Master Drainage Plan
Phase I

September, 1993

Prepared By:

CLAUNCH & MILLER,INC.
Engineering Consultants

ALBERT H. HALFF ASSOCIATES, INC.
ENGINEERS • SCIENTISTS • SURVEYORS

3701 Kirby Drive, Suite 860 ○ Houston, Texas 77098 ○ (713) 524-7113

CLAUNCH & MILLER, INC.
Engineering Consultants

November 1993

City of Friendswood
109 Willowick
Friendswood, Texas 77546

Attn: Mr. James E. Thompson, P.E.
City Engineer

Re: Master Drainage Plan, Phase I

Dear Mr. Thompson:

Transmitted herewith is a report entitled Master Drainage Plan, Phase I authorized by the City of Friendswood. Preparation of this report included the mapping of the City's drainage system, the determination of peak flow rates from all drainage areas in the City and the analysis of twenty designated problem outfalls. With the information provided within this study and the associated mapping, the City has a tool to assist it's planning efforts and to proceed to a Phase II analysis of the entire system.

The draft report was submitted for review on September 8, 1993. Staff review and comments were received and incorporated into this final report.

It has been a privilege for our firms to perform this study. We especially appreciate the cooperation of you and your staff, who have assisted in the development of this study.

Respectfully submitted,

CLAUNCH & MILLER, INC.
Houston, Texas

Christopher E. Claunch, P.E.
President

ALBERT H. HALFF ASSOCIATES, INC.
Dallas, Texas

Walter E. Skipwith, P.E.
Vice President

3701 Kirby Drive, Suite 860 • Houston, Texas 77098 • (713) 524-7113

MASTER DRAINAGE PLAN
PHASE I

FOR

THE CITY OF
FRIENDSWOOD, TEXAS

Prepared By:

Claunch & Miller, Inc.
Engineering Consultants
3701 Kirby Drive, Suite 860
Houston, Texas 77098

and

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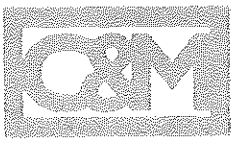
Engineers Scientists Surveyors
8616 Northwest Plaza Drive
Dallas, Texas 75225

November 1993



for

THE CITY OF FRIENDSWOOD

Evelyn Newman
Mayor

Kitten Hajecate

Mel Measeles

Tom Manison

Ed Stuart

Harold Raley

Janis Lowe

COUNCILPERSONS

Ronald E. Cox
City Manager

Melvin Meinecke
Public Works Director

James E. Thompson, P.E.
City Engineer

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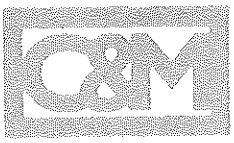


ACKNOWLEDGEMENTS

The study team of Claunch & Miller, Inc. and Albert H. Halff Associates, Inc. wishes to acknowledge the valuable assistance of the various organizations and individuals who have assisted in the preparation of this report. We wish to express our gratitude to all those listed below who have contributed their time and effort to this study.

Mr. James E. Thompson, P.E., City Engineer, has provided invaluable assistance and advice. Mr. James Bishop and Mr. Robert Knape have provided plans, sketches and field surveys of the existing drainage system.

The Employees of Claunch & Miller who have worked most closely with the project include: Mr. Christopher E. Claunch, Mr. John D. Rudloff and Mr. Ron D. Gilbert. We also express our thanks to Mr. Walter E. Skipwith and Mr. Richard A. Westsmith of Halff Associates for their hydrologic and hydraulic analysis of the City's drainage system and problem outfalls. Claunch & Miller, Inc. and Albert H. Halff Associates, Inc. deeply appreciates the dedicated efforts of all groups and individuals who have helped in the performance of this study.

EXECUTIVE SUMMARY

On September 21, 1992 the City of Friendswood contracted with Claunch & Miller, Inc. (CMI) to perform Phase One of the Master Drainage Plan. The purposes of this study was to create a planning tool to be used by the City and developers to provide guidance for provision of adequate drainage for the continued growth of the city. This was to be accomplished by providing the City with a city-wide drainage map with the delineated drainage areas, determining run off flows from each drainage area and analyzing existing capacities of twenty designated outfalls.

Mapping the existing drainage system was a cooperative process between City of Friendswood staff and CMI. As the City acquired information on the existing drainage system, they provided it to CMI in the form of plans, sketches and field surveys. This information was compiled by CMI into a master drainage map.

It must be pointed out that this comprehensive mapping has been prepared, reviewed and refined with the City to a point where this study could proceed and the City would have a useful working tool. There may be inconsistencies in the City provided base map and storm data. This mapping effort was not intended to search out and rectify all inconsistencies but to provide a map for "working" purposes that the City of Friendswood can utilize and improve upon as the system evolves and inconsistencies are discovered.

Upon completion of the master drainage map the project moved into the analysis phase. The analysis was performed by Albert H. Halff Associates, Inc.

The purpose of the drainage area analysis was to provide the City with the magnitude of the flows that could be expected from each drainage area for given frequency storms. This analysis was based on existing land use. These flows are to be used as a planning tool to provide guidance for the provision of adequate drainage as the City continues to grow.

The third phase of the study was an analysis of twenty designated problem outfalls. It was determined that many of the problems stem from undersized storm sewer systems and/or a lack of drainage ditch capacity. This analysis did not examine any downstream impact from increased flows to the creeks.

For each problem site, a proposed solution was determined. It is important to understand that the solutions presented in this planning study are only conceptual. The stated pipe sizes may vary based upon eventual detailed engineering and topographic surveying which will be performed during project design. The proposed solutions presented in this study provide the City a possible solution, magnitude of cost and a basis for planning future engineering and construction. It is expected that after initiation of actual design engineering, acquisition of detailed survey data and analysis of alternatives, site specific parameters and city requirements, a more refined and cost effective solution can be obtained.

PROJECT DESCRIPTION

This study has been prepared to meet the City of Friendswood's desires to develop a master drainage plan and drainage mapping documents for use as a planning tool to be used by the City and developers to provide guidance for provision of adequate drainage for the continued growth of the City. Due to the magnitude of such a master plan study, the City of Friendswood intends to accomplish the development of such a master plan study in two phases. Phase One includes all the system inventory, mapping and existing condition information as well as an analysis of 20 critical areas in the City's system. Phase Two includes the analysis of the remaining system and its' hydraulic characteristics and identification of alternative design and recommended improvements.

Claunch & Miller, Inc. (CMI) was contracted by the City of Friendswood on September 21, 1992 to perform Phase One of the master drainage plan and study.

The Scope of Services for the Phase One services is as follows:

1. Acquire subdivision, roadway and drainage plans from City records to include an existing conditions mapping. Review prior studies, master plans and reports as provided by the City for further mapping data. Coordinate with Clear Creek Drainage District to determine any projects that they have planned or are planned on the major outfalls that will need to be incorporated.

2. Digitize all information accumulated using Intergraph Microstation or compatible software to provide the City with both a hard copy and computer disk copy of the mapping produced. the City will provide the base files of the City map with roadway rights-of-way and parcel lines.

3. Utilize the existing City of Friendswood computer base map for which shows city limits, roadways, rights-of-way and property lines for base mapping.

4. The City of Friendswood shall gather and provide to CMI storm drainage layout maps and storm drainage facilities construction plans. Input the assembled information and data provided into the computer map.

5. Meet with City of Friendswood staff members who are familiar with the City's drainage system to verify pertinent information.

6. The City of Friendswood shall supply necessary field survey work to verify drainage system pipe and ditch sizes, locations and other pertinent data and provide sketches of such data to augment existing mapping data.

7. It is understood that there may be inconsistencies within the City of Friendswood's existing base map. this mapping effort is not intended to search out and rectify such inconsistencies but to provide a base map for "working" purposes which the City of Friendswood can utilize and improve as the system evolves and inconsistencies are discovered.

8. The mapping shall indicate general location of storm sewer piping with sizes and ditches.

9. From existing contour maps, existing aerial photographs, USGS topographic maps, subdivision plans, City supplied field survey work and examination of the system layout determine the approximate location of drainage area divides and include them in the computer mapping.

10. Plot maps at a scale suitable for presentation of data. Each individual map showing a portion of the City will be on 24" x 36" sheets and have suitable matchlines for connecting the maps. It is estimated the maps will be at a scale of 1" = 400'.

11. Provide an overall map at a scale of 1" = 1000' showing the drainage area divides and matchlines for the 1"=400' drawings.

12. Determine the appropriate run-off coefficients, time of concentration, etc. to calculate the existing peak flow rates from the various drainage areas based on current developed property.

13. Model existing conditions to determine peak flow rates from subareas, using the rational formula.

14. In coordination with the City of Friendswood, identify no more than twenty drainage basins or problem areas and analyze the hydraulic characteristics of the existing drainage basin outfall or the problem within the basin to determine existing conveyances and storage capabilities. This analysis may not necessarily include full system analysis of each drainage basin.

15. CMI will utilize existing reports and studies for base information pertaining to stream data and other basic data.

16. Prepare a report for the City of Friendswood indicating the results of the analysis and providing recommendations for a subsequent Phase Two study to further refine the study for the entire City.

Phase One of the master drainage plan was accomplished in three phases. The first was the comprehensive mapping of the City's drainage system to include all drainage area divides. The second phase was the determination of peak flow rates from all drainage areas. The third was the analysis of the hydraulic characteristics of twenty problem outfalls which are prone to flooding.

I. COMPREHENSIVE MAPPING

The main focus of this phase of the project was to provide the City of Friendswood a comprehensive map of its' storm drainage system that could be used as a planning tool and provide easy access to information relating to drainage throughout the City. This comprehensive mapping is provided to the City of Friendswood under separate cover and in three forms.

1. On a computer disk which uses the City's cfmap.dgn DGN file as a base map.

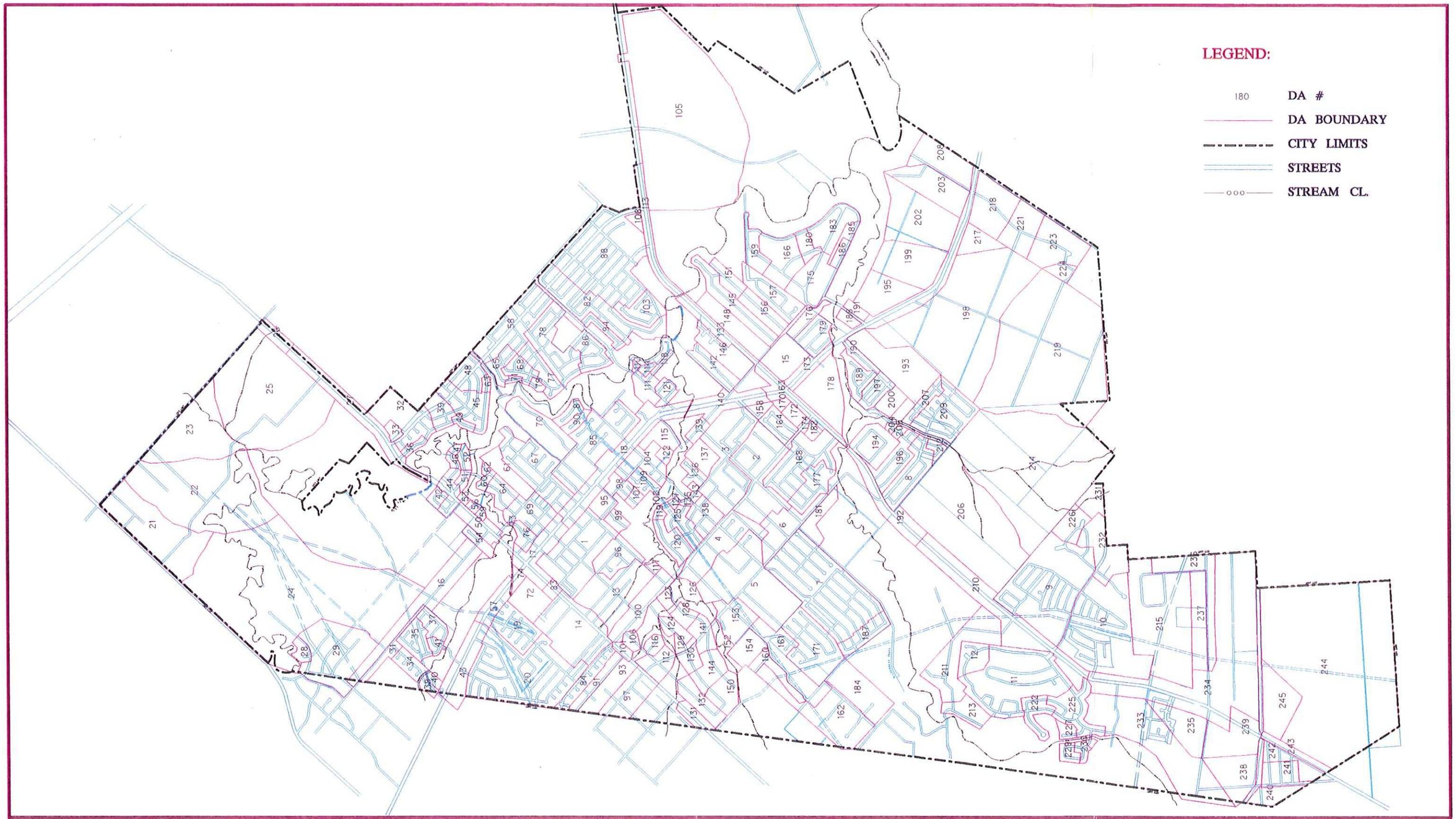
2. On eleven individual maps each showing a portion of the city plotted on 24" x 36" sheets at a scale of 1" = 400' with suitable matchlines for connecting the maps.

3. On an overall map at a scale of 1" = 1000' showing the drainage area divides, drainage area numbers and matchlines for the 1" =400' drawings.

The initial mapping of the city's entire storm drainage system was a cooperative process between City of Friendswood staff and Claunch & Miller, Inc (CMI). The City staff provided CMI with a microstation file, which contained all the city street right-of-ways and lot lines, to be used as the base map. They also provided plans, sketches and field surveys of the existing drainage system. As the City acquired the information of the existing drainage system for a particular area it was delivered to CMI. CMI compiled all the information as it was received and prepared the master drainage map of the city from the plans and sketches. During this process several sets of prints were provided to the City so the staff could view the progress and provide any necessary comments or corrections. The drainage system map was finalized in June 1993. After the Drainage system map was completed, CMI placed the location of the drainage area divides using existing contour maps, aerial photographs, USGS topographical maps, subdivision plans, city supplied field survey work, first hand knowledge of the area and discussion with City staff. After all the drainage areas were mapped, an overall map was prepared for the City to review. After review and refinement based on input from City staff the drainage area boundaries were finalized.

It must be pointed out that this comprehensive mapping has been reviewed and refined with the City to a point where this study could proceed and the City had a useful working tool. There may be inconsistencies in the City provided base map and storm system data. This mapping effort was not intended to search out and rectify all inconsistencies but to provide a base map for "working" purposes that the City of Friendswood can utilize and improve upon as the system evolves and inconsistencies are discovered. This was the reason for preparing the mapping in a CADD format compatible with the City's system.

Completion of the comprehensive mapping and drainage area determination allowed the project to move into the drainage area analysis phase.



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SCALE IN FEET

CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN
DRAINAGE AREAS

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II. DRAINAGE AREA ANALYSIS

The purpose of this analysis was to determine the magnitude of run off flows that can be expected from the various drainage areas. The analysis is based on existing land use. The intent of this analysis is to give the City a planning tool to provide guidance for the provision of adequate drainage as the City continues to grow.

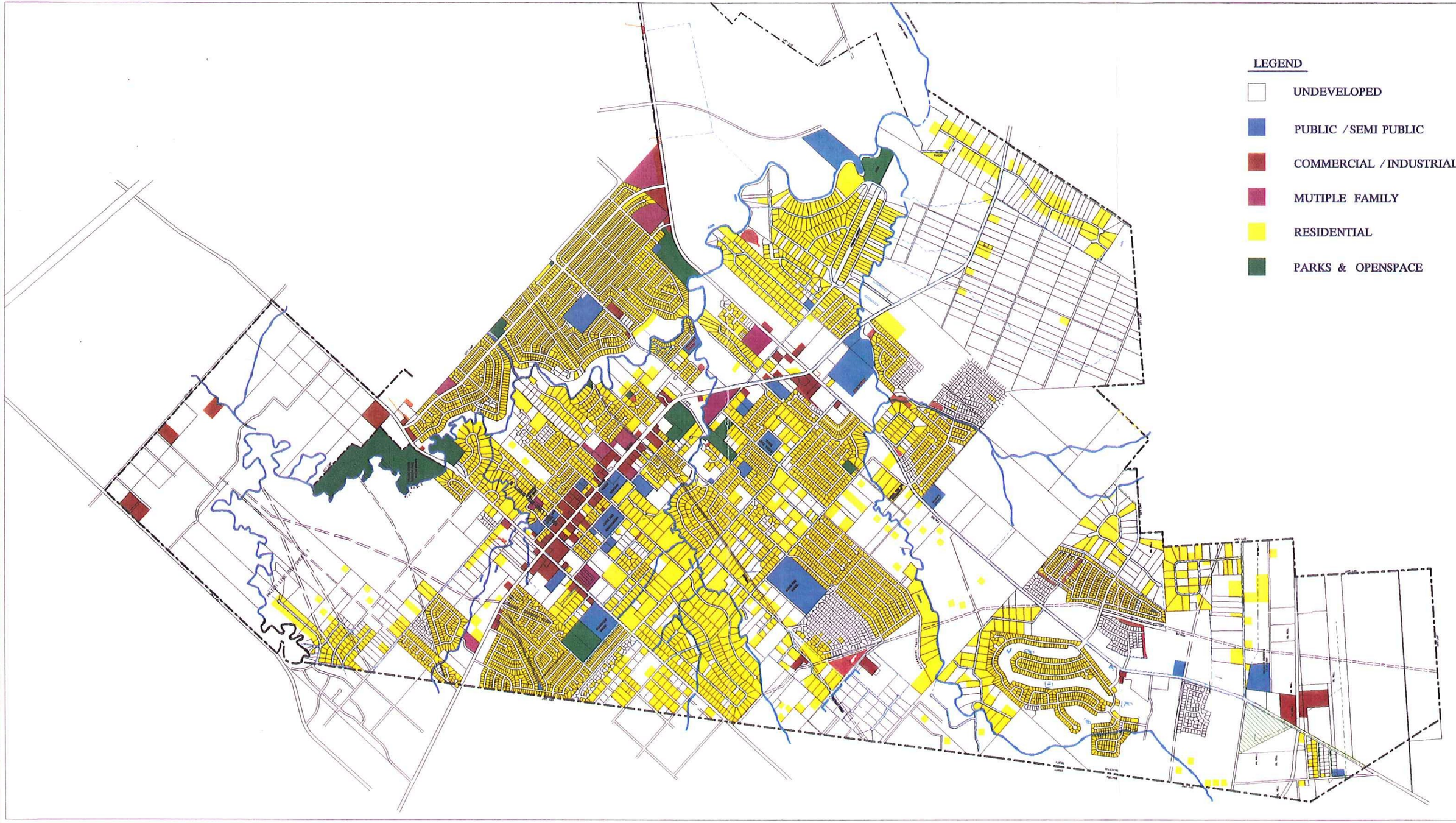
There are 226 defined drainage areas within the City of Friendswood's city limits. They were analyzed based on existing land usage (see Figure 2-1 & 2-2) using the rational method for a 5 year, 25 year and 100 year storm. This analysis was performed by Albert H. Halff Associates, Inc. and the results from this analysis are presented in Table 2-1. The area numbers in the table correspond to the areas defined in Figure 2-1. This flow analysis produced index discharges for each area and storm event that could be used as a tool for future planning. A more detailed analysis is needed to accurately reflect the individual and complex characteristics of each drainage basin.

The rational method is the most common means for determining runoff on small to medium size drainage basins. It expresses runoff as a fraction of the rainfall (Q=CIA). "Q" is the runoff amount expressed in cubic feet per second (cfs). The "C" factor, called the runoff coefficient, is the percentage of rain that appears as direct runoff. The "I" value is the average rainfall intensity in inches per hour. "A" is the area of the drainage basin in acres.

The runoff coefficients for each type of land use were obtained from the "Dickinson Bayou Watershed Regional Drainage Plan" Drainage Criteria Manual (shown on Table 2-2). An exception to the Drainage Criteria Manual's recommended "C" values was that developed areas with detention were considered to have undeveloped runoff flows, hence were given a runoff coefficient of .30. The coefficient for each drainage basin was derived from a weighted average of the "C" values within the drainage area based on its percentage of the area in the basin. This weighted averaging was performed by the GIS program Arc Info.

The next step in this analysis was to develop the time of concentration (t_c) for each area. The time of concentration is defined as the time taken for a drop of water falling on the most remote point of the drainage basin to reach the outlet. This is the time after the start of the rainfall when all portions of the basin are contributing simultaneously to flow at the outfall. The t_c was derived using an empirical method from the Harris County Flood Control manual "Hydrolgy for Harris Country". This method relates the average length to the centroid of the drainage area (Lca) to the t_c . The "Lca" is determined by the area of the drainage basin (see Fig. 2-3). The "Lca" then can be related to the t_c (see Fig 2-4). For the analysis fifteen minutes was established as the minimum t_c to be used. The time of concentration was needed to determine the rainfall intensities for each basin.

The rainfall intensities were obtained from TP-40 rainfall frequency curves for Galveston County. The values for the 5 year and 100 year storm are listed in Table 2-3. The 5 year storm is the City of Friendswood's design criteria for all storm sewers. The 25 year and 100 year storms were easily calculated as part of the analysis and are provided for the benefit of the City of Friendswood.



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CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

CITY OF FRIENDSWOOD
LANDUSE

CITY OF FRIENDSWOOD
HYDRAULIC COMPUTATIONS FOR INDEX DISCHARGES

AREA #	AREA (sf)	AREA (Ac)	C	Lca (mi)	S (ft/mi)	Lca/ sqrt(s)	Tc (hr)	Tc (dqn (hr)	I 5 (in/hr)	I 25 (in/hr)	I 100 (in/hr)	Q 5 (cfs)	Q 25 (cfs)	Q 100 (cfs)
1	3881414.4	89.1	0.46	0.34	1	0.34	0.30	0.30	6.07	7.78	9.63	248	317	392
2	3639786.1	83.6	0.37	0.33	1	0.33	0.29	0.29	6.20	7.94	9.83	191	245	303
3	3915796.3	89.9	0.39	0.35	1	0.35	0.31	0.31	6.06	7.75	9.60	214	275	340
4	2571467.8	59.0	0.34	0.27	1	0.27	0.24	0.25	6.80	8.68	10.80	137	174	217
5	5473731.2	125.7	0.44	0.42	1	0.42	0.37	0.37	5.46	7.02	8.64	299	384	473
6	1768090.4	40.6	0.34	0.22	1	0.22	0.19	0.25	6.80	8.68	10.80	94	120	149
7	6925862.6	159.0	0.38	0.47	1	0.47	0.43	0.43	5.11	6.58	8.07	307	395	485
8	1738333.3	39.9	0.30	0.22	1	0.22	0.19	0.25	6.80	8.68	10.80	81	104	129
9	6898874.1	158.4	0.30	0.47	1	0.47	0.43	0.43	5.12	6.59	8.08	243	313	384
10	6942848.3	159.4	0.31	0.47	1	0.47	0.43	0.43	5.11	6.58	8.07	249	320	392
11	5702397.5	130.9	0.40	0.43	1	0.43	0.38	0.38	5.40	6.94	8.54	286	367	452
12	950112.14	21.8	0.40	0.16	1	0.16	0.13	0.25	6.80	8.68	10.80	59	75	94
13	3037828	69.7	0.34	0.30	1	0.30	0.26	0.26	6.59	8.42	10.46	157	201	249
14	3748921.3	86.1	0.42	0.34	1	0.34	0.30	0.30	6.14	7.86	9.74	223	286	354
15	1441775.6	33.1	0.33	0.20	1	0.20	0.17	0.25	6.80	8.68	10.80	73	93	116
16	2906424.8	66.7	0.31	0.29	1	0.29	0.26	0.26	6.69	8.54	10.62	140	179	223
17	1856212.7	42.6	0.61	0.23	1	0.23	0.20	0.25	6.80	8.68	10.80	178	227	283
18	3366985	77.3	0.44	0.32	1	0.32	0.28	0.28	6.36	8.14	10.09	218	278	345
19	1584540.8	36.4	0.43	0.21	1	0.21	0.18	0.25	6.80	8.68	10.80	108	137	171
20	6797330.5	156.0	0.40	0.47	1	0.47	0.42	0.42	5.14	6.61	8.11	317	408	500
21	5048015.2	115.9	0.35	0.40	1	0.40	0.35	0.35	5.60	7.18	8.85	225	289	356
22	9374289.5	215.2	0.30	0.56	1	0.56	0.51	0.51	4.70	6.06	7.41	304	391	478
23	4374646.1	100.4	0.35	0.37	1	0.37	0.33	0.33	5.85	7.49	9.26	208	267	330
24	20963145	481.2	0.30	0.87	1	0.87	0.81	0.81	3.47	4.34	5.33	505	632	776
25	10581612	242.9	0.30	0.60	1	0.60	0.55	0.55	4.48	5.75	7.03	326	419	512

CITY OF FRIENDSWOOD
HYDRAULIC COMPUTATIONS FOR INDEX DISCHARGES

AREA #	AREA (sf)	AREA (Ac)	C	Lca (mi)	S (ft/mi)	Lca/ sqrt(s)	Tc (hr)	Tc (dqn (hr)	I 5 (in/hr)	I 25 (in/hr)	I 100 (in/hr)	Q 5 (cfs)	Q 25 (cfs)	Q 100 (cfs)
26	567317.93	13.0	0.30	0.12	1	0.12	0.10	0.25	6.80	8.68	10.80	27	34	42
27	2517596.6	57.8	0.30	0.27	1	0.27	0.24	0.25	6.80	8.68	10.80	119	152	189
28	361666.45	8.3	0.32	0.09	1	0.09	0.08	0.25	6.80	8.68	10.80	18	23	29
29	4148720.5	95.2	0.33	0.36	1	0.36	0.32	0.32	5.95	7.62	9.42	184	236	292
31	599388.66	13.8	0.36	0.12	1	0.12	0.10	0.25	6.80	8.68	10.80	34	43	53
32	2234244.8	51.3	0.37	0.25	1	0.25	0.22	0.25	6.80	8.68	10.80	129	164	204
33	265357.32	6.1	0.31	0.08	1	0.08	0.06	0.25	6.80	8.68	10.80	13	16	20
34	655638.67	15.1	0.44	0.13	1	0.13	0.11	0.25	6.80	8.68	10.80	45	57	72
35	972563.93	22.3	0.44	0.16	1	0.16	0.14	0.25	6.80	8.68	10.80	67	85	106
36	257022.38	5.9	0.44	0.08	1	0.08	0.06	0.25	6.80	8.68	10.80	18	23	28
37	665104.55	15.3	0.47	0.13	1	0.13	0.11	0.25	6.80	8.68	10.80	48	62	77
38	244670.11	5.6	0.38	0.08	1	0.08	0.06	0.25	6.80	8.68	10.80	14	18	23
39	786820.88	18.1	0.52	0.14	1	0.14	0.12	0.25	6.80	8.68	10.80	64	81	101
40	170953.2	3.9	0.41	0.06	1	0.06	0.05	0.25	6.80	8.68	10.80	11	14	17
41	243882	5.6	0.45	0.08	1	0.08	0.06	0.25	6.80	8.68	10.80	17	22	27
42	284044.91	6.5	0.45	0.08	1	0.08	0.07	0.25	6.80	8.68	10.80	20	26	32
43	1919225.7	44.1	0.36	0.23	1	0.23	0.20	0.25	6.80	8.68	10.80	107	137	170
44	817302.06	18.8	0.40	0.15	1	0.15	0.12	0.25	6.80	8.68	10.80	51	65	81
45	1647513.7	37.8	0.45	0.22	1	0.22	0.18	0.25	6.80	8.68	10.80	117	149	186
46	178422.83	4.1	0.43	0.06	1	0.06	0.05	0.25	6.80	8.68	10.80	12	15	19
47	103616.54	2.4	0.39	0.05	1	0.05	0.04	0.25	6.80	8.68	10.80	6	8	10
48	999641.36	22.9	0.47	0.16	1	0.16	0.14	0.25	6.80	8.68	10.80	74	94	117
49	225736.57	5.2	0.42	0.07	1	0.07	0.06	0.25	6.80	8.68	10.80	15	19	24
50	877474.95	20.1	0.33	0.15	1	0.15	0.13	0.25	6.80	8.68	10.80	45	58	72
51	234915.4	5.4	0.42	0.07	1	0.07	0.06	0.25	6.80	8.68	10.80	15	20	24

TABLE 2-1

CITY OF FRIENDSWOOD
HYDRAULIC COMPUTATIONS FOR INDEX DISCHARGES

AREA #	AREA (sf)	AREA (Ac)	C	Lca (mi)	S (ft/mi)	Lca/ sqrt(s)	Tc (hr)	Tc (dqn (hr)	I 5 (in/hr)	I 25 (in/hr)	I 100 (in/hr)	Q 5 (cfs)	Q 25 (cfs)	Q 100 (cfs)
52	307992.52	7.1	0.37	0.09	1	0.09	0.07	0.25	6.80	8.68	10.80	18	23	28
53	105859.93	2.4	0.42	0.05	1	0.05	0.04	0.25	6.80	8.68	10.80	7	9	11
54	416016.86	9.6	0.31	0.10	1	0.10	0.08	0.25	6.80	8.68	10.80	20	26	32
56	137199.22	3.1	0.40	0.05	1	0.05	0.04	0.25	6.80	8.68	10.80	9	11	14
57	846212.83	19.4	0.39	0.15	1	0.15	0.13	0.25	6.80	8.68	10.80	51	66	82
58	2798527.6	64.2	0.45	0.29	1	0.29	0.25	0.25	6.78	8.65	10.77	195	249	310
59	109448.02	2.5	0.43	0.05	1	0.05	0.04	0.25	6.80	8.68	10.80	7	9	12
60	214389.94	4.9	0.39	0.07	1	0.07	0.06	0.25	6.80	8.68	10.80	13	17	21
61	1009792.6	23.2	0.32	0.16	1	0.16	0.14	0.25	6.80	8.68	10.80	50	64	80
62	104870.86	2.4	0.43	0.05	1	0.05	0.04	0.25	6.80	8.68	10.80	7	9	11
63	150943.61	3.5	0.44	0.06	1	0.06	0.05	0.25	6.80	8.68	10.80	10	13	17
64	738799.12	17.0	0.39	0.14	1	0.14	0.12	0.25	6.80	8.68	10.80	45	58	72
65	627053.28	14.4	0.45	0.13	1	0.13	0.11	0.25	6.80	8.68	10.80	44	56	70
67	3094963.8	71.1	0.42	0.30	1	0.30	0.27	0.27	6.55	8.37	10.39	194	247	307
68	642843.31	14.8	0.47	0.13	1	0.13	0.11	0.25	6.80	8.68	10.80	47	60	74
69	1479234.5	34.0	0.49	0.20	1	0.20	0.17	0.25	6.80	8.68	10.80	114	145	181
70	2119902.2	48.7	0.33	0.25	1	0.25	0.21	0.25	6.80	8.68	10.80	109	139	173
71	108882.91	2.5	0.42	0.05	1	0.05	0.04	0.25	6.80	8.68	10.80	7	9	11
72	1203691	27.6	0.41	0.18	1	0.18	0.15	0.25	6.80	8.68	10.80	78	99	124
73	22279.221	0.5	0.52	0.02	1	0.02	0.02	0.25	6.80	8.68	10.80	2	2	3
74	237232.49	5.4	0.53	0.07	1	0.07	0.06	0.25	6.80	8.68	10.80	20	25	31
76	491793.92	11.3	0.52	0.11	1	0.11	0.09	0.25	6.80	8.68	10.80	40	51	63
77	1019287.6	23.4	0.44	0.17	1	0.17	0.14	0.25	6.80	8.68	10.80	70	90	111
78	2342686.3	53.8	0.46	0.26	1	0.26	0.23	0.25	6.80	8.68	10.80	167	213	265
79	162493.45	3.7	0.39	0.06	1	0.06	0.05	0.25	6.80	8.68	10.80	10	13	16

TABLE 2-1

CITY OF FRIENDSWOOD
HYDRAULIC COMPUTATIONS FOR INDEX DISCHARGES

AREA #	AREA (sf)	AREA (Ac)	C	Lca (mi)	S (ft/mi)	Lca/ sqrt(s)	Tc (hr)	Tc (dgn) (hr)	I 5 (in/hr)	I 25 (in/hr)	I 100 (in/hr)	Q 5 (cfs)	Q 25 (cfs)	Q 100 (cfs)
82	3223830.2	74.0	0.46	0.31	1	0.31	0.27	0.27	6.46	8.25	10.25	220	282	350
83	259281.02	6.0	0.50	0.08	1	0.08	0.06	0.25	6.80	8.68	10.80	20	26	32
84	1041437.1	23.9	0.33	0.17	1	0.17	0.14	0.25	6.80	8.68	10.80	54	68	85
85	3834809.5	88.0	0.43	0.34	1	0.34	0.30	0.30	6.10	7.81	9.66	230	295	365
86	1792418.3	41.1	0.40	0.23	1	0.23	0.19	0.25	6.80	8.68	10.80	112	143	178
87	422499.07	9.7	0.40	0.10	1	0.10	0.08	0.25	6.80	8.68	10.80	26	34	42
88	6747521.9	154.9	0.50	0.47	1	0.47	0.42	0.42	5.15	6.63	8.13	399	513	629
90	351297.8	8.1	0.42	0.09	1	0.09	0.07	0.25	6.80	8.68	10.80	23	29	37
91	734695.07	16.9	0.33	0.14	1	0.14	0.12	0.25	6.80	8.68	10.80	38	48	60
93	2438296.5	56.0	0.33	0.27	1	0.27	0.23	0.25	6.80	8.68	10.80	127	163	202
94	486210.37	11.2	0.46	0.11	1	0.11	0.09	0.25	6.80	8.68	10.80	35	45	56
95	545930.24	12.5	0.44	0.12	1	0.12	0.10	0.25	6.80	8.68	10.80	38	48	60
96	1326829.1	30.5	0.32	0.19	1	0.19	0.16	0.25	6.80	8.68	10.80	67	85	106
97	1714338.5	39.4	0.33	0.22	1	0.22	0.19	0.25	6.80	8.68	10.80	87	112	139
98	527621.35	12.1	0.52	0.12	1	0.12	0.10	0.25	6.80	8.68	10.80	43	55	68
99	383634.05	8.8	0.36	0.10	1	0.10	0.08	0.25	6.80	8.68	10.80	22	27	34
100	1650978.5	37.9	0.35	0.22	1	0.22	0.18	0.25	6.80	8.68	10.80	89	114	142
101	251041.14	5.8	0.34	0.08	1	0.08	0.06	0.25	6.80	8.68	10.80	13	17	21
102	4501877.6	103.3	0.38	0.37	1	0.37	0.33	0.33	5.80	7.43	9.18	227	291	360
103	1147489.7	26.3	0.45	0.18	1	0.18	0.15	0.25	6.80	8.68	10.80	81	104	129
104	1320039.2	30.3	0.41	0.19	1	0.19	0.16	0.25	6.80	8.68	10.80	85	108	134
105	19922803	457.4	0.30	0.85	1	0.85	0.79	0.79	3.53	4.43	5.43	484	607	746
106	309714.83	7.1	0.35	0.09	1	0.09	0.07	0.25	6.80	8.68	10.80	17	22	27
107	245300.99	5.6	0.41	0.08	1	0.08	0.06	0.25	6.80	8.68	10.80	16	20	25
108	202537.21	4.6	0.78	0.07	1	0.07	0.05	0.25	6.80	8.68	10.80	25	32	39

