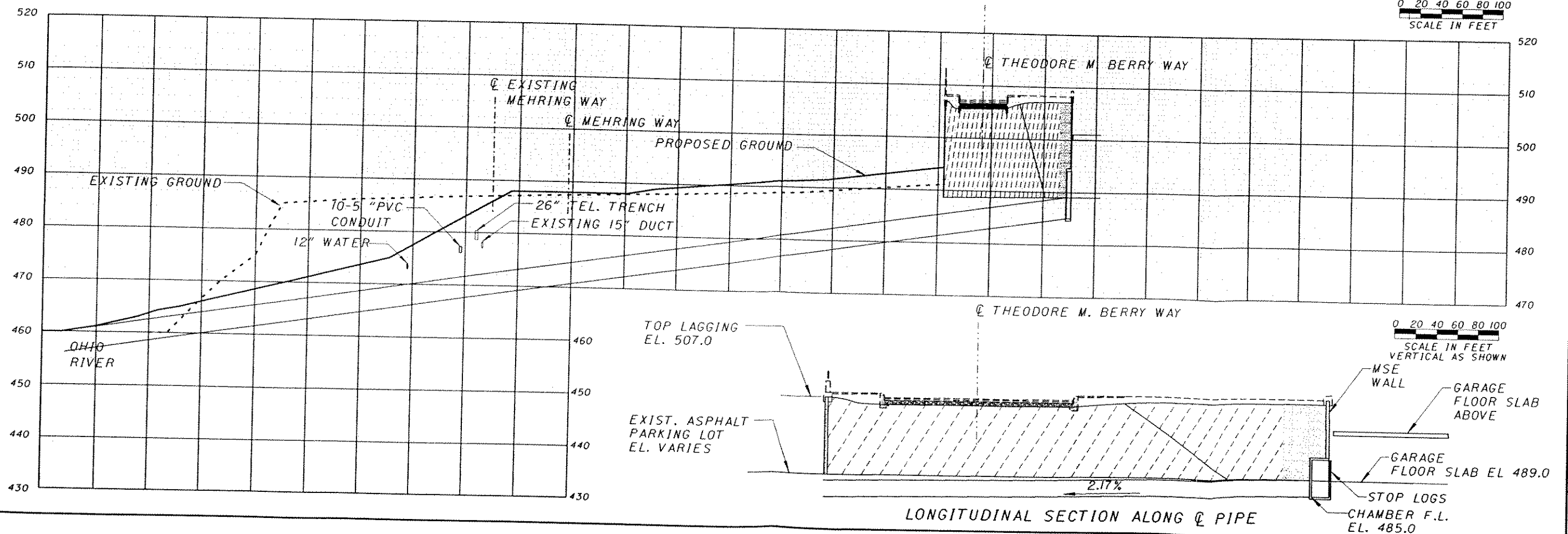
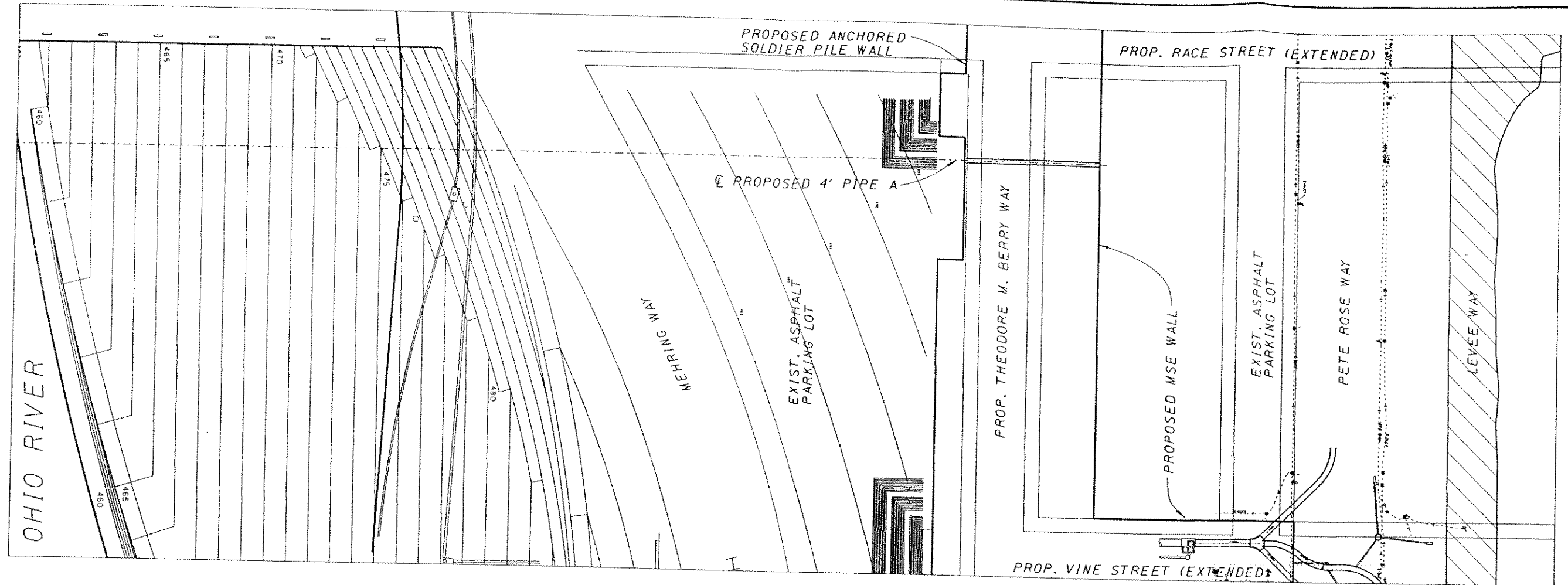


