FLOODPLAIN LIMITS AND FLOOD CONTROL PLAN

for the

WAIKOLOA HIGHLANDS SUBDIVISION

Waikoloa, Island of Hawaii
TMK: 6-8-02:16, 6-8-03:32
Subdivision No. 89-179
DPW Folder No. 6858

SEPTEMBER 2006

R. M. TOWILL CORPORATION
SINCE 1930

Prepared For:

Waikoloa Mauka, LLC

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(RMTC Ref: 1-20580-0-E)

Exhibit "50"

R. M. TOWILL CORPORATION
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September, 2006

Prepared for:

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Prepared by:

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1 INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this study is to update a previous flood analyses report (Reference 1), prepared by R.M. Towill Corporation (RMTC) for the Waikoloa Highlands Subdivision. The analyses will determine the design flows for each Flood Route identified within the project site and size appropriate channels and culverts to pass the design flows. It will also include determining the floodplain limits for the Flood Routes through the project site.

1.2 PROJECT LOCATION AND DESCRIPTION

The project site is located 22 miles northeast of Keahole International Airport in Waikoloa, District of South Kohala, Island of Hawaii (Tax Map Key: Third Division 6-8-02:16, 6-8-03:32). The prpject consists of 744.4 acres located south of Waikoloa Villages, north of Puu Hinai Cinder Cone between Auwaiakeakua Gulch and Waikoloa Road. It consists of grading, construction of roadways and utilities for the purpose of 398 single-family residential lots for Phases 1 and 2 (Figures 1 and 2).

2 GENERAL AND METHODOLOGY

There is one (1) major stream identified in this study, which is Auwaiakeakua Gulch. The gulch and its sub-tributaries pass south of the project site. A previous flood study conducted by R.M. Towill Corporation (RMTC, Reference 1) indicated that there were nine (9) Flood Routes within the project site (Auwaiakeakua Gulch and 8 tributaries). Figure 3, which is taken from Reference 1, shows the location of each Flood Route.

2.1 HYDROLOGIC CRITERIA AND METHODOLOGY

The RMTC report utilized the regression equation to calculate 100-year storm for the 9 Flood Routes. The regression equation was adopted in the 1995 Hawaii County Flood Insurance Study published by Federal Emergency Management Agency (FEMA, Reference 2). It was intended to incorporate basin and climatological characteristics to determine peak discharge-frequency relationships. Two groups of regression equations were established for windward and leeward areas. Waikoloa Highlands is located at leeward side (Figure 4).

For this study, the regression equation was mainly used to determine the 100-year peak discharges for Flood Routes originated off-site (Flood Routes 1, 3, and 5) and the culverts at roadway crossing. Flood Routes 2, 6, 7, 8, and 9, which originate onsite, are concentration areas contributing to the Auwaiakeakua Gulch (Flood Route 5. They have drainage areas considerably below 100 acres, and are not considered for flood mapping under proposed conditions. Instead, they will be considered as subdivision drainage, which is not the scope of this study.

Hydrologic Criteria

- Flood Mapping, Ditches, Culverts (off-site Flood Routes, area > 100acres)

Method	Regression Equation
Return Interval	100-year
Design Storm Duration	24-hour

Hydrologic Methodology

- Flood Mapping, Ditches, Culverts (off-site Flood Routes, area > 100acres)

$Q_{100} = 34.3\ (DA)^{0.77}\ (P24\text{-}2)^{2.26}$

where:

Q_{100}	=	Peak discharge with 100-year return interval (cfs)
DA	=	Drainage area (mi^2)
P24-2	=	2-year, 24-hour rainfall depth (inches)
	=	3" for Waikoloa Highlands area (Reference 1)

2.2 HYDROLOGIC ANALYSIS

Drainage areas were delineated and interpolated based on the field observation and previous report (Reference 1), and the watershed boundary was digitized on the USGS Quadrangle Map (Figure 5). Runoff quantities were calculated using the regression equation. The final tabulated results of hydrologic analysis were presented in Table 1

Table 1 Hydrologic Analysis Results

Location	Drainage Area (acres)	Q_{100} (cfs)
Flood Route 1		
at Waikoloa Road before entering project site	888	529
at Road "A" crossing	975	567
at d/s project boundary exiting project site	1,023	590
Flood Route 3		
at Waikoloa Road before entering project site	64.4	70
before confluence point with Flood Route 5	136	125
Flood Route 5		
before entering project site	32,217	8,396
before confluence point with Flood Route 3	32,685	8,489
after confluence point with Flood Route 3	32,821	8,516
at d/s project boundary exiting project site	33,314	8,615