TABLE 2-1

CITY OF FRIENDSWOOD
HYDRAULIC COMPUTATIONS FOR INDEX DISCHARGES

AREA #	AREA (sf)	AREA (Ac)	C	Lca (mi)	S (ft/mi)	Lca/ sqrt(s)	Tc (hr)	Tc (dqn (hr)	I 5 (in/hr)	I 25 (in/hr)	I 100 (in/hr)	Q 5 (cfs)	Q 25 (cfs)	Q 100 (cfs)
109	561269.7	12.9	0.44	0.12	1	0.12	0.10	0.25	6.80	8.68	10.80	38	49	61
110	70578.429	1.6	0.35	0.04	1	0.04	0.03	0.25	6.80	8.68	10.80	4	5	6
111	723556.19	16.6	0.33	0.14	1	0.14	0.11	0.25	6.80	8.68	10.80	37	48	59
112	870886.85	20.0	0.35	0.15	1	0.15	0.13	0.25	6.80	8.68	10.80	47	60	75
113	1337327.3	30.7	0.41	0.19	1	0.19	0.16	0.25	6.80	8.68	10.80	85	108	135
114	162522.98	3.7	0.47	0.06	1	0.06	0.05	0.25	6.80	8.68	10.80	12	15	19
115	757704.24	17.4	0.31	0.14	1	0.14	0.12	0.25	6.80	8.68	10.80	37	47	59
116	336946.73	7.7	0.36	0.09	1	0.09	0.07	0.25	6.80	8.68	10.80	19	24	30
117	132555.58	3.0	0.34	0.05	1	0.05	0.04	0.25	6.80	8.68	10.80	7	9	11
118	148492.49	3.4	0.44	0.06	1	0.06	0.05	0.25	6.80	8.68	10.80	10	13	16
119	142658.27	3.3	0.42	0.06	1	0.06	0.04	0.25	6.80	8.68	10.80	9	12	15
120	959768.79	22.0	0.40	0.16	1	0.16	0.13	0.25	6.80	8.68	10.80	59	76	94
121	461414.9	10.6	0.32	0.11	1	0.11	0.09	0.25	6.80	8.68	10.80	23	30	37
122	220132.56	5.1	0.34	0.07	1	0.07	0.06	0.25	6.80	8.68	10.80	12	15	19
123	289715.94	6.7	0.35	0.08	1	0.08	0.07	0.25	6.80	8.68	10.80	16	20	25
124	496690.33	11.4	0.35	0.11	1	0.11	0.09	0.25	6.80	8.68	10.80	27	35	43
125	1016837.2	23.3	0.38	0.17	1	0.17	0.14	0.25	6.80	8.68	10.80	61	78	97
126	1138289.5	26.1	0.34	0.18	1	0.18	0.15	0.25	6.80	8.68	10.80	61	78	97
127	107313.32	2.5	0.37	0.05	1	0.05	0.04	0.25	6.80	8.68	10.80	6	8	10
128	461085.12	10.6	0.36	0.11	1	0.11	0.09	0.25	6.80	8.68	10.80	26	33	41
129	255269.45	5.9	0.35	0.08	1	0.08	0.06	0.25	6.80	8.68	10.80	14	18	22
130	517175.4	11.9	0.34	0.11	1	0.11	0.09	0.25	6.80	8.68	10.80	28	35	44
131	559950.22	12.9	0.34	0.12	1	0.12	0.10	0.25	6.80	8.68	10.80	30	38	48
132	1125395.3	25.8	0.34	0.17	1	0.17	0.15	0.25	6.80	8.68	10.80	61	77	96
133	1551589.6	35.6	0.34	0.21	1	0.21	0.18	0.25	6.80	8.68	10.80	82	105	130

CITY OF FRIENDSWOOD
HYDRAULIC COMPUTATIONS FOR INDEX DISCHARGES

AREA #	AREA (sf)	AREA (Ac)	C	Lca (mi)	S (ft/mi)	Lca/ sqrt(s)	Tc (hr)	Tc (dqn) (hr)	I 5 (in/hr)	I 25 (in/hr)	I 100 (in/hr)	Q 5 (cfs)	Q 25 (cfs)	Q 100 (cfs)
135	87938.877	2.0	0.36	0.04	1	0.04	0.03	0.25	6.80	8.68	10.80	5	6	8
136	467289.01	10.7	0.30	0.11	1	0.11	0.09	0.25	6.80	8.68	10.80	22	28	35
137	783726.8	18.0	0.32	0.14	1	0.14	0.12	0.25	6.80	8.68	10.80	39	50	62
138	1013039.9	23.3	0.37	0.16	1	0.16	0.14	0.25	6.80	8.68	10.80	59	75	93
139	359480.66	8.3	0.48	0.09	1	0.09	0.08	0.25	6.80	8.68	10.80	27	34	43
140	1592054.6	36.5	0.43	0.21	1	0.21	0.18	0.25	6.80	8.68	10.80	108	137	171
141	794587	18.2	0.35	0.14	1	0.14	0.12	0.25	6.80	8.68	10.80	43	55	69
142	1047002.3	24.0	0.36	0.17	1	0.17	0.14	0.25	6.80	8.68	10.80	59	76	94
143	201837.21	4.6	0.37	0.07	1	0.07	0.05	0.25	6.80	8.68	10.80	12	15	19
144	1087965.5	25.0	0.36	0.17	1	0.17	0.14	0.25	6.80	8.68	10.80	60	77	96
145	1775699.8	40.8	0.34	0.22	1	0.22	0.19	0.25	6.80	8.68	10.80	95	121	150
146	1411064.3	32.4	0.31	0.20	1	0.20	0.17	0.25	6.80	8.68	10.80	68	87	108
148	1629283.8	37.4	0.31	0.21	1	0.21	0.18	0.25	6.80	8.68	10.80	79	101	126
150	1049427.7	24.1	0.35	0.17	1	0.17	0.14	0.25	6.80	8.68	10.80	58	74	92
151	658995.51	15.1	0.35	0.13	1	0.13	0.11	0.25	6.80	8.68	10.80	36	46	57
152	657941.51	15.1	0.34	0.13	1	0.13	0.11	0.25	6.80	8.68	10.80	35	44	55
153	1364907.9	31.3	0.32	0.19	1	0.19	0.17	0.25	6.80	8.68	10.80	69	88	109
154	937040.87	21.5	0.32	0.16	1	0.16	0.13	0.25	6.80	8.68	10.80	46	59	74
156	1032809.5	23.7	0.37	0.17	1	0.17	0.14	0.25	6.80	8.68	10.80	59	76	94
157	1635269.9	37.5	0.34	0.21	1	0.21	0.18	0.25	6.80	8.68	10.80	88	112	139
158	289500.73	6.6	0.50	0.08	1	0.08	0.07	0.25	6.80	8.68	10.80	23	29	36
159	885498.86	20.3	0.35	0.15	1	0.15	0.13	0.25	6.80	8.68	10.80	48	61	76
160	732494.66	16.8	0.38	0.14	1	0.14	0.12	0.25	6.80	8.68	10.80	43	55	68
161	2227220.9	51.1	0.31	0.25	1	0.25	0.22	0.25	6.80	8.68	10.80	109	139	173
162	3397656.1	78.0	0.31	0.32	1	0.32	0.28	0.28	6.34	8.11	10.06	154	196	244

CITY OF FRIENDSWOOD
HYDRAULIC COMPUTATIONS FOR INDEX DISCHARGES

AREA #	AREA (sf)	AREA (Ac)	C	Lca (mi)	S (ft/mi)	Lca/ sqrt(s)	Tc (hr)	Tc (dan (hr)	I 5 (in/hr)	I 25 (in/hr)	I 100 (in/hr)	Q 5 (cfs)	Q 25 (cfs)	Q 100 (cfs)
163	1408199.5	32.3	0.34	0.20	1	0.20	0.17	0.25	6.80	8.68	10.80	74	95	118
164	865302.42	19.9	0.34	0.15	1	0.15	0.13	0.25	6.80	8.68	10.80	46	59	73
166	1869753.7	42.9	0.35	0.23	1	0.23	0.20	0.25	6.80	8.68	10.80	101	129	161
168	2764950.8	63.5	0.40	0.29	1	0.29	0.25	0.25	6.80	8.68	10.80	172	219	273
170	169951.28	3.9	0.30	0.06	1	0.06	0.05	0.25	6.80	8.68	10.80	8	10	13
171	2948870.9	67.7	0.30	0.30	1	0.30	0.26	0.26	6.66	8.50	10.57	135	173	215
172	363908.34	8.4	0.30	0.09	1	0.09	0.08	0.25	6.80	8.68	10.80	17	22	27
173	765816.6	17.6	0.35	0.14	1	0.14	0.12	0.25	6.80	8.68	10.80	41	53	66
174	221100.01	5.1	0.33	0.07	1	0.07	0.06	0.25	6.80	8.68	10.80	11	15	18
175	1860427.1	42.7	0.34	0.23	1	0.23	0.20	0.25	6.80	8.68	10.80	100	128	159
176	537055.7	12.3	0.31	0.12	1	0.12	0.10	0.25	6.80	8.68	10.80	26	33	41
177	1329339.6	30.5	0.36	0.19	1	0.19	0.16	0.25	6.80	8.68	10.80	76	97	120
178	2410832.7	55.3	0.51	0.27	1	0.27	0.23	0.25	6.80	8.68	10.80	191	243	303
179	1052662.9	24.2	0.38	0.17	1	0.17	0.14	0.25	6.80	8.68	10.80	62	79	98
180	535393.54	12.3	0.35	0.12	1	0.12	0.10	0.25	6.80	8.68	10.80	29	37	46
181	856779.98	19.7	0.32	0.15	1	0.15	0.13	0.25	6.80	8.68	10.80	43	55	69
182	221908.19	5.1	0.34	0.07	1	0.07	0.06	0.25	6.80	8.68	10.80	12	15	19
183	1565252.8	35.9	0.34	0.21	1	0.21	0.18	0.25	6.80	8.68	10.80	82	105	130
184	2165827.7	49.7	0.34	0.25	1	0.25	0.22	0.25	6.80	8.68	10.80	116	148	184
185	343382.35	7.9	0.34	0.09	1	0.09	0.07	0.25	6.80	8.68	10.80	18	23	29
186	321774.82	7.4	0.37	0.09	1	0.09	0.07	0.25	6.80	8.68	10.80	19	24	30
187	974037.92	22.4	0.38	0.16	1	0.16	0.14	0.25	6.80	8.68	10.80	59	75	93
188	262235.52	6.0	0.30	0.08	1	0.08	0.06	0.25	6.80	8.68	10.80	12	16	20
189	889521.32	20.4	0.30	0.15	1	0.15	0.13	0.25	6.80	8.68	10.80	42	53	66
190	441977.08	10.1	0.30	0.10	1	0.10	0.09	0.25	6.80	8.68	10.80	21	26	33

CITY OF FRIENDSWOOD
HYDRAULIC COMPUTATIONS FOR INDEX DISCHARGES

AREA #	AREA (sf)	AREA (Ac)	C	Lca (mi)	S (ft/mi)	Lca/ sqrt(s)	Tc (hr)	Tc (dqn (hr)	I 5 (in/hr)	I 25 (in/hr)	I 100 (in/hr)	Q 5 (cfs)	Q 25 (cfs)	Q 100 (cfs)
191	284898.06	6.5	0.30	0.08	1	0.08	0.07	0.25	6.80	8.68	10.80	13	17	21
192	1642702.4	37.7	0.34	0.21	1	0.21	0.18	0.25	6.80	8.68	10.80	87	111	138
193	3127843.7	71.8	0.31	0.31	1	0.31	0.27	0.27	6.52	8.34	10.35	144	184	228
194	1501361.4	34.5	0.33	0.20	1	0.20	0.17	0.25	6.80	8.68	10.80	78	100	125
195	1885687.6	43.3	0.30	0.23	1	0.23	0.20	0.25	6.80	8.68	10.80	88	113	140
196	1356491.4	31.1	0.30	0.19	1	0.19	0.16	0.25	6.80	8.68	10.80	64	81	101
197	784245.96	18.0	0.30	0.14	1	0.14	0.12	0.25	6.80	8.68	10.80	37	47	58
198	13054170	299.7	0.30	0.67	1	0.67	0.62	0.62	4.12	5.25	6.43	372	474	581
199	2768852.8	63.6	0.30	0.29	1	0.29	0.25	0.25	6.80	8.68	10.80	130	166	206
200	610388.25	14.0	0.30	0.12	1	0.12	0.10	0.25	6.80	8.68	10.80	29	36	45
202	3831997.3	88.0	0.30	0.34	1	0.34	0.30	0.30	6.10	7.81	9.67	161	206	256
203	2289811.9	52.6	0.32	0.26	1	0.26	0.22	0.25	6.80	8.68	10.80	113	144	180
204	97961.251	2.2	0.33	0.05	1	0.05	0.04	0.25	6.80	8.68	10.80	5	6	8
205	145137.1	3.3	0.30	0.06	1	0.06	0.04	0.25	6.80	8.68	10.80	7	9	11
206	9997993.5	229.5	0.31	0.58	1	0.58	0.53	0.53	4.58	5.89	7.20	322	414	506
207	614204.93	14.1	0.30	0.13	1	0.13	0.10	0.25	6.80	8.68	10.80	29	37	46
208	1904819.2	43.7	0.32	0.23	1	0.23	0.20	0.25	6.80	8.68	10.80	94	120	149
209	2531130.1	58.1	0.30	0.27	1	0.27	0.24	0.25	6.80	8.68	10.80	119	151	188
210	4458263.9	102.3	0.30	0.37	1	0.37	0.33	0.33	5.81	7.45	9.20	180	230	284
211	3160395	72.6	0.34	0.31	1	0.31	0.27	0.27	6.50	8.31	10.32	158	202	251
212	274183.48	6.3	0.30	0.08	1	0.08	0.06	0.25	6.80	8.68	10.80	13	16	20
213	948414.96	21.8	0.32	0.16	1	0.16	0.13	0.25	6.80	8.68	10.80	47	60	75
214	14874714	341.5	0.30	0.72	1	0.72	0.67	0.67	3.92	4.98	6.10	402	510	625
215	7127067.9	163.6	0.31	0.48	1	0.48	0.43	0.43	5.07	6.53	8.01	261	335	411
217	908437.85	20.9	0.30	0.16	1	0.16	0.13	0.25	6.80	8.68	10.80	43	55	68

TABLE 2-1

CITY OF FRIENDSWOOD
HYDRAULIC COMPUTATIONS FOR INDEX DISCHARGES

AREA #	AREA (sf)	AREA (Ac)	C	Lca (mi)	S (ft/mi)	Lca/ sqrt(s)	Tc (hr)	Tc (dqn (hr)	I 5 (in/hr)	I 25 (in/hr)	I 100 (in/hr)	Q 5 (cfs)	Q 25 (cfs)	Q 100 (cfs)
218	2295442.1	52.7	0.31	0.26	1	0.26	0.22	0.25	6.80	8.68	10.80	110	141	175
219	16053956	368.5	0.30	0.75	1	0.75	0.70	0.70	3.81	4.82	5.91	422	534	654
221	1684213.1	38.7	0.32	0.22	1	0.22	0.19	0.25	6.80	8.68	10.80	84	107	133
222	907070.02	20.8	0.42	0.16	1	0.16	0.13	0.25	6.80	8.68	10.80	60	76	95
223	2204473	50.6	0.32	0.25	1	0.25	0.22	0.25	6.80	8.68	10.80	110	140	174
224	407462.58	9.4	0.33	0.10	1	0.10	0.08	0.25	6.80	8.68	10.80	21	27	33
225	1796317	41.2	0.40	0.23	1	0.23	0.19	0.25	6.80	8.68	10.80	111	142	177
226	935661.36	21.5	0.30	0.16	1	0.16	0.13	0.25	6.80	8.68	10.80	44	56	70
227	301149.57	6.9	0.36	0.08	1	0.08	0.07	0.25	6.80	8.68	10.80	17	22	27
229	371942.67	8.5	0.44	0.09	1	0.09	0.08	0.25	6.80	8.68	10.80	26	33	41
230	257811.05	5.9	0.42	0.08	1	0.08	0.06	0.25	6.80	8.68	10.80	17	22	27
231	783441.13	18.0	0.30	0.14	1	0.14	0.12	0.25	6.80	8.68	10.80	37	47	58
232	2085727.7	47.9	0.30	0.25	1	0.25	0.21	0.25	6.80	8.68	10.80	98	125	155
233	6365191.9	146.1	0.30	0.45	1	0.45	0.41	0.41	5.23	6.73	8.27	230	296	363
234	11596605	266.2	0.34	0.63	1	0.63	0.58	0.58	4.32	5.52	6.76	385	493	603
235	1781906.8	40.9	0.30	0.22	1	0.22	0.19	0.25	6.80	8.68	10.80	83	107	133
236	2017019.4	46.3	0.31	0.24	1	0.24	0.21	0.25	6.80	8.68	10.80	99	126	156
237	1724359.8	39.6	0.32	0.22	1	0.22	0.19	0.25	6.80	8.68	10.80	86	109	136
238	1932305.5	44.4	0.30	0.23	1	0.23	0.20	0.25	6.80	8.68	10.80	90	116	144
239	2250477.3	51.7	0.35	0.26	1	0.26	0.22	0.25	6.80	8.68	10.80	122	155	193
240	759058.34	17.4	0.30	0.14	1	0.14	0.12	0.25	6.80	8.68	10.80	36	46	57
241	1078283.9	24.8	0.33	0.17	1	0.17	0.14	0.25	6.80	8.68	10.80	55	70	88
242	928339.7	21.3	0.34	0.16	1	0.16	0.13	0.25	6.80	8.68	10.80	49	62	78
243	599617.61	13.8	0.30	0.12	1	0.12	0.10	0.25	6.80	8.68	10.80	28	36	45
244	22566102	518.0	0.30	0.91	1	0.91	0.85	0.85	3.38	4.22	5.18	525	655	806

CITY OF FRIENDSWOOD
HYDRAULIC COMPUTATIONS FOR INDEX DISCHARGES

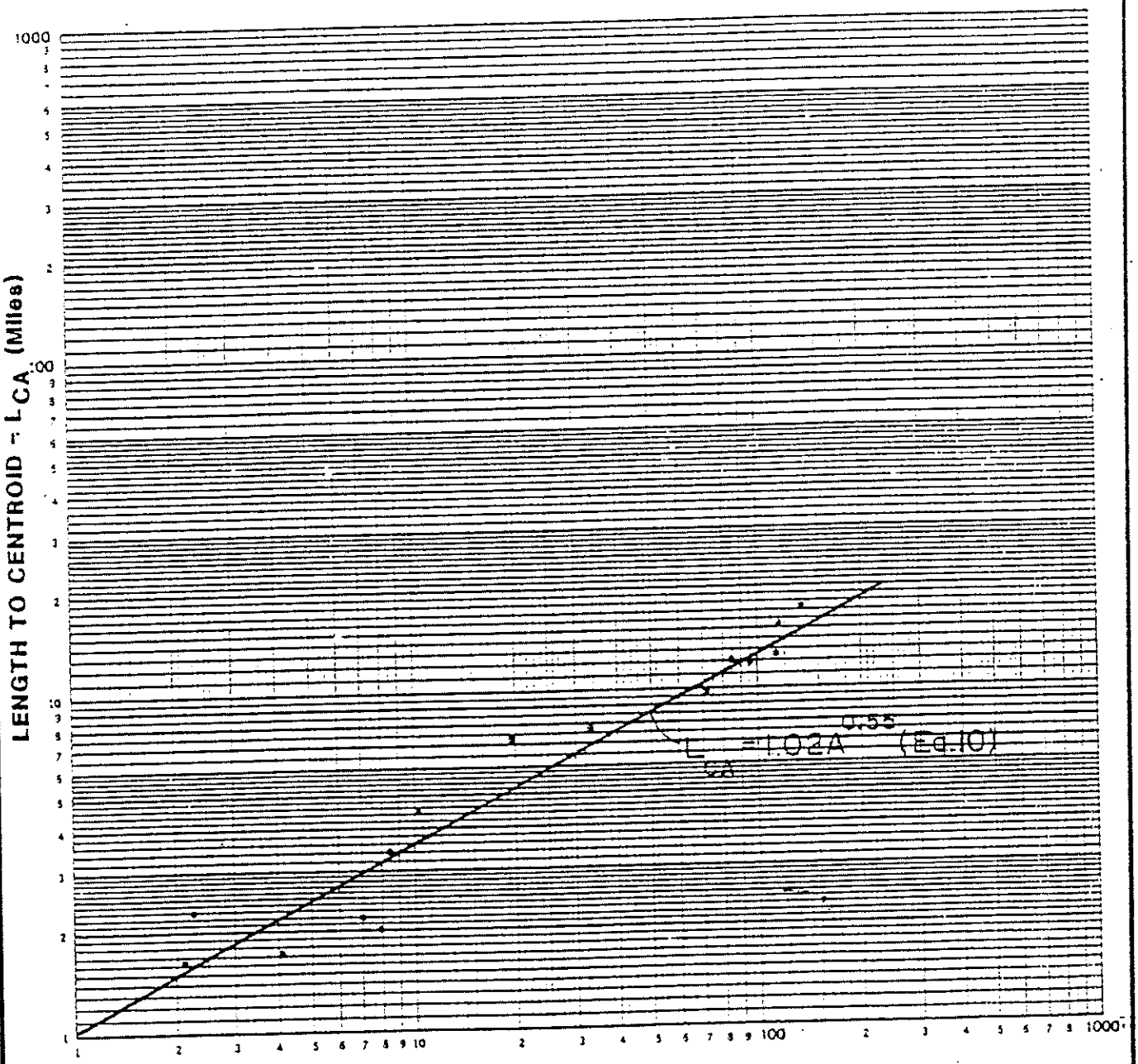
AREA #	AREA (sf)	AREA (Ac)	C	Lca (mi)	S (ft/mi)	Lca/ sqrt(s)	Tc (hr)	Tc (dqn (hr)	I 5 (in/hr)	I 25 (in/hr)	I 100 (in/hr)	Q 5 (cfs)	Q 25 (cfs)	Q 100 (cfs)
245	2147936.8	49.3	0.43	0.25	1	0.25	0.22	0.25	6.80	8.68	10.80	145	185	230

"C" values obtained from the "Dickinson Bayou Watershe Regional Drainage Plan" Drainage Criteria Manual,August 1992.
"Lca" is determined from Exhibit C-1, manual to accompany seminar; Hydrology for Harris County
"S" is the slope of the area, assumed to be 1 foot per mile.
"Tc" values obtained from Exhibit C-3, manual to accompany seminar; Hydrology for Harris County.
"I" values obtained from TP-40 rainfall frequency curves, Exhibit 3-2, manual to accompany seminar; Hydrology for Harris County.
"Q" values obtained by application of the Rational Method. (Q = C * I * A)

TABLE 2-2

Rational Method Runoff Coefficients for 5-10 Year Frequency Storms (From Dickinson Bayou Policy and Criteria Manual Table 3.1)

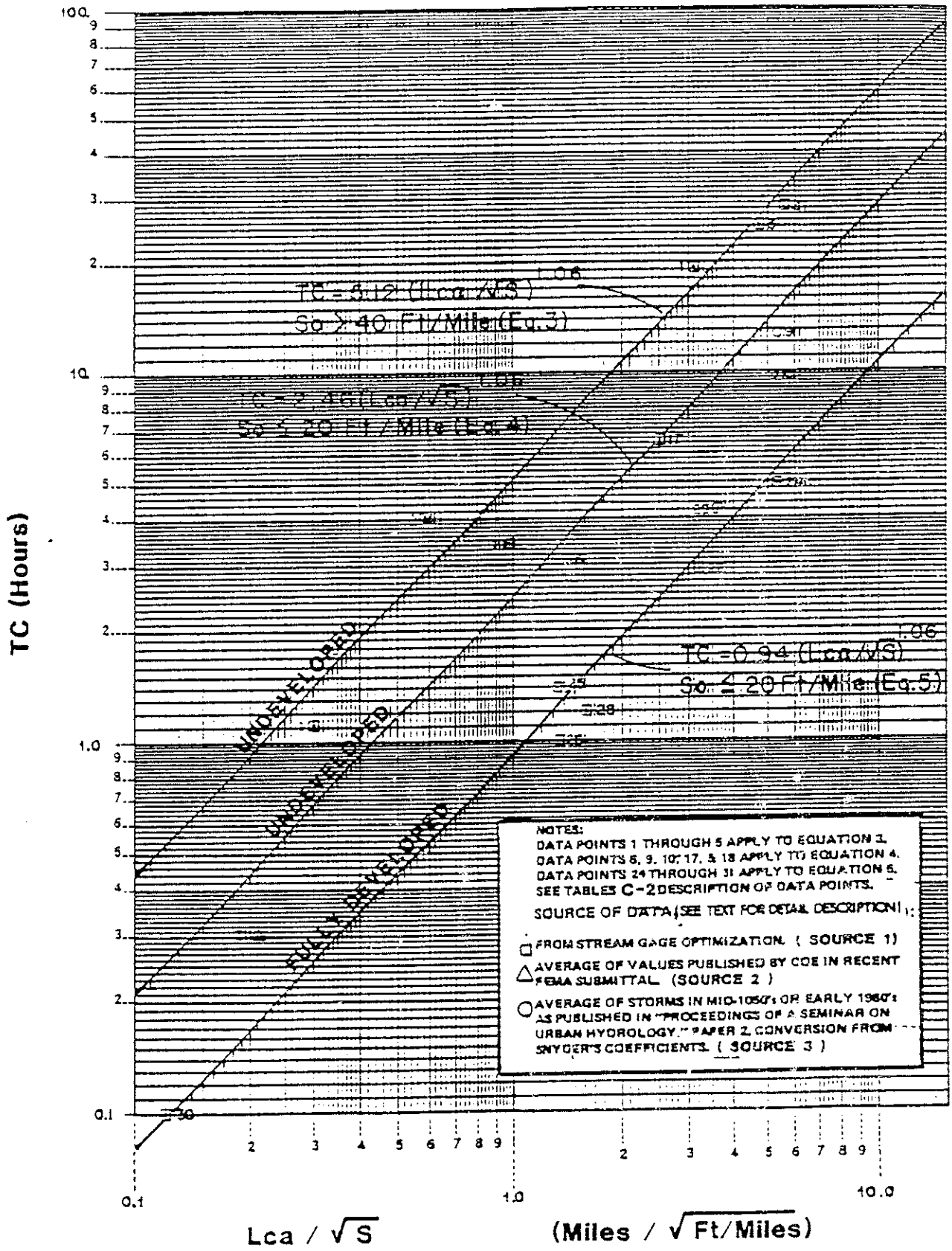
Description of Area	Basin Slope < 1%	Basin Slope 1% - 3.5%	Basin Slope 3.5% - 5.5%
Single Family Residental Districts			
Lots greater than 1/2acre	0.30	0.35	0.40
Lots 1/4 - 1/2 acre	0.40	0.45	0.50
Lots less than 1/4 acre	0.50	0.55	0.60
Multi- Family Residential Districts	0.60	0.65	0.70
Apartment Dwelling Areas	0.75	0.80	0.85
Business Districts			
Downtown	0.85	0.87	0.90
Neighborhood	0.75	0.80	0.85
Industrial Districts			
Light	0.50	0.65	0.80
Heavy	0.60	0.75	0.90
Railroad Yard Areas	0.20	0.30	0.40
Cemeteries	0.10	0.18	0.25
Playgrounds	0.20	0.28	0.35
Streets	0.80		
Asphalt	0.85	0.85	0.85
Concrete	0.85	0.85	0.85
Concrete Drives and Walks	0.85	0.85	0.85
Roofs	0.85	0.85	0.85
Lawn Areas			
Sandy Soil	0.05	0.08	0.25
Clay Soils	0.18	0.20	0.30
Woodlands			
Sandy Soil	0.15	0.18	0.25
Clay Soil	0.18	0.20	0.30
Pasture			
Sandy Soil	0.25	0.35	0.40
Clay Soil	0.30	0.40	0.50
Cultavated			
Sandy Soil	0.30	0.55	0.70
Clay Soil	0.35	0.60	0.80



DRAINAGE AREA (Square miles)

AVERAGE LENGTH TO CENTROID (L_{CA})
-VS- DRAINAGE AREA
(Gaged locations)

EXHIBIT 2-3



RELATIONSHIP FOR T C

EXHIBIT 2-4

TABLE 2-3

Rainfall Intensities
from TP-40 rainfall frequency curves for Galveston County

TC min.	TC hr	I 5-yr	I 100-yr
5	0.08	7.90	11.00
6	0.10	7.20	10.50
7	0.12	7.00	10.00
8	0.13	6.80	9.80
9	0.15	6.60	9.50
10	0.17	6.50	9.30
11	0.18	6.40	9.00
12	0.20	6.20	8.80
13	0.22	6.00	8.60
14	0.23	5.90	8.40
15	0.25	5.70	8.20
16	0.27	5.60	8.00
17	0.28	5.40	7.80
18	0.30	5.30	7.60
19	0.32	5.10	7.40
20	0.33	5.00	7.20
21	0.35	4.90	7.20
22	0.37	4.80	7.10
23	0.38	4.80	7.10
24	0.40	4.70	7.00
25	0.42	4.60	7.00
25	0.43	4.50	7.00
27	0.45	4.40	6.90
28	0.47	4.40	6.90
29	0.48	4.30	6.80
30	0.50	4.20	6.80
31	0.52	4.10	6.70
32	0.53	4.10	6.60
33	0.55	4.00	6.50
34	0.57	4.00	6.40
35	0.58	3.90	6.30
36	0.60	3.90	6.20
37	0.62	3.80	6.10
38	0.63	3.80	6.00
39	0.65	3.70	5.90

TC min.	TC hr	I 5-yr	I 100-yr
40	0.67	3.70	5.80
41	0.68	3.60	5.70
42	0.70	3.60	5.60
43	0.72	3.50	5.50
44	0.73	3.50	5.50
45	0.75	3.40	5.40
46	0.77	3.40	5.30
47	0.78	3.30	5.20
48	0.80	3.30	5.10
49	0.82	3.20	5.10
50	0.83	3.20	5.00
51	0.85	3.20	4.90
52	0.87	3.10	4.90
53	0.88	3.10	4.80
54	0.90	3.10	4.70
55	0.92	3.00	4.60
56	0.93	3.00	4.60
57	0.95	3.00	4.50
58	0.97	3.00	4.40
59	0.98	2.90	4.54
60	1.00	2.90	4.30
61	1.02	2.90	4.30
62	1.03	2.90	4.30
63	1.05	2.80	4.30
64	1.07	2.80	4.30
65	1.08	2.80	4.30
66	1.10	2.80	4.20
67	1.12	2.80	4.20
68	1.13	2.70	4.20
69	1.15	2.70	4.20
70	1.17	2.70	4.20

III. PROBLEM OUTFALL ANALYSIS

A. Introduction

On June 14, 1993 at a drainage workshop, Claunch & Miller, Inc. and City of Friendswood staff presented to City Council the 20 designated drainage areas for a more detailed analysis. As each area was delineated, the reason for its selection was presented to Council. There was no opposition put forth by council members to the selected areas for analysis. Table 3-1 is a list of these specific sites with a general description of the problem. The sites are shown on Figure 3-1. Many of the problems stem from undersized storm sewer systems and/or a lack of roadside drainage ditch capacity.

The following sections discuss the problems and proposed solutions for the problem sites. It is important to understand that the proposed solutions are only conceptional. The intent of this study is to provide a planning tool for preliminary budgeting. When project design commences and more detailed field survey information is obtained, these proposed solutions may be revised for more beneficial and cost effective solutions. The solutions proposed in this study are designed to convey the 5-year flood. No consideration was given for downstream impact from the increased flows to the creeks. It is anticipated that this work would be done subsequent to the Clear Creek Project's completion.

Estimates of probable cost are calculated using unit prices. These were provided to assist in budgeting for drainage relief of the problem outfall. Contingencies were added due to potential utility relocations, potential additional engineering, surveying and geotechnical services. Contingency amounts are also included to cover easement document preparation, and other unknowns that may be associated with the proposed improvements. Some proposed solutions will require easement acquisition prior to implementation. Since easement costs can vary substantially based upon individual property owner and property value, these cost have not been included within the cost estimates.

B. Assumptions

Where no plans existed for existing storm sewers the capacity was assumed to be flowing at full capacity with a velocity of 3 feet per second. A detailed analysis with topographic surveying during project design may show additional existing capacity. Proposed storm sewers are also assumed to be at minimum grade. Detailed design may result in smaller storm drain pipes if steeper grades can be obtained.

Table 3-1
Local Drainage Analysis Sites

Problem Site #	Location	Drainage Problem
1 $350K ✓	Woodlawn Storm Sewer Outfalls at Spreading Oaks	Street Flooding
2 $ 1.2M ✓	Briarmeadow Ditch	Area Flooding
3	Leslyn/Sterlingwood Outfall along Merriewood	Street Flooding
4 $500K ✓	Sunset Ditch - Mills to Coward's Creek	Ditch Flooding
5	High School Outfall	Street Flooding
6	Greenbriar Ditch to Chigger Creek	Area Flooding
7	Wilderness Trails/Glennshannon Outfall	Street Flooding
8	Falcon Ridge I	Street Flooding
9	Mission Estates Outfall	Street Flooding
10	Carmel Village at San Joaquin Parkway	Street Flooding
11	Sun Meadow Main Outfall	Street Flooding
12	Sun Meadow Relief Storm Sewer	Street Flooding
13	Garden Drive Ditch @ Spreading Oaks	Area Flooding
14	Garden Road Ditch at FM 2351	Area Flooding
15	Block Bounded by FM 528 FM 518, Winding Way, and Leisure Lane	Area Flooding
16	Melody Lane	Inadequate Drainage
17	FM 518 - Willowick to Mary's Creek Tributary	Street Flooding
18	FM 518 - Willowick to Coward's Creek	Street Flooding
19	Annalea Outfall @ FM 518	Street Flooding
20 $850K ✓	Whitehall outfall at FM 518	Street Flooding

X - Done
○ - Developer Assistance or other agency assistance

CLAUNCH & MILLER, INC.
Engineering Consultants

ALBERT H. HALFF ASSOCIATES, INC.
ENGINEERS • SCIENTISTS • SURVEYORS

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CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

CITY OF FRIENDSWOOD
20 DETAIL PROBLEM AREAS

#1 Woodlawn Storm Sewer

1. Statement of Problem:

Localized flooding occurs frequently in the intersections of Heritage and Dawn at Woodlawn. This flooding is caused by an approximate 2 1/2' rise in the elevation of Woodlawn near its intersection with W. Shadowbend. This rise is producing a damming effect at this intersection and is backing-up the storm water to Dawn and Heritage. The rise in the street elevation is due to the changing of Woodlawn from a curb and gutter street to a roadside ditch street.