FIGURE 5
ALTERNATIVE 2

removed. The stop logs would act as a weir allowing water to spill into the chamber below and then on to the river through the drainpipe. While sediment is a problem, this system would allow only the water from the top of the water column in the garage, which should be the cleanest, to spill over first. The stop logs would not be removed until the available hydraulic gradient between the water level in the garage and the river level is such that the flow of water in the drain pipe has the ability to hold the sediment in suspension, thereby not causing plugging of the drain pipe. The greater the differences between the water level in the garage and the river level, the greater the ability of the pipe to carry high-suspended solid loads. At lower depths in the garage, the maintenance vehicles could drive in the garage to cause, and to keep the sediment in suspension until the river recedes. When the river has receded sufficiently, the remaining stop logs would be removed to allow the remaining water and sediment to enter the pipe and flow to the river under minimal backwater conditions.

The stop log, chamber, and pipe flows are all influenced by the elevation of the upstream weir and the elevation of the river during that time step. The time step that the logs are lifted, the number lifted and the water surface elevation in the river all contribute to the performance of the system. A model was developed to evaluate the system's operation by removing the logs at varying times, and elevations. This iteration process occurred until the backwater conditions at the Ohio River did not inhibit the flow of the pipe, and tractive forces were large enough to avoid sedimentation in the pipe. Results of this analysis are presented in Table 4 and table 5 for the garage flood-protected to 493 and 491 respectively.