2.3 HYDRAULIC CRITERIA AND METHODOLOGY

Hydraulic Criteria

- Culverts sizing

Method	CulvertMaster (Reference 5)
Entrance Type	Headwall
Max. HW/D	1.0 – 1.1
Material	CMP

- Ditches sizing

Method	HEC-RAS FlowMaster (Reference 6)
Flow Regime	Mixed Flow
Boundary Condition	Normal Depth
Manning's n	0.040 for rock channel 0.045 for overbank areas

- Flood Mapping:

Method	HEC-RAS
Flow Regime	Mixed Flow
Boundary Condition	Normal Depth, Known Water Surface Elevation
Manning's n	0.040 for rock channel 0.045 for overbank areas

Hydraulic Methodology

The standard step method, using the Corps of Engineer's hydraulic model HEC-RAS and GIS pre-process tool HEC-GeoRAS to take geometry data, was used to determine the bare floodwater surface elevations and 100-year flood limits.

The mixed flow regime method was in the analysis due to slopes generally observed in the field. As expected of watercourses in Hawaii, majority of the stream segments were under supercritical conditions.

Boundary conditions were determined using the normal depth and known water surface elevation options in HEC-RAS. The normal depth could be entering as energy slope. The energy slope could be approximated by calculating the channel bed slope.

Manning's roughness coefficient, n, was estimated from the Hawaii County's standard and field observation. The Hawaii County's standard suggested values of n between 0.035 to 0.04 for unlined channel with rock ranging from smooth and uniform to jagged and irregular. In this study, values of n for unlined channel and overbank areas were estimated to be 0.04 to 0.045. The higher n value was used to account for rougher surface as observed in the field.

With the given design flows from the hydrologic analysis, HEC-RAS and FlowMaster were utilized to size the ditches. Freeboard was provided for the ditches following the guideline stated in the Hawaii County Drainage Standard. Culverts sizing was performed by using CulvertMaster and entrance control nomograph (Reference 3).

2.4 HYDRAULIC ANALYSIS

With the given geometry and flow data, hydraulic analysis was performed by using the chosen computer programs and nomograph. Ditches and culverts information were presented in Appendex A. HEC-RAS output files and summary were prepared in Appendex B. The 100-year flood boundary was shown in Figure 6. Cross-section labels used in the HEC-RAS analysis was presented in Figure 7.

2.5 FLOODPLAIN MAPPING

The 100-year floodplain boundaries were delineated using the HEC-RAS modeling results. The HEC-RAS model provided water surface elevation and flood limits at each cross section of the stream. The HEC-RAS output files were imported back to HEC-GeoRAS for automatic floodplain delineation. Where there was disconnecting portion of the floodplain from HEC-GeoRAS outputs, the floodplain boundaries were drawn manually using engineer's judgment by checking left and right flood limit at said cross section and connected to downstream flood limits.

3 EXISTING DRAINAGE CONDITIONS

The nine (9) Flood Routes stated in previous study (Reference 1) that impact the project site are Auwaiakeakua Gulch (Flood Route 5) and its tributaries (Flood Routes 1 to 4, 6 to 8) (see Figure 3). Auwaiakeakua Gulch, originating from the summit of Mauna Kea, flows in a northwest direction, ending up Pacific Ocean.

Auwaiakeakua Gulch passes south of project site and crosses Waikoloa Road further downstream of the project site. The existing topography consists of rolling terrain with flat to moderately steep slopes. Slopes are steep in the upper watershed areas and gradually reduce to flat through the project site. Ground cover primarily consists of low lying brush and scattered Kiawe trees. Flood Routes 1 and 3 originate off-site and enter the project site from east through culverts at Waikoloa Road. Flood Route 4 is located outside of the project site and is upstream of Auwaiakeakua Gulch. Other Flood Routes are minor tributaries originate onsite eventually contribute to Auwaiakeakua Gulch.