2. Summary of Data:

No storm drain plans or ditch plans were available for this area. Information was determined from the drainage area map developed for this study indicating the drainage area, inlet locations and existing pipe sizes. No topography or cross sections were available.

3. Analysis of Existing Conditions:

This area is drained by three storm sewer systems which all converge together south of Woodlawn Drive before flowing south and crossing under Spreading Oaks into a tributary of Coward's Creek. The area is composed of vacant lots, residential and commercial areas and the Junior High property. The Capacity of any existing storm sewer was computed assuming a pipe velocity of 3 feet-per-second and maximum inlet capacity of 5 cubic feet per second (cfs). Based on these computations, the existing storm sewers are inadequate to convey the 5-year flood.

One half of the drainage area drains to the intersection of Woodlawn Drive and Shadowbend Avenue. Flows in excess of the 42 inch and 36 inch pipes between Shadowbend and Spreading Oaks ponds to a depth in excess of 2 feet before flowing east along Woodlawn Avenue. The combined capacity of the 36 inch and 42 inch storm sewers from Woodlawn Avenue to Spreading Oaks is 51 cfs (sufficient for only drainage area Number 2's 5-year discharge).

The other half of the drainage area flows via ditches in Woodlawn toward Spreading Oaks or via a storm drain system in Laurel Drive in front of the Administration building then down Spreading Oaks to Woodlawn Drive. The ditch along the south side of Woodlawn Drive is lined with mature trees and crossed by driveway culverts. The capacity of this ditch is estimated to be 20 cfs.

The total drainage area converges at Woodlawn and Spreading Oaks Drive and

drains southward through double 36 inch pipes and crosses under Spreading Oaks to a poorly maintained ditch which flows southeast to Coward's Creek. The City is planning to budget for rectification of this ditch in their 93-94 budget.

4. Proposed Solution:

a. Woodlawn at Shadowbend:

There are three possible solutions for flooding at this point. (See Exhibit)

(1) One solution is to construct a detention basin in the vicinity of Woodlawn and Shadowbend to collect the flows which cannot enter the storm sewer system. This detention basin would collect the peak flows and release them through a 24" pipe connection to the storm drain as the storm drains emptied. About 6 acre feet of detention is required for the 5-year flood and 10 acre feet for the 100 year flood. This could be a temporary solution until Woodlawn Drive is repaved under the 5-year plan as proposed, or kept as a permanent solution to reduce downstream flooding.

(2) Another solution is to replace the existing storm drains from Shadowbend with two 60 inch storm drains. These can convey 60 cfs each assuming 3 f.p.s. At the same time ditch conveyance on both sides of the street should be increased to convey a total of 30 cfs each. Flows in excess of the storm drainage system's capacity will sheet flow along the new street grades when Woodlawn is improved. Until the road is improved ponding would still occur upstream, but a less frequent intervals. Additional inlets are required on the Woodlawn storm drain west of Shadowbend Avenue with a parallel storm drain.

(3) A third solution to the flooding in this area is to convey the flows from the drainage areas north of Shadowbend down a ditch along the back property lines between Woodlawn and David St. The proposed 48" and 54" storm drains along Shadowbend and Woodlawn, listed in solution 2, are needed to bring the flows to the intersection. From this intersection, 2-48" pipes are needed to carry the flows west along Shadowbend to the proposed ditch. The ditch will need to convey 80 cfs. A 'V' ditch with a top width of 20 feet and a depth of 5 feet can convey 80 cfs at a slope of .0003 ft/ft. To carry the flow across Spreading Oaks the pipe needed is a 72" or 2-48". The proposed storm drain along Spreading Oaks from Woodlawn to the tributary could be reduced to a single 72" pipe or dual 48" pipes. This solution is not depicted on the exhibit.

b. Laurel Drive Storm Drain:

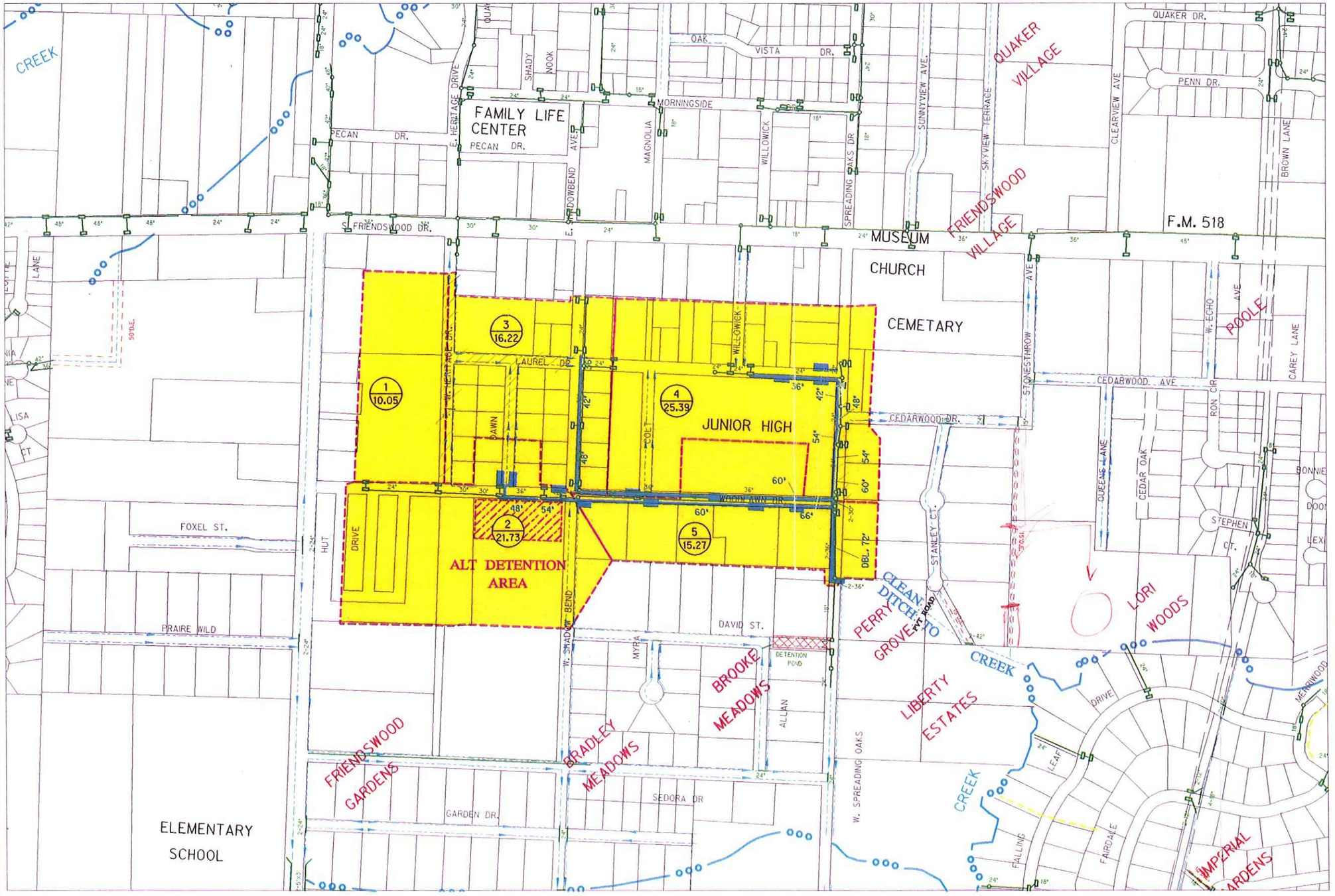
This system requires complete reconstruction beginning at Woodlawn Drive by replacing the 24 inch storm drain with a 60" storm drain and ending with a 36" storm drain on Laurel Drive.

c. Spreading Oaks from Woodlawn to the tributary of Coward's Creek:

The double 36" storm drain pipes are too small and require replacement with double 72" pipes to convey the 185 cfs flow to the tributary of Coward's Creek.

d. Tributary of Coward's Creek:

The Tributary should be cleaned out, widened and grass lined in order to convey the greater discharge resulting from these upstream improvements. No analysis was done for the tributary downstream of Spreading Oaks.



LEGEND

- (10 / 36.14) AREA NO. / AREA (ACRES)
- EXISTING DETENTION AREA
- DETENTION AREA
- DRAINAGE DIVIDE
- 18" EXIST. STORM DRAINAGE
- 36" PROP. STORM DRAINAGE
- 36" PROP. FUTURE STORM DRAINAGE
- DETENTION POND
- DRAINAGE DITCH IMPROVEMENT
- DRAINAGE DITCH NEW

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MASTER DRAINAGE PLAN

WOODLAWN STORM SEWER PROBLEM AREA NO. 1

Friendswood Drainage Plan Cost Estimates

Problem Area Number 1 Woodlawn storm sewer	Item	Quantity	Units	Unit Cost	Cost	
	Alternative 1. Detention Basin:					
	24" Reinforced Concrete Pipe	200	L.F.	39	$7,800	
	Headwall for 24"	1	Each	767	$767	
	Pipe to Pipe Connection	1	Each	425	$425	
	Concrete Curb	100	L.F.	10	$1,000	
	Earth Excavation	18553	C.Y.	5	$92,767	
	Concrete Pavement	400	S.Y.	28	$11,200	
SubTotal:					$113,958	
	Engineering		15%		$17,094	
	Contingencies		28%		$31,908	
*Total:						$162,960

* This improvement requires easement acquisition. Costs for easement acquisition are not reflected in this estimate. These costs should be investigated prior to budgeting for this improvement. *

	Alternative 2. Storm Drain:					
	24" Reinforced Concrete Pipe	200	L.F.	39	$7,800	
	Headwall for 24"	2	Each	767	$1,533	
	Ditch Cleaning	1600	L.F.	4	$6,400	
	42" Reinforced Concrete Pipe	450	L.F.	70	$31,500	
	48" Reinforced Concrete Pipe	600	L.F.	80	$48,000	
	36" Reinforced Concrete Pipe	550	L.F.	57	$31,350	
	54" Reinforced Concrete Pipe	550	L.F.	112	$61,600	
	60" Reinforced Concrete Pipe	950	L.F.	126	$119,700	
	60" Reinforced Concrete Pipe	1360	L.F.	126	$171,360	
	66" Reinforced Concrete Pipe	600	L.F.	135	$81,000	
	Manhole	8	Each	1200	$9,600	
	Inlet	13	Each	1200	$15,600	
	72" Reinforced Concrete Pipe	450	L.F.	150	$67,500	
	72" Reinforced Concrete Pipe	450	L.F.	150	$67,500	
	Headwall for 72"	2	Each	2850	$5,700	
SubTotal:					$726,143	
	Engineering		15%		$108,922	
	Contingencies		15%		$108,922	
Total:						$943,986

	Alternative 3. Combination Storm Drain & Ditch					
	72" Reinforced Concrete Pipe	50	L.F.	150	$7,500	
	54" Reinforced Concrete Pipe	200	L.F.	112	$22,400	
	48" Reinforced Concrete Pipe	850	L.F.	80	$68,000	
	42" Reinforced Concrete Pipe	250	L.F.	70	$17,500	
	36" Reinforced Concrete Pipe	50	L.F.	57	$2,850	
	Inlet	5	Each	1200	$6,000	
	Manhole	3	Each	1200	$3,600	
	Earth Excavation	2500	C.Y.	5	$12,500	
	Inlet	13	Each	1200	$15,600	
	Headwall for 72"	2	Each	2850	$5,700	
SubTotal:					$161,650	
	Engineering		15%		$24,248	
	Contingencies		28%		$45,262	
*Total:	This alternative used for the grand total					$231,160

* This improvement requires easement acquisition. Costs for easement acquisition are not reflected in this estimate. These costs should be investigated prior to budgeting for this improvement. *

#2 Briarmeadow Ditch

1. Statement of Problem:

Street flooding is occurring along Murphy and Briarmeadow south of Sunset. The ditches are shallow and the lots are about 300' deep along these streets; this generates problems in draining the rear of the lots.

2. Summary of Data:

Ditch cross sections were surveyed by the City of Friendswood. Two cross sections of Briarmeadow ditches at Merriewood and one at Sunset Drive were taken. Approximate grades were assumed based on U.S.G.S. Quadrangle maps.

3. Analysis of Existing Conditions:

Flows from Murphy Lane, South Briarmeadow and the Sunpark Subdivision all join at the intersection of Briarmeadow and Sunset Drive. The flowline of the ditch indicates that the runoff is to be conveyed north toward Merriewood Lane via the Briarmeadow ditches. However, the ditch along Briarmeadow is inadequate and overloaded from the local runoff from the school property. In addition, the Briarmeadow / Merriewood intersection and the associated detention facility north of Merriewood are already at capacity (See Problem No. 3). Increasing the capacity of the ditch north to Merriewood or installing storm drains to handle the 5-year flow from Briarmeadow and discharging into the detention north of Merriewood would negate the usefulness of the detention facility and create more flooding in Sterlingwood and Leslyn Subdivisions.

The existing ditch along Briarmeadow is between 3 to 4 feet deep with 2:1 sideslopes. The capacity of the ditch is about 25 cfs. The peak 5-year flow from the local area north of Sunset is 74 cfs. The flows which can not travel north along Briarmeadow must flow to the west along Sunset, adding to the problem in area number 4, or south along Briarmeadow, increasing flooding in area number 6.

Improving the Briarmeadow ditches south or installing a storm drain along Briarmeadow from Sunset to Greenbriar and Chigger Creek was considered but not pursue because this would be diverting flows across the Coward's/Chigger Creek drainage divide.

Another alternative would be to install a storm drain along Sunset to Coward's Creek. This alternative could be used to solve the drainage problem in this area along with problem area number 4. However, due to the current creek flooding problems on Coward's Creek downstream of Sunset, this option was rejected.

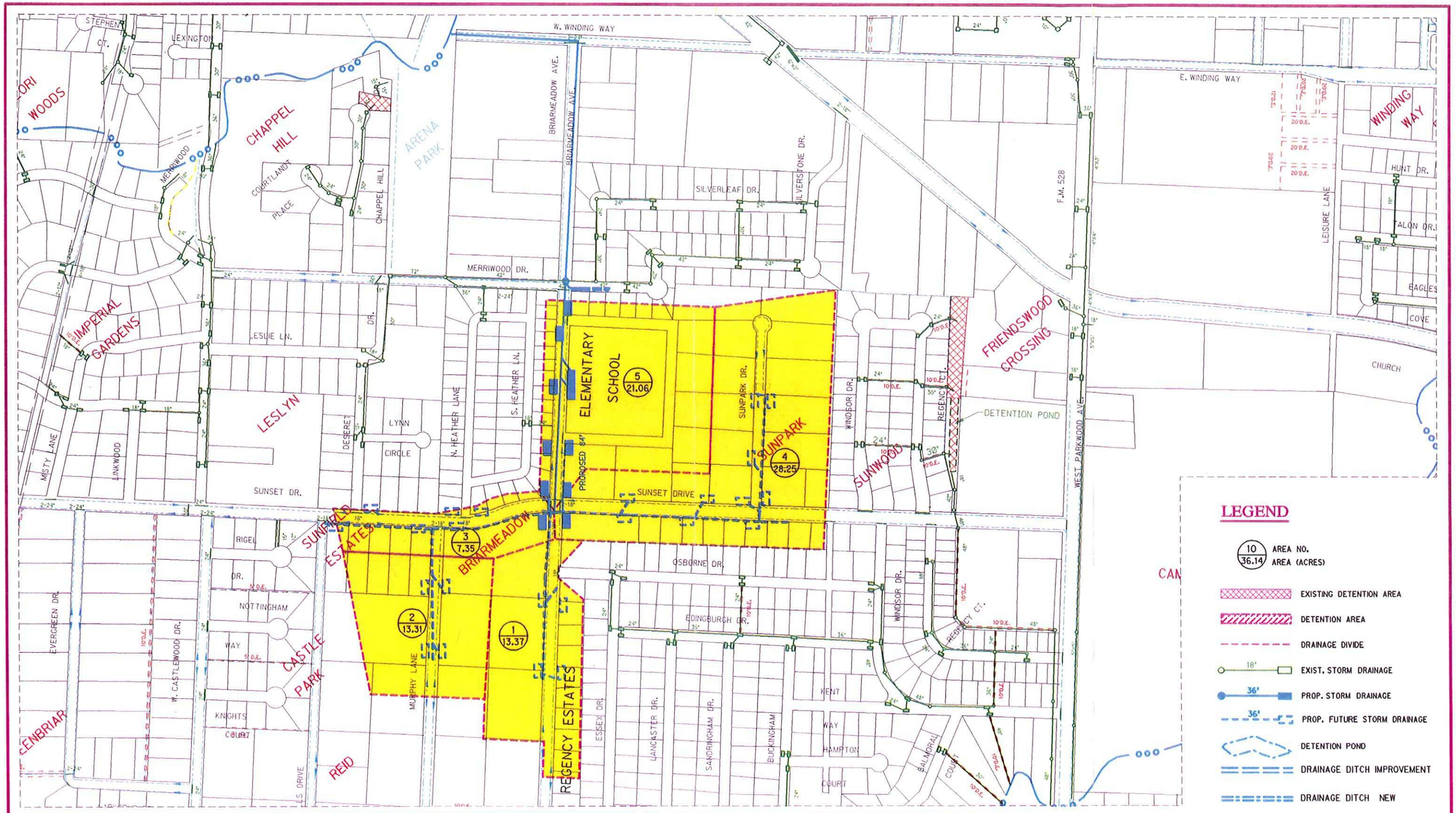
A third possibility is to install a storm drain north along Briarmeadow to Coward's Creek. This line could either parallel the Merriewood Drive storm drain or continue north along Briarmeadow to Winding Way and then to Coward's Creek via Winding Way. If the parallel system along Merriewood Drive is chosen then the existing detention pond north of Merriewood will have to be increased to prevent flooding in the Sterlingwood and Leslyn subdivisions.

4. Proposed Solution:

a. Construct a storm drain from the intersection of Sunset Drive and Briarmeadow north to Winding Way then west to Coward's Creek. The required pipe will be equivalent to an 84" inch diameter rcp.

b. Install a 84" storm drain at a slope of .00006 ft/ft along Briarmeadow toward the north. Connect it to the existing 48" storm sewer in Problem Number 3. Continue north along Briarmeadow, then west along Winding Way to Coward's Creek, with a 84" storm drain. At northwest corner of Sunset and Briarmeadow intersection place a junction box with a 36" stub-out to pick up the flows from west in the north roadside ditch of Sunset. Cross Briarmeadow with a 60" rcp to pick up flows from the east of Briarmeadow. Cross Sunset Drive with 60" rcp and install a junction box with a 48" pipe to the west and a 42" pipe to the South. These pipes should be used in the future to extend the storm drain system south along Briarmeadow and west along Sunset.

c. As roads are improved, extend storm drains south, east and west.



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CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

BRIARMEADOW DITCH
PROBLEM AREA NO. 2

Friendswood Drainage Plan Cost Estimates

Problem Area Number 2 Briarmeadow Ditch	Item	Quantity	Units	Unit Cost	Cost	
	84" Reinforced Concrete Pipe	3300	L.F.	185	$610,500	
	60" Culvert	100	L.F.	126	$12,600	
	48" Culvert	10	L.F.	80	$800	
	36" Culvert	20	L.F.	57	$1,140	
	Junction Box	4	Each	6000	$24,000	
	Headwall for 84"	1	Each	6000	$6,000	
	Headwall for 60"	1	Each	4000	$4,000	
	Concrete Pavement	334	S.Y.	28	$9,352	
	Saw Cut	600	L.F.	8	$4,800	
	Inlet	6	Each	1200	$7,200	
SubTotal:					$680,392	
	Engineering		15%		$102,059	
	Contingencies		15%		$102,059	
Total:						$884,510

#3 Leslyn/Sterlingwood Outfall along Merriewood

1. Statement of Problem:

Street flooding occurs in both subdivisions due to lack of capacity in the storm sewers and the height of Merriewood and Briarmeadow which prevents sheet flow out of subdivisions when storm sewer capacity is reached. Presently drainage area #2 is also routed through this storm sewer which cannot handle the flow.

2. Summary of Data:

Sterlingwood and Leslyn Subdivision plans were available. These plans showed the street grades, drainage systems for the subdivisions and the detention facility north of Merriewood. Merriewood ditch profiles and plans for a 36" RCP crossing were also available. U.S.G.S. Quadrangle maps were used in determining elevations where field surveys or plans were not available. Surveyed cross sections at Briarmeadow and Merriewood were available for determining ditch capacity. Structure information at Castlewood and Falling Leaf was unavailable.

3. Analysis of Existing Conditions:

The existing system appears adequate for the Sterlingwood subdivision with only minor adjustments, if offsite drainage areas are separately conveyed.

The Leslyn subdivision does not have sufficient pipe capacity or inlet capacity for the 5-year flood. Storm water must pond to a depth of at least 1.8 ft in the Leslyn subdivision, before flowing north to Sunset Drive. Currently, ponding is relieved by overflow through private lots to the ditch on the south side of Merriewood. The city has recently installed a 36 inch pipe under Merriewood to reduce the amount of flooding which would have to occur if excess runoff had to overtop Merriewood.

The inadequate ditches along Sunset (See Problem Area No. 4) could be adding to the flooding in the Leslyn subdivision. However, insufficient data was available analyze this possibility.

The Briarmeadow subdivision east of Leslyn flows via a 24 inch pipe north to a 36 inch storm drain on the south side of Merriewood appears to have adequate drainage facilities for the 5-year flood. No plans were available for this subdivision; therefore the 100-year flood ponding depths or direction of flow could not be determined.

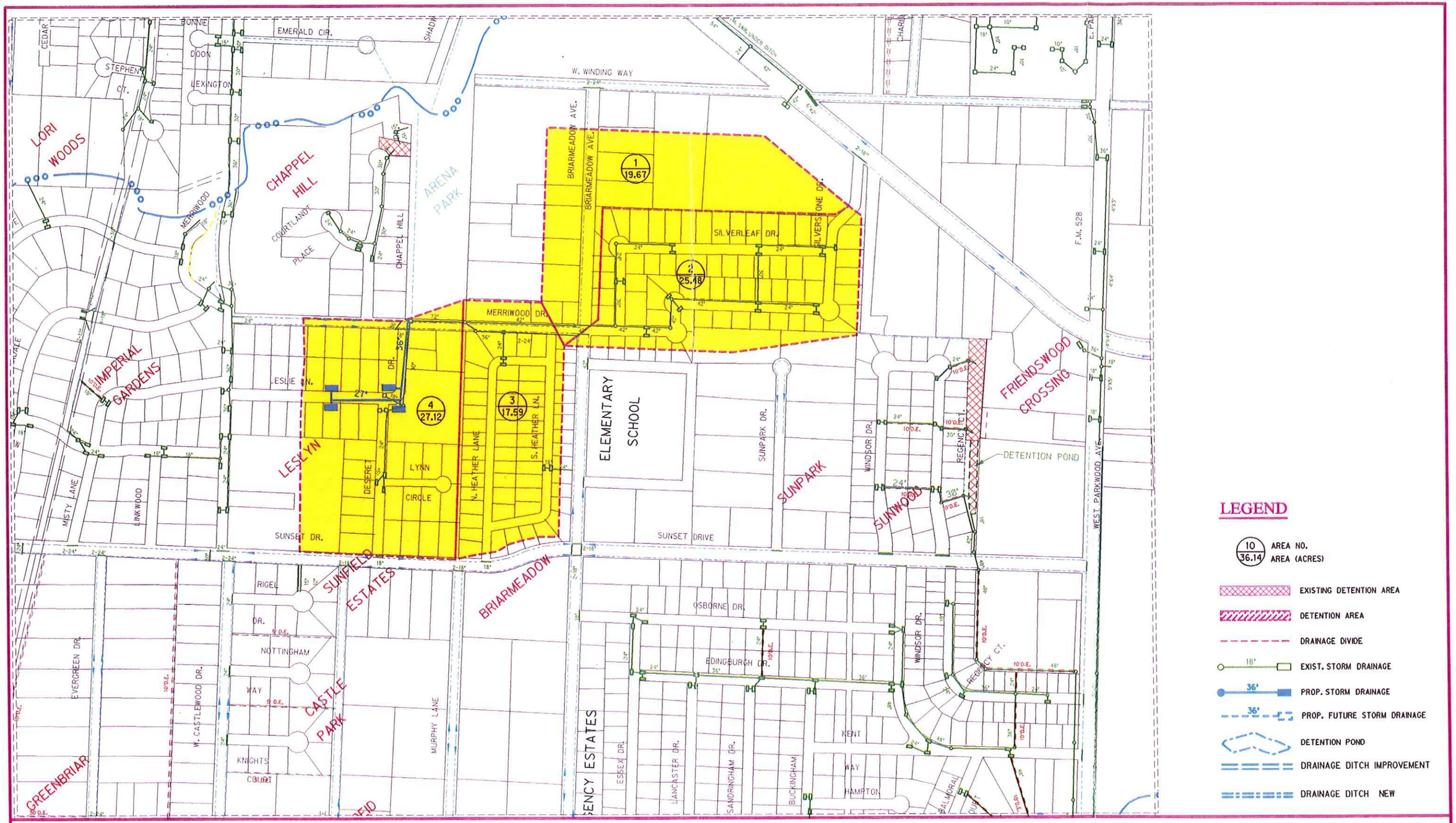
Currently the Briarmeadow ditch south of Merriewood brings storm flows from another drainage area to the north into this problem area. (See Problem Area No. 2)

4. Proposed Solution:

a. Runoff from the Sterlingwood subdivision requires both the existing 48 inch storm pipe on the north side of Merriewood and the double 24 inch storm drain on the south side. The southern pipes currently accept flow from areas outside this problem area. The 24 inch storm pipes should be connected to the manhole on the north side of Merriewood and the pipes which drain the Briarmeadow ditch from the south should be blocked off. (See Problem Area # 2)

b. Leslyn Subdivision requires four additional inlets, and a 36 inch storm drain to the north paralleling the existing system. The new 36 inch storm drain under Merriewood could be extended to the Deseret and Leslie intersection, grades permitting. (See Exhibit) If this pipe is utilized, an additional inlet will be required to drain the ditch south of Merriewood.

c. When designed in the 5-year street replacement program, Merriewood and the crest in Deseret Drive should be lowered to allow relief of 100-year flood flows down Deseret and across Merriewood to the detention pond north of Merriewood.



LEGEND

- (10 / 36.14) AREA NO., AREA (ACRES)
- EXISTING DETENTION AREA
- DETENTION AREA
- DRAINAGE DIVIDE
- 18" EXIST. STORM DRAINAGE
- 36" PROP. STORM DRAINAGE
- 36" PROP. FUTURE STORM DRAINAGE
- DETENTION POND
- DRAINAGE DITCH IMPROVEMENT
- DRAINAGE DITCH NEW

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CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

LESLYN SUBDIVISION
PROBLEM AREA NO. 3

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Friendswood Drainage Plan Cost Estimates

Problem Area Number 3 Leslyn Subdivision	Item	Quantity	Units	Unit Cost	Cost	
	36" Reinforced Concrete Pipe	500	L.F.	57	$28,500	
	Pipe to Manhole Connection	2	Each	500	$1,000	
	24" Reinforced Concrete Pipe	100	L.F.	39	$3,900	
	27" Reinforced Concrete Pipe	400	L.F.	45	$18,000	
	18" Reinforced Concrete Pipe	70	L.F.	34	$2,345	
	Inlet	4	Each	1200	$4,800	
	Manhole	3	Each	1200	$3,600	
SubTotal:					$62,145	
	Engineering		15%		$9,322	
	Contingencies		28%		$17,401	
Total:						$88,867

#4 Sunset Ditch

1. Statement of Problem:

Shallow roadside ditches and inadequate cross structures along Sunset are causing street flooding along W. Castlewood and in the subdivisions of Sunfield Estates and Castle Park.

2. Summary of Data:

Plans available include roadside ditch profiles, subdivision plans for Sunfield and Castle Park. U.S.G.S. quadrangle maps indicating general elevations were also utilized. In addition, elevations for the 10-, 50-, 100-, and 500- year flood at the Coward's Creek outfall were available from the "Regional Flood Control Plan for the Clear Creek Watershed". Surveyed cross sections of Sunset, Mills and Murphy were available to determine the capacity of the roadside ditches.

3. Analysis of Existing Conditions:

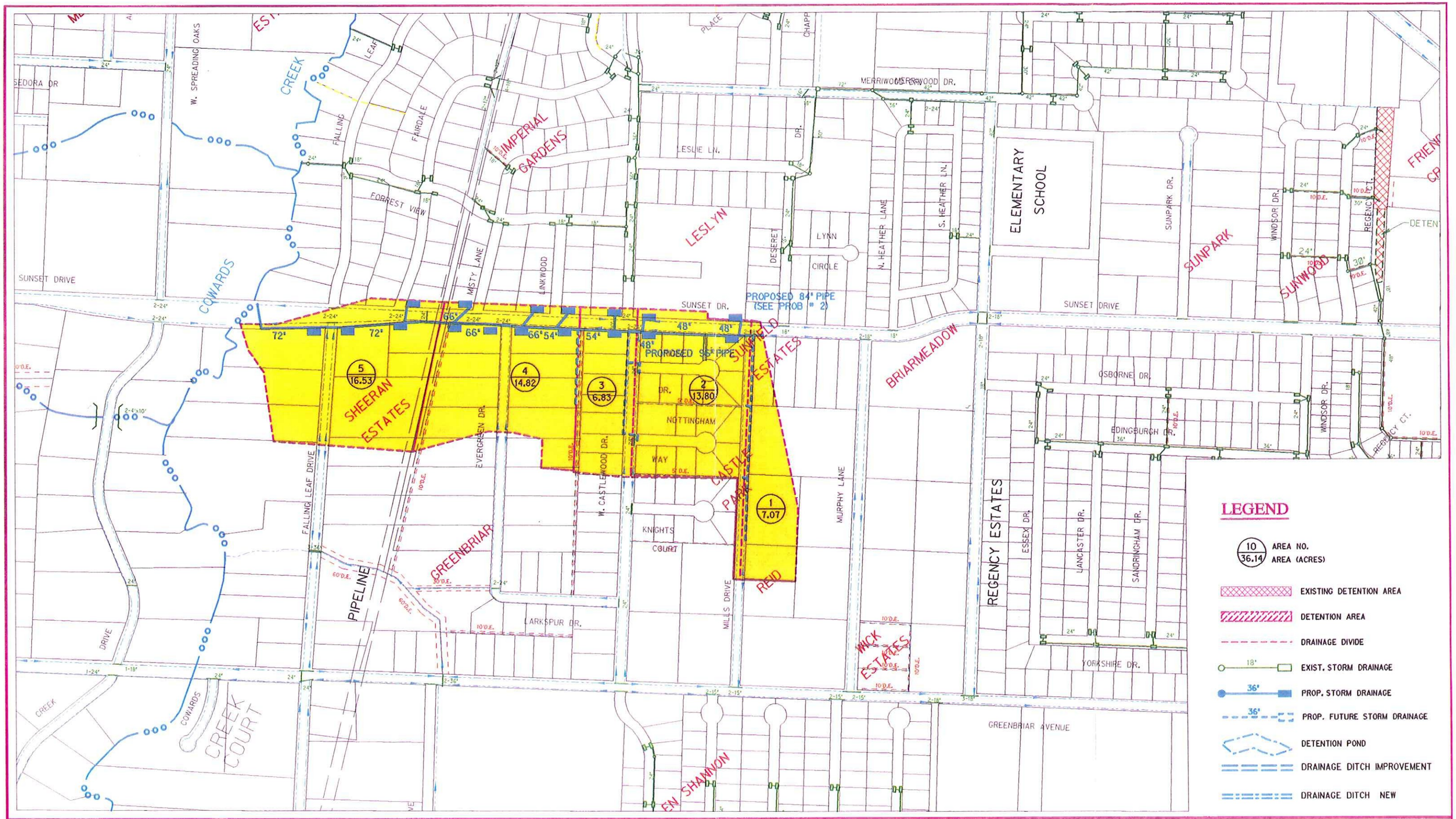
The storm flows discharging into Coward's Creek from the Sunset drainage ditches are 82 cfs for the 5-year flood and 133 cfs for the 100-year flood. The capacity of the ditch on the south side of Sunset is about 30 cfs. The capacity of the north ditch ranges from 10 to 20 cfs. The total capacity of the ditches ranges between 40 to 50 cfs.

In addition to the local flows contributing to the Sunset ditches there is additional flow from the east. (See problem Area number 2). This is attributed to the inability of the ditch along Briarmeadow to coney the flows in area 2 to the north. These additional flows more than double the flows attempting to flow down Sunset.

Collecting all the flows from Problem Area 2 and discharging the flows west along Sunset was investigated. However, as discussed in problem number 2's solution this was not feasible due to existing downstream creek flooding problems.

4. Proposed Solution:

Install a storm drain pipe on the south side of Sunset Drive from Mills to Cowards Creek. (See Exhibit) Outfall the storm drain at Coward's Creek on the north (downstream) side of Sunset. If 5-year capacity storm drains are installed, the sizes will range from 72" at the outfall to 48" at Mills. Install 24 inch pipes with headwalls in the ditches on both sides of Murphy, Mills and W. Castlewood Avenue to pick up flows from these roadside ditches and possible storm drain expansion..