TABLE 4
Alternative 2 Analysis
Flood Protection to 493

Garage Stage (ft)	Comments	Weir Elevation (ft)	Weir Head (ft)	Discharge from Garage $Q = (5.19) H^{1.4}$ (ft ³ /s)	Volume Removed based on discharge (ft ³)	new depth in garage (ft)	Pipe Chamber Minor Losses (ft)	Headloss Due to Backflow Preventor (ft)	Headloss Pipe (ft)	Total Headloss (ft)	Difference in Head (ft)	Flow to River	Tractive Force (lb/ft ²)	Minimum Tractive Force (lb/ft ²)
505.65	stop logs closed													
506.30	stop logs closed													
506.95	stop logs closed													
509.60	stop logs closed													
509.40	stop logs closed													
509.20	stop logs closed													
506.80	stop logs closed													
506.40	stop logs closed													
507.90	stop logs closed													
507.40	stop logs closed													
506.55	stop logs closed													
505.70	stop logs closed													
504.70	stop logs closed													
503.70	stop logs closed													
502.45	stop logs closed													
501.20	stop logs closed													
499.55	stop logs closed													
497.90	stop logs closed													
495.70	stop logs closed													
493.00	stop logs closed													
493.00	stop logs closed													
493.00	stop logs closed													
493.00	stop logs closed													
493.00	stop logs closed													
492.77	open	492.20	0.80	11.27	486855	492.77	1.40	0.25	8.4	10.02	12.20	FLOW	0.50	0.50
492.30	open	491.50	1.27	22.48	970986	492.30	2.09	0.50	12.5	15.13	15.97	FLOW	0.69	0.50
492.30	open	490.70	1.60	31.99	1362148	491.64	2.58	0.50	15.5	18.56	19.50	FLOW	0.80	0.50
491.64	open	490.00	1.64	33.20	1434302	490.96	2.64	0.50	15.8	18.99	23.09	FLOW	0.81	0.50
490.96	open	489.00	1.96	43.19	1865956	490.07	3.06	0.75	18.3	22.14	26.66	FLOW	0.91	0.50
490.07	open	489.00	1.07	17.39	751353	489.71	1.83	0.38	11.0	13.16	29.22	FLOW	0.61	0.50
489.71	free outlet	489.00	0.71	9.42	406740	489.52	1.25	0.20	7.5	8.96	32.31	FLOW	0.47	0.50
489.52	free outlet	489.00	0.52	5.83	251785	489.40	0.96	0.06	5.8	6.78	32.67	FLOW	0.37	0.50
489.40	free outlet	489.00	0.40	3.91	169056	489.31	0.74	0.00	4.4	5.19	33.10	FLOW	0.31	0.50
489.31	free outlet	489.00	0.31	2.78	120010	489.25	0.61	0.00	3.6	4.25	31.11	FLOW	0.27	0.50
489.25	free outlet	489.00	0.25	2.05	86757	489.21	0.58	0.00	3.5	4.09	29.16	FLOW	0.22	0.50
489.21	free outlet	489.00	0.21	1.57	67752	489.18	0.51	0.00	3.0	3.55	26.86	FLOW	0.19	0.50
489.18	free outlet	489.00	0.18	1.23	53041	489.16	0.40	0.00	2.4	2.81	24.58	FLOW	0.18	0.50