4 PROPOSED DRAINAGE PLAN

For this study, the main focus is to prepare a flood control plan for the future development of Waikoloa Highlands. Sizing culverts at the proposed roadway crossing and proposed diversion ditches will be discussed. A brief description of the proposed drainage improvements is summarized as follows:

Ditches:

- Ditch 1:

  Off-site Flood Route 1 enters the project site though existing 2 – 8'-2" x 5'-9" pipe arch culverts at Waikoloa Road. The proposed ditch will route Flood Route 1 flows along Waikoloa Road and pass through Culvert A at the proposed Road "A" crossing. The proposed ditch is 15' wide bottom width with a 2:1 side slope. The excavated ditch is a rock channel with maximum channel slope of 7%, and the design flow (Q_{100}) is 567 cfs. The ditch is designed to meet the requirement specified in the Hawaii County Drainage Standard.

Culverts:

- Culvert A

  Culver A (2-84" CMP) is located at STA. 2+11.33 of Road "A" crossing. The culverts are at the end of Ditch 1 and will pass the design flows to the existing terrain. The design peak discharge, (Q_{100}) calculated using regression equation, is 567 cfs.

- Culvert F (60" CMP) is located at STA. 44+55.64 of Road "A" crossing. The drainage area is part of Flood Route 3, which originates off-site. Flood Route 3 enters the project site through existing 42" CMP at Waikoloa Road. It flows in southwest direction, crossing proposed Road "A" and eventually connects to Flood Route 5 as its triburary. The design peak discharge, (Q_{100}) calculated using regression equation, is 125 cfs.

5 SUMMARY AND CONCLUSION

To protect the project site from flooding problems, drainage improvements are proposed in this study to accommodate the design flows. This will increase the developable lands in the future Waikoloa Highlands development.

A proposed ditch (Ditch 1) will direct Flood Route 1 flow (567 cfs) along Waikoloa Road to downstream open area. There are 2 culverts (Culvert A and F) proposed at roadway crossing to pass the design 100-year flows to open area. Culvert A (2-84" CMP) is located at the proposed Road "A" crossing to pass Flood Route 1 flow. Culvert F (60" CMP) passes Flood Route 3 flow (125 cfs) at another Road "A" crossing. The proposed drainage improvements will decrease the risk of flooding problems in the Waikoloa Highlands development and are in compliance with current design standard.

6 REFERENCES

1. "Floodway Limits and Flood Control Plan for the Highlands Golf Estate at Waikoloa", R.M. Towill Corporation, 12/1992

2. "Flood Insurance Study for Hawaii County", Federal Emergency Management Agency, 6/2/1995

3. "Storm Drainage Standard", Department of Public Works, County of Hawaii, 10/1970