LEGEND

- 10 / 36.14 — AREA NO. / AREA (ACRES)
- EXISTING DETENTION AREA
- DETENTION AREA
- DRAINAGE DIVIDE
- 18' EXIST. STORM DRAINAGE
- 36' PROP. STORM DRAINAGE
- 36' PROP. FUTURE STORM DRAINAGE
- DETENTION POND
- DRAINAGE DITCH IMPROVEMENT
- DRAINAGE DITCH NEW

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CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

SUNSET SOUTH DITCH FLOWING WEST
PROBLEM AREA NO. 4

Friendswood Drainage Plan Cost Estimates

Problem Area Number 4 Sunset Ditch South	Item	Quantity	Units	Unit Cost	Cost	
	72" Reinforced Concrete Pipe	900	L.F.	150	$135,000	
	66" Reinforced Concrete Pipe	650	L.F.	135	$87,750	
	54" Reinforced Concrete Pipe	550	L.F.	112	$61,600	
	48" Reinforced Concrete Pipe	850	L.F.	80	$68,000	
	24" Reinforced Concrete Pipe	60	L.F.	39	$2,340	
	Concrete Pavement	667	S.Y.	28	$18,667	
	Saw Cut	800	L.F.	8	$6,400	
	Headwall for 72"	1	Each	5000	$5,000	
	Headwall for 24"	6	Each	800	$4,800	
	Inlet	17	Each	1200	$20,400	
	Manhole	6	Each	3400	$20,400	
	Junction Box	1	Each	5000	$5,000	
	18" Reinforced Concrete Pipe	600	L.F.	34	$20,100	
SubTotal:					$232,707	
	Engineering		15%		$34,906	
	Contingencies		28%		$65,158	
Total:						$332,771

#5 Outfall from High School

1. Statement of Problem:

Localized street flooding is occurring along Greenbriar at the High School and along Evergreen and Larkspur. This flooding is caused by inadequate cross structures at Falling Leaf and Evergreen.

2. Summary of Data:

Ditch Cross sections for the drainage ditches between Falling Leaf and the High School and the side ditch to Larkspur were available to determine the ditch capacities. The city's Greenbriar Ditch Improvement plans were available. These plans showed the drainage improvements along Greenbriar and indicated a tie-in to two 30 inch pipes at Mustang Drive. In addition, elevations for the 10-, 50-, 100-, and 500- year flood at the Coward's Creek outfall were available from the "Regional Flood Control Plan for the Clear Creek Watershed".

3. Analysis of Existing Conditions:

A capacity analysis was performed for the ditch between the High School Outfall and Coward's Creek. The culvert at Falling Leaf were analyzed. Cross section information was available for the ditch. However, dimensions and elevations of the culvert at Falling Leaf were estimated from the information on the Friendswood Drainage Map and the U.S.G.S. maps. The analysis of the culverts under Falling Leaf assumed a 1 foot surcharge could exist upstream without flooding adjacent streets. The capacity of the junction box at the corner of Mustang and Greenbriar with two 36 inch storm drains flowing north and double 24 inch pipes feeding in from the east and double 30 inch pipes feeding in from the south was investigated.

The ditch capacity is adequate for the 5-year and 100-year flows of 217 cfs and 311 cfs respectively. However, the culvert's under Falling Leaf (based on above assumption) cannot convey the flow converging at the outfall structure. The capacity of the culverts is about 100 cfs. In order to convey the 5-year flood through the culverts four 60 inch pipes are required, or 4 more 36" culverts can be added to the 3 existing culverts.

The two 24 inch culverts at the end of Larkspur cannot handle the 5-year peak flow from drainage area #3 (35 cfs). Some of the flows from West Castlewood ditches turn the corner at Larkspur drive increasing the flooding at the low point on Larkspur.

The total flow from the drainage area south of Greenbriar is far in excess of the double 36 inch storm drains leaving the junction box at Mustang and Greenbriar. However, the junction box can handle the flows which enter it from the east and the south.

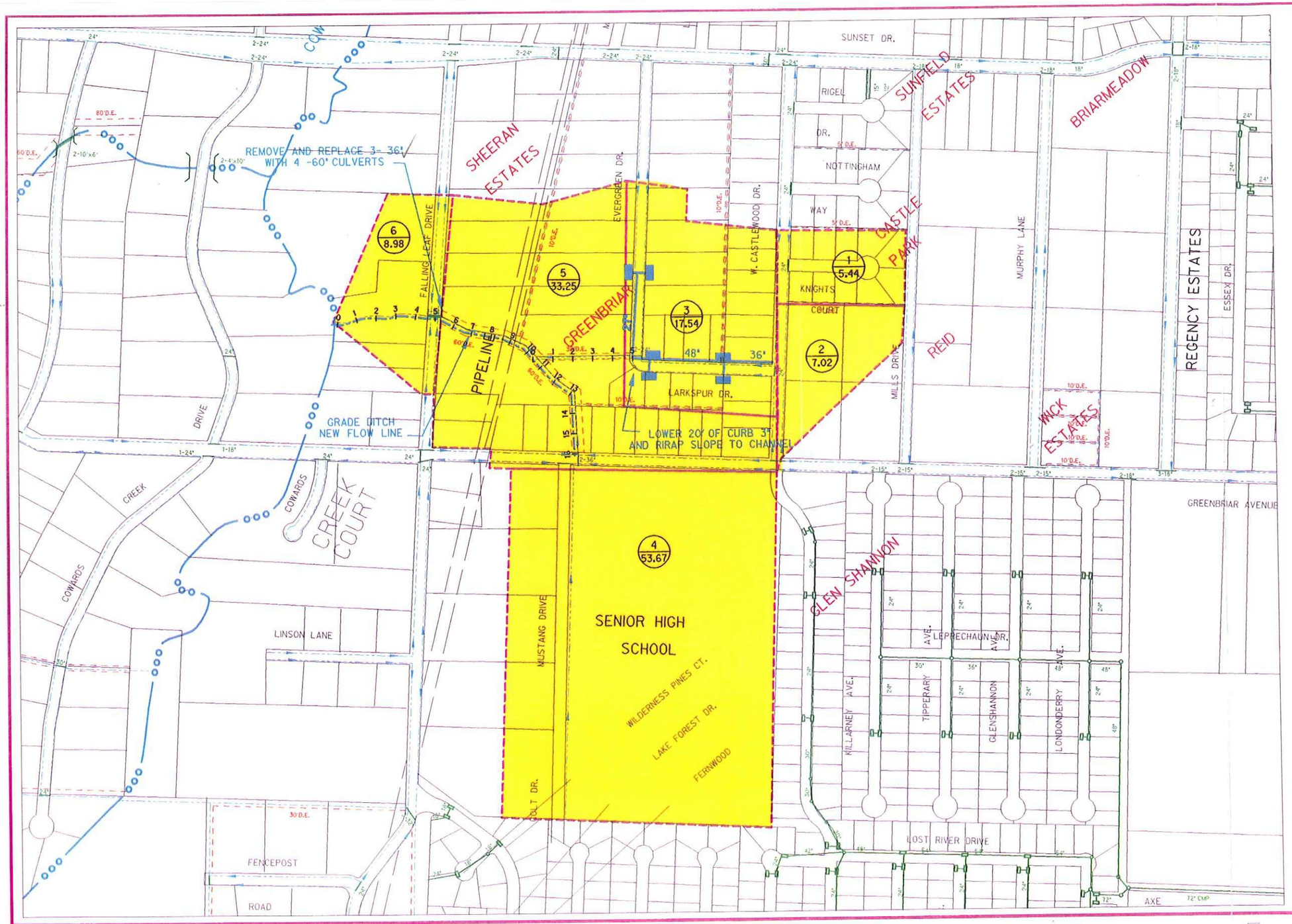
4. Proposed Solution:

a. Remove and replace three 36 inch pipes under Falling Leaf Drive with four 60 inch RCP's, lower the flow line of the ditch to allow positive drainage. (See Exhibit)

b. Install a 48 inch storm drain in Larkspur toward West Castlewood with inlets at the sag, and at the outfall of the drainage easement behind the properties facing West Castlewood. Extend a 36 inch culvert to Castlewood Drive with a headwall in the Castlewood Ditch to collect the 5-year flows from Castlewood Drive.

c. Construct a riprap overflow section from Larkspur to the ditch for flows exceeding the storm drain capacity.

d. Perform a detail drainage analysis on the High School property and adjacent neighborhood. The analysis performed for this study indicates that double 60 inch storm drain outfalls would be required to discharge the 5-year flood. Currently there is only the double 36 inch pipes crossing Greenbriar. Detail plans of the High School drainage would be necessary to size the pipes required crossing Greenbriar.



LEGEND

- 10 / 36.14 — AREA NO. / AREA (ACRES)
- EXISTING DETENTION AREA
- DETENTION AREA
- DRAINAGE DIVIDE
- 18" — EXIST. STORM DRAINAGE
- 36" — PROP. STORM DRAINAGE
- 36" — PROP. FUTURE STORM DRAINAGE
- DETENTION POND
- DRAINAGE DITCH IMPROVEMENT
- DRAINAGE DITCH NEW

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CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

OUTFALL FROM HIGH SCHOOL
PROBLEM AREA NO. 5

Friendswood Drainage Plan Cost Estimates

Problem Area Number 5 Outfall from High School	Item	Quantity	Units	Unit Cost	Cost	
	36" Reinforced Concrete Pipe	250	L.F.	57	$14,250	
	Headwall for 36"	1	Each	1100	$1,100	
	Concrete Pavement	300	S.Y.	28	$8,400	
	Grouted Rip rap	110	S.Y.	80	$8,800	
	Saw Cut	400	L.F.	8	$3,200	
	48" Reinforced Concrete Pipe	400	L.F.	80	$32,000	
	27" Reinforced Concrete Pipe	540	L.F.	45	$24,300	
	18" Reinforced Concrete Pipe	220	L.F.	34	$7,370	
	Manhole	3	Each	1200	$3,600	
	60" Culvert	200	L.F.	126	$25,200	
SubTotal:					$128,220	
	Engineering		15%		$19,233	
	Contingencies		28%		$35,902	
Total:						$183,355

#6 Greenbriar Ditch

1. Statement of Problem:

Street flooding is occurring along Greenbriar, Briarmeadow and Murphy. The ditches are shallow along Briarmedow and Murphy while the lots are about 300' deep, this generates problems draining the back of the lots along these two streets.

2. Summary of Data:

One surveyed cross section was available to determine the capacity of the Greenbriar ditches. This section was located at the corner of Greenbriar and Briarmeadow. Additional surveyed cross sections were taken on Murphy and Mills. These sections were used to determine the respective street's discharge capacity. U.S.G.S. quadrangle maps were used to determine the average slope of the street. In addition, elevations for the 10-, 50-, 100-, and 500- year flood at the Chigger Creek outfall were available from the "Regional Flood Control Plan for the Clear Creek Watershed".

3. Analysis of Existing Conditions:

The Greenbriar ditch slope estimated from U.S.G.S. Quadrangle maps is 0.0007 feet per foot. The existing ditch capacity at this slope is 40 cfs. based on the one surveyed cross section at Greenbriar and Briarmeadow. The 5-year flow to the ditch at Mills Drive is 47 cfs. By the time the flows reach Buckingham the 5-year flow has increased to 85 cfs and the 100 year flow is 120 cfs.

In order to convey the flows via ditches, both sides of Greenbriar Avenue would require 4 foot deep ditches. If the flow were confined to only the south side downstream of Briarmeadow the ditch would have to be 6 feet deep, requiring a minimum 24 foot top width.

If storm drains are installed, the sizes would range from 72 inch at the outfall to 42 inch at Mills Drive.

The ditches on Mills and Murphy were analyzed in addition to the Greenbriar Avenue ditches. These ditches can convey 10 cfs without overtopping the road. The peak flow down these roads during the 5-year flood are around 8 cfs. The 100-year flows can be as high as 29 cfs.

4. Proposed Solution:

a. Install a storm drain from Chigger Creek to Briarmeadow.

(i) One alternative is to install 1200 feet of 72 inch storm drain pipe from Chigger Creek and 600 feet of 60 inch storm sewer to Briarmeadow west along the south side of Greenbriar Avenue. West of Buckingham install 24 inch cross culverts to the north ditch every 300 feet and inlets in the south ditch at the same interval. (See Exhibit)

(ii) Another alternative would be to tie the drainage from this area to the proposed solution for Problem #7. This would require a 60 inch from Briarmeadow to Chigger Creek via Wilderness Trails to the Glenshannon subdivision outfall then parallel to the storm drain proposed in Problem #7.

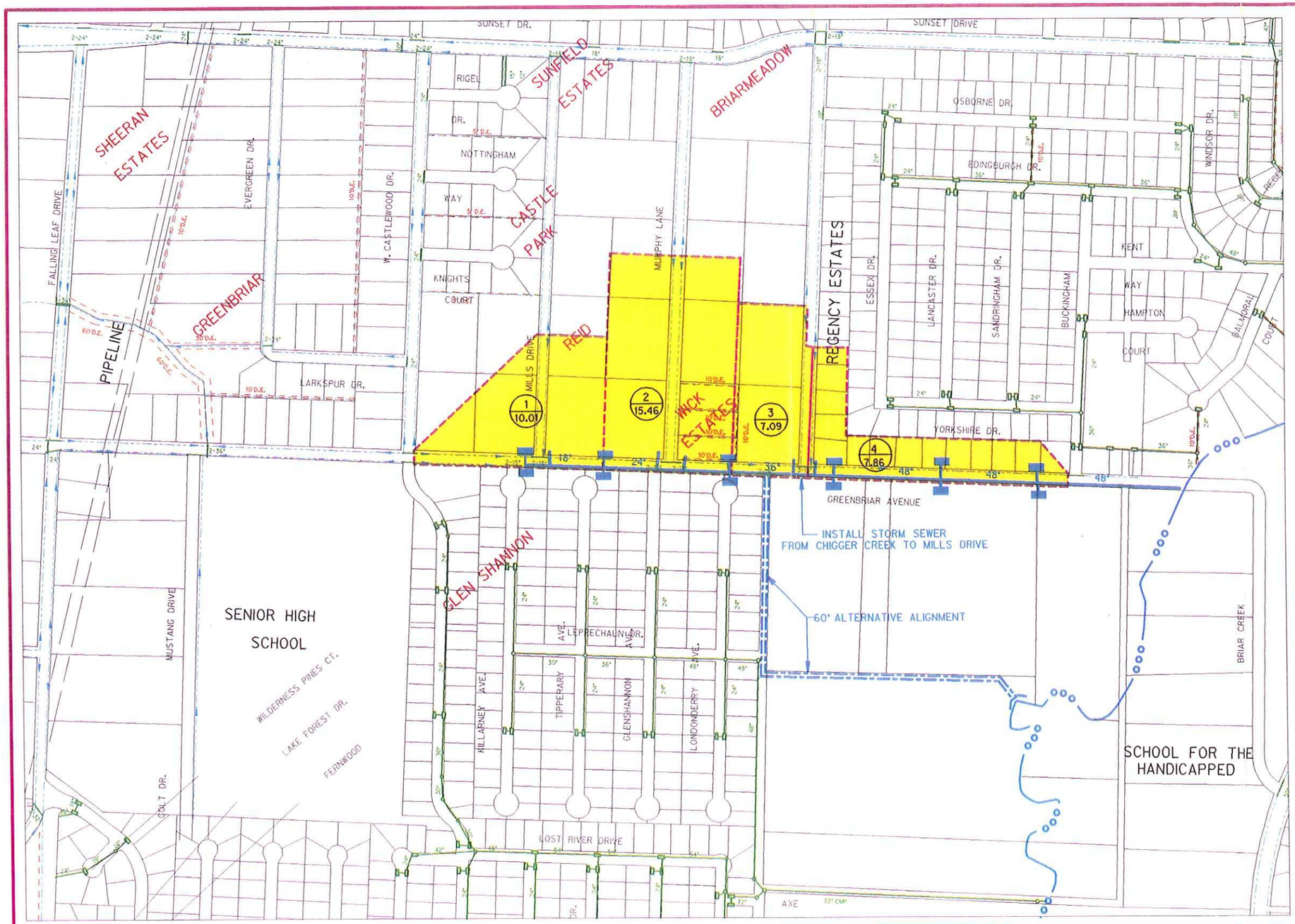
(ii) The third alternative would be to maintain the ditches and install a smaller (48 inch) storm drain along either of the two paths outlined above (i) & (ii).

b. Install double 24 inch cross connections to the north at Briarmeadow, install 1 cross connector to the north ditch at the 10 foot easement north of Londonderry, stub out to the south at Wilderness Trail West ditch.

c. Install 600 feet of 54 inch (36 inch for smaller line) storm drain west from the 60 inch. Install 24" cross connectors to the north ditch each side of Murphy Lane and install inlets in the south ditch at the same location.

d. Install 400 feet of 48 inch (24 inch for smaller line) storm drain west from the 54 inch to midway between Murphy and Mills Drive and install a 24" cross connector.

e. Install 400 feet of 42 inch (18 inch for smaller line) storm drain west from the 48 inch to Mills drive and two 18 inch cross connectors to the north at Mills drive and inlets on the south ditch at the same location.



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MASTER DRAINAGE PLAN

GREENBRIAR DITCH TO CHIGGER PROBLEM AREA NO. 6

12894 / dgn\894drn13.dgn, refs: 894area.dgn, 894tryit.dgn

Friendswood Drainage Plan Cost Estimates

Problem Area Number 6 Greenbriar ditch to Chigger Creek	Item	Quantity	Units	Unit Cost	Cost	
	72" Reinforced Concrete Pipe	1200	L.F.	150	$180,000	
	60" Reinforced Concrete Pipe	600	L.F.	126	$75,600	
	54" Reinforced Concrete Pipe	600	L.F.	112	$67,200	
	48" Reinforced Concrete Pipe	400	L.F.	80	$32,000	
	42" Reinforced Concrete Pipe	400	L.F.	70	$28,000	
	24" Reinforced Concrete Pipe	250	L.F.	39	$9,750	
	18" Reinforced Concrete Pipe	250	L.F.	34	$8,375	
	Concrete Pavement	550	S.Y.	28	$15,400	
	Saw Cut	600	L.F.	8	$4,800	
	Inlet	12	Each	1200	$14,400	
	Manhole	6	Each	2000	$12,000	
	Headwall for 24"	5	Each	767	$3,833	
	Headwall for 72"	1	Each	5000	$5,000	
SubTotal:					$456,358	
	Engineering		15%		$68,454	
	Contingencies		28%		$127,780	
Total:						$652,592

Alternate Route down Wilderness Trails to Glen Shannon
Replace 72" RCP with the Following

	60" Reinforced Concrete Pipe	2500	L.F.	126	$315,000	
	60" Reinforced Concrete Pipe	550	L.F.	126	$69,300	
	54" Reinforced Concrete Pipe	520	L.F.	112	$58,240	
	Concrete Pavement	175	S.Y.	28	$4,900	
	Saw Cut	300	L.F.	8	$2,400	
	24" Reinforced Concrete Pipe	250	L.F.	39	$9,750	
	48" Reinforced Concrete Pipe	620	L.F.	80	$49,600	
	42" Reinforced Concrete Pipe	400	L.F.	70	$28,000	
	18" Reinforced Concrete Pipe	250	L.F.	34	$8,375	
	Inlet	6	Each	1200	$7,200	
	Manhole	6	Each	2000	$12,000	
	Headwall for 24"	5	Each	767	$3,833	
	Headwall for 60"	1	Each	2600	$2,600	
SubTotal:					$571,198	
	Engineering		15%		$85,680	
	Contingencies		15%		$85,680	
*Total:						$742,558

* This improvement requires easement acquisition. Costs for easement acquisition are not reflected in this estimate. These costs should be investigated prior to budgeting for this improvement. *

Alternate with ditches to remain to carry part of the flow.

	48" Reinforced Concrete Pipe	1800	L.F.	80	$144,000	
	36" Reinforced Concrete Pipe	600	L.F.	57	$34,200	
	24" Reinforced Concrete Pipe	650	L.F.	39	$25,350	
	18" Reinforced Concrete Pipe	650	L.F.	34	$21,775	
	Concrete Pavement	550	S.Y.	28	$15,400	
	Saw Cut	600	L.F.	8	$4,800	
	Inlet	12	Each	1200	$14,400	
	Manhole	6	Each	1500	$9,000	
	Headwall for 24"	5	Each	767	$3,833	
	Headwall for 48"	1	Each	2500	$2,500	
SubTotal:					$275,258	
	Engineering		15%		$41,289	
	Contingencies		28%		$77,072	
Total:	This alternative used for the grand total					$393,619

#7 Wilderness Trails/Glen Shannon Outfall

1. Statement of Problem:

Street flooding occurs in both subdivisions particularly along Lost River Road. There is also fairly deep street flooding at the intersection of Bayou Oak and Axe. The 72" outfall which now serves these two subdivisions was originally designed for Wilderness Trails Sections I, II, & III or parts thereof. This problem is compounded by the fact that Wilderness Trail Road is a high, open ditch road that will not allow sheet flow out of the subdivisions to Chigger Creek.

2. Summary of Data:

The plans for the Wilderness Trails and Glenshannon Subdivisions were used to determine the drainage pattern and the existing storm drain capacities. The U.S.G.S. quadrangle maps were used to determine the probable outfall channel slope. In addition, elevations for the 10-, 50-, 100-, and 500- year flood at the Chigger Creek outfall were available from the "Regional Flood Control Plan for the Clear Creek Watershed".

3. Analysis of Existing Conditions:

Review of the subdivision plans revealed the following:

Wilderness Trails: The storm drain pipe system for Wilderness Trails including the 72 inch outfall pipe is adequate for this subdivision. The 5-year peak flow from the subdivision is 227 cfs and the 100-year peak flow is 395 cfs based on a 20 minute time of concentration at Wilderness Trail.

The curb elevations in the subdivision along Lost River Drive are saw-toothed around elevation 28. The lowest elevation 27 is at the entrance to the subdivision 100 feet from Wilderness Trail. The crest elevation of Wilderness Trail at the intersection of Lost River Drive is 29±. The capacity of the 72 inch pipe assuming elevation 27 at the sag is 300 cfs. Assuming that there would be some attenuation of the 100-year peak flow due to street detention this system should be adequate.

Glenshannon: The storm drain pipe system for GlenShannon is not as adequate as that for Wilderness Trails. The peak flows for the 5-year and 100-year frequency flood are 136 cfs and 245 cfs respectively. The capacity of the 48 inch pipe in Leprechaun Drive 60 cfs.

The top of curb at Leprechaun Drive and Wilderness Trail is elevation 29 (the same as Wilderness Trail at the 72 inch crossing). Flows which do not enter the storm drain system pond to elevation 29, enter the Wilderness Trail road ditch system or cross Wilderness

system pond to elevation 29, enter the Wilderness Trail road ditch system or cross Wilderness Trail. Little or no flooding occurs in this area, however, the pipe flows from this subdivision flow into the 72 inch pipe for the Wilderness Trails Subdivision. The 72 inch line cannot handle the both subdivision flows. In addition the ditch will fill to elevation 29 during the 5-year flood and flow back toward Lost River Drive.

4. Proposed Solution

a. Install a 72 inch RCP with headwall from the west side of Wilderness Trail at GlenShannon Subdivision to Chigger Creek along the back of the property's facing Greenbriar Avenue. Install ditch headwall and modify ditch to accommodate the 72 inch line. Tie existing 48 inch line to the 72 inch RCP.

b. When and if Wilderness Trail is changed to curb and gutter install parallel line in GlenShannon, add inlets at street intersections, tie parallel line to 72 inch and block off headwall. This will allow the existing sheet flow along Leprechaun to Wilderness Trail's ditch to enter the storm drain before it reaches Wilderness Trail road.

SENIOR HIGH SCHOOL

SCHOOL FOR THE HANDICAPPED

GLEN SHANNON

WILDERNESS TRAILS

1 — 54.89
2 — 14.82
3 — 12.13
4 — 15.17
5 — 35.18
6 — 27.23

YORKSHIRE DR.
GREENBRIAR AVENUE
MUSTANG DRIVE
WILDERNESS PINES CT.
LAKE FOREST DR.
FERNWOOD
COLT DR.
BEECHWOOD DR.
BLUEBERRY LN.
BUTTONWOOD DR.
PINE NEEDLE DR.
DETENTION POND
MEADOWS
RILLARNEY AVE.
LEPRECHAUN DR.
TIPPERARY AVE.
GLENSHANNON AVE.
LONDONDERRY AVE.
LOST RIVER DRIVE
CAMBRIDGE DR.
CASTLEWOOD DR.
PINEY WOODS DR.
OAK HOLLOW DR.
FRONTIER LANE
BAYOU OAK DR.
INDIAN SPRING
HIDDEN FORREST
SPRING CREEK
TRAIL
72"
AXE
72" CMP
OX
CREEK
F.M. 528
BRIAR CREEK
INSTALL STORM DRAIN FROM CHIGGER CREEK TO GLENSHANNON SUBDIVISION

LEGEND

- 10 / 36.14 — AREA NO. / AREA (ACRES)
- EXISTING DETENTION AREA
- DETENTION AREA
- DRAINAGE DIVIDE
- 18" — EXIST. STORM DRAINAGE
- 36' — PROP. STORM DRAINAGE
- 36' — PROP. FUTURE STORM DRAINAGE
- DETENTION POND
- DRAINAGE DITCH IMPROVEMENT
- DRAINAGE DITCH NEW

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0 125 250 500
SCALE IN FEET

CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

WILDERNESS TRAILS GLENSHANNON OUT FALL PROBLEM AREA NO. 7

Friendswood Drainage Plan Cost Estimates

Problem Area Number 7 Wilderness Trails / Glenshannon outfall	Item	Quantity	Units	Unit Cost	Cost	
	72" Reinforced Concrete Pipe	2600	L.F.	150	$390,000	
	Headwall for 72"	2	Each	5000	$10,000	
	Junction Box	1	Each	5000	$5,000	
	Concrete Pavement	100	S.Y.	28	$2,800	
	Saw Cut	100	L.F.	8	$800	
SubTotal:					$405,000	
	Engineering		15%		$60,750	
	Contingencies		28%		$113,400	
*Total:						$579,150

* This improvement requires easement acquisition. Costs for easement acquisition are not reflected in this estimate. These costs should be investigated prior to budgeting for this improvement. *

#8 Falcon Ridge Section 1 Outfall

1. Statement of Problem:

Street flooding occurs along Falcon Ridge Blvd. west of pipeline easement. This flooding is especially deep at the intersection of Falcon Ridge Blvd. and White Wing Circle. Elevation of street crossing the pipeline easement is high relative to the intersection and prevents sheet flow down the street to the creek.

2. Summary of Data:

The subdivision plans for Falcon Ridge were available. These plans were used to determining street grades and elevations, existing storm sewer capacities and bypass flow elevations. The U.S.G.S. quadrangle maps were used to determine approximate outfall channel slopes.

3. Analysis of Existing Conditions:

Street detention is part of the plan for this subdivision; therefore designing for 5-year or 100-year flood protection with out detention in the streets is not necessary. However, due to the elevation of Falcon Ridge Blvd east of White Wing Circle where it crosses the gas company's pipeline easement, flooding has occurred at excessive depths making them incapable of handling emergency equipment.

The existing drainage system will discharge 60 cfs to the outfall ditch. Currently the streets flood to depths in excess of 2 feet increasing the peak flow from 60 to 90 cfs. The 5-year peak flow is 110 cfs and the peak 100-year flow is 160 cfs.

A parallel storm sewer system would have to convey an additional 60 cfs for the 5-year peak flow. The 100-year flood would pond to the depths that 5-year flood ponds to today after a parallel system was installed.

4. Proposed Solution:

An alternative to installing a parallel system would be to create an overflow path to the creek other than Falcon Ridge Blvd. Currently an open space exists at the south east corner of White Wing Circle. This open space is adjacent to a utility right-of-way along the south property line of the subdivision. The top of curb elevation at this open area is 27 based on the subdivision plans. The adjacent ground elevation based on the existing grades from plans is about 28±.

The overflow elevation at the gutter along Falcon Ridge Blvd toward the east is elevation 28. This is 2 feet above the lowest sag inlet in the subdivision, and

approximately the same as the ground elevation at the open area on White Wing Circle.

The lowest elevation in the subdivision is 26 located west of the intersection of White Wing Circle and Falcon Ridge Blvd north of the park. In order to keep flood levels at or below 1 foot in depth in the streets, an overflow elevation between 26.5 and 26.7 is necessary. The total flow which would have to bypass through the overflow would be 50 cfs during a 5-year flood and 100 cfs during a 100-year flood.

In order to maintain a maximum elevation of 26.8 ponding in the subdivision a 100-foot long weir at elevation 26 is required. An alternative plan would be to increase the weir length to 243 feet with the weir elevation at 26.4.

A two foot deep swale is required to convey the 100-year discharge of 100 cfs for a distance of 1100 ft at an approximate slope of .0025 ft / ft.

In summary, the proposed solution is as follows: (See Exhibit)

a. Remove the curb at southeast corner of White Wing Circle for a length of 243 feet. Install ballards to keep pedestrians and cars from entering the proposed swale.

b. Construct a grass lined swale from the southwest corner of White Wing Circle southeast to the utility easement line. The swale would continue down the easement line to a tributary of Chigger Creek. This swale should have a minimum depth of 2.5 feet, a 5 foot bottom width with 5:1 side slopes for ease of maintenance on a minimum slope of 0.0025 ft/ft slope.

GREENBRIAR AVENUE

SCHOOL FOR THE HANDICAPPED

BRIAR CREEK

FOX MEADOWS

DET. POND

LAYFAIR PLACE

KEYSTONE DR.

KEYSTONE MEADOWS

BRILL DRIVE

MIDDLECREEK ST.

EAGLE LAKES SEC.4

DOVE CT.

BLUE QUAIL DR.

OSPREY CT.

EAGLE LAKES DR.

ROBIN HILL DR.

TWIN OAKS ST.

FALCON RIDGE BLVD.

WHITE WING CIRCLE

FALCON RIDGE

1 3.05

2 10.28

3 9.49

4 2.71

5 4.41

6 4.64

7 4.55

CLOUD CROFT DR.

REMOVE 100' OF CURB

1100' OF SWALE TO CHIGGER CREEK TRIB 0.001 FEET/FOOT

DRAINAGE DISTRICT

F.M. 528

CREEK

AXE

72" CMP

1 / 5

2.5'

TYPICAL SWALE SECTION

LEGEND

- 10 / 36.14 — AREA NO. / AREA (ACRES)
- EXISTING DETENTION AREA
- DETENTION AREA
- DRAINAGE DIVIDE
- 18" — EXIST. STORM DRAINAGE
- 36" — PROP. STORM DRAINAGE
- 36" — PROP. FUTURE STORM DRAINAGE
- DETENTION POND
- DRAINAGE DITCH IMPROVEMENT
- DRAINAGE DITCH NEW

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SCALE IN FEET

CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

FALCON RIDGE I OUTFALL
PROBLEM AREA NO. 8

Friendswood Drainage Plan Cost Estimates

Problem Area Number 8 Falcon Ridge I outfall	Item	Quantity	Units	Unit Cost	Cost	
Overflow Swale:						
	Earth Excavation	3704	C.Y.	5	$18,519	
	Guard Posts	35	Each	50	$1,750	
	Grouted Rip rap	550	S.Y.	80	$44,000	
	Pipe Handrail Set In Concrete	250	L.F.	25	$6,250	
	Remove 6" curb	243	L.F.	10	$2,430	
SubTotal:					$72,949	
	Engineering		15%		$10,942	
	Contingencies		28%		$20,426	
*Total:						$104,316

* This improvement requires easement acquisition. Costs for easement acquisition are not reflected in this estimate. These costs should be investigated prior to budgeting for this improvement. *

#9 Mission Estates Outfall

1. Statement of Problem:

The large ditch is the detention system for Mission Estates, Somerset, and San Joaquin. Street flooding occurs especially in Mission Estates Section III. At the outfall, the ditch is restricted with berm and culverts.

2. Summary of Data:

The subdivision plans for Somerset and Mission Estates were available. These plans were used to determine inlet capacities, pipe capacities, ponding depths in the streets, and the capacity of the detention ditch. U.S.G.S. quad maps were available to determine approximate elevations in adjoining areas.

3. Analysis of Existing Conditions

Since the detention facility within the subdivision is affected by upstream inflows from Carmel Village (Problem area number 10) the analysis of the drainage ditch as a whole must consider all of these areas. The analysis was performed using the Corps of Engineers' HEC-1 computer program to test the effects of the detention volumes.

The Mission Estates ditch also conveys the flood waters from the Southern San Joaquin subdivision. The existing ditch can only convey the 5-year discharge at bank full capacity. This is primarily due to two (2) problems. The first problem is the restricted outfall constructed as part of the development. The three (3) 54 inch rcp's have an estimated 1 foot of coverage based on a visual inspection. This causes the flood waters for a 5-year discharge to be at or near the top of bank. The berm at the triple 54 inch restriction structure is overtopped during a 5-year flood.

Another reason for the high water elevations currently experienced in the subdivision is the access road located about 50 feet downstream from the restriction structure. This road has triple 60 inch pipes conveying flow toward the north. However, the top of the road is about 3 feet above the pipes based on field visual inspection. The 60 inch pipes have more capacity than the upstream 54 inch pipes, yet the road is still overtopped during the 5-year flood. This increases flooding upstream to even higher elevations.

All storm drain pipes and ditches from the subdivision have been designed for the 5-year flood. Emergency overflow provisions for larger floods are not shown on the plans. In order for the 100-year flood elevations not to exceed 1 foot in depth overflow swales from Mission Street to the ditch are necessary to convey the excess (approximate 850 cfs) above the 5-year discharge.