TABLE 5
Alternative 2 Analysis
Flood Protection to 491

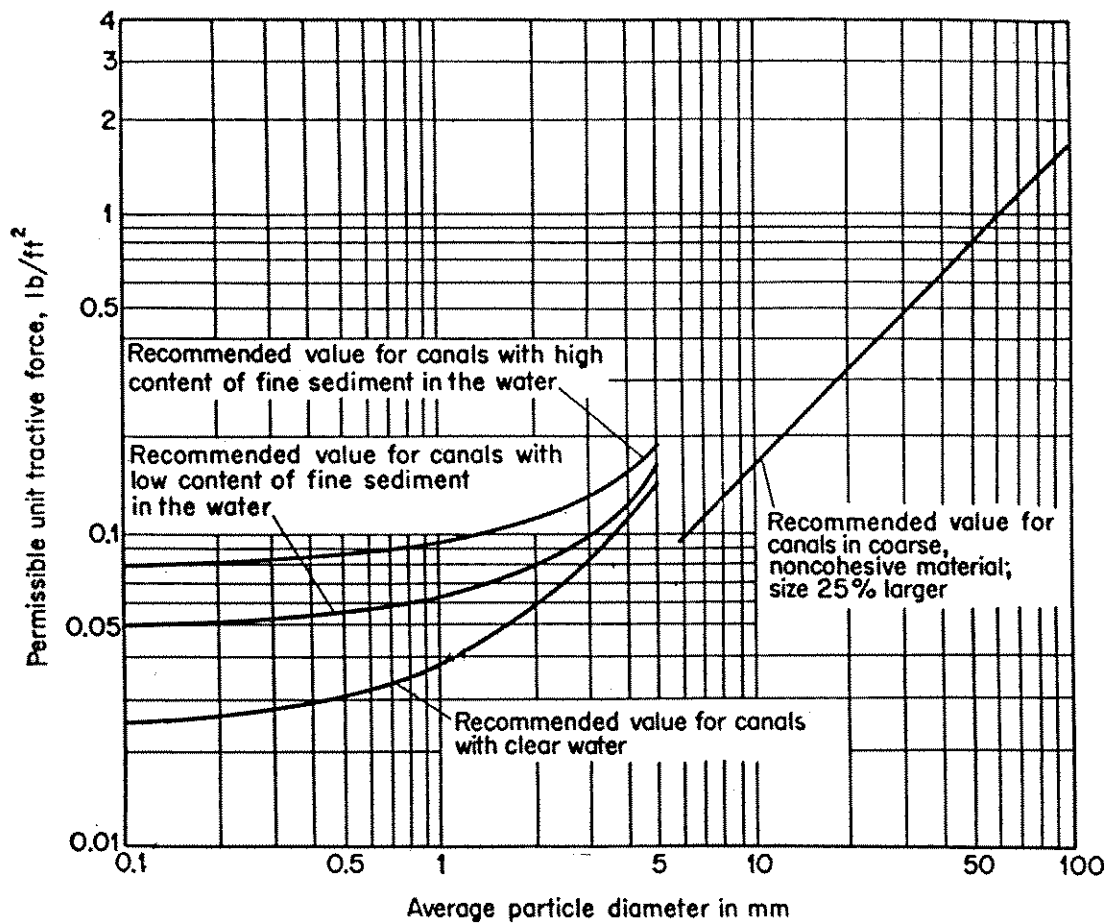
Time Day	River Stage (ft)	Garage Stage (ft)	Comments	Weir Elevation (ft)	Weir Head (ft)	Discharge from Garage $Q = (3.15) L H^{1.5}$ (ft ³)	Volume Removed based on Discharge (ft ³)	New Depth in Garage (ft)	Pipe/ Chamber Minor Losses (ft)	Headloss Due to Backflow Preventor (ft)	Headloss Pipe (ft)	Total Headloss (ft)	Difference in Head (ft)	Flow to River	Tractive Force (lb/ft ²)	Minimum Tractive Force (lb/ft ²)
25.50	505.65	505.65	stop logs closed													
26.00	508.30	508.30	stop logs closed													
26.50	508.95	508.95	stop logs closed													
27.00	509.60	509.60	stop logs closed													
27.50	509.40	509.40	stop logs closed													
28.00	509.20	509.20	stop logs closed													
28.50	508.80	508.80	stop logs closed													
29.00	508.40	508.40	stop logs closed													
29.50	507.90	507.90	stop logs closed													
30.00	507.40	507.40	stop logs closed													
30.50	506.55	506.55	stop logs closed													
31.00	505.70	505.70	stop logs closed													
31.50	504.70	504.70	stop logs closed													
32.00	503.70	503.70	stop logs closed													
32.50	502.45	502.45	stop logs closed													
33.00	501.20	501.20	stop logs closed													
33.50	499.55	499.55	stop logs closed													
34.00	497.90	497.90	stop logs closed													
34.50	495.70	495.70	stop logs closed													
35.00	493.50	494.00	stop logs closed													
35.50	490.65	492.60	stop logs closed													
36.00	487.80	492.60	stop logs closed													
36.50	484.30	492.60	stop logs closed													
37.00	480.80	492.60	open	491.80	0.80	11.27	486855	492.37	1.40	0.25	8.4	10.02	11.80	FLows	0.50	0.50
37.50	476.80	492.37	open	491.00	1.37	25.19	1088130	491.85	2.26	0.50	13.5	16.30	15.57	FLows	0.72	0.50
38.00	472.80	491.85	open	490.00	1.85	39.57	1709339	491.03	2.91	0.75	17.5	21.13	19.05	FLows	0.87	0.50
38.50	468.55	491.03	open	489.00	2.03	45.62	1970709	490.09	3.14	1.00	18.8	22.99	22.48	FLows	0.93	0.50
39.00	464.30	490.09	open	489.00	1.09	17.95	775366	489.72	1.84	0.40	11.0	13.28	25.70	FLows	0.62	0.50
39.50	460.85	489.72	open	489.00	0.72	9.64	416389	489.52	1.27	0.20	7.6	9.07	28.87	FLows	0.47	0.50
40.00	457.40	489.52	free outlet	489.00	0.52	5.94	256616	489.40	1.00	0.08	6.0	7.04	32.12	FLows	0.37	0.50
40.50	456.85	489.40	free outlet	489.00	0.40	3.98	171800	489.32	0.77	0.00	4.6	5.36	32.55	FLows	0.31	0.50
41.00	460.10	489.32	free outlet	489.00	0.32	2.62	121705	489.26	0.62	0.00	3.7	4.37	29.22	FLows	0.27	0.50
41.50	462.35	489.26	open	489.00	0.26	2.08	89870	489.22	0.51	0.00	3.0	3.56	26.91	FLows	0.23	0.50
42.00	464.60	489.22	open	489.00	0.22	1.59	68517	489.18	0.52	0.00	3.1	3.64	24.62	FLows	0.19	0.50

The results of both situations indicate that no stop logs should be removed until the river has reached an elevation of approximately 480.80 feet. At this stage, the upstream head will push the water through the pipe with the tractive force necessary to carry the sediment. In addition, at this elevation the river does not inhibit flow due to backwater conditions. The garage would be empty within approximately 6 days with flood protection to 493 and 5 days with flood protection to 491 after the flood control system is opened.