4. USGS Quadrangle (7.5 Minutes Series, 1:24K): Puu Hinai, Nohonaohae, Makahalau, Keamulu, Ahumoa, and Mauna Kea

5. CulvertMaster v3.1, Bently System, Inc., 12/2005

6. FlowMaster v7.0, Haestad Methods, Inc., 6/2003

7. "HEC-GeoRAS User's Manual", U.S. Army Corps of Engineers, v3.1, 10/2002

8. HEC-RAS v3.1.3, U.S. Army Corps of Engineers, 5/2005

Appendix A

Culverts and Ditches

Route1 Proposed Channel
8/8/2006, StartofRAChl.prj, Plan 4

River Station	Q (cfs)	Inv. Elev (ft)	WS Elev (ft)	Depth (ft)	Vel Total (fps)	FB (ft)	Elev Total (ft)	Remark
4235.067	567	1170.66	1172.77	2.11	13.95	2.45	1175.22	STA 20+26.34
4122.012	567	1168.40	1171.50	3.10	8.61	2.31	1173.81	STA 19+13.30
4108.728	567	1167.46	1169.78	2.32	12.45	2.41	1172.19	STA 19+00
4058.730	567	1163.96	1166.00	2.04	14.60	2.46	1168.46	HRC-RAS interpolated XS
4008.734	567	1160.46	1162.52	2.06	14.38	2.46	1164.98	STA 18+00
3908.738	567	1153.46	1155.51	2.05	14.46	2.46	1157.97	STA 17+00
3766.138	567	1143.48	1145.54	2.06	14.43	2.46	1148.00	STA 15+57.39
3631.330	567	1137.68	1140.19	2.51	11.26	2.38	1142.57	STA 14+22.58
3608.754	567	1136.71	1139.13	2.42	11.79	2.40	1141.53	STA 14+00
3588.753	567	1135.31	1137.48	2.17	13.49	2.44	1139.92	STA 13+80
3508.758	567	1129.73	1131.76	2.03	14.69	2.47	1134.23	STA 13+00
3408.757	567	1122.75	1124.82	2.07	14.27	2.45	1127.27	STA 12+00
3188.773	567	1107.40	1109.45	2.05	14.50	2.46	1111.91	STA 9+80
3008.784	567	1103.80	1106.88	3.08	8.67	2.32	1109.20	STA 8+00
2918.795	567	1102.00	1104.78	2.78	9.92	2.35	1107.13	STA 7+10
2898.787	567	1100.80	1103.08	2.28	12.71	2.42	1105.50	STA 6+90
2858.805	567	1098.40	1100.55	2.15	13.64	2.44	1102.99	STA 6+50
2808.793	567	1095.40	1097.55	2.15	13.70	2.44	1099.99	STA 6+00
2728.793	567	1090.60	1092.74	2.14	13.73	2.44	1095.18	STA 5+20
2608.796	567	1088.20	1091.30	3.10	8.64	2.31	1093.61	STA 4+00
2498.798	567	1086.00	1088.74	2.74	10.11	2.35	1091.09	STA 2+90
2453.790	567	1082.85	1084.84	1.99	15.02	2.47	1087.31	HRC-RAS interpolated XS
2408.798	567	1079.70	1081.77	2.07	14.30	2.46	1084.23	STA 2+00
2308.798	567	1072.70	1074.75	2.05	14.49	2.46	1077.21	STA 1+00
2252.798	567	1068.78	1075.84	7.06	2.71	2.13	1077.97	STA 0+44
2234.946	567	1068.68	1075.83	7.15	2.71	2.13	1077.96	STA 0+24, u/s of culvert
2200								**2 - 84" CMP Culverts @ Road "A"**
2121.584	567	1068.14	1070.99	2.85	7.99	2.28	1073.27	d/s of culvert
2024.821	590	1062.00	1064.23	2.23	14.49	2.47	1066.70	
1875.048	590	1052.00	1054.70	2.70	12.78	2.44	1057.14	
1751.102	590	1042.00	1044.01	2.01	15.68	2.49	1046.50	
1592.063	590	1031.46	1034.46	3.00	12.74	2.46	1036.92	
1503.453	590	1026.00	1028.47	2.47	14.42	2.49	1030.96	
1368.255	590	1020.00	1022.36	2.36	11.91	2.40	1024.76	
1241.424	590	1018.00	1020.12	2.12	6.73	2.22	1022.34	
1058.547	590	1014.00	1016.04	2.04	8.10	2.26	1018.30	
851.562	590	1008.00	1010.80	2.80	8.82	2.31	1013.11	
606.114	590	1004.00	1006.43	2.43	7.27	2.24	1008.67	
441.491	590	1000.00	1002.47	2.47	1.64	2.06	1004.53	flow splits to right over bank
321.898	590	998.00	999.11	1.11	10.17	2.26	1001.37	
257.760	590	996.00	997.37	1.37	4.27	2.12	999.49	
177.159	590	993.69	995.06	1.37	4.53	2.13	997.19	
20.877	590	989.77	992.90	3.13	0.98	2.04	994.94	

Culvert at Start of Road A
2-84" CMP, L = 107.83 ft
Slope = 0.5%

Culvert Calculator Report
90806 WH Culvert A Rd A (FR-1)

Solve For: Section Size

Culvert Summary			
Allowable HW Elevation	1,076.00 ft	Headwater Depth/Height	0.99
Computed Headwater Elevation	1,075.62 ft	Discharge	567.00 cfs
Inlet Control HW Elev.	1,075.15 ft	Tailwater Elevation	0.00 ft
Outlet Control HW Elev.	1,075.62 ft	Control Type	Outlet Control

Grades			
Upstream Invert	1,068.68 ft	Downstream Invert	1,068.14 ft
Length	107.83 ft	Constructed Slope	0.005008 ft/ft

Hydraulic Profile			
Profile	M2	Depth, Downstream	4.43 ft
Slope Type	Mild	Normal Depth	N/A ft
Flow Regime	Subcritical	Critical Depth	4.43 ft
Velocity Downstream	11.06 ft/s	Critical Slope	0.012714 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	7.00 ft
Section Size	84 inch	Rise	7.00 ft
Number Sections	2		