4. Proposed Solution:

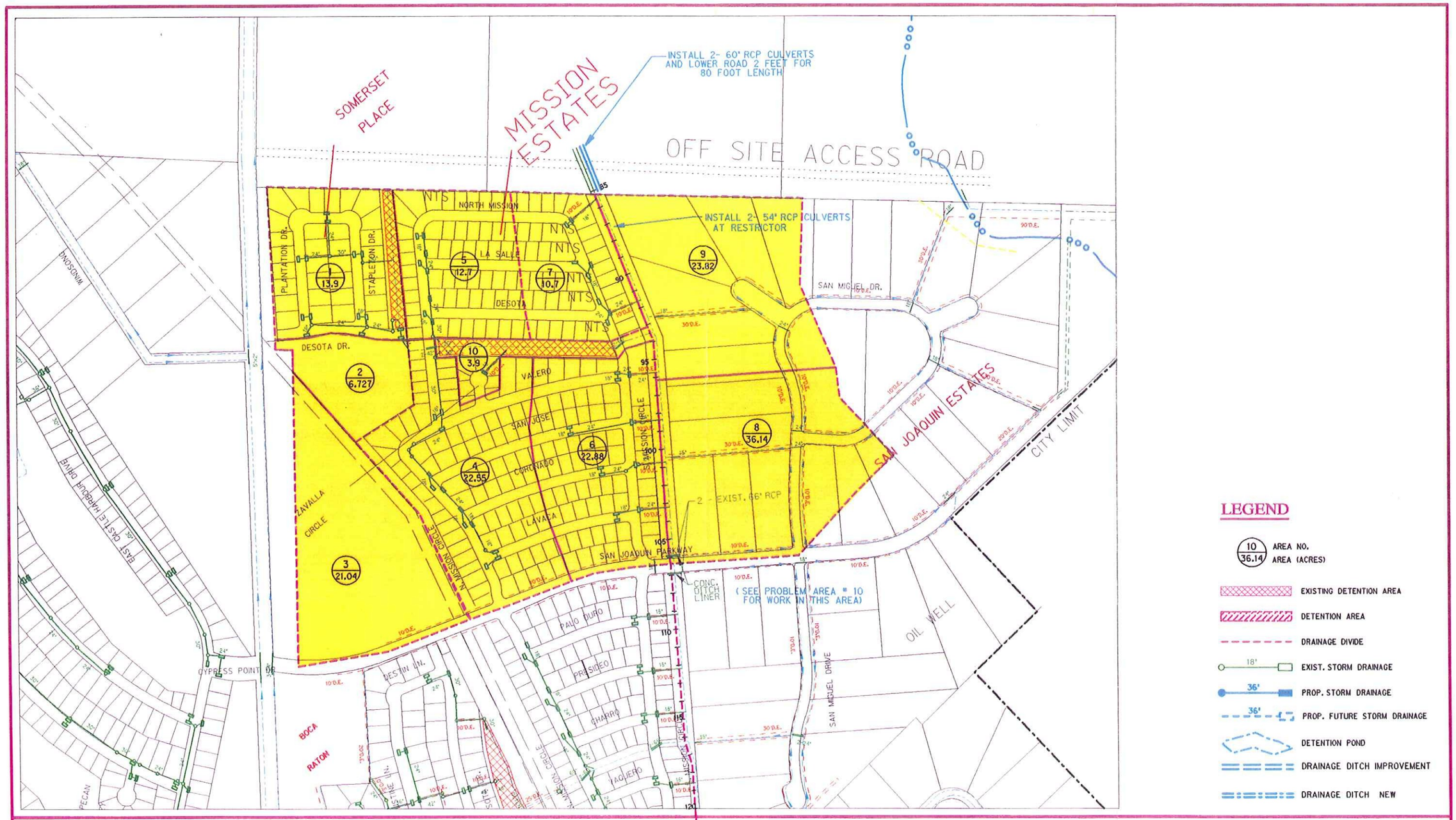
a. Improve conveyance through the off site access road downstream from the 54 inch constriction structure.

i) span the creek with a bridge with the low beam at least 8 feet above the flow line. or

ii) Install additional 60 inch culverts through the road and lower the top of road by 2 feet. Additional structural work may be necessary to support the truck loads traveling this roadway.

b. Install one additional 54 inch culvert through the restriction berm resulting in a 1.5 foot freeboard during the 5-year flood and the ability to accommodate larger floods

c. Insure adequate outfall ditches to convey the difference between the 5-year flow in the pipes and the 100-year flow through the streets allowing a maximum 1 foot depth of flooding in the streets.



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SCALE IN FEET

CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

MISSION ESTATES OUTFALL
PROBLEM AREA NO. 9

12894 / dgn=894drn9.dgn, ref= 894area.dgn, 894fry11.dgn

Friendswood Drainage Plan Cost Estimates

Problem Area Number 9 Mission Estates Outfall	Item	Quantity	Units	Unit Cost	Cost	
	60" Culvert	100	L.F.	126	$12,600	
	Gravel Road Surface	533	S.Y.	30	$16,000	
	Gravel Road Base	533	S.Y	8	$4,267	
	54" Culvert	100	L.F.	112	$11,200	
	Earth Excavation	593	C.Y.	5	$2,963	
SubTotal:					$47,030	
	Engineering		15%		$7,054	
	Contingencies		28%		$13,168	
Total:						$67,252

#10 Carmel Village Outfall

1. Statement of Problem:

Street flooding is experienced throughout subdivision. Elevation of San Joaquin Parkway is high relative to streets in subdivision and has inadequate cross structures causing high water in the streets.

2. Summary of Data:

Subdivision plans for Boca Raton, San Joaquin Estates and Carmel Village were available. These plans were used to analyze the existing storm drain and detention facilities. (See also Problem Number 9)

3. Analysis of Existing Conditions:

Detention in the ditch flowing into Mission Estates was analyzed in conjunction with problem number 9 since any improvements in one affects the analysis in the other.

The detention ditch flowing south to north into the Mission Estates ditch can currently convey only the 5-year discharges developed in the local drainage area. This is partly due to the outfall constrictions noted in Problem # 9, but is also due to the culvert's at San Joaquin Parkway.

The San Joaquin Parkway top of road is near elevation 34 while most of the streets in the subdivisions south of the Parkway have street elevations between 31 and 33. Therefore any flow required to overtop San Joaquin Parkway will flood the streets and possibly some buildings in the southern subdivision.

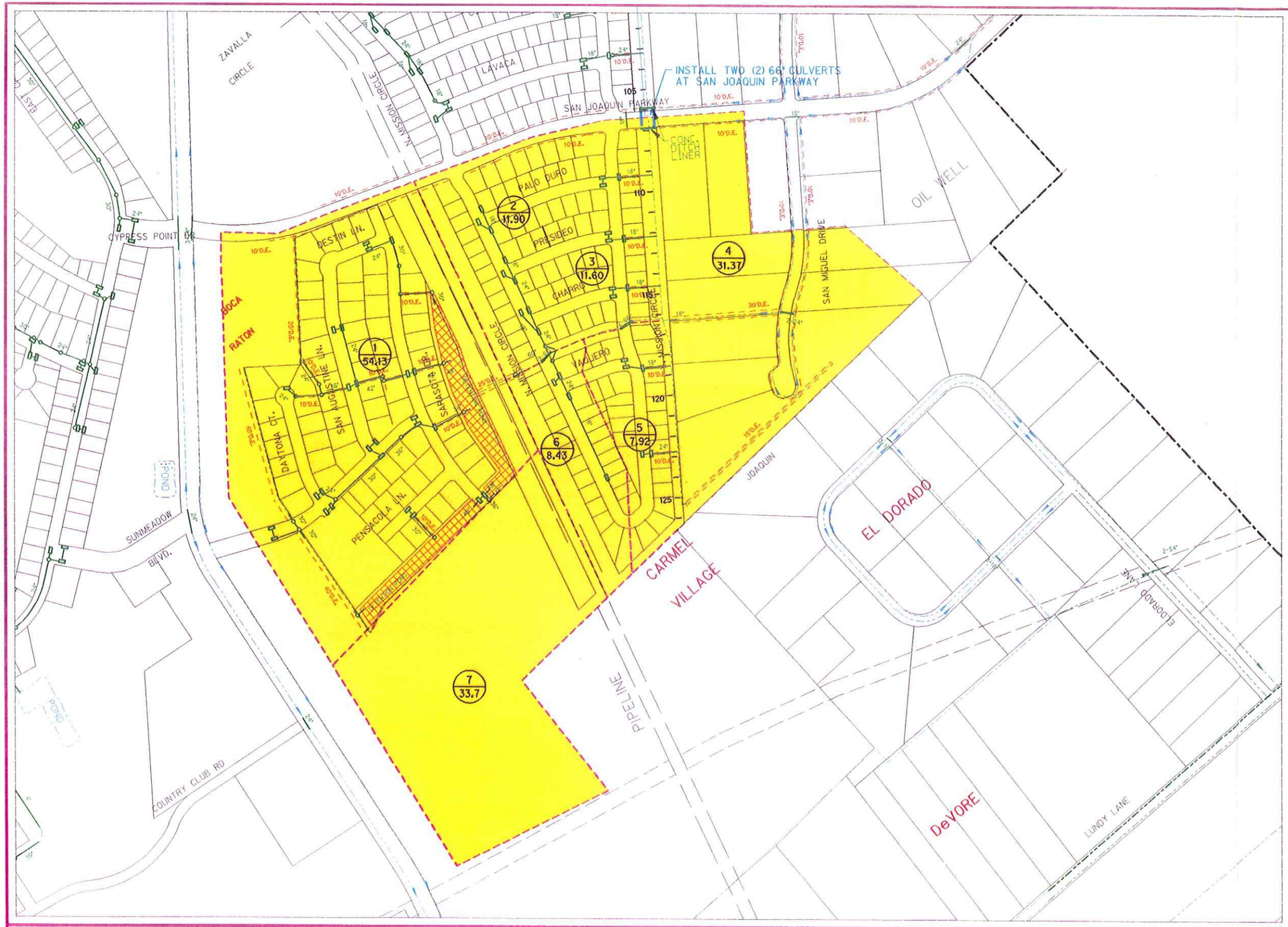
The 5-year flood runoff from the subdivision currently fills the ditch so that larger floods have to pond in the streets. Based on the subdivision plans, there are no safe emergency overflow paths from South Mission Street into the detention ditch.

4. Proposed Solution:

a. See Problem # 9's solution (outfall modification).

b. Install Two (2) additional 66 inch RCP culverts under San Joaquin Parkway

c. Purchase at least 2 lots between South Mission and the Ditch at sag locations and install overflow ditches capable of conveying the 100-year flow to the ditch without flooding the streets to a depth greater than 1 foot.



LEGEND

- 10 / 36.14 — AREA NO. / AREA (ACRES)
- EXISTING DETENTION AREA
- DETENTION AREA
- DRAINAGE DIVIDE
- 18" EXIST. STORM DRAINAGE
- 36" PROP. STORM DRAINAGE
- 36" PROP. FUTURE STORM DRAINAGE
- DETENTION POND
- DRAINAGE DITCH IMPROVEMENT
- DRAINAGE DITCH NEW

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CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

CARMEL VILLAGE OUTFALL AT SAN JOAQUIN PARKWAY PROBLEM AREA NO. 10

Friendswood Drainage Plan Cost Estimates

Problem Area Number 10 Carmel Village outfall	Item	Quantity	Units	Unit Cost	Cost	
	Headwall for 66"	4	Each	2350	$9,400	
	66" Culvert	2	Each	27750	$55,500	
SubTotal:					$64,900	
	Engineering		15%		$9,735	
	Contingencies		28%		$18,172	
Total:						$92,807

#11 Sunmeadow's Main Outfall

1. Statement of Problem:

The 72" outfall experiences high tailwater conditions which limit its capacity during high intensity rainfalls. When the storm sewer reaches capacity the water sheet flows along Castle Harbor to Sun Court and Doral Court. Even though these streets are on the uphill end of the storm sewer, they are the lowest points in the subdivision. The system appears to have been designed for less than a three year storm event.

2. Summary of Data:

Plans for SunMeadow Phase I subdivision and for the recently installed relief storm sewer flowing north from the subdivision were available. These plans were used to determine elevations, grades, and existing pipe capacities. In addition, elevations for the 10-, 50-, 100-, and 500- year flood at the Chigger Creek outfall were available from the "Regional Flood Control Plan for the Clear Creek Watershed".

3. Analysis of Existing Conditions:

Measured floor elevations along Sun Court are at elevation 33.1 based on relief storm sewer plans in city files (1992). The Sun Court top of curb from the subdivision plans (not dated) is around elevation 34 whereas the city's relief storm sewer plans indicate elevation 31±. The elevation of Windsong to the north is 34±. The difference in elevations is either due to different benchmark datum's or the street may have been constructed lower than proposed on the subdivision plan's. The elevation of Castle Harbor Drive at the outfall based on subdivision plans is around 35±. The average hydraulic grade available in the existing drainage system from the 72 inch outfall to Sun Court is 0.0007 ft / ft. Any slope greater than this will cause ponding in the streets.

Except for the outfall (elevation 35±) or at Windsong to the north (34±) there are no emergency overflow for this subdivision. At either of these elevations East Castle Harbor Drive would be flooded and impassible.

Chigger Creek water surface elevations at the outfall based on the "Regional Flood Control Plan for the Clear Creek Watershed" for the 10,50,100,and 500-year floods are 30.17±, 30.18±, 30.19±, 32.5±. The flow line of Chigger Creek shown in the flood study at the outfall is 21±, whereas the flow line shown in the subdivision plans is 23.5±. Assuming that this difference is due to the datum differences and not due to channel improvements the subdivision would flood from Chigger Creek backwater through the storm sewer.

The pipe system in SunMeadow was analyzed at 4 points.

Point A:	36 inch Storm Drain from East Castle Harbor Drive	
	5-year peak flow:	66 cfs
	100-year peak flow:	95 cfs
	Pipe Capacity at .0007 ft/ft	18 cfs
Point B:	54 inch Storm Drain between Gleneagles Drive and Old Course Drive	
	5-year peak flow:	110 cfs
	100-year peak flow:	160 cfs
	Pipe Capacity at .0007 ft / ft	51 cfs
Point C:	66 inch Storm Drain from GlenEagles Drive to Castle Drive	
	5-year peak flow:	200 cfs
	100-year peak flow:	300 cfs
	Pipe Capacity at 0.0007 ft / ft	90 cfs
Point D:	72 inch Storm Drain major Outfall	
	5-year peak flow:	280 cfs
	100-year peak flow:	455 cfs
	Peak Capacity at 0.0007 ft / ft	120 cfs

The existing outfall storm drain was designed based on the assumption that the street grades would be above elevation 35±. Had this elevation been maintained the average hydraulic slope would have been 0.001 and the pipe capacity's would be about 50 percent greater than shown above. However, for the pipe system to be adequate to handle the five year flood, the capacity of the system needs to be doubled.

An option to doubling the existing system capacity is to utilize the vacant golf course area for storm water detention. In order to reduce the peak flows to the outfall without flooding the adjacent areas, 61 acre feet of detention is required. In addition overflow points from the street would be necessary to convey the flows to the detention pond(s) since the existing pipe capacities are inadequate for this purpose.

4. Proposed Solution:

a. Purchase a drainage easement within the golf course area (approximately 7 acres). Excavate 61 acre feet for a detention pond below elevation 31. Total estimated excavation assuming ground elevation at 34± is 82 acre feet. (See Exhibit)

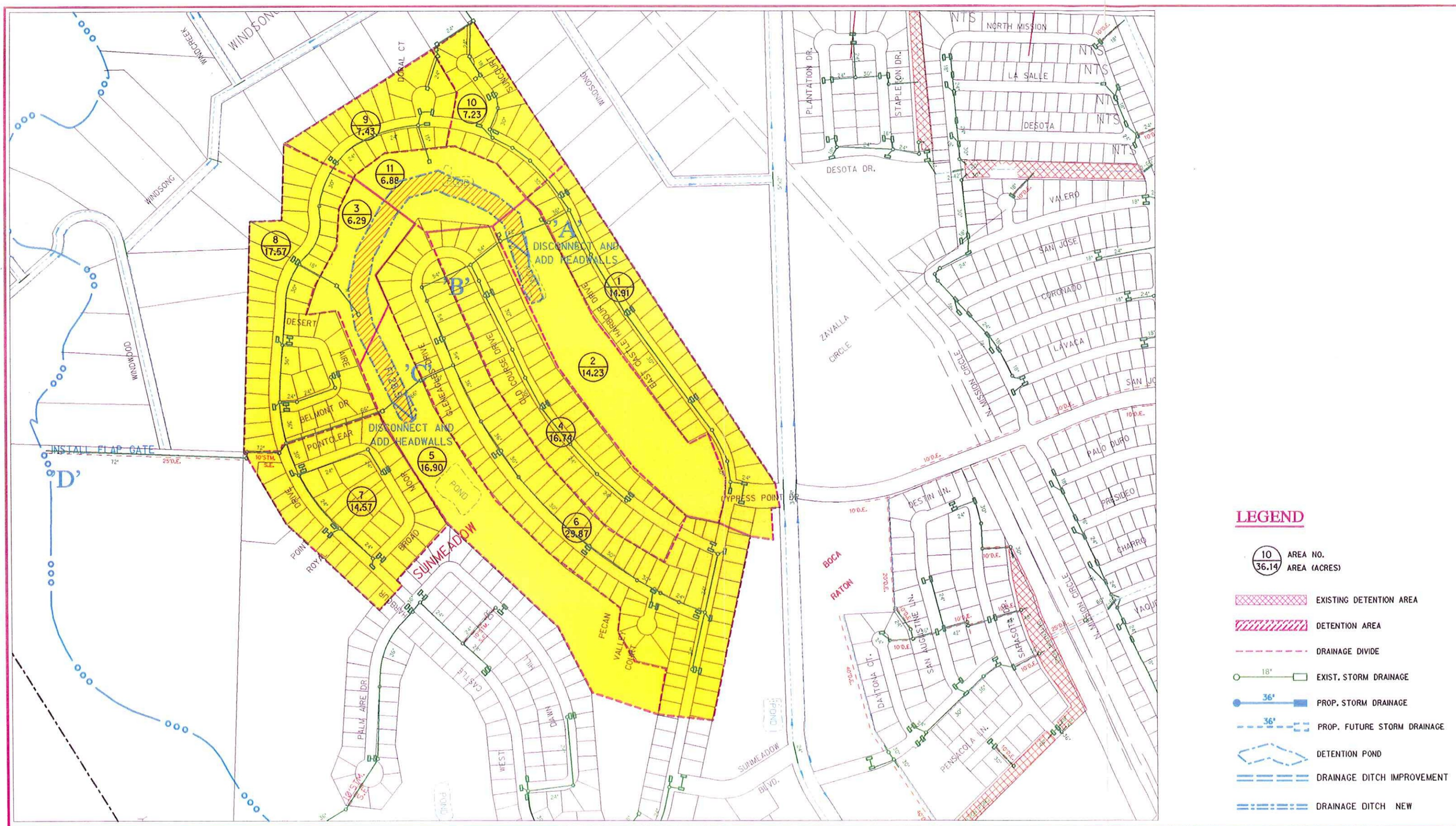
b. Disconnect existing pipes at detention pond crossing(s), and install headwalls at each outfall.

c. Construct concrete overflow swales from East Castle Harbor Drive to the open area. Average overflow width is 10 feet.

d. Install a flap gate at end of 72 inch outfall so that Chigger Creek flows will not back up into the local detention facility.

e. Connect the relief storm sewer which flows north to the detention pond.

f. Evaluate the "Regional Flood Control Plan for the Clear Creek Watershed" for improvements to Chigger Creek to reduce flooding in this subdivision.



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SCALE IN FEET

CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

SUNMEADOW MAJOR OUTFALL
PROBLEM AREA NO. 11

Friendswood Drainage Plan Cost Estimates

Problem Area Number 11 Sunmeadow's main outfall	Item	Quantity	Units	Unit Cost	Cost	
	Headwall for 42"	2	Each	2000	$4,000	
	Headwall for 66"	2	Each	4000	$8,000	
	72" FlapGate	1	Each	13000	$13,000	
	Earth Excavation	98500	C.Y.	5	$492,500	
SubTotal:					$517,500	
	Engineering		15%		$77,625	
	Contingencies		15%		$77,625	
*Total:						$672,750

* This improvement requires easement acquisition. Costs for easement acquisition are not reflected in this estimate. These costs should be investigated prior to budgeting for this improvement. *

#12 Sunmeadow's Relief Outfall

1. Statement of Problem:

Street flooding occurs throughout subdivision (see Problem #11). A 36" outlet has recently been installed to Windsong ditch. The attempt was to provide an overflow with the largest single pipe size feasible considering depth requirements, etc.

2. Summary of Data:

The relief storm sewer plans prepared by the City of Friendswood were available. These plans were used to determine the capacity of the existing system and overflow elevations along the storm drain alignment. In addition, elevations for the 10-, 50-, 100-, and 500- year flood at the Chigger Creek outfall were available from the "Regional Flood Control Plan for the Clear Creek Watershed".

3. Analysis of Existing Conditions:

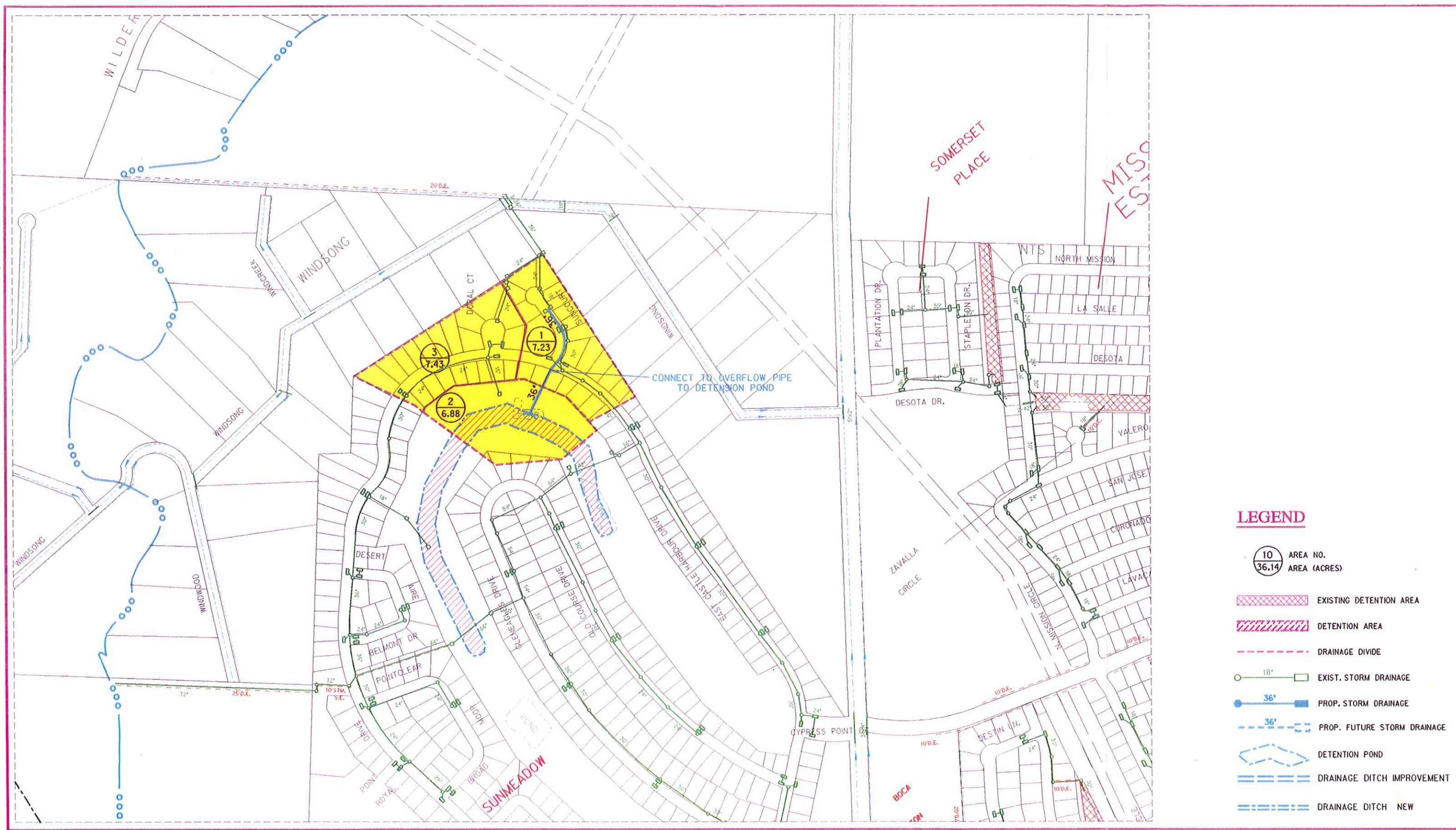
The Sunmeadow Subdivision was analyzed as a whole as described in the discussion of Problem 11. The relief storm drain was constructed to relieve the excessive ponding which was occurring in Doral Court, due to the insufficient capacity of the subdivision's storm drains. This relief storm sewer is currently restricted at the outfall northeast of Windsong. The capacity of the storm drain at the outfall, when the constrictors are removed, will be 30 cfs.

The 10, 50, 100, and 500 year flood water surface elevations at Chigger Creek from the "Regional Flood Control Plan for the Clear Creek Watershed" at the end of the ditch into which the relief storm sewer flows are 27±, 28±, 28.6±, and 30± respectively. These elevations are 2 - 6 feet lower than the corresponding elevations at the main outfall of the Sunmeadow subdivision.

There is no acceptable emergency overflow path from the subdivision at this time. Floods in excess of the 5-year flood cannot escape either along the existing main outfall alignment nor along the relief storm drain's alignment. Windsong is at elevation 33.9 which is above the finish floors at Doral. The ground elevation above the main outfall, shown in the subdivision plans, is 35.

4. Proposed Solution:

a. Connect the existing relief storm drain to the proposed detention facility (See problem area 11)



LEGEND

- (10) 36.14 — AREA NO. / AREA (ACRES)
- EXISTING DETENTION AREA
- DETENTION AREA
- DRAINAGE DIVIDE
- 18" — EXIST. STORM DRAINAGE
- 36" — PROP. STORM DRAINAGE
- 36" — PROP. FUTURE STORM DRAINAGE
- DETENTION POND
- DRAINAGE DITCH IMPROVEMENT
- DRAINAGE DITCH NEW

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CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

SUNMEADOW NORTH OUTFALL
PROBLEM AREA NO. 12

Friendswood Drainage Plan Cost Estimates

Problem Area Number 12 Sunmeadow relief storm sewer	Item	Quantity	Units	Unit Cost	Cost	
	Headwall for 36"	1	Each	2000	$2,000	
	36" Reinforced Concrete Pipe	650	L.F.	57	$37,050	
	Manhole	1	Each	1200	$1,200	
SubTotal:					$40,250	
	Engineering		15%		$6,038	
	Contingencies		28%		$11,270	
*Total:						$57,558

* This improvement requires easement acquisition. Costs for easement acquisition are not reflected in this estimate. These costs should be investigated prior to budgeting for this improvement. *

#13 Garden Drive Ditch at W. Spreading Oaks

1. Statement of Problem:

Street flooding along Garden Drive and W. Shadowbend. Coward's Creek tributary which drains this area is shallow, silted-in and cannot be maintained due to lack of right-of-way.

2. Summary of Data:

School expansion plans detailing the detention pond were available. These were used to evaluate the detention upstream of this area. Where access was allowed cross sections of the drainage ditch between W. Edgewood Drive and Coward's Creek were surveyed. Typical surveyed roadside ditch cross sections were used for determining ditch capacities. In addition, elevations for the 10-, 50-, 100-, and 500- year flood at the Coward's Creek outfall were available from the "Regional Flood Control Plan for the Clear Creek Watershed". Spot elevations from the Elementary School's plans were available for determining the ditch capacity along W. Edgewood Drive.

3. Analysis of Existing Conditions:

The complete watershed was modeled using the Corps of Engineer's HEC-1 computer model to account for the detention at the Elementary School. Storm runoff from the residential area north of the school flows via the W. Edgewood ditches to the outfall of the school's detention facility. The school runoff also drains to these ditches. A 42 inch pipe is currently planned to pick up the ditch flows at this point and convey the flow east of Spreading Oaks to the Coward's Creek tributary draining this area.

The tributary of Coward's Creek which drains this area presently flows behind the south property line of the residential lots facing Garden Drive. The flows entering this ditch from W. Edgewood are from Stadium Lane and Brigadoon through a double 5' x 3' box culvert.

The storm runoff which currently drains into the ditch on the east side of W. Edgewood Drive flows via the ditches along Garden Drive to W. Shadow Bend. These flows coupled with the local runoff are greater than the ditches can convey.

4. Proposed Solution:

a. Improve the swales along W. Shadow Bend from Sedora Drive to the tributary draining this area (See Exhibit).

b. Install a 48" culvert across Garden Drive on the west side of Shadow Bend to convey the ditch flow across the road.

DRAINAGE SWALE TO SHADOW BEND

1 / 19.56

2 / 19.56

3 / 13.9

4 / 27.86

48" CULVERT UNDER GARDEN

IMPROVE DITCH

107 cfs

223 cfs

275 cfs

EXIST. 42"

JUNIOR HIGH

ELEMENTARY SCHOOL

KINGS PARK

DETENTION POND

FRIENDSWOOD GARDENS

BRADLEY MEADOWS

BROOKE MEADOWS

PERRY GROVE

LIBERTY ESTATES

LORI WOODS

CHAPPEL HILL

IMPERIAL GARDENS

SUNSET MEADOWS

SHEERAN ESTATES

CREEK

CEDARWOOD AVE.

CEDARWOOD DR.

WOODLAWN DR.

DAVID ST.

SUNSET DRIVE

STADIUM LANE

PRAIRE WILD

FOXEL ST.

GARDEN DR.

SEDORA DR

W. SPREADING OAKS

COWARDS

FORREST VIEW

LESLIE LN.

CHESTER DRIVE

W. EDGEWOOD DRIVE

LEGEND

- 10 / 36.14 — AREA NO. / AREA (ACRES)
- EXISTING DETENTION AREA
- DETENTION AREA
- DRAINAGE DIVIDE
- 18" — EXIST. STORM DRAINAGE
- 48" — PROP. STORM DRAINAGE
- 48" — PROP. FUTURE STORM DRAINAGE
- DETENTION POND
- DRAINAGE DITCH IMPROVEMENT
- DRAINAGE DITCH NEW

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CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

GARDEN DRIVE DITCH
AT W. SPREADING OAKS
PROBLEM AREA NO. 13

Friendswood Drainage Plan Cost Estimates

Problem Area Number 13 Garden Drive at Spreading Oaks	Item	Quantity	Units	Unit Cost	Cost	
	Ditch Cleaning	600	L.F.	4	$2,400	
	48" Reinforced Concrete Pipe	100	L.F.	75	$7,500	
	Earth Excavation	963	C.Y.	5	$4,815	
SubTotal:					$14,715	
	Engineering		15%		$2,207	
	Contingencies		28%		$4,120	
Total:						$21,042

#15 Block bounded by FM 528, FM 518, Winding Way, and Leisure Lane

1. Statement of Problem:

Street flooding along Winding Way and Leisure Lane. This drainage area is currently drained by systems in F.M. 518 and F.M.528 and minor roadside ditches along Winding Way and Leisure Lane. Only typical frontage along F.M. 518 and F.M. 528 was accounted for in these systems. Currently this block is mostly undeveloped but future dense commercial development is anticipated.

2. Summary of Data:

The proposed highway plans for the sound barrier wall from Leisure Lane to Cowards Creek were available. These plans showed the proposed storm drain pipe from Leisure Lane to the creek. U.S.G.S. quad maps were available to determine approximate elevations.

3. Analysis of Existing Conditions:

Peak discharge from the developed and undeveloped area enclosed by Highway 518, Parkwood Avenue, Leisure Lane and Winding Way is 38 cfs and 75 cfs for the 5-year and 100-year frequency floods respectively. There is currently little development except for one commercial property on the west side of the lot and the north east corner's residential development on 1 acre lots. The commercial development currently drains via storm sewer to the center of the block then along an ill defined swale to the west side of the block discharging into the ditch on the east side of leisure lane. The residential lots drain east to the same ditch in shallow swales adjacent to their property line.

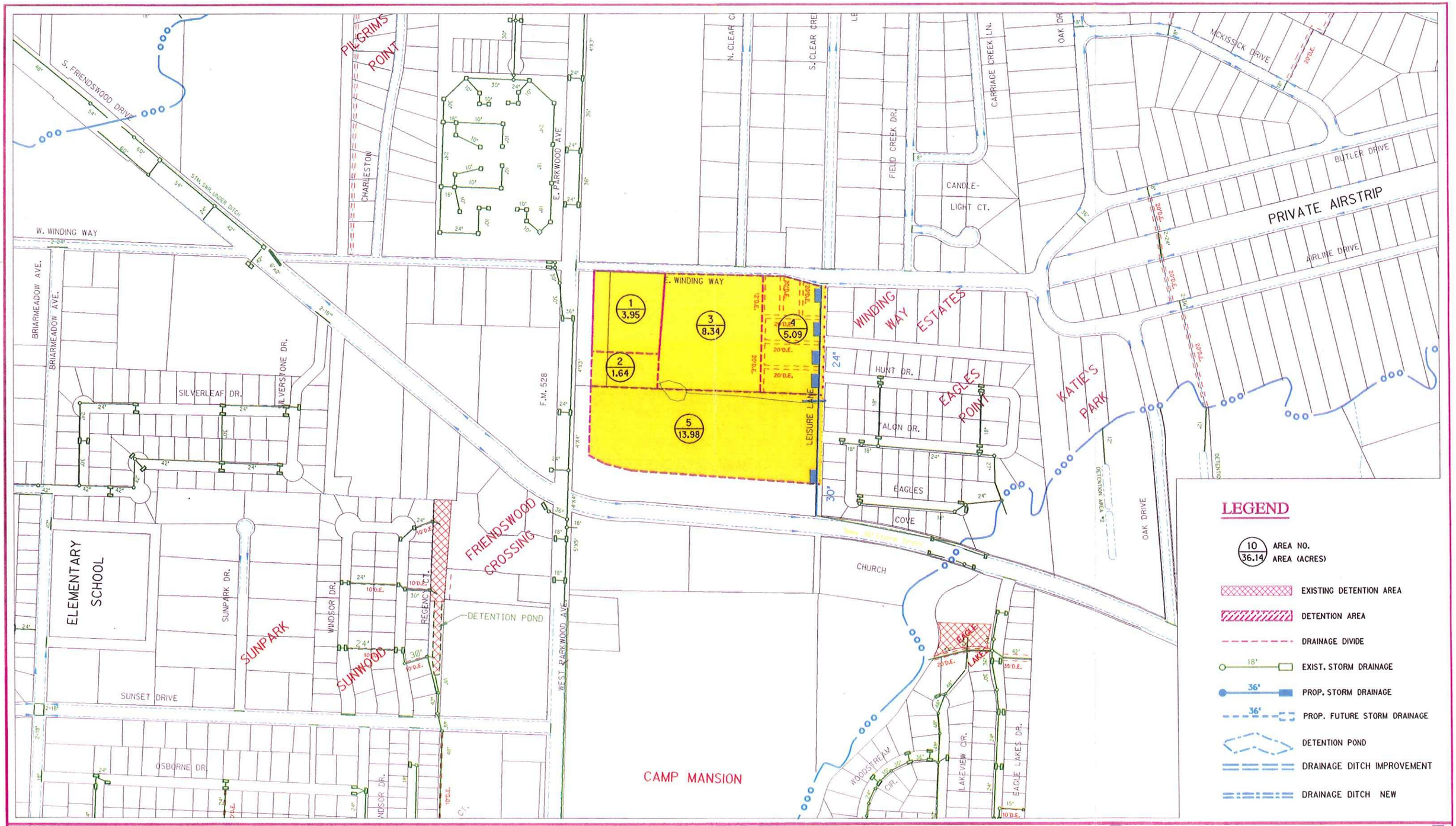
The ditch along Leisure Lane can currently carry 10 - 20 cfs on the east side (visual estimate no measurements). At Highway 518 there is a 29" x 45" elliptical RCP culvert under Leisure Lane. The TXDOT has recently installed a 36 inch storm drain from Chigger Creek to Leisure Lane. This pipe has a capacity of 65 cfs. Above this pipe is a concrete "V" ditch at a slope of 0.25 percent. The flowline of the ditch is about 4 feet from the pavement, however only 1 to 2 feet below the properties to the north. This ditch capacity is 10 cfs for 1 foot depth and 50 cfs at a two (2) foot depth.

The 100-year water surface elevation in Chigger Creek at 518 is 15.83 based on backwater effects from Clear Creek. The elevation at the intersection of Leisure Lane and Highway 518 (from U.S.G.S. Quad sheets) is 25.