A tractive force is the force acting on the particles composing the perimeter of the pipe and is the result of the flow of water past these particles. Curves showing the tractive force that will cause erosion, and therefore minimize sedimentation are presented in Figure 6. The tractive force should be maintained above approximately 0.5 lbs/ft² to keep the sediment in suspension. In addition, at this elevation the river does not inhibit flow due to backwater conditions.

FIGURE 6

**Recommended permissible unit tractive forces
For canals in noncohesive material**



Reference: Ven Te Chow, "Open Channel Hydraulics", McGraw-Hill Book Company, Inc., 1959, pg. 173.

4.0 Cost Analysis

The cost differential between the two alternatives is presented in Appendix E. The drainage and sediment calculations determined that one culvert or one stop log system could drain the entire garage. The cost estimate indicates that the approximate construction costs for one 9x12 culvert on the west side and associated trenching to Mehring Way would be approximately \$400,000. The costs for the construction of one stop log system and drainpipe to the river would be approximately \$600,000. These costs were based on current prices for construction on the City of Cincinnati Fort Washington Way project and vendor data.

5.0 Alternatives Analysis

There are numerous advantages and disadvantages for each of the alternatives, as outlined in Table 4 below.

TABLE 4
Alternatives Analysis
Alternative 1 - Culverts

Advantages	Disadvantages
Culverts are large enough to drive a truck through and push sediment out of the garages.	Significantly impacts the park in a flooding scenario.
Provides access during construction.	Ventilation.
Can pass a large volume of water/sediment.	Lighting.
Initial capital cost.	Need a floodgate to be consistent with the remainder of garage that will be flood-protected to el. 493 or el. 491.
Garage floodwaters would drain approximately 4 days faster than Alternative 2.	Preclude public access into the culverts.
	Penetration needed to architecturally treated park wall.
	Structurally engineered wall needed above culvert flood gate
	Permanent drainage trench required in park.
	Post flooding operations including removal of trench soil and floodgate.
	Park reconstruction costs post flooding.

Alternative 2 – Stop Log System

Advantages	Disadvantages
No impacts to the park during flooding.	Initial capital cost.
Backflow preventor prevents garage flooding when river elevation is below the flood-protected elevation.	It could take several days more than the culvert to drain the garages.
Can pass a large volume of water/sediment.	
Can convey re-suspended garage sediment to the Ohio River.	
Does not allow sedimentation in the piping system.	
No additional cleanup costs following a flood.	

6.0 Conclusions and Recommendations

The goal of the drainage system is to provide a system that has the hydraulic capacity to drain the floodwater, will not allow suspended sediments to settle out and cause extensive sediment problems and allow the least damage to the park.

Based on the sedimentation calculations and hydraulic analyses discussed above, both Alternative 1 and 2 will drain the garages. However, there are advantages and disadvantages of both alternatives to be considered. Capital costs, maintenance costs, and park repair costs after a flood need to be considered. Other issues include the safety of the workers and the time required to drain the garages to facilitate the continuation of proposed operations.

Alternative 1 provides a means to drain and remove sediment from the garages as the flood recedes. However, this alternative causes damage to the park. The safety of the workers working in a 150-foot long culvert without lighting or ventilation is also a concern.

Alternative 2 provides a means to drain the garages and remove sediment from the garages without damage to the park. However, the capital costs associated with this alternative are larger than Alternative 1 and the time required for draining the garages is longer than Alternative 1.

Based on discussion with City and County representatives and review of this study, one culvert (Culvert B), a modification to Alternative 1, will be constructed at this time. This recommendation was reached based on the following reasons:

1. The floodwaters have the ability to enter the eastern garage of the Paul Brown stadium and return to the river,

2. Cost savings by constructing only one culvert,
3. Culvert A could not be placed in a favorable location,
4. Minimal damage to the park would occur from the construction and operation of Culvert B, and
5. Lower costs would be needed to repair the park for the Culvert B alternative.

The designers will proceed based on this decision.

**EXHIBIT B –
DEPICTION OF FLOODABLE FEATURES**

Floodable Parking Garage Facility



Floodable Parking Garage Facility



Floodable Parking Garage Elements



Floodable Parking Garage Design Elements



Floodable Parking Garage Design Elements