Outlet Control Properties			
Outlet Control HW Elev.	1,075.62 ft	Upstream Velocity Head	1.17 ft
Ke	0.20	Entrance Loss	0.23 ft

Inlet Control Properties			
Inlet Control HW Elev.	1,075.15 ft	Flow Control	N/A
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels	Area Full	77.0 ft²
K	0.00180	HDS 5 Chart	3
M	2.50000	HDS 5 Scale	B
C	0.02430	Equation Form	1
Y	0.83000		

Culvert Calculator Report
90806 WH Culvert F Rd A (FR-3)

Solve For: Section Size

Culvert Summary					
Allowable HW Elevation	1,106.30	ft	Headwater Depth/Height	1.03	
Computed Headwater Elevation	1,106.09	ft	Discharge	125.00	cfs
Inlet Control HW Elev.	1,105.63	ft	Tailwater Elevation	0.00	ft
Outlet Control HW Elev.	1,106.09	ft	Control Type	Outlet Control	

Grades					
Upstream Invert	1,100.94	ft	Downstream Invert	1,100.42	ft
Length	104.72	ft	Constructed Slope	0.004966	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	3.20	ft
Slope Type	Mild		Normal Depth	N/A	ft
Flow Regime	Subcritical		Critical Depth	3.20	ft
Velocity Downstream	9.43	ft/s	Critical Slope	0.014379	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	5.00	ft
Section Size	60 inch		Rise	5.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	1,106.09	ft	Upstream Velocity Head	0.78	ft
Ke	0.20		Entrance Loss	0.16	ft

Inlet Control Properties				
Inlet Control HW Elev.	1,105.63 ft	Flow Control	Unsubmerged	
Inlet Type	Beveled ring, 33.7° (1.5:1) bevels	Area Full	19.6	ft²
K	0.00180	HDS 5 Chart	3	
M	2.50000	HDS 5 Scale	B	
C	0.02430	Equation Form	1	
Y	0.83000			