4. Proposed Solution:

a. Extend the Highway storm drain to Winding Way via Leisure Lane and install inlets and ditch headwall to pick up ditch flows. (See Exhibit) or

b. Improve ditches along Leisure Lane, and as the vacant areas develop include detention to maintain existing flows.



LEGEND

- 10 / 36.14 — AREA NO. / AREA (ACRES)
- EXISTING DETENTION AREA
- DETENTION AREA
- DRAINAGE DIVIDE
- 18' EXIST. STORM DRAINAGE
- 36' PROP. STORM DRAINAGE
- 36' PROP. FUTURE STORM DRAINAGE
- DETENTION POND
- DRAINAGE DITCH IMPROVEMENT
- DRAINAGE DITCH NEW

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CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

BLOCK BOUNDED BY F.M.258,
F.M. 518, WINDING WAY, & LEISURE LANE
PROBLEM AREA NO. 15

Friendswood Drainage Plan Cost Estimates

Problem Area Number 15 block bounded by 4 streets	Item	Quantity	Units	Unit Cost	Cost	
	30" Reinforced Concrete Pipe	650	L.F.	51	$33,150	
	24" Reinforced Concrete Pipe	750	L.F.	39	$29,250	
	Inlet	5	Each	1200	$6,000	
	Manhole	3	Each	1200	$3,600	
	Junction Box	1	Each	2500	$2,500	
	18" Reinforced Concrete Pipe	100	L.F.	34	$3,350	
SubTotal:					$77,850	
	Engineering		15%		$11,678	
	Contingencies		28%		$21,798	
Total:						$111,326

#16 Melody Lane

1. Statement of Problem:

Melody Lane drainage system consists of varying depth ditches with uneven slopes. Roadside ditches along Melody drain from the Pearland City Limits 7,000' +/- to F.M. 2351. An intermediate outfall to Mary's Creek is needed before the development of small subdivisions along either side of Melody Lane.

2. Summary of Data:

The U.S.G.S. quad maps were used to determine the general slope of the terrain.

3. Analysis of Existing Conditions:

Currently Melody Lane ditches collect runoff primarily from the north side of the street west of the Dunbar Estates Subdivision. Some of the area on the south side of Melody also contributes to the flows of the ditches.

The area north of Melody Lane is currently undeveloped. The overland flow path from the north is approximately 300 feet. The length of road west of and including the Dunbar Estates Subdivision draining toward the east is about 3650 feet. The total flow from this area, based on above computations is 26.4 cfs (5-year flow) and 51.1 cfs (100-year flow).

The length of road east of the Dunbar Estates Subdivision draining currently toward the east is about 2640 feet. The total flow from this area 19.1 cfs (5- year flow) on the north side and another 19.1 cfs on the south side totalling 38.2 cfs for the 5-year flood. The total for the 100-year flood for this area is 74 cfs.

The slope of Melody Lane (from U.S.G.S. Quad Maps) is approximately 0.0003 ft/ft. The ditches along Melody Lane average 1 to 2 feet in depth but are not at a consistent slope. Some places the ditches have been filled in and the streets entering Dunbar Estates have either 18 inch culverts or 24 inch culverts. The existing ditch capacity is approximately 10 to 20 cfs based on visual inspection, no survey information was available, before street flooding occurs.

The total flow toward the east along Melody Lane for the 5-year flood is 64.6 cfs, and the total flow for the 100-year flood is 112.1 cfs.

In order to convey the 5-year storm runoff using ditches laid on 0.0003 ft/ft (approximate slope for Melody Lane) 'V' ditches with 3:1 sideslopes would have to be 3.5

feet deep with a top width of 21 feet. To convey the 100-year flow the ditches would have to be 4 feet deep with a top width of 24 feet.

To convey the 5-year flows via pipe would require a 60" rcp at the outfall with sizes ranging to 18 inches near the west county boundary line. However, the 100-year flow would still flood the street if the existing ditches are not enlarged.

One alternative is to shorten the distance which the flows have to travel at the slope dictated by the layout of Melody lane. A drainage easement along the east property line of Dunbar Estates could be designed to pick up all flows from the west and even some of the flow from the east. The shorter distance to the creek increases the carrying capacity for a given size ditch above that of one's laid the full length of Melody Lane.

A 'V' ditch with a depth of 3.5 feet at a slope of 0.004 ft/ft with grassed side slopes could convey 120 cfs. The top width would be 21 feet. The drainage easement minimum would be 25 feet. A smaller ditch could be provided assuming that some of the roadside ditches still drained to the west. Eighty (80) cfs could be conveyed through an 18 foot top width ditch at the prescribed slope requiring a 20 foot drainage easement.

Culverts under Melody Lane would have to convey flows from the north side ditch to the south. These culverts would have to convey about 40 cfs assuming that some of the flows would still drain east to F.M. 2351. (dbl 24 rcp)

The Ditches along the Melody Lane would have to be improved to convey the flows to the culvert and to this new drainage easement. One-half of the drainage area east of Dunbar Estates (36.95 cfs 100-yr or 19.1 cfs 5-year flood) could still be conveyed east to the highway inlets.

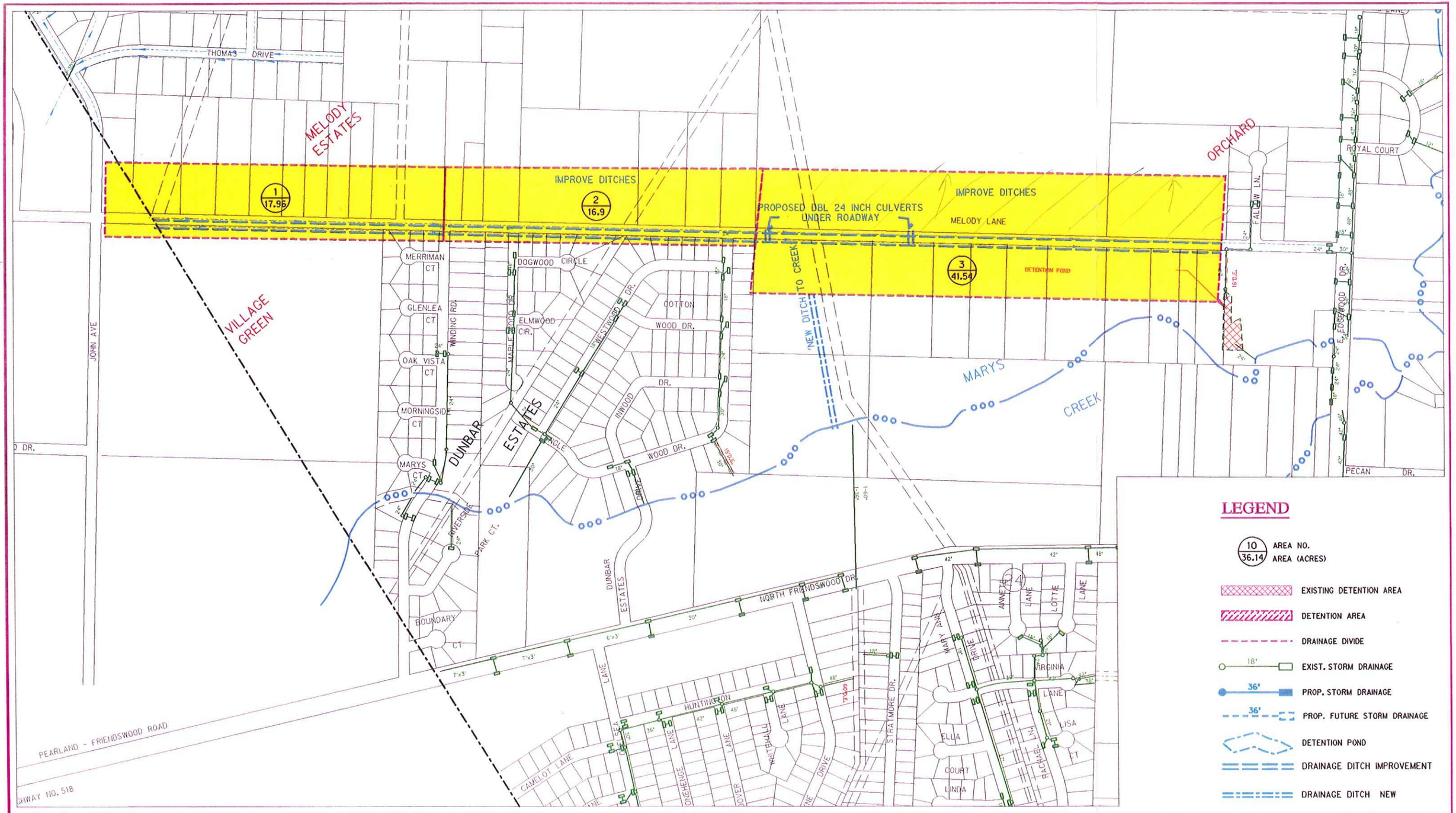
4. Proposed Solution:

a. Acquire a 30 foot drainage easement from Melody Lane to Mary's Creek east of the Dunbar Estates subdivision. Construct a 4 ft deep ditch in the easement at a slope of 0.004 ft/ft. with 3:1 side slopes. (See Exhibit)

b. Install two (2) double 24 inch culverts under Melody Lane east of Dunbar Estates at an equal distant from the proposed swale. (item a)

c. Improve the ditches on both sides of Melody Lane to have a consistent slope toward the double 24" culverts (item b).

d. As development occurs encourage detention to maintain the existing low flows from the area. As a last resort the drainage easement could be used for installing a large storm drainage system as development causes the peak flows to exceed the ditch capacity.



LEGEND

- (10 / 36.14) AREA NO. / AREA (ACRES)
- EXISTING DETENTION AREA
- DETENTION AREA
- DRAINAGE DIVIDE
- EXIST. STORM DRAINAGE
- PROP. STORM DRAINAGE
- PROP. FUTURE STORM DRAINAGE
- DETENTION POND
- DRAINAGE DITCH IMPROVEMENT
- DRAINAGE DITCH NEW

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CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

MELODY LANE
PROBLEM AREA NO 16

Friendswood Drainage Plan Cost Estimates

Problem Area Number 16 Melody Lane	Item	Quantity	Units	Unit Cost	Cost	
	24" Culvert	200	L.F.	39	$7,800	
	Saw Cut	200	L.F.	8	$1,600	
	Concrete Pavement	225	S.Y.	28	$6,300	
	Ditch Cleaning	6000	L.F.	4	$24,000	
	Earth Excavation	1630	C.Y.	5	$8,148	
SubTotal:					$47,848	
	Engineering		15%		$7,177	
	Contingencies		28%		$13,397	
*Total:						$68,423

* This improvement requires easement acquisition. Costs for easement acquisition are not reflected in this estimate. These costs should be investigated prior to budgeting for this improvement. *

#17 F.M. 518 Outfall at Mary's Creek

1. Statement of Problem:

F.M. 518 floods during high intensity rains.

2. Summary of Data:

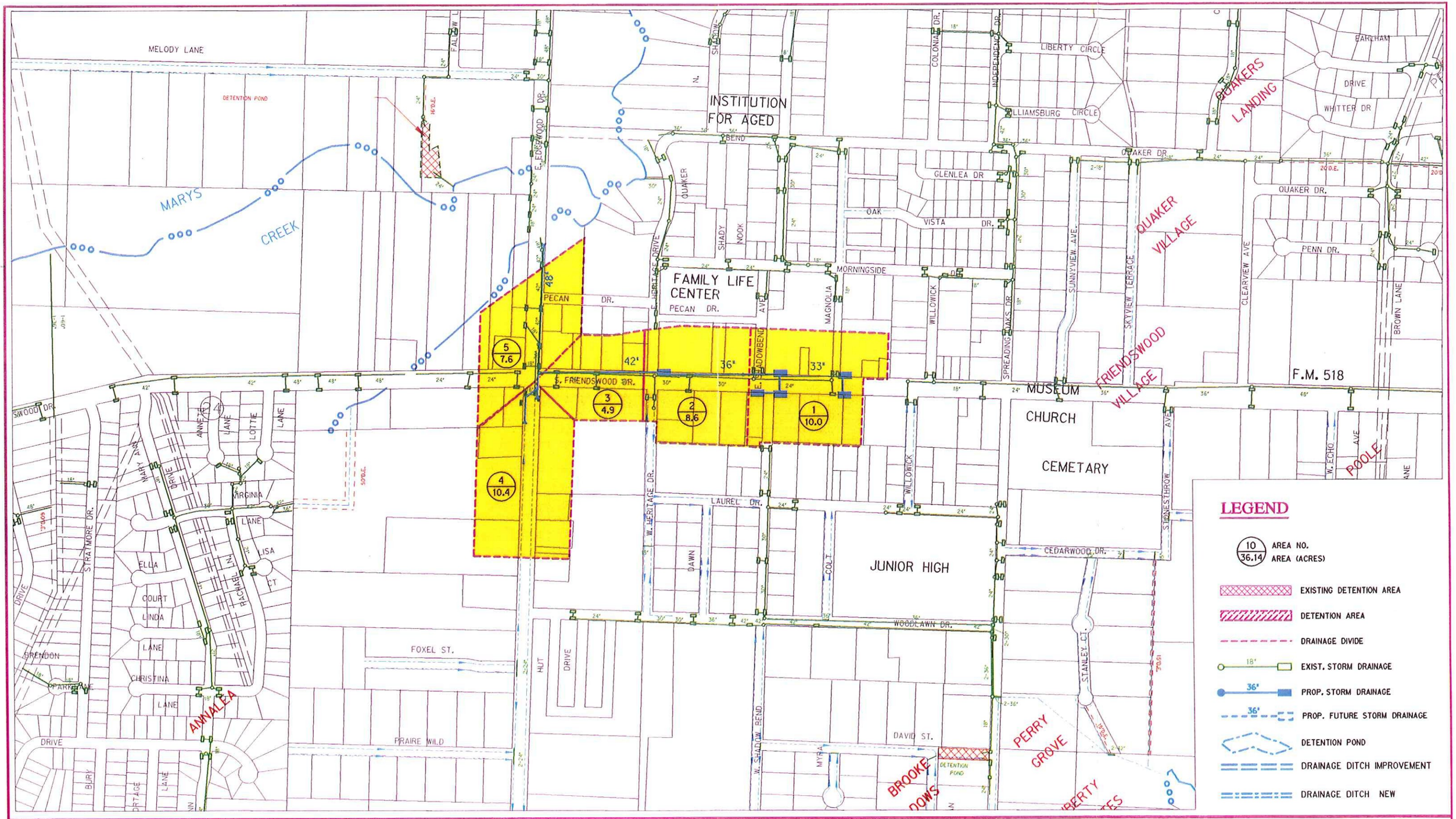
Paving and Drainage plans for FM 518 (S. Friendswood Drive) were available. These plans included drainage for FM 2351 (Edgewood Drive) between FM 518 and the tributary of Mary's Creek that is the system outfall. In addition, elevations for the 10-, 50, 100-, and 500- year flood at the Mary's Creek outfall were available from the "Regional Flood Control Plan for the Clear Creek Watershed".

3. Analysis of Existing Conditions:

This part of Friendswood is commercial/industrial, characterized by high imperviousness, with associated high rates of storm runoff. Based on a review of the TxDoT FM 518 drainage plans, the existing drainage system for this area is inadequate to convey the 5-year flood. Main trunk storm sewer capacity varies from approximately 30 percent of desired 5-year flood near the S. Friendswood/Shadowbend intersection to 60 percent of desired 5-year flood on Edgewood west of S. Friendswood. Storm water must pond to a depth of almost 1 foot before overflowing down Edgewood to the Mary's Creek tributary outfall. Detention sites are not available.

4. Proposed Solution:

The solution proposed for this problem area consist of constructing a parallel relief storm along Edgewood and South Friendswood. (See Exhibit) The proposed relief consists of a 48" RCP along Edgewood from the Mary's Creek tributary outfall to South Friendswood Drive. Continuing south on S. Friendswood, the proposed system would consist of 42" to 33 inch RCP. Along Edgewood west of S. Friendswood, the system would be sized as a 27" to 24" RCP. Six new inlets will be added to the system and 10 existing inlets will be disconnected from the existing storm sewer and connected to the new parallel system. Two headwalls will be constructed along Edgewood west of S. Friendswood to pick up ditch flows. Final alignments, inlet locations and facility sizes should be established in the detailed design phase (not a part of this study).



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CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

F.M. 518 WILLOWWICK
TO MARY'S CREEK OUTFALL
PROBLEM AREA NO. 17

Friendswood Drainage Plan Cost Estimates

Problem Area Number 17 F.M. 518 to Mary's Creek	Item	Quantity	Units	Unit Cost	Cost	
	24" Reinforced Concrete Pipe	300	L.F.	39	$11,700	
	27" Reinforced Concrete Pipe	150	L.F.	45	$6,750	
	48" Reinforced Concrete Pipe	700	L.F.	80	$56,000	
	42" Reinforced Concrete Pipe	650	L.F.	70	$45,500	
	36" Reinforced Concrete Pipe	650	L.F.	57	$37,050	
	Box Culvert Concrete	300	C.Y.	450	$135,000	
	18" Reinforced Concrete Pipe	150	L.F.	34	$5,025	
	Inlet	6	Each	1750	$10,500	
	Manhole	7	Each	1200	$8,400	
	Headwall for 24"	1	Each	767	$767	
	36" Culvert	1	Each	14250	$14,250	
	Saw Cut	5800	L.F.	8	$46,400	
	Concrete Pavement	6444	S.Y.	28	$180,444	
	Headwall for 48"	1	Each	1600	$1,600	
SubTotal:					$559,386	
	Engineering		15%		$83,908	
	Contingencies		15%		$83,908	
Total:						$727,202

#18 F.M. 518 Outfall at Coward's Creek

1. Statement of Problem:

F.M. 518 floods during high intensity rains especially near Spreading Oaks intersection.

2. Summary of Data:

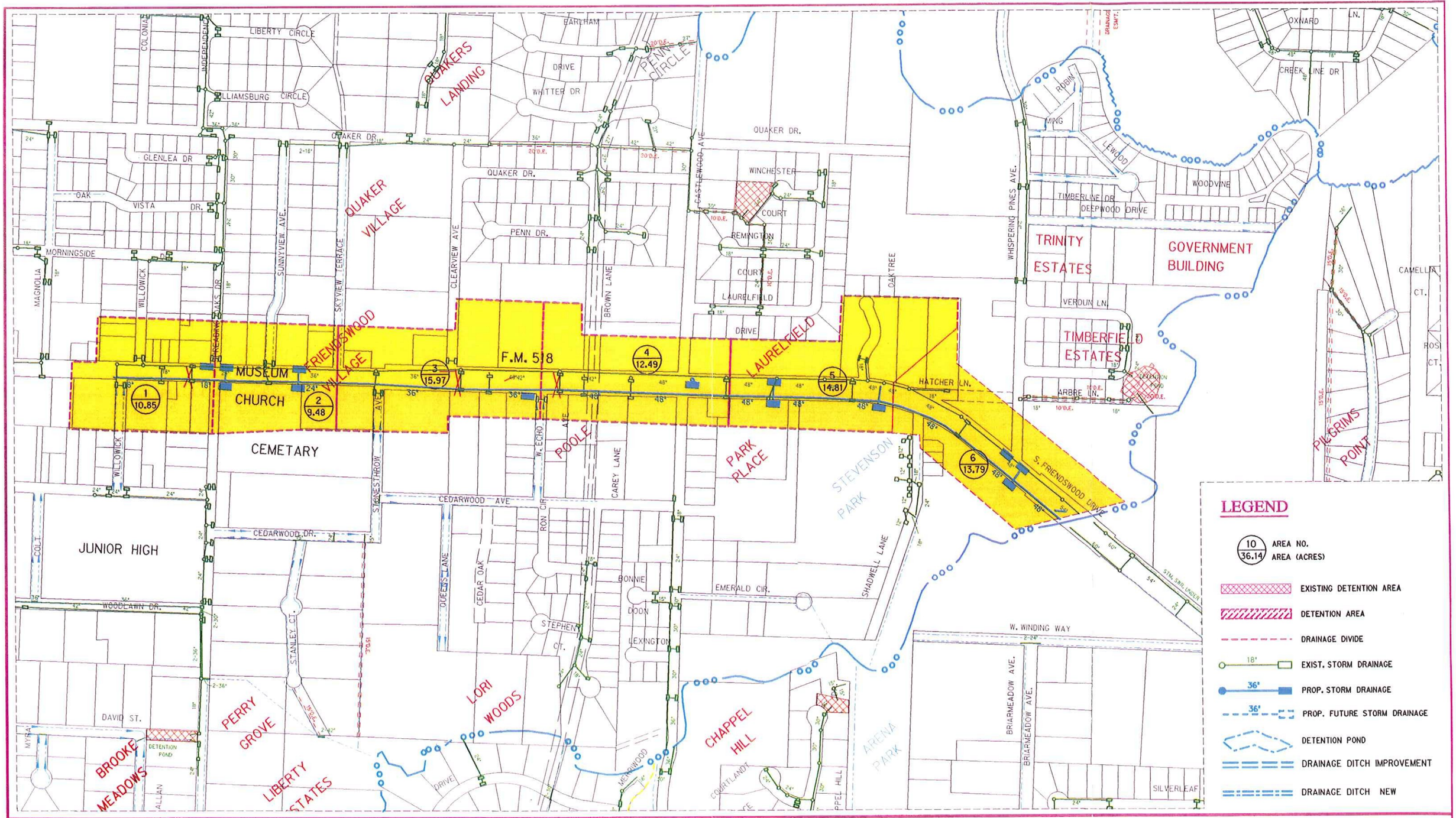
Paving and Drainage plans for FM 518 (S. Friendswood Drive) were available. These plans included drainage for FM 518 between Willowick and Coward's Creek which is the system outfall. In addition, elevations for the 10-, 50-, 100-, and 500- year flood at the Coward's Creek outfall were available from the "Regional Flood Control Plan for the Clear Creek Watershed".

3. Analysis of Existing Conditions:

This part of Friendswood is primarily commercial/industrial, characterized by high imperviousness, with associated high rates of storm runoff. Based on a review of the TxDoT FM 518 drainage plans, the existing drainage system for this area is inadequate to convey the 5-year flood. Main trunk storm sewer capacity varies from approximately 40 to 50 percent of desired 5-year flood flows. Detention sites are not available. Street grades are inadequate to handle the excess flows of a 100 year event.

4. Proposed Solution:

The solution proposed for this problem area consists of constructing a parallel relief storm sewer line along the southwest edge of F.M. 518. (See Exhibit) The proposed relief consists of an 18" RCP at the beginning (F.M. 518 and Willowick) and increases in increments to a 48" RCP at the outfall to Coward's Creek. The system would require approximately 270 linear feet of 18" RCP, 555 L.F. of 24" RCP, 642 L.F. of 30" RCP, 897 L.F. of 36" RCP, 3086 L.F. of 48" RCP. Thirteen new inlets will be added to the system. In the event that the current storm water drainage system is upgraded to handle a 5-year event, the street grades (F.M. 518) are inadequate to handle the excess flows of a 100-yr event. Flows in excess of a 5-year event will pond in the street and overflow into side streets (Stonesthrow and Castlewood are affected the most) intersecting F.M. 518. There is not enough information presently to analyze this flow to side streets in any detail. Flows east of Castlewood will flow east along the highway right-of-way to Coward's creek. Final alignments, inlet locations and facility sizes should be established in the detailed design phase (not a part of this study).



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CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

F.M. 518 WILLOWICK TO
COWARDS CREEK OUTFALL
PROBLEM AREA NO. 18

Friendswood Drainage Plan Cost Estimates

Problem Area Number 18 FM 518 to Cowards Creek	Item	Quantity	Units	Unit Cost	Cost	
	Inlet	13	Each	1200	$15,600	
	18" Reinforced Concrete Pipe	270	L.F.	34	$9,180	
	24" Reinforced Concrete Pipe	555	L.F.	39	$21,645	
	30" Reinforced Concrete Pipe	642	L.F.	51	$32,742	
	36" Reinforced Concrete Pipe	897	L.F.	57	$51,129	
	48" Reinforced Concrete Pipe	3860	L.F.	80	$308,800	
	Saw Cut	11908	L.F.	5	$59,540	
	Concrete Pavement	2646	S.Y.	28	$74,094	
SubTotal:					$572,730	
	Engineering		15%		$85,910	
	Contingencies		15%		$85,910	
Total:						$744,549

#19 Analea Outfall

1. Statement of Problem:

Street flooding occurs throughout subdivision. Flooding is especially deep at the intersection of Virginia and Rachael.

2. Summary of Data:

The Analea subdivision plans were available for determining street grades, pipe capacities, and overflow elevations. Ditch cross sections between FM 518 and Virginia were available to determine any backwater effects.

3. Analysis of Existing Conditions:

The capacity of the original 42 inch storm sewer outfall from the subdivision at the cul-de-sac at Virginia, assuming free outfall is 50 cfs. The addition of the 36 inch RCP and the inlet at the end of the cul-de-sac increases the total outfall to 70 cfs. The 5-year rainfall runoff from the subdivision is 122 cfs. The 100-year rainfall runoff is 170 cfs.

Flows which cannot enter the storm sewer system will pond at the intersection of Mary Anne Drive and Virginia Lane for a depth of about 1 foot before flowing toward the Virginia cul-de-sac at the east boundary. Ponding which occurs at the cul-de-sac will force water back toward Lottie Lane and thence to the highway. From plans the top of curb at the cul-de-sac at the Virginia outfall is 30.8. The top of curb at Lottie Lane's storm sewer inlet is 30.0.

Prior to the new construction of FM-518 the highway at Lottie Lane was at elevation 32.7. The new construction apparently has lowered this elevation (no plans available at this time to verify the elevation).

The storm drain along Mary Ann from the south cannot convey the 5-year flows entering the inlets at both Christina and Linda Lanes.

The existing outfall can discharge the 5-year runoff from the areas north of Virginia lane, but not from the entire area. The proposed solutions apportion the flows to the outfalls so that the existing pipe will collect only the north area while the proposed pipes will collect all the south area.

4. Proposed Solutions:

Proposed solutions are listed in order of priority.

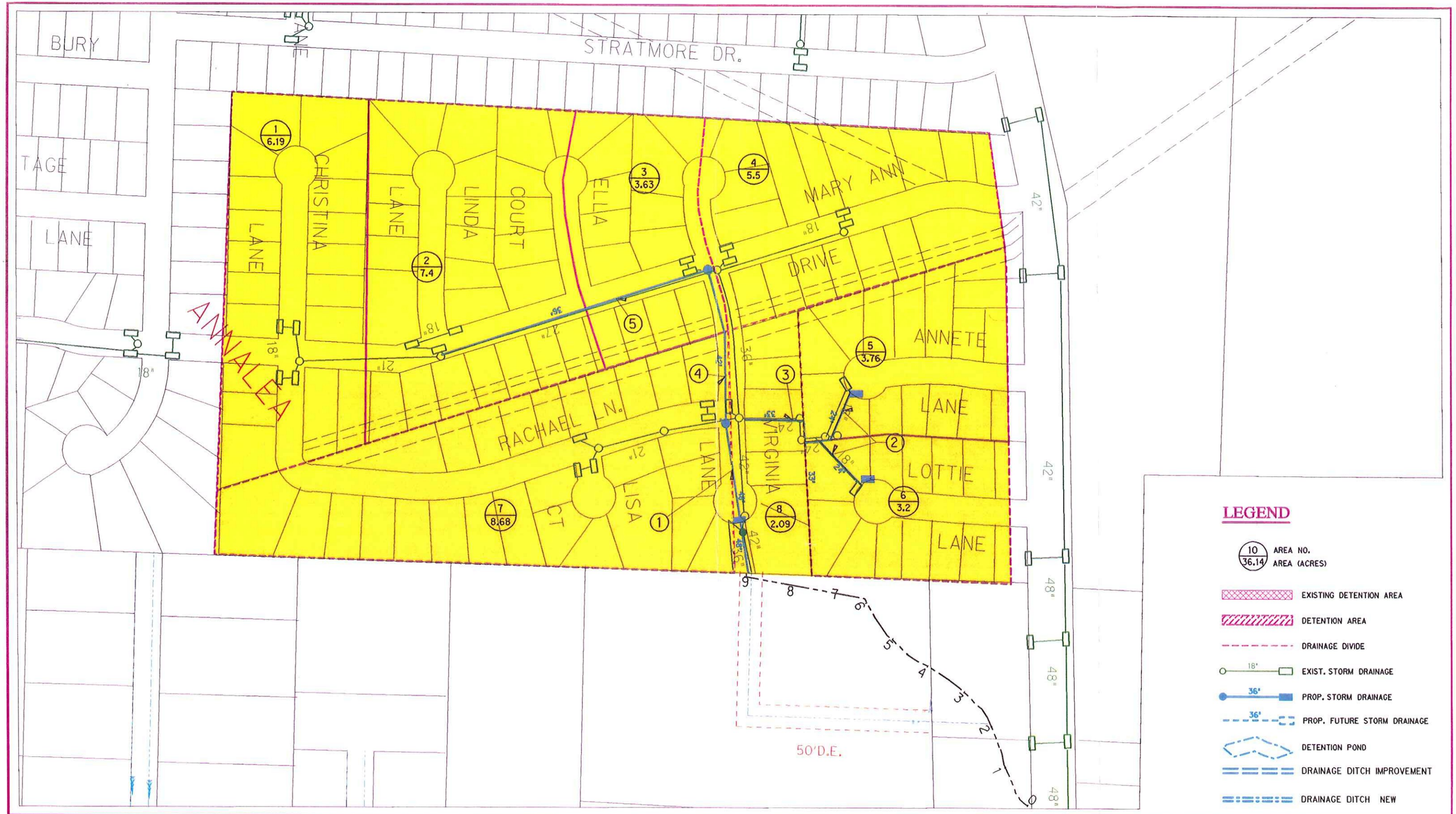
a. Replace recent 36 inch r.c.p. at the outfall from Virginia toward the drainage ditch with a 48 inch RCP. Extend this line to the pipe from Rachael. Connect the two inlets on the south side of Virginia at Rachael to this new line. (See Exhibit)

b. Replace the existing 24 inch line from Annette and Lottie Lanes with a 33 inch line.

c. Add an Inlet at Lottie Lane , add a Manhole at Lottie Lane and replace 18 inch line with a 24 inch line.

d. Extend the 48 inch line to Mary Ann Lane and connect south inlets at this intersection to the new line.

e. Extend a 36 inch line south along Mary Anne to the inlets at Linda Lane.



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CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

ANNALEA SUBDIVISION
PROBLEM AREA NO. 19

Friendswood Drainage Plan Cost Estimates

Problem Area Number 19 Analea outfall	Item	Quantity	Units	Unit Cost	Cost	
	48" Reinforced Concrete Pipe	330	L.F.	80	$26,400	
	42" Reinforced Concrete Pipe	300	L.F.	70	$21,000	
	Remove & Salvage Existing 36" RCP	115	L.F.	10	$1,150	
	30" Reinforced Concrete Pipe	325	L.F.	51	$16,575	
	Manhole	5	Each	1200	$6,000	
	Inlet	3	Each	1200	$3,600	
	Pipe to Pipe Connection	5	Each	425	$2,125	
	30" Reinforced Concrete Pipe	235	L.F.	51	$11,985	
	24" Reinforced Concrete Pipe	275	L.F.	39	$10,725	
	Headwall for 48"	1	Each	1600	$1,600	
	Ditch Cleaning	900	L.F.	4	$3,600	
	Remove & Salvage Existing 24" RCP	275	L.F.	10	$2,750	
	Saw Cut	660	L.F.	8	$5,280	
	Concrete Pavement	367	S.Y.	28	$10,267	
	Remove & Salvage Existing 18" RCP	275	L.F.	10	$2,750	
	Box Culvert Concrete	28	C.Y.	450	$12,500	
SubTotal:					$138,307	
	Engineering		15%		$20,746	
	Contingencies		28%		$38,726	
Total:						$197,779

#20 Whitehall Outfall

1. Statement of Problem:

Street flooding occurs throughout subdivision.

2. Summary of Data:

Subdivision plans were available for a part of the Whitehall subdivision. The available plans were used to analyze the drainage capacities, overflow elevations, and street slopes. Assumptions were made for the areas for which plans were unavailable. U.S.G.S quad maps were used to determine an approximate elevation in the areas where plans were unavailable. Surveyed ditch cross sections for the open channel were available for determining the capacity of the channel. A local resident at the end of the drainage ditch was not aware that the ditch had ever overflowed toward the highway.

3. Analysis of Existing Conditions:

The Whitehall subdivision is drained by an open channel from the southeast toward the north. All outfalls to the open channel was assumed to be free outfall for evaluating the existing system.

The drainage ditch was analyzed using the Corps of Engineer's HEC-2 computer model. Flows were determined using the rational method assuming all flows could enter the channel. The analysis of the channel indicated that the existing outfall consisting of a 60" and 36" culvert under North Friendswood Drive can convey only 1/3 of the 5-year discharges. The triple 36" culverts under the pipe line and Castle Lake are also undersized for the flows converging at these points.

Under current conditions as the channel fills due to the low capacity of the culverts the water flows out of the ditch to Stratmore Drive, or in some cases never gets to the ditch, then flows down the streets to North Friendswood Drive and ponds until Friendswood Drive is overtopped or flows east toward Problem Area number 19 compounding the problem at Lottie Lane.

4. Proposed Solution:

a. At Drainage area 1: Replace 18" with 24" -- & add one (1) additional inlet

b. At Drainage area 2: Parallel Existing 48" up to Whitehall with 30" RCP and intercept all inlets(3) at Whitehall and (3) at Brandywyne. Add additional inlet at Brandywyne. !! NO PLANS upstream of Whitehall

c. At Drainage area 3: Replace upper 160 feet of 18" culvert with a 30" culvert. The 100-year will pond 1 foot before flowing north along Stratmore Drive.

d. At Drainage area 8: Probably needs additional 24 " rcp and another inlet from Avondale to the Ditch

e. At Drainage area 9: Replace existing 18" storm drain with 24"

f. At Drainage area 11: Increase inlet capacity by adding one inlet

g. At Drainage area 12: Add one more inlet at Bellmar Lane at the sag.

h. At Drainage area 13: Replace the existing 24" with a 36" storm drain.

i. At the Outfall: Add two 60" RCP culverts under Friendswood Drive to convey the 5-year flow across the highway.

j. At the Pipe Crossing Replace existing triple 36" culverts with four (4) 48" culverts.

k. At Castle Lake Replace existing triple 36" culverts with four (4) 48" culverts.

ADD 2 - 60" RCP CULVERTS
UNDER FRIENDSWOOD DRIVE

REPLACE EXIST. 3 - 36" CULVERTS
WITH 4 - 48" CULVERTS

CITY LIMIT

KINGS PARK

ELEMENTARY SCHOOL

FRIENDSWOOD GARDENS

SUNSET MEADOWS

WHITEHALL

ANNIALEA

NORTH FRIENDSWOOD DR.

STRATMORE DR.

FOXEL ST.

PRAIRE WILD

STADIUM LANE

AVONDALE LANE

KINGS LANE

BELLMAR LANE

BRIGADOON

W. SUNSET DRIVE

BOUNDARY CT.