Appendix B

HEC-RAS Output

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Appendix B1

Flood Route 1

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SINCE 1930

Appendix B2

Flood Route 3

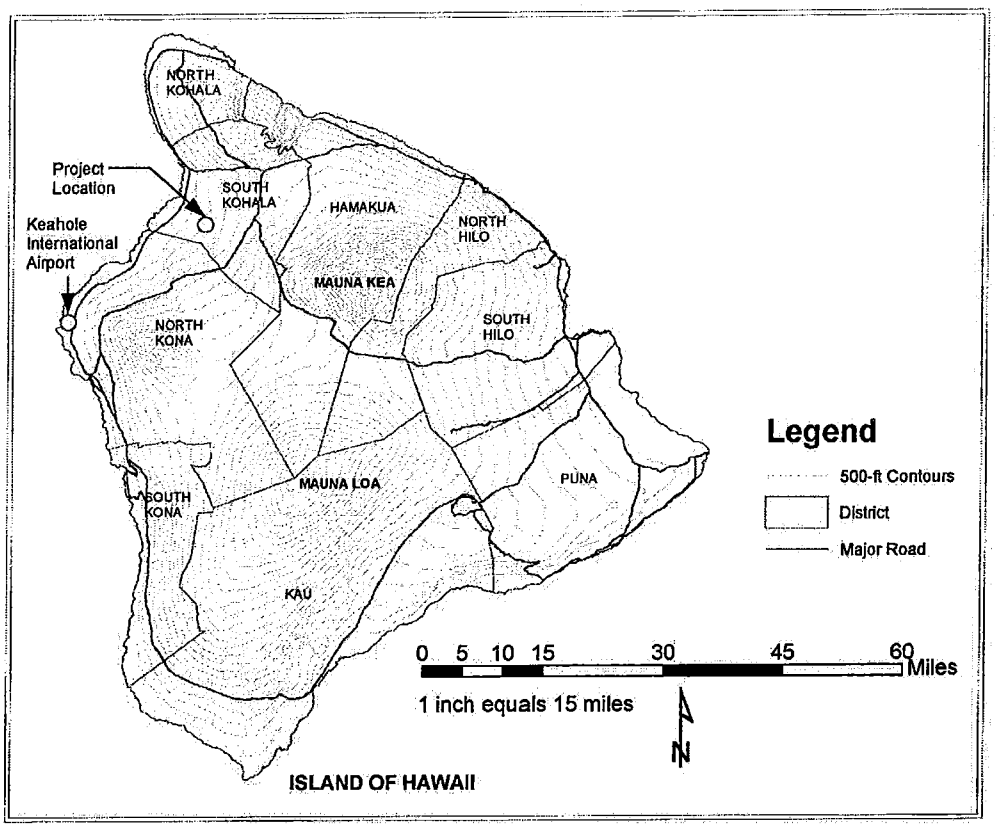
R. M. TOWILL CORPORATION
SINCE 1930

Appendix B3

Flood Route 5

Appendix C

Figures



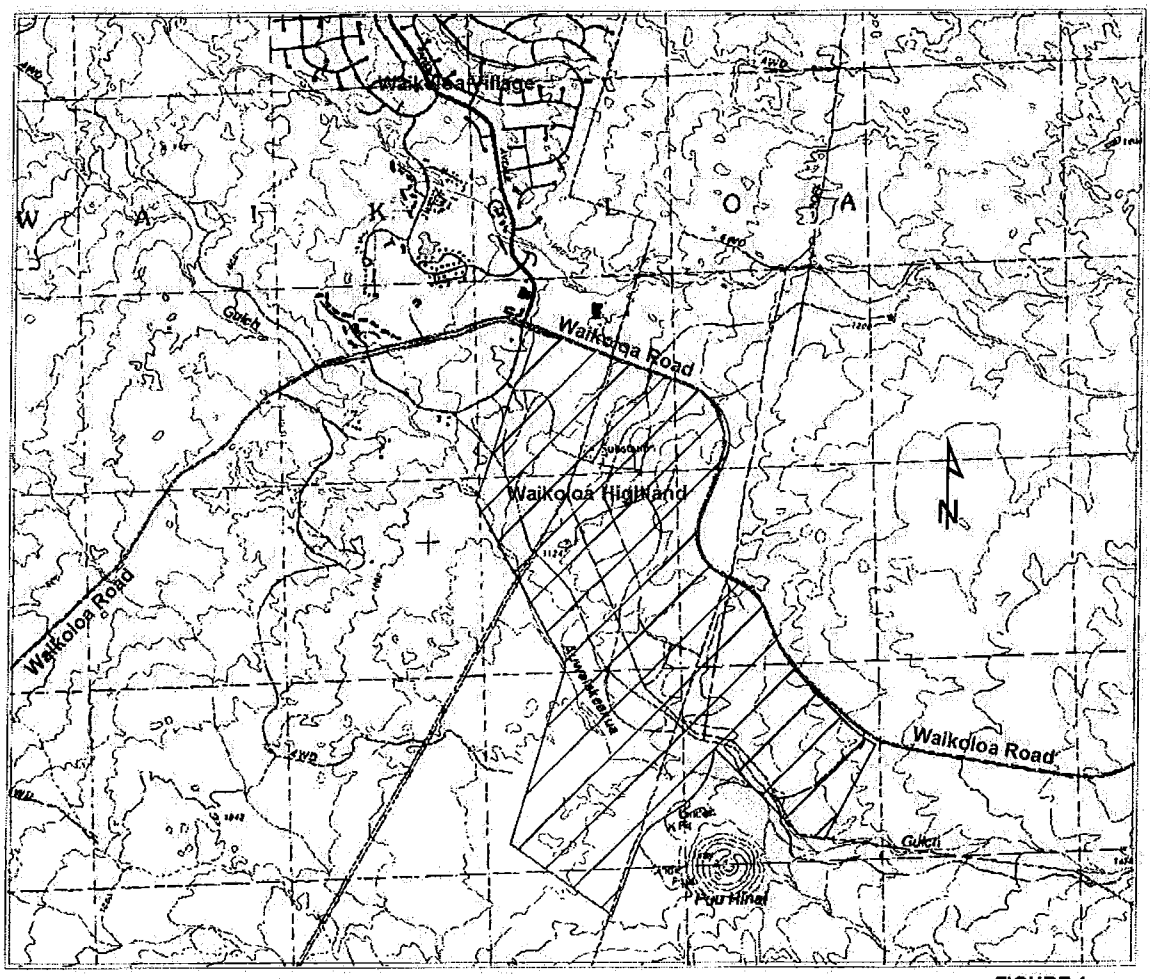