DUNBAR ESTATES

CAMELOT LANE

MERRIBROOK LANE

LOCHMOOR LANE

STONEHENGE

DOVER

WHITEHALL

BRANDYWYNE

BRENDON

CHRISTINA

COURT

LINDA

ELLA

RACHAEL

LISA

CT

MARY ANN

DRIVE

LANE

BURY

PORTAGE

BRITISH

WOODS

WEST STADIUM COURT

STADIUM CIRCLE

EAST STADIUM COURT

MIRAGE CT.

CALIBER CT.

HUT

DRIVE

1	7.79
2	41.79
3	6.28
4	4.60
5	3.89
6	12.41
7	7.94
8	10.29
9	4.60
10	32.5
11	3.63
12	6.62
13	12.06

LEGEND

- 10 / 36.14 — AREA NO. / AREA (ACRES)
- EXISTING DETENTION AREA
- DETENTION AREA
- DRAINAGE DIVIDE
- 18" EXIST. STORM DRAINAGE
- 36" PROP. STORM DRAINAGE
- 36" PROP. FUTURE STORM DRAINAGE
- DETENTION POND
- DRAINAGE DITCH IMPROVEMENT
- DRAINAGE DITCH NEW

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CITY OF FRIENDSWOOD
MASTER DRAINAGE PLAN

WHITEHALL OUTFALL @ F.M. 518
PROBLEM AREA NO. 20

Friendswood Drainage Plan Cost Estimates

Problem Area Number 20 Whitehall outfall	Item	Quantity	Units	Unit Cost	Cost	
	24" Reinforced Concrete Pipe	160	L.F.	39	$6,240	
	30" Reinforced Concrete Pipe	250	L.F.	51	$12,750	
	30" Reinforced Concrete Pipe	160	L.F.	51	$8,160	
	24" Reinforced Concrete Pipe	300	L.F.	39	$11,700	
	24" Reinforced Concrete Pipe	150	L.F.	39	$5,850	
	36" Reinforced Concrete Pipe	650	L.F.	57	$37,050	
	48" Culvert	6	Each	18750	$112,500	
	60" Culvert	2	Ea	24750	$49,500	
	60" Culvert	800	L.F.	126	$100,800	
	Earth Excavation	10000	C.Y.	3	$30,000	
	Headwall for 48"	4	Each	1600	$6,400	
	Headwall for 60"	6	Each	2100	$12,600	
	Inlet	6	Each	1750	$10,500	
	Saw Cut	700	L.F.	8	$5,600	
	Concrete Pavement	500	S.Y.	28	$14,000	
	Remove & Salvage Existing 18" RCP	160	L.F.	10	$1,600	
	Remove & Salvage Existing 18" RCP	300	L.F.	10	$3,000	
	Remove & Salvage Existing 24" RCP	650	L.F.	10	$6,500	
	Remove & Salvage Existing 18" RCP	300	L.F.	10	$3,000	
SubTotal:					$437,750	
	Engineering		15%		$65,663	
	Contingencies		28%		$122,570	
Total:						$625,983

Grand Total: $6,263,489

IV. CONCLUSIONS & RECOMMENDATIONS

A summarization of the Drainage Analysis Sites (Problem Areas), solutions and costs are given in Table 4-1(pg 4-3).

The following is recommended:

This report be utilized as a tool for future planning to provide guidance for the provision of adequate drainage.

When the design phase is implemented for the twenty problem areas, the proposed solutions should be closely evaluated during detailed engineering design and after comprehensive survey data is obtained to determine if more economical methods are available.

Additional tasks are recommended to complete the City of Friendswood Comprehensive Master Drainage Plan. These tasks can also be performed in phases over a period of years. In summary these additional tasks are:

Update Flood Plain Information. With the exception of Clear Creek and tributaries, existing flood plain information for streams in Friendswood dates back to the land uses and channel conditions that existed at the time the original flood insurance studies were completed. This phase would update the hydrology to reflect current and possible fully developed watershed landuses. In addition, stream hydraulics would be updated to reflect new bridges, culverts, channel improvements and other changes not reflected in the Flood Insurance Study. Lastly, flood profiles (5-year, 25-year, 100-year) would also be established for minor streams and ditches not previously studied. This would allow a complete inventory of flood problems to be compiled throughout the city.

PH II December 2000

Erosion and Sediment Deposition. Using the updated and expanded Flood Plain Information and field reconnaissance, erosion and sediment deposition sites would be identified in this phase.

PH II (or III?)

Storm Water Management. In this phase, Storm Water Management alternatives and strategies would be developed to address problems inventoried in the Flood Plain Information stage. Solutions would consider drainage, flood control, water quality, and sediment control. Watershed management alternatives including detention and open space preservation will also be evaluated. This phase will be especially useful in identifying drainage needs and requirements for the remaining undeveloped areas in Friendswood.

Flood Plain Ordinance and Drainage Criteria. In this phase, revision and additions to the City of Friendswood's Flood Plain Ordinance and Drainage Criteria will be developed consistent with the Storm Water Management recommendations.

Miscellaneous. The following tasks should also be included in the comprehensive Master Drainage Plan.

- Funding Alternatives
- Flood Alert Systems
- Survey Monumentation
- First Floor Elevation Certification
- Implementation Strategies and Schedules

TABLE 4-1
Summary of Analysis and Costs

Problem #	Location	Drainage Problem	Solution	Cost
1	Woodlawn Storm Sewer Outfall at Spreading Oaks	Street Flooding	Additional Ditch & Increase Storm Sewer Size	$231,160
2	Briarmeadow Ditch	Area Flooding	Install Storm Sewer	$884,510
3	Leslyn/Sterlingwood Outfall along Merriewood	Street Flooding	Install Additional Storm Sewer	$88,867
4	Sunset Ditch Mills to Coward's Creek	Area Flooding	Install Storm Sewer	$332,771
5	High School Outfall	Street Flooding	Increase Outfall Structure Size	$183,355
6	Greenbriar Ditch to Chigger Creek	Area Flooding	Install Storm Sewer	$393,619
7	Wilderness Trails/Glennshannon Outfall	Street Flooding	Increase Outfall Structure Size	$579,150
8	Falcon Ridge Section I	Street Flooding	Install Overflow Swale	$104,316
9	Mission Estates Outfall	Street Flooding	Increase Outfall Structure Size	$67,252
10	Carmel Village at San Joaquin Parkway	Street Flooding	Increase Outfall Structure Size	$92,807
11	Sun Meadows Main Outfall	Street Flooding	Install Detention Pond	$672,750
12	Sun Meadows Relief Storm Sewer	Street Flooding	Install Additional Storm Sewer	$57,558
13	Garden Drive at Spreading Oaks	Area Flooding	Install Storm Sewer	$21,042
14	Garden Drive at FM 2351	Area Flooding	Install Storm Sewer & Swale	$79,072
15	Block Bounded by FM 528, FM 518, Winding Way and Leisure Lane	Area Flooding	Install Storm Sewer	$111,326
16	Melody Lane	Inadequate Drainage	New Outfall Ditch	$68,423
17	FM 518 - Willowick to Mary's Creek Tributary	Street Flooding	Install Additional Storm Sewer	$727,202
18	FM 518 - Willowick to Coward's Creek	Street Flooding	Install Additional Storm Sewer	$744,549
19	Annalea Outfall at FM 518	Street Flooding	Install Additional Storm Sewer	$197,779
20	Whitehall Outfall at FM 518	Street Flooding	Install Additional Storm Sewer	$625,983
			Grand Total	$6,263,491

Problem Area no. 1
Woodlawn Street Outfall

da #	area	tc	cfac	ca	i - 5	i - 100	q - 5	q - 100
1	10.05	33	0.3	3.015	4.0	6.5	12	20
2	21.73	16	0.45	9.7785	5.6	8.0	55	78
3	16.22	15	0.55	8.921	5.8	8.2	51	73
4	25.39	22	0.45	11.4255	4.8	7.1	55	81
5	15.27	17	0.40	6.108	5.5	7.8	33	48

Point A Laurel & Shadow Bend

tc	i - 5	i - 100
37	3.8	6.1

da	area	C*A	q-5	q-100
1	10.05	3.015	12	18
3	16.22	8.921	32	51
total	26.27	11.936	44	69

or If area 1 is dropped the tc is smaller and flows increase.

tc	i - 5	i - 100
16	5.6	8.0

da	area	C*A	q-5	q-100
1	10.05	0	0	0
3	16.22	8.921	45	64
total	26.27	8.921	45	64

Point B Shadow Bend and WoodLawn

tc	i - 5	i - 100
41	3.6	5.7

da	area	C*A	q-5	q-100
1	10.05	3.015	11	17
2	21.73	9.7785	35	55
3	16.22	8.921	32	51
total	48.00	21.7145	78	123

or

tc	i - 5	i - 100
20	5.0	7.2

da	area	C*A	q-5	q-100
1	10.05	0	0	0
2	21.73	9.7785	49	70
3	16.22	8.921	45	64
total	48.00	18.6995	93	135

Point B Woodlaw Drive at Speading Oaks
(Woodlawn Drive Only)

tc	i - 5	i - 100
48	3.3	5.2

da	area	C*A	q-5	q-100
1	10.05	3.015	10	16
2	21.73	9.7785	32	50
3	16.22	8.921	29	46
5	15.27	6.108	20	31
total	63.27	27.8225	92	143

or

tc	i - 5	i - 100
27	4.4	6.9

da	area	C*A	q-5	q-100
1	10.05	0	0	0
2	21.73	9.7785	43	68
3	16.22	8.921	40	62
5	15.27	6.108	27	42
total	63.27	24.8075	110	172

Point C System Outfall

tc	i - 5	i - 100
50	3.2	5.0

da	area	C*A	q-5	q-100
1	10.05	3.015	10	15
2	21.73	9.7785	31	49
3	16.22	8.921	29	45
5	15.27	6.108	20	31
4	25.39	11.4255	37	57
total	88.66	39.248	126	196

tc	i - 5	i - 100
29	4.3	6.8

da	area	C*A	q-5	q-100
1	10.05	0	0	0
2	21.73	9.7785	42	67
3	16.22	8.921	38	61
5	15.27	6.108	26	42
4	25.39	11.4255	49	78
total	88.66	36.233	155	248

Problem # 2
Briar Meadow Ditch

Local Peaks

area #	area	avg c	Local Tc	C*A	i-5	i-100	q-5	q-100
1	13.37	0.359	12	4.80	6.2	8.8	30	42
2	13.31	0.42	17	5.59	5.5	7.8	30	44
3	7.35	0.4	12	2.94	6.2	8.8	18	26
4	28.25	0.393	22	11.10	4.8	7.1	54	79

Sunset & Briar Meadow
tc = 22 min

		da	5-yr q	100-yr q
5-year intensity	4.84	1	23	34
100-year intensity	7.12	2	27	40
		3	14	21
		4	54	79
Total flow from West:			41	61
Total Flow From South			23	34
Total Flow From East			54	79
Total @ Sunset & Briarmeadow			118	174

area #	area	avg c	Local Tc	C*A	q-5	q-100	i-5	i-100
5	21.06	0.4	20	8.42	42	61	5.0	7.2
Total @ Merriewood & Briarmeadow					160	235		

Problem Area No. 3
Leslyn / Sterlingwood Subdivision Outfall

da #	area	tc	cfac	ca	i - 5	i - 100	q - 5	q - 100
1	19.67	55	0.45	8.8515	3.1	4.7	27	41
2	25.48	17	0.55	14.014	5.5	7.8	76	110
3	17.59	13	0.55	9.6745	6.1	8.6	59	84
4	27.12	28	0.43	11.6616	4.4	6.9	51	80

At point A: Intersetion of Briarmeadow and Merriewood

tc	i - 5	i - 100
55	3.05	4.65

da	area	ca	q - 5	q - 100
1	19.67	8.8515	27	41
2	25.48	14.014	43	65
total	45.15	22.8655	70	106

At Point B Junction with 36 inch pipe

tc	i - 5	i - 100
59	2.93	4.37

da	area	ca	q - 5	q - 100
1	19.67	8.8515	26	39
2	25.48	14.014	41	61
3	17.59	9.6745	28	42
total	62.74	32.54	95	142

At Point C Outfall of 72 inch RCP

tc	i - 5	i - 100
61	2.9	4.3

da	area	ca	q - 5	q - 100
1	19.67	8.8515	26	38
2	25.48	14.014	41	60
3	17.59	9.6745	28	42
4	27.12	11.6616	34	50
total	89.86	44.2016	128	190

Problem Area No. 4
Sunset Drainage Ditch to Cowarts Creek

da #	area	tc	cfac	ca	i - 5	i - 100	q - 5	q - 100
1	7.07	18	0.35	2.475	5.3	7.61	13	19
2	13.8	17	0.35	4.83	5.45	7.815	26	38
3	6.83	14	0.35	2.391	5.9	8.43	14	20
4	14.82	15	0.35	5.187	5.75	8.225	30	43
5	16.53	16	0.3	4.959	5.6	8.02	28	40

Point A West Castlewood

tc	i - 5	i - 100
22	4.84	7.12

da	area	ca	q - 5	q - 100
1	7.07	2.4745	12	18
2	13.8	4.83	23	34
total	20.87	7.3045	35	52

Point B Gas Pipe Line Crossing

tc	i - 5	i - 100
28	4.36	6.88

da	area	ca	q - 5	q - 100
1	7.07	2.4745	11	17
2	13.8	4.83	21	33
3	6.83	2.3905	10	16
4	14.82	5.187	23	36
total	42.52	14.882	65	102

Point C Outfall at Creek

tc	i - 5	i - 100
31	4.145	6.695

da	area	ca	q - 5	q - 100
1	7.07	2.4745	10	17
2	13.8	4.83	20	32
3	6.83	2.3905	10	16
4	14.82	5.187	22	35
5	16.53	4.959	21	33
total	59.05	19.841	82	133

Problem # 5
Highschool Drainage

DA #	Area	cfac	tc	ca	i -5	i -100	q - 5	q - 100
1	5.44	0.45	9.0	2.448	6.6	9.5	16	23
2	7.02	0.35	12.0	2.457	6.2	8.84	15	22
3	17.54	0.35	12.0	6.139	6.2	8.84	38	54
4	53.67	0.45	26.0	24.1515	4.52	6.96	109	168
5	15.84	0.325	8.0	5.148	6.8	9.8	35	50
6	17.41	0.35	14.0	6.0935	5.9	8.43	36	51
7	8.98	0.325	12.0	2.9185	6.2	8.84	18	26

Ditch From highschool

tc	i-5	i-100
26	4.52	6.96

da # 4	area	ca	q - 5	q - 100
	53.67	33.8121	109	168

Ditch From Larkspur

tc	i 5	i 100
15	5.75	8.225

da	Area	ca	q - 5	q - 100
1	5.44	2.448	14	20
2	7.02	2.457	14	20
3	17.54	6.139	35	50
total	30	11.044	64	91

Total At Ditch Junction

tc	i 5	i 100
18	5.3	7.61

da	Area	ca	q - 5	q - 100
1	5.44	2.448	13	19
2	7.02	2.457	13	19
3	17.54	6.139	33	47
4	53.67	24.1515	128	184
5	15.84	5.148	27	39
total	99.51	40.3435	214	307

Total At Falling Leaf Drive

tc	i 5	i 100
20	5	7.2

da	Area	ca	q - 5	q - 100
1	5.44	2.448	12	18
2	7.02	2.457	12	18
3	17.54	6.139	31	44
4	53.67	24.1515	121	174
5	15.84	5.148	26	37
6	17.41	6.0935	30	44
total	116.92	46.437	232	334

Problem # 5
Highschool Drainage

Total At Outfall

tc	i 5	i 100
23	4.76	7.08

da	Area	ca	q - 5	q - 100
1	5.44	2.448	12	17
2	7.02	2.457	12	17
3	17.54	6.139	29	43
4	53.67	24.1515	115	171
5	15.84	5.148	25	36
6	17.41	6.0935	29	43
7	8.98	2.9185	14	21
total	125.9	49	235	349

Problem Area Number 6
GreenBriar Ditch to Chigger Creek

da #	area	tc	cfac	ca	i - 5	i - 100	q-5	q-100
1	10.01	15	0.35	3.5035	5.8	8.2	19	27
2	15.46	18	0.35	5.411	5.3	7.6	29	41
3	7.09	14	0.35	2.4815	5.9	8.4	15	21
4	7.86	12	0.55	4.323	6.2	8.8	27	38

D.S. Murphy

tc	i-5	i-100
18	5.3	7.6

da	area	ca	q-5	q-100
1	10.01	3.5035	19	27
2	15.46	5.411	29	41
total	25.47	8.9145	47	68

At BriarMeadow

tc	i-5	i-100
20	5.0	7.2

da	area	ca	q-5	q-100
1	10.01	3.5035	19	27
2	15.46	5.411	29	41
3	7.09	2.4815	13	19
total	32.56	11.396	60	87

At Outfall

tc	i-5	i-100
27	4.4	6.9

da	area	ca	q-5	q-100
1	10.01	3.5035	19	27
2	15.46	5.411	29	41
3	7.09	2.4815	13	19
4	7.86	4.323	23	33
total	40.42	15.719	83	120

Problem Area No. 7
Wilderness Trails / GlenShannon Outfall

da #	area	tc	cfact	ca	i - 5	i - 100	q - 5	q-100
1	54.89	17	0.55	30.1895	5.5	7.8	165	236
2	14.82	15	0.55	8.151	5.8	8.2	47	67
3	12.13	11	0.55	6.6715	6.4	9.0	42	60
4	15.17	9	0.55	8.3435	6.6	9.5	55	79
5	35.18	16	0.55	19.349	5.6	8.0	108	155
6	27.23	15	0.55	14.9765	5.8	8.2	86	123

Point A South Pipe of Wilderness Trails

tc	i - 5	i - 100
16	5.6	8.02

da	area	ca	q-5	q-100
4	15.17	8.3435	47	67
5	35.18	19.349	108	155
total	50.35	27.693	155	222

Point B North Wilderness Trails before joining South

tc	i - 5	i - 100
22	4.84	7.12

da	area	ca	q-5	q-100
2	14.82	8.151	39	58
3	12.13	6.6715	32	48
6	27.23	14.977	72	107
total	54.18	29.799	144	212

Point C Outfall for Wilderness Trails

tc	i - 5	i - 100
22	4.84	7.12

da	area	ca	q-5	q-100
2	14.82	8.151	39	58
3	12.13	6.6715	32	48
4	15.17	8.3435	40	59
5	35.18	19.349	94	138
6	27.23	14.977	72	107
total	104.53	57.492	278	409

Point D GlenShannon Outfall

tc	i - 5	i - 100
17	5.45	7.815

da	area	ca	q-5	q-100
1	54.89	30.19	165	236

Problem Area No. 7
Wilderness Trails / GlenShannon Outfall

Combined Wilderness Trails and Glen Shannon Outfall

tc	i - 5	i - 100
23	4.76	7.08

da		ca	q-5	q-100
1	54.89	30.19	144	214
2	14.82	8.151	39	58
3	12.13	6.6715	32	48
4	15.17	8.3435	40	59
5	35.18	19.349	94	138
6	27.23	14.977	72	107
total	159.42	87.681	421	623

Problem Area no. 8
Falcon Ridge I Outfall

da #	area	tc	cfac	ca	i - 5	i - 100	q - 5	q - 100
1	3.05	10	0.55	1.6775	6.5	9.3	11	16
2	10.28	10	0.55	5.654	6.5	9.3	37	52
3	9.49	10	0.55	5.2195	6.5	9.3	34	48
4	2.71	10	0.55	1.4905	6.5	9.3	10	14
5	5.41	10	0.55	2.9755	6.5	9.3	19	28
6	4.64	10	0.55	2.552	6.5	9.3	17	24
7	4.55	10	0.55	2.5025	6.5	9.3	16	23

At point A: Intersection of White Wing Circle and Falcon Ridge Blvd

tc	i - 5	i - 100
15	5.75	8.225

da	area	ca	q - 5	q - 100
1	3.05	1.6775	10	14
2	10.28	5.654	33	47
3	9.49	5.2195	30	43
4	2.71	1.4905	9	12
5	5.41	2.9755	17	24
6	4.64	2.552	15	21
total	35.58	19.569	113	161

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1*****************************************
*                                       *
*  FLOOD HYDROGRAPH PACKAGE (HEC-1)     *
*        MAY  1991                      *
*      VERSION 4.0.1E                   *
*                                       *
*  RUN DATE 08/25/93  TIME 09:33:17     *
*                                       *
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*****************************************
*                                       *
*          U.S. ARMY CORPS OF ENGINEERS *
*  HYDROLOGIC ENGINEERING CENTER        *
*       609 SECOND STREET               *
*  DAVIS, CALIFORNIA 95616              *
*       (916) 551-1748                  *
*                                       *
*****************************************
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X   X X     X  X     X   XX
X   X X     X  X         X
XXXXXXX XXXX   X     XXXXX X
X   X X     X  X         X
X   X X     X  X  X      X
X   X XXXXXXX  XXXXX     XXX
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THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


```
LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

          *DIAGRAM
    1     ID  FRIENDSWOOD MASTER DRAINAGE STUDY
    2     ID  HYDROLOGY FOR SAN JUAQUIN ESTATES ( AREA 9 AND 10)
    3     ID  DETENTION AREAS / CONVEYANCE FLOWS FOR DITCH 'A'
    4     IT    5 4AUG93   0100   300
    5     IO    5
    6     JP    3
          *     3 PLANS  #1 = 5YR #2 = 25YR  #3 = 100YR
          ***********

    7     KK  BRA2
    8     KM  Basin runoff calculation for  BRA2
    9     KM      BASIN AREA UNDEVELOPED AT THIS TIME – FLOWS TO DETENTION BASIN
   10     KM      BOCA RATON PHASE II ( 1500 FT OVERLAND FLOW AT 600 FT / HR )
   11     KM      DRAINS VIA DRAINAGE DITCH ALONG SOUTH END OF PROPERTY?
   12     KM      DA = 33.7
   13     KP    1
   14     PH    .2       .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
   15     BA .05265
   16     LS        72
   17     US   2.5   .72
   18     KP    2
   19     PH   .04       1.7  2.17  3.80  4.93  5.61   7.0   8.5  10.01
   20     KP    3
   21     PH   .01      1.95   2.7  4.68  6.14   7.1   8.9  10.9    13
          **********

   22     KK MISSN5
```

```
23      KM       SAN JUAQUIN SUBDIVISION – S. MISSION CIRCLE SOUTH OF VAQUERO
24      KM        DA # 5 7.92 ACRES
25      KM
26      KM  Basin runoff calculation for MISSS2
27      KP    1
28      PH   .2        .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
29      BA .01237
30      LS         80
31      US   .2   .72
32      KP    2
33      PH   .04        1.7  2.17  3.80  4.93  5.61   7.0   8.5  10.01
34      KP    3
35      PH   .01       1.95   2.7  4.68  6.14   7.1   8.9  10.9    13
        * ••••••••••

36      KK CHANQ1
37      KM  Combining two hydrographs at control point  DETEN2
38      HC    2
        * ••••••••••

39      KK BRATON
40      KM  Basin runoff calculation for BRATON
41      KM       DRAINAGE BASIN BOCA RATAN 54.73 ACRES – HAS DETENTION BASIN
42      KM       BOCA RATON PHASE I 54 MINUTES TC = 12 (TP = 12/.6 = 0.33 HRS
43      KP    1
44      PH   .2        .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
45      BA .08457
1                          HEC-1 INPUT                              PAGE  2

LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

46      LS         80
47      US   .33   .72
48      KP    2
49      PH   .04        1.7  2.17  3.80  4.93  5.61   7.0   8.5  10.01
50      KP    3
51      PH   .01       1.95   2.7  4.68  6.14   7.1   8.9  10.9    13
        * ••••••••••

52      KK DETEN1
53      KM       BOCA RATON DETENTION BASIN PRIOR TO CROSSING PIPE LINE TO SAN
54      KM        JUAQUIN SUBDIVISION
55      KM  Reservoir routing operation
56      RS
57      SA     0  4.07
58      SE  26.8  32.8
59      SL 29.30 39.27  0.65   0.5
60      SS  32.7    80   2.5   1.5
        * ••••••••••

61      KK MISSN2
62      KM       SAN JUAQUIN SUBDIVION – N. MISSION CIRCLE BETWEEN VAQUERO AND
63      KM        SAN JUAQUIN PARKWAY
64      KM  Basin runoff calculation for  MISSN
65      KP    1
66      PH   .2        .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
67      BA .01859
68      LS         80
69      US   .2   .72
70      KP    2
71      PH   .04        1.7  2.17  3.80  4.93  5.61   7.0   8.5  10.01
72      KP    3
73      PH   .01       1.95   2.7  4.68  6.14   7.1   8.9  10.9    13
        * ••••••••••

74      KK  MISSN
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 75      KM  Combining two hydrographs at control point  DETEN2
 76      HC    2
         * ********** 

 77      KK  MISSN6
 78      KM  Basin runoff calculation for MISSN2
 79      KM       SAN JUAQUIN SUBDIVSION – N. MISSION CIRCLE BEWEEN CARMEL VILLAGE
 80      KM       AND VAUEERO DRIVE  DA. = 8.43 ACRES
 81      KP    1
 82      PH   .2       .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
 83      BA .01317
 84      LS         80
 85      US   .2   .72
 86      KP    2
 87      PH   .04       1.7  2.17  3.80  4.93  5.61   7.0   8.5  10.01
 88      KP    3
 89      PH   .01      1.95   2.7  4.68  6.14   7.1   8.9  10.9    13
         * ********** 
1                        HEC-1 INPUT                          PAGE  3

LINE     ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

 90      KK  MISSN2
 91      KM  Combining two hydrographs at control point  DETEN2
 92      HC    2
         * ********** 

 93      KK  EAST4
 94      KM       SAN JUAQUIN SUBDIVISION – LARGE LOTS EAST OF DRAINAGE DITCH
 95      KM       SOUTH OF SAN JUAQUIN PARKWAY – TREATED AS ONE INFLOW AREA
 96      KM  Basin runoff calculation for  EAST
 97      KP    1
 98      PH   .2       .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
 99      BA .04901
100      LS         75
101      US   .3   .72
102      KP    2
103      PH   .04       1.7  2.17  3.80  4.93  5.61   7.0   8.5  10.01
104      KP    3
105      PH   .01      1.95   2.7  4.68  6.14   7.1   8.9  10.9    13
         * ********** 

106      KK  CHAN2
107      KM  COMBINING ALL FLOWS ENTERING VIA DBL 66 INCH RCP
108      HC    3

109      KK  MISSN3
110      KM       SAN JUAQUIN SUBDIVISION – S. MISSION CIRCLE BETWEEN VAQUERO AND
111      KM       SAN JUAQUIN PARKWAY  DA = 11.60 AC
112      KM  Basin runoff calculation for  MISSS
113      KP    1
114      PH   .2       .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
115      BA .01812
116      LS         80
117      US   .2   .72
118      KP    2
119      PH   .04       1.7  2.17  3.80  4.93  5.61   7.0   8.5  10.01
120      KP    3
121      PH   .01      1.95   2.7  4.68  6.14   7.1   8.9  10.9    13
         * ********** 

122      KK  CHAN4
123      KM  Combining two hydrographs at control point  DETEN2
124      HC    2
         * ********** 
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125       KK DETEN2
126       KM       ROUTE THROUGH DETENTION AREA SOUTH OF SAN JUAQUIN PARKWAY
127       KM       TREAT BRIDGE AS CONTROL
128       KM       HEC2 MODEL USED FOR RATING CURVE -- PLANS FOR VOLUMES
129       KM  Reservoir routing operation
130       RS    1
131       SV    0   1.0    2.    3.    5.    6.    9    10.
132       SE  25.2  26.47  27.61  28.80  30.13  31.59  32.92  33.50
133       SQ    0   25.    75.   150   250   400   600   1000
134       SE  25.2  26.47  27.61  28.80  30.13  31.59  32.92  33.50
1                              HEC-1 INPUT                              PAGE 4

LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10


135       KK UNDEV2
136       KM       UNDEVELOPED AREA SOUTH OF PIPELINE WEST OF N. MISSION
137       KM       DA = 21.04 TC = 45 MINUTES
138       KM       I THINK FLOWS ARE SUPPOSED TO FLOW ALONG SAN JOAQUIN PKWY TO DITCH
139       KP    1
140       PH   .2        .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
141       LS         72
142       US  1.25    .72
143       BA .03288
144       KP    2
145       PH   .04        1.7  2.17  3.80  4.93  5.61   7.0   8.5  10.01
146       KP    3
147       PH   .01       1.95   2.7  4.68  6.14   7.1   8.9  10.9    13

148       KK CHAN5
149       HC    2

150       KK  SMM6
151       KM       MISSION ESTATES SOUTH OF DITCH ON S. MISSION
152       KM       D.A. = 22.88 TC. = 9 MIN TP=0.24
153       KP    1
154       PH   .2        .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
155       BA .0358
156       LS         80
157       US   .24   .72
158       KP    2
159       PH   .04        1.7  2.17  3.80  4.93  5.61   7.0   8.5  10.01
160       KP    3
161       PH   .01       1.95   2.7  4.68  6.14   7.1   8.9  10.9    13

162       KK SMM6
163       KM       ADD IN HYDROGRAPH
164       HC    2

165       KK  SMM8
166       KM       MISSSION ESTATES LARGE LOTS SOUTH DITCH
167       KM       D.A. = 36.14  TC = 15
168       KP    1
169       PH   .2        .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
170       BA .05647
171       LS         78
172       US   .42   .72
173       KP    2
174       PH   .04        1.7  2.17  3.80  4.93  5.61   7.0   8.5  10.01
175       KP    3
176       PH   .01       1.95   2.7  4.68  6.14   7.1   8.9  10.9    13

177       KK CHAN6
178       HC    2
          **********
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```
LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

  179     KK  SOMMR
  180     KM      SOMERSET DRAINAGE SUBDIVISION -- HAS
  181     KM      DETENTION
  182     KP    1
  183     PH   .2       .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
  184     BA  .02172
  185     LS        80
  186     US   .2   .72
  187     KP    2
  188     PH  .04       1.7  2.17  3.80  4.93  5.61   7.0   8.5 10.01
  189     KP    3
  190     PH  .01      1.95   2.7  4.68  6.14   7.1   8.9  10.9    13

  191     KK DSOMMR
  192     KM      DETENTION INSIDE MISSION ESTATES 1
  193     KM      BASED ON ELEVATIONS / PIPE FLOW FROM
  194     RS
  195     SA   0   .65  1.119  1.2
  196     SE 26.2  26.6 30.71  32.8
  197     SL 27.40 7.06  0.65   0.5
  198     SS 32.7   80   2.5   1.5
        * *****

  199     KK UNDEV1
  200     KM      AREA SOUTH OF SOMERSET -- UNDEVELOPED - EAST OF PIPE LINE
  201     KM      DA = 6.727 TC = 20 MIN
  202     KP    1
  203     BA .01051
  204     PH   .2       .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
  205     LS        72
  206     US   .55   .72
  207     KP    2
  208     PH   .04       1.7  2.17  3.80  4.93  5.61   7.0   8.5 10.01
  209     KP    3
  210     PH   .01      1.95   2.7  4.68  6.14   7.1   8.9  10.9    13

  211     KK  SOMMA
  212     KM      COMBINE FLOWS TO THE WEST FLOWING TO MISSION ESTATES DITCH
  213     HC    2

  214     KK  NMM4
  215     KM      MISSION ESTATES SOUTH OF DITCH ON N. MISSION
  216     KM      TC = 22 MINUTES D.A. = 22.55
  217     KP    1
  218     BA  .035
  219     PH   .2       .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
  220     LS        80
  221     US   .37   .72
  222     KP    2
  223     PH   .04       1.7  2.17  3.80  4.93  5.61   7.0   8.5 10.01
  224     KP    3
  225     PH   .01      1.95   2.7  4.68  6.14   7.1   8.9  10.9    13
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LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

  226     KK MDITC1
  227     KM      KEEP ADDING FLOWS TO THE DITCH BETWEEN VALERO AN DDESOTO
  228     HC    2
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```
229      KK  NMM5
230      KM       MISSION ESTATES NORTH OF DITCH ON N. MISSION ESTATES
231      KM       TC = 12 MINUTES d.a = 12.17
232      KP    1
233      BA  .0198
234      PH   .2        .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
235      LS         80
236      US   .32   .72
237      KP    2
238      PH   .04       1.7  2.17  3.80  4.93  5.61   7.0   8.5  10.01
239      KP    3
240      PH   .01      1.95   2.7  4.68  6.14   7.1   8.9  10.9    13

241      KK  MDITC2
242      HC    2

243      KK NMM10
244      KM       LOCAL FLOW AT CROSS DITCH
245      KM       D.A. = 3.9 TC = 5 MIN ( OR LESS)
246      KP    1
247      PH   .2        .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
248      BA .0061
249      LS         80
250      US   .14   .72
251      KP    2
252      PH   .04       1.7  2.17  3.80  4.93  5.61   7.0   8.5  10.01
253      KP    3
254      PH   .01      1.95   2.7  4.68  6.14   7.1   8.9  10.9    13

255      KK SIDEQ
256      HC    2

257      KK CHAN7
258      HC    2

259      KK  SMM7
260      KM       MISSION ESTATES NORTH OF DITCH ON S. MISSION
261      KM       DA = 10.7 TC = .24
262      KP    1
263      PH   .2        .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
264      BA  .0167
265      LS         80
266      US   .24   .72
267      KP    2
268      PH   .04       1.7  2.17  3.80  4.93  5.61   7.0   8.5  10.01
269      KP    3
270      PH   .01      1.95   2.7  4.68  6.14   7.1   8.9  10.9    13
1                      HEC-1 INPUT                              PAGE  7

LINE     ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10


271      KK  MDITC4
272      HC    2

273      KK  SMM9
274      KM       MISSION ESTATES LARGE LOTS NORTH DITCH
275      KM       DA = 23.82 TC = 15 MIN
276      KP    1
277      PH   .2        .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
278      BA  .0372
279      LS         78
280      US   .42   .72
281      KP    2
282      PH   .04       1.7  2.17  3.80  4.93  5.61   7.0   8.5  10.01
283      KP    3
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      284       PH   .01       1.95    2.7   4.68   6.14    7.1    8.9   10.9     13

      285       KK  CHAN8
      286       HC    2

      287       KK  DETEN3
      288       KM       ROUTE THROUGH DETENTION AREA SOUTH OF SAN JUAQUIN PARKWAY
      289       KM        TREAT BRIDGE AS CONTROL
      290       KM       HEC2 MODEL USED FOR RATING CURVE – PLANS FOR VOLUMES
      291       KM  Reservoir routing operation
      292       RS    1
      293       SV    0   1.0    2.    3.    5.    9.   11.   15.
      294       SE  22.8 23.96  24.75 25.47 26.18   27.  27.84 29.11
      295       SQ    0   25.   75.   150   250   400   600   1000
      296       SE  22.8 24.18  25.15 26.15 27.29 29.32 30.00 30.80
      297       ZZ
1
          SCHEMATIC DIAGRAM OF STREAM NETWORK
INPUT
 LINE   (V) ROUTING       (—>) DIVERSION OR PUMP FLOW

  NO.   (.) CONNECTOR     (<—) RETURN OF DIVERTED OR PUMPED FLOW

   7    BRA2
          .
          .
  22       .   MISSN5
           .       .
           .       .
  36    CHANQ1.....
          .
          .
  39       .   BRATON
           .       V
           .       V
  52       .   DETEN1
           .       .
           .       .
  61       .       .   MISSN2
           .       .       .
           .       .       .
  74       .   MISSN.....
           .       .
           .       .
  77       .       .   MISSN6
           .       .       .
           .       .       .
  90       .   MISSN2.....
           .       .
           .       .
  93       .       .   EAST4
           .       .       .
           .       .       .
 106    CHAN2.....
          .
          .
 109       .   MISSN3
           .       .
           .       .
 122    CHAN4 .....
          V
          V
 125    DETEN2
          .
          .
 135       .   UNDEV2
```

PEAK FLOW AND STAGE (END-OF-PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND, AREA IN SQUARE MILES
TIME TO PEAK IN HOURS

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS RATIO 1
				1.00
HYDROGRAPH AT				
+	BRA2	0.05	1 FLOW	22.
			TIME	14.67
			2 FLOW	40.
			TIME	14.58
			3 FLOW	56.
			TIME	14.58
HYDROGRAPH AT				
+	MISSN5	0.01	1 FLOW	30.
			TIME	12.25
			2 FLOW	55.
			TIME	12.25
			3 FLOW	70.
			TIME	12.25
2 COMBINED AT				
+	CHANQ1	0.07	1 FLOW	34.
			TIME	12.25
			2 FLOW	62.
			TIME	12.25
			3 FLOW	83.
			TIME	12.25
HYDROGRAPH AT				
+	BRATON	0.08	1 FLOW	155.
			TIME	12.42
			2 FLOW	276.
			TIME	12.42
			3 FLOW	356.
			TIME	12.33
ROUTED TO				
+	DETEN1	0.08	1 FLOW	128.
			TIME	12.50
			2 FLOW	227.
			TIME	12.50
			3 FLOW	295.
			TIME	12.50
			** PEAK STAGES IN FEET **	
			1 STAGE	30.39
			TIME	12.50
			2 STAGE	31.23
			TIME	12.50
			3 STAGE	31.81
			TIME	12.50
HYDROGRAPH AT				
+	MISSN2	0.02	1 FLOW	45.
			TIME	12.25
			2 FLOW	82.
			TIME	12.25
			3 FLOW	105.
			TIME	12.25

```
 2 COMBINED AT
+          MISSN    0.10   1  FLOW      148.
                      TIME      12.50
                    2  FLOW      262.
                      TIME      12.50
                    3  FLOW      340.
                      TIME      12.50

 HYDROGRAPH AT
+          MISSN6   0.01   1  FLOW       32.
                      TIME      12.25
                    2  FLOW       58.
                      TIME      12.25
                    3  FLOW       75.
                      TIME      12.25

 2 COMBINED AT
+          MISSN2   0.12   1  FLOW      166.
                      TIME      12.42
                    2  FLOW      293.
                      TIME      12.33
                    3  FLOW      382.
                      TIME      12.33

 HYDROGRAPH AT
+          EAST4    0.05   1  FLOW       83.
                      TIME      12.33
                    2  FLOW      156.
                      TIME      12.33
                    3  FLOW      206.
                      TIME      12.33

 3 COMBINED AT
+          CHAN2    0.23   1  FLOW      278.
                      TIME      12.33
                    2  FLOW      504.
                      TIME      12.33
                    3  FLOW      661.
                      TIME      12.33

 HYDROGRAPH AT
+          MISSN3   0.02   1  FLOW       44.
                      TIME      12.25
                    2  FLOW       80.
                      TIME      12.25
                    3  FLOW      103.
                      TIME      12.25

 2 COMBINED AT
+          CHAN4    0.25   1  FLOW      316.
                      TIME      12.33
                    2  FLOW      571.
                      TIME      12.33
                    3  FLOW      747.
                      TIME      12.33

 ROUTED TO
+          DETEN2   0.25   1  FLOW      260.
                      TIME      12.50
                    2  FLOW      407.
                      TIME      12.58
                    3  FLOW      423.
                      TIME      12.75

                   ** PEAK.STAGES IN FEET **
                    1  STAGE    30.22
```

```
                    TIME      12.50
                  2 STAGE     31.64
                    TIME      12.58
                  3 STAGE     31.74
                    TIME      12.75

HYDROGRAPH AT
+          UNDEV2  0.03   1 FLOW       21.
                    TIME      13.33
                  2 FLOW        40.
                    TIME      13.33
                  3 FLOW        55.
                    TIME      13.33

 2 COMBINED AT
+          CHAN5   0.28   1 FLOW      271.
                    TIME      12.50
                  2 FLOW       437.
                    TIME      12.92
                  3 FLOW       471.
                    TIME      13.00

HYDROGRAPH AT
+          SMM6    0.04   1 FLOW       79.
                    TIME      12.25
                  2 FLOW       142.
                    TIME      12.25
                  3 FLOW       183.
                    TIME      12.25

 2 COMBINED AT
+          SMM6    0.32   1 FLOW      317.
                    TIME      12.50
                  2 FLOW       558.
                    TIME      12.33
                  3 FLOW       613.
                    TIME      12.33

HYDROGRAPH AT
+          SMM8    0.06   1 FLOW       85.
                    TIME      12.50
                  2 FLOW       154.
                    TIME      12.50
                  3 FLOW       201.
                    TIME      12.50

 2 COMBINED AT
+          CHAN6   0.37   1 FLOW      402.
                    TIME      12.50
                  2 FLOW       696.
                    TIME      12.33
                  3 FLOW       794.
                    TIME      12.33

HYDROGRAPH AT
+          SOMM    0.02   1 FLOW       51.
                    TIME      12.25
                  2 FLOW        93.
                    TIME      12.25
                  3 FLOW       119.
                    TIME      12.25

ROUTED TO
+          DSOMMR  0.02   1 FLOW       31.
                    TIME      12.42
                  2 FLOW        50.
```

```
                    TIME      12.42
                  3 FLOW        58.
                    TIME      12.50

                  ** PEAK STAGES IN FEET **
                  1 STAGE     28.41
                    TIME      12.42
                  2 STAGE     29.23
                    TIME      12.42
                  3 STAGE     29.85
                    TIME      12.50

HYDROGRAPH AT
+          UNDEV1   0.01   1 FLOW        11.
                    TIME      12.58
                  2 FLOW        22.
                    TIME      12.58
                  3 FLOW        29.
                    TIME      12.58

 2 COMBINED AT
+          SOMMA    0.03   1 FLOW        41.
                    TIME      12.50
                  2 FLOW        70.
                    TIME      12.50
                  3 FLOW        86.
                    TIME      12.58

HYDROGRAPH AT
+          NMM4     0.04   1 FLOW        60.
                    TIME      12.42
                  2 FLOW       106.
                    TIME      12.42
                  3 FLOW       137.
                    TIME      12.42

 2 COMBINED AT
+          MDITC1   0.07   1 FLOW       100.
                    TIME      12.42
                  2 FLOW       175.
                    TIME      12.42
                  3 FLOW       220.
                    TIME      12.42

HYDROGRAPH AT
+          NMM5     0.02   1 FLOW        37.
                    TIME      12.33
                  2 FLOW        65.
                    TIME      12.33
                  3 FLOW        85.
                    TIME      12.33

 2 COMBINED AT
+          MDITC    0.09   1 FLOW       136.
                    TIME      12.42
                  2 FLOW       238.
                    TIME      12.42
                  3 FLOW       302.
                    TIME      12.42

HYDROGRAPH AT
+          NMM10    0.01   1 FLOW        18.
                    TIME      12.17
                  2 FLOW        33.
                    TIME      12.17
                  3 FLOW        43.
```

```
                    TIME      12.17

 2 COMBINED AT
+          SIDEQ    0.09   1  FLOW      142.
                      TIME     12.42
                    2  FLOW      249.
                      TIME     12.42
                    3  FLOW      315.
                      TIME     12.42

 2 COMBINED AT
+          CHAN7    0.47   1  FLOW      542.
                      TIME     12.42
                    2  FLOW      940.
                      TIME     12.33
                    3  FLOW     1105.
                      TIME     12.33

 HYDROGRAPH AT
+          SMM7     0.02   1  FLOW       37.
                      TIME     12.25
                    2  FLOW       66.
                      TIME     12.25
                    3  FLOW       85.
                      TIME     12.25

 2 COMBINED AT
+          MDITC    0.48   1  FLOW      571.
                      TIME     12.42
                    2  FLOW     1006.
                      TIME     12.33
                    3  FLOW     1189.
                      TIME     12.33

 HYDROGRAPH AT
+          SMM9     0.04   1  FLOW       56.
                      TIME     12.50
                    2  FLOW      102.
                      TIME     12.50
                    3  FLOW      132.
                      TIME     12.50

 2 COMBINED AT
+          CHAN8    0.52   1  FLOW      627.
                      TIME     12.42
                    2  FLOW     1096.
                      TIME     12.33
                    3  FLOW     1308.
                      TIME     12.33

 ROUTED TO
+          DETEN3   0.52   1  FLOW      467.
                      TIME     12.75
                    2  FLOW     1034.
                      TIME     12.50
                    3  FLOW     1259.
                      TIME     12.50

                    ** PEAK STAGES IN FEET **
                    1  STAGE    29.55
                      TIME     12.75
                    2  STAGE    30.87
                      TIME     12.50
                    3  STAGE    31.32
                      TIME     12.50
```

*** NORMAL END OF HEC-1 ***

Problem Area No. 11
SunMeadow Major Outfall

da #	area	tc	cfac	ca	i - 5	i - 100	q - 5	q - 100
1	14.91	17	0.55	8.2005	5.5	7.8	45	64
2	14.23	100	0.3	4.269	2.9	4.3	12	18
3	6.29	30	0.3	1.887	4.2	6.8	8	13
4	16.74	15	0.55	9.207	5.8	8.2	53	76
5	16.9	120	0.3	5.07	2.9	4.3	15	22
6	29.87	19	0.55	16.4285	5.2	7.4	85	122
7	14.57	14	0.55	8.0135	5.9	8.4	47	68
8	17.57	11	0.55	9.6635	6.4	9.0	61	87
9	7.43	10	0.55	4.0865	6.5	9.3	27	38
10	7.23	10	0.55	3.9765	6.5	9.3	26	37
11	6.88	30	0.3	2.064	4.2	6.8	9	14

Point A Outfall from East Castle Harbor Drive

tc	i - 5	i - 100
17	5.45	7.815

da	ca	q - 5	q - 100
10	3.9765	22	31
1	8.2005	45	64
total	12.177	66	95

Point B Old Concourse Drive

tc	i - 5	i - 100
19	5.15	7.405

da	ca	q - 5	q - 100
10	3.9765	20	29
1	8.2005	42	61
4	9.207	47	68
total	21.384	110	158

or

tc	i - 5	i - 100
100	2.9	4.3

da	ca	q - 5	q - 100
10	3.9765	12	17
1	8.2005	24	35
2	4.269	12	18
4	9.207	27	40
total	25.653	74	110

Point C Outfall at Glen Eagles Drive

tc	i - 5	i - 100
25	4.6	7

da	ca	q - 5	q - 100
10	3.9765	18	28
1	8.2005	38	57
4	9.207	42	64
5	5.07	23	35
6	16.4285	76	115
total	42.8825	197	300

or

tc	i - 5	i - 100
107	2.9	4.3

da	ca	q - 5	q - 100
10	3.9765	12	17
1	8.2005	24	35
4	9.207	27	40
2	4.269	12	18
6	16.4285	48	71
5	5.07	15	22
total	47.1515	137	203

Point D Main Outfall

tc	i - 5	i - 100
30	4.2	6.8

da	ca	q - 5	q - 100
10	3.9765	17	27
1	8.2005	34	56
4	9.207	39	63
5	5.07	21	34
6	16.4285	69	112
7	8.0135	34	54
8	9.6635	41	66
9	4.0865	17	28
11	2.064	9	14
total	66.71	280	454

or

tc	i - 5	i - 100
113	2.9	4.3

da	ca	q - 5	q - 100
10	3.9765	12	17
1	8.2005	24	35
4	9.207	27	40
2	4.269	12	18
5	5.07	15	22
6	16.4285	48	71
7	8.0135	23	34
8	9.6635	28	42
9	4.0865	12	18
11	2.064	6	9
3	1.887	5	8
5	5.07	15	22
total	77.936	226	335

```
1*************************************
*                                   *
*  FLOOD HYDROGRAPH PACKAGE (HEC-1) *
*         MAY 1991                  *
*       VERSION 4.0.1E              *
*                                   *
*  RUN DATE 08/25/93 TIME 13:03:05  *
*                                   *
*************************************
```

```
*************************************
*                                   *
*  U.S. ARMY CORPS OF ENGINEERS     *
*  HYDROLOGIC ENGINEERING CENTER    *
*       609 SECOND STREET           *
*  DAVIS, CALIFORNIA 95616          *
*       (916) 551-1748              *
*                                   *
*************************************
```

```
X   X XXXXXXX  XXXXX      X
X   X X     X  X    X    XX
X   X X     X  X         X
XXXXXXX XXXX   X    XXXXX X
X   X X     X  X         X
X   X X     X  X    X    X
X   X XXXXXXX  XXXXX      XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


```
LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10
          *DIAGRAM
    1     ID  FRIENDSWOOD MASTER DRAINAGE STUDY Problem # 13, 14
    2     ID  HYDROLOGY FOR SCHOOL IMPROVEMENTS 42 inch rcp assumed installed
    3     ID  STREAM HYDRAULICS / STREET HYDRAULICS SEE DITCH.DAT STREET?.DAT
    4     IT     5 17JUN93  0100   300
    5     IO     5
          ***********

    6     KK  KINGS
    7     KM  Basin runoff calculation for  KINGS PARK (RENWICK PARK)
    8     BA .01559
    9     PH    .2        .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
          *     TYPE D SOIL ASSUMED -  LAWNS - GOOD CONDITION
   10     LS         80
   11     US   .30   .72
          **********

   12     KK  PRKING
   13     KM  Basin runoff from school parking along Stadium Lane
   14     BA .00808
   15     PH    .2        .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
          *  ALL IMPERVIOUS AREA -- CN = 98
   16     LS         98
   17     US    .2   .72
          *********

   18     KK  STADM
   19     KM  Combine two hydrographs at Stadium Lane
```

```
20      HC    2
        * *********

21      KK   BRG
22      KM  Basin runoff calculation from Brigadoon and N Sunset Drive
23      BA  .0117
24      PH   .2        .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
        *      TYPE D SOIL ASSUMED - RESIDENTIAL DISCTRICT LOTS 1/4 ACRE
25      LS         87
26      US   .25   .72
        * **********

27      KK  stadm2
28      KM  Combining two hydrographs at INTERSECTION OF stadium AND FM 2351
29      HC    2
        * **********

30      KK  OSCHL
31      KM  Basin runoff calculation for  OLD SCHOOL AREA
32      BA  .00865
33      PH   .2        .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
        *      TYPE D SOIL ASSUMED - 50 PERCENT IMPERVIOUS
34      LS         89
35      US   .25   .72
        * **********
1                          HEC-1 INPUT                          PAGE  2

LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

36      KK  OSCHL
37      KM  Combining two hydrographs at UPSTREAM OF 3 X 5 FOOT BOX CULVERT – STREAM
38      HC    2
        * **********

39      KK  POND
40      KM  Basin runoff calculation for  POND
41      BA  .01449
42      PH   .2        .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
        *      TYPE D SOIL ASSUMED - 1/2 GRASS 1/2 PAVED
43      LS         89
44      US   .25   .72
        * **********

45      KK  PARK
46      BA  .00872
47      PH   .2        .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
        *      TYPE D SOIL ASSUMED - GOOD GRASS COVER
48      LS         .80
49      US   .25   .72
        * **********

50      KK  POND
51      KM  Combining two hydrographs inflowing to school detention pond
52      HC    2
        * **********

53      KK  DETEN
54      KM  Reservoir routing operation
55      RS    1  FLOW     0
56      SA    0   .02  1.63  2.65  3.13
57      SE  27.0    28  29.4   30.  34.4
58      SL  27.5   .78   .65    .5
59      SS    30    30   2.5   1.5
        * **********
```

```
60      KK  CULV1
61      KM  Combine brigadoon and flows from school at 3 x 5 box culverts
62      HC    2
        * **********

63      KK  PRWILD
64      KM  Basin runoff calculation for PRWILD - NORTH OF SCHOOL PROPERTY
65      BA  .0397
66      PH   .2       .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
        *     TYPE D SOIL ASSUMED - RESIDENTIAL LOTS OVER 2 ACRES
67      LS        82
68      US   .4   .72
        * **********
```



```
LINE     ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

69      KK  PRWILD
70      KM  Combining two hydrographs at culverts through Edgemere Drive
71      HC    2
        * **********

72      KK  GARDEN
73      KM  Basin runoff along Garden Drive
74      BA  0.023
75      PH   .2       .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
        * TYPE D SOIL ASSUMED - 1 ACRE LOTS
76      LS        84
77      US   .25  .72
        *     compute north flows as if they go down sedora drive
        * **********

78      KK  FRND1
79      KM  Basin runoff calculation from Friendswood Gardens
80      BA  .0314
81      PH   .2       .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
        *     TYPE D SOIL ASSUMED - RESIDENTIAL LOTS > 2 ACRES
82      LS        82
83      US   .3   .72
        * **********

84      KK  FRND2
85      KM  Basin runoff calculation from Friendswood Gardens
86      BA  .0314
87      PH   .2       .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
        *     TYPE D SOIL ASSUMED - RESIDENTIAL LOTS > 2 ACRES
88      LS        82
89      US   .3   .72
        * **********

90      KK  CREEK
91      KM  Basin runoff calculation for  CREEK
92      BA  .0628
93      PH   .2       .8   1.4   2.4   2.9   4.0   4.8   5.7   6.8
        *     CREEK LOTS - OVER 2 ACRE RESIDENTIAL
94      LS        82
95      US   .3   .71
        * **********

96      KK  IN2CR
97      KM  Combining two hydrographs at control point    SP2 prior to routing
98      HC    2
        * **********

99      KK  CREEK
```

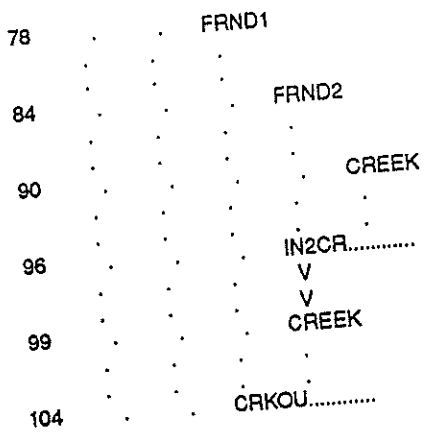
```
      100      KM  Modified puls channel routing from  STREET to    SP2
      101      RS    2  FLOW    0
      102      SV    0  1.89  2.27  2.46  2.71  2.95
      103      SQ    0   50   100   200   300   400
               * **********
1                                HEC-1 INPUT                                PAGE  4

     LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10


      104      KK  CRKOUT
      105      KM      Combine two hydrographs at east end of Garden Drive
      106      HC    2
      107      ZZ
1
          SCHEMATIC DIAGRAM OF STREAM NETWORK
 INPUT
 LINE   (V) ROUTING       (—>) DIVERSION OR PUMP FLOW

  NO.   (.) CONNECTOR     (<—) RETURN OF DIVERTED OR PUMPED FLOW

    6   KINGS
          .
          .
   12       .   PRKING
          .       .
          .       .
   18   STADM.....
          .
          .
   21       .     BRG
          .       .
          .       .
   27   stadm2.....
          .
          .
   30       .   OSCHL
          .       .
          .       .
   36   OSCHL.....
          .
          .
   39       .     POND
          .       .
          .       .
   45       .       .     PARK
          .       .       .
          .       .       .
   50       .     POND.....
          .       V
          .       V
   53       .   DETEN
          .       .
          .       .
   60   CULV1.....
          .
          .
   63       .   PRWILD
          .       .
          .       .
   69   PRWILD.....
          .
          .
   72       .   GARDEN
          .       .
          .       .
```



(***) RUNOFF ALSO COMPUTED AT THIS LOCATION

1**********

* FLOOD HYDROGRAPH PACKAGE (HEC-1) *
* MAY 1991 *
* VERSION 4.0.1E *
* *
* RUN DATE 08/25/93 TIME 13:03:05 *
* *
****

****

* U.S. ARMY CORPS OF ENGINEERS *
* HYDROLOGIC ENGINEERING CENTER *
* 609 SECOND STREET *
* DAVIS, CALIFORNIA 95616 *
* (916) 551-1748 *
****

FRIENDSWOOD MASTER DRAINAGE STUDY Problem # 13, 14
HYDROLOGY FOR SCHOOL IMPROVEMENTS 42 inch rcp assumed installed
STREAM HYDRAULICS / STREET HYDRAULICS SEE DITCH.DAT STREET?.DAT

5 IO OUTPUT CONTROL VARIABLES
IPRNT 5 PRINT CONTROL
IPLOT 0 PLOT CONTROL
QSCAL 0. HYDROGRAPH PLOT SCALE

IT HYDROGRAPH TIME DATA
NMIN 5 MINUTES IN COMPUTATION INTERVAL
IDATE 17JUN93 STARTING DATE
ITIME 0100 STARTING TIME
NQ 300 NUMBER OF HYDROGRAPH ORDINATES
NDDATE 18JUN93 ENDING DATE
NDTIME 0155 ENDING TIME
ICENT 19 CENTURY MARK

COMPUTATION INTERVAL 0.08 HOURS
TOTAL TIME BASE 24.92 HOURS

ENGLISH UNITS
DRAINAGE AREA SQUARE MILES
PRECIPITATION DEPTH INCHES
LENGTH, ELEVATION FEET
FLOW CUBIC FEET PER SECOND
STORAGE VOLUME ACRE-FEET
SURFACE AREA ACRES
TEMPERATURE DEGREES FAHRENHEIT

1 RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

	OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
+	HYDROGRAPH AT	KINGS	30.	12.33	6.	2.	2.	0.02		
+	HYDROGRAPH AT	PRKING	25.	12.25	4.	1.	1.	0.01		
+	2 COMBINED AT	STADM	52.	12.25	10.	3.	3.	0.02		
+	HYDROGRAPH AT	BRG	29.	12.33	5.	2.	2.	0.01		
+	2 COMBINED AT	stadm2	80.	12.25	15.	5.	5.	0.04		
+	HYDROGRAPH AT	OSCHL	22.	12.33	4.	1.	1.	0.01		
+	2 COMBINED AT	OSCHL	102.	12.33	19.	6.	6.	0.04		
+	HYDROGRAPH AT	POND	37.	12.33	7.	2.	2.	0.01		
+	HYDROGRAPH AT	PARK	0.	0.08	0.	0.	0.	0.01		
+	2 COMBINED AT	POND	37.	12.33	7.	2.	2.	0.02		
+	ROUTED TO	DETEN	6.	13.75	6.	2.	2.	0.02		
+								29.68	13.83	
+	2 COMBINED AT	CULV1	107.	12.33	24.	8.	8.	0.07		
+	HYDROGRAPH AT	PRWILD	67.	12.42	16.	5.	5.	0.04		
+	2 COMBINED AT	PRWILD	169.	12.33	40.	13.	13.	0.11		
+	HYDROGRAPH AT	GARDEN	54.	12.33	10.	3.	3.	0.02		
+	HYDROGRAPH AT	FRND1	63.	12.33	13.	4.	4.	0.03		
+	HYDROGRAPH AT	FRND2	63.	12.33	13.	4.	4.	0.03		
+	HYDROGRAPH AT	CREEK	124.	12.33	25.	8.	8.	0.06		
+	2 COMBINED AT	IN2CR	187.	12.33	38.	12.	11.	0.09		
+	ROUTED TO	CREEK	208.	12.33	38.	12.	11.	0.09		
	2 COMBINED AT									

+	CRKOU	270.	12.33	50.	16.	15.	0.13

*** NORMAL END OF HEC-1 ***

Problem Area No.15
Block Bounded by FM 518, FM 528, Winding Way and Leisure Lane

DA #	area	tc	cfact	ca	i-5	i-100	q-5	q-100
1	3.95	15	0.30	1.19	5.75	8.225	6.81	9.75
2	1.64	10	0.80	1.31	6.5	9.25	8.53	12.14
3	8.34	30	0.30	2.50	4.2	6.8	10.51	17.01
4	5.09	20	0.35	1.78	5	7.2	8.91	12.83
5	13.98	30	0.30	4.19	4.2	6.8	17.61	28.52
Totals:	33			10.9745			52.37	80.24

Total Flows at Leisure Lane and FM 518

tc	i-5	i-100	q-5	q-100
30	4.2	6.8	46.09	74.63

Problem Area No. 16
Melody Lane

da #	area	tc	cfac	ca	i - 5	i - 100	q - 5	q - 100
1	17.96	30	0.3	5.388	4.2	6.8	23	37
2	16.9	30	0.35	5.915	4.2	6.8	25	40
3	41.54	30	0.3	12.462	4.2	6.8	52	85

At point A: East side of Subdivision

tc	i - 5	i - 100
40	3.65	5.75

da	area	ca	q - 5	q - 100
1	17.96	5.388	20	31
2	16.9	5.915	22	34
3	41.54	12.462	45	72
total	76.4	23.765	87	137

Problem Area No. 17
F.M. 518 Willowwick to Mary's Creek Outfall

da #	area	tc	cfac	ca	i - 5	i - 100	q - 5	q - 100
1	10	14	0.8	8	5.9	8.4	47	67
2	8.6	10	0.8	6.88	6.5	9.3	45	64
3	4.9	10	0.8	3.92	6.5	9.3	25	36
4	10.4	10	0.7	7.28	6.5	9.3	47	67
5	7.6	10	0.8	6.08	6.5	9.3	40	56

At point A: Heritage / S. Frienswood (F.M. 518)

tc	i - 5	i - 100
17	5.45	7.815

da	area	ca	q - 5	q - 100
1	10	8	44	63
2	8.6	6.88	37	54
total	18.6	14.88	81	116

At point B: Edgewood / S. Friendswood (F.M. 518) (from East)

tc	i - 5	i - 100
20	5	7.2

da	area	ca	q - 5	q - 100
1	10	8	40	58
2	8.6	6.88	34	50
3	4.9	3.92	20	28
total	23.5	18.8	94	135

At point C: Edgewood / S. Friendswood (F.M. 518) (toward north)

tc	i - 5	i - 100
20	5	7.2

da	area	ca	q - 5	q - 100
1	10	8	40	58
2	8.6	6.88	34	50
3	4.9	3.92	20	28
4	10.4	7.28	36	52
total	33.9	26.08	130	188

Problem Area No. 17
F.M. 518 Willowwick to Mary's Creek Outfall
|::
At point D: Outfall - Edgewood & Mary's Creek

tc	i - 5	i - 100
24	4.68	7.04

da	area	ca	q - 5	q - 100
1	10	8	37	56
2	8.6	6.88	32	48
3	4.9	3.92	18	28
4	10.4	7.28	34	51
5	7.6	6.08	28	43
total	41.5	32.16	151	226

Problem Area no. 18
S. Friendswood St., Outfall to Cowart Creek

da #	area	tc	cfac	ca	i - 5	i - 100	q - 5	q - 100
1	10.85	19	0.72	7.812	5.2	7.4	40	58
2	9.48	15	0.56	5.3088	5.8	8.2	31	44
3	15.97	32	0.625	9.98125	4.1	6.6	41	66
4	12.49	24	0.55	6.8695	4.7	7.0	32	48
5	14.81	30	0.53	7.8493	4.2	6.8	33	53
6	13.79	26	0.35	4.8265	4.5	7.0	22	34

DRAINAGE AREA 1 & 2

tc	i - 5	i - 100
23	4.8	7.1

da	area	ca	Q - 5	Q - 100
1	10.85	7.812	37	55
2	9.48	5.3088	25	38
total	20.33	13.1208	62	93

DRAINAGE AREA 1 - 3

tc	i - 5	i - 100
32	4.1	6.6

da	area	ca	Q - 5	Q - 100
1	10.85	7.812	32	51
2	9.48	5.3088	22	35
3	15.97	9.98125	41	66
total	36.30	23.1021	94	152

DRAINAGE AREA 1 - 4

tc	i - 5	i - 100
38	3.8	6.0

da	area	ca	Q - 5	Q - 100
1	10.85	7.812	29	47
2	9.48	5.3088	20	32
3	15.97	9.98125	38	59
4	12.49	6.8695	26	41
total	48.79	29.9716	113	179

Problem Area no. 18
S. Friendswood St., Outfall to Cowart Creek

DRAINAGE AREA 1 - 5

tc	i - 5	i - 100
43	3.5	5.5

da	area	ca	Q - 5	Q - 100
1	10.85	7.812	27	43
2	9.48	5.3088	19	29
3	15.97	9.98125	35	55
4	12.49	6.8695	24	38
5	14.81	7.8493	28	43
total	63.60	37.8209	133	209

DRAINAGE AREA 1-6, OUTFALL TO COWART CREEK

tc	i - 5	i - 100
50	3.2	5.0

da	area	ca	Q - 5	Q - 100
1	10.85	7.812	25	39
2	9.48	5.3088	17	27
3	15.97	9.98125	32	50
4	12.49	6.8695	22	34
5	14.81	7.8493	25	39
6	13.79	4.8265	15	24
total	77.39	42.6474	136	213

Problem Area no. 19
Annalea Subdivision Outfall

da #	area	tc	cfac	ca	i - 5	i - 100	q - 5	q - 100
1	6.19	10	0.55	3.4045	6.5	9.3	22	31
2	7.4	10	0.55	4.07	6.5	9.3	26	38
3	3.63	10	0.55	1.9965	6.5	9.3	13	18
4	5.5	10	0.55	3.025	6.5	9.3	20	28
5	3.76	10	0.55	2.068	6.5	9.3	13	19
6	3.2	10	0.55	1.76	6.5	9.3	11	16
7	8.8	10	0.55	4.84	6.5	9.3	31	45

At point A: Mary Ann @ Linda Lane

tc	i - 5	i - 100
15	5.75	8.225

da	area	ca	q - 5	q - 100
1	6.19	3.4045	20	28
2	7.4	4.07	23	33
total	13.59	7.4745	43	61

At point B: Mary Ann @ Virginia (South)

tc	i - 5	i - 100
16	5.6	8.02

da	area	ca	q - 5	q - 100
1	6.19	3.4045	19	27
2	7.4	4.07	23	33
3	3.63	1.9965	11	16
total	17.22	9.471	53	76

At point C: Mary Ann @ Virginia (North & South)

tc	i - 5	i - 100
16	5.6	8.02

da	area	ca	q - 5	q - 100
1	6.19	3.4045	19	27
2	7.4	4.07	23	33
3	3.63	1.9965	11	16
4	5.5	3.025	17	24
total	22.72	12.496	70	100

Problem Area no. 19
Annalea Subdivision Outfall

At point E: Outfall

tc	i - 5	i - 100
17	5.45	7.815

da	area	ca	q - 5	q - 100
1	6.19	3.4045	19	27
2	7.4	4.07	22	32
3	3.63	1.9965	11	16
4	5.5	3.025	16	24
5	3.76	2.068	11	16
6	3.2	1.76	10	14
7	8.8	4.84	26	38
total	38.48	21.164	115	165

AVO 12894
TYPICAL FRIENDSWOOD 28 FT STREET
DATE : 08/25/93

1. SLOPE = .108 FT/100FT [MARY ANN DRIVE No.1]

DEPTH =	0.53	FT, FOR Q =	10	CFS
	0.71		20	
	0.95		40	
	1.11		60	
	1.25		80	
	1.37		100	

2. SLOPE = .221 FT/100FT [MARY ANN DRIVE No.2]

DEPTH =	0.46	FT, FOR Q =	10	CFS
	0.61		20	
	0.82		40	
	0.96		60	
	1.08		80	
	1.18		100	

3. SLOPE = .220 FT/100FT [VIRGINIA LANE]

DEPTH =	0.46	FT, FOR Q =	10	CFS
	0.61		20	
	0.82		40	
	0.97		60	
	1.08		80	
	1.18		100	

4. SLOPE = .181 FT/100FT [RACHAEL LANE]

DEPTH =	0.48	FT, FOR Q =	10	CFS
	0.64		20	
	0.85		40	
	1.00		60	
	1.12		80	
	1.23		100	

Problem Area no. 20
Whitehall Outfall

da #	area	tc	cfac	ca	i - 5	i - 100	q - 5	q - 100
1	7.79	10	0.55	4.2845	6.5	9.3	28	40
2	41.79	19	0.55	22.9845	5.2	7.4	118	170
3	6.28	9	0.55	3.454	6.6	9.5	23	33
4	4.6	9	0.55	2.53	6.6	9.5	17	24
5	3.89	7	0.55	2.1395	7.0	10.0	15	21
6 **	19.91	15	0.55	10.9505	5.8	8.2	63	90
7	7.94	10	0.55	4.367	6.5	9.3	28	40
8	10.29	11.5	0.55	5.6595	6.4	9.0	36	51
9	4.6	8	0.55	2.53	6.8	9.8	17	25
10	32.5	18	0.55	17.875	5.3	7.6	95	136
11	3.63	8	0.55	1.9965	6.8	9.8	14	20
12	6.62	9	0.55	3.641	6.6	9.5	24	35
13	12.06	13	0.55	6.633	6.1	8.6	40	57

** Actual drainage area = 12.41, 7.5 acres added from offsite

Point A Culverts at castlelake

tc	i - 5	i - 100
22	4.8	7.1

da	area	ca	Q - 5	Q - 100
13	12.06	6.633	32	47
12	6.62	3.641	18	26
11	3.63	1.9965	10	14
9	4.6	2.53	12	18
10	32.5	17.875	87	127
8	10.29	5.6595	27	40
7	7.94	4.367	21	31
total	77.64	42.702	207	304

Point B outfall at FM518

tc	i - 5	i - 100
32	4.1	6.6

da	area	ca	Q - 5	Q - 100
1	7.79	4.2845	18	28
2	41.79	22.9845	94	151
3	6.28	3.454	14	23
4	4.6	2.53	10	17
5	3.89	2.1395	9	14
6	19.91	10.9505	45	72
7	7.94	4.367	18	29
8	10.29	5.6595	23	37
9	4.6	2.53	10	17
10	32.5	17.875	73	118
11	3.63	1.9965	8	13
12	6.62	3.641	15	24
13	12.06	6.633	27	44
total	161.90	89.045	364	587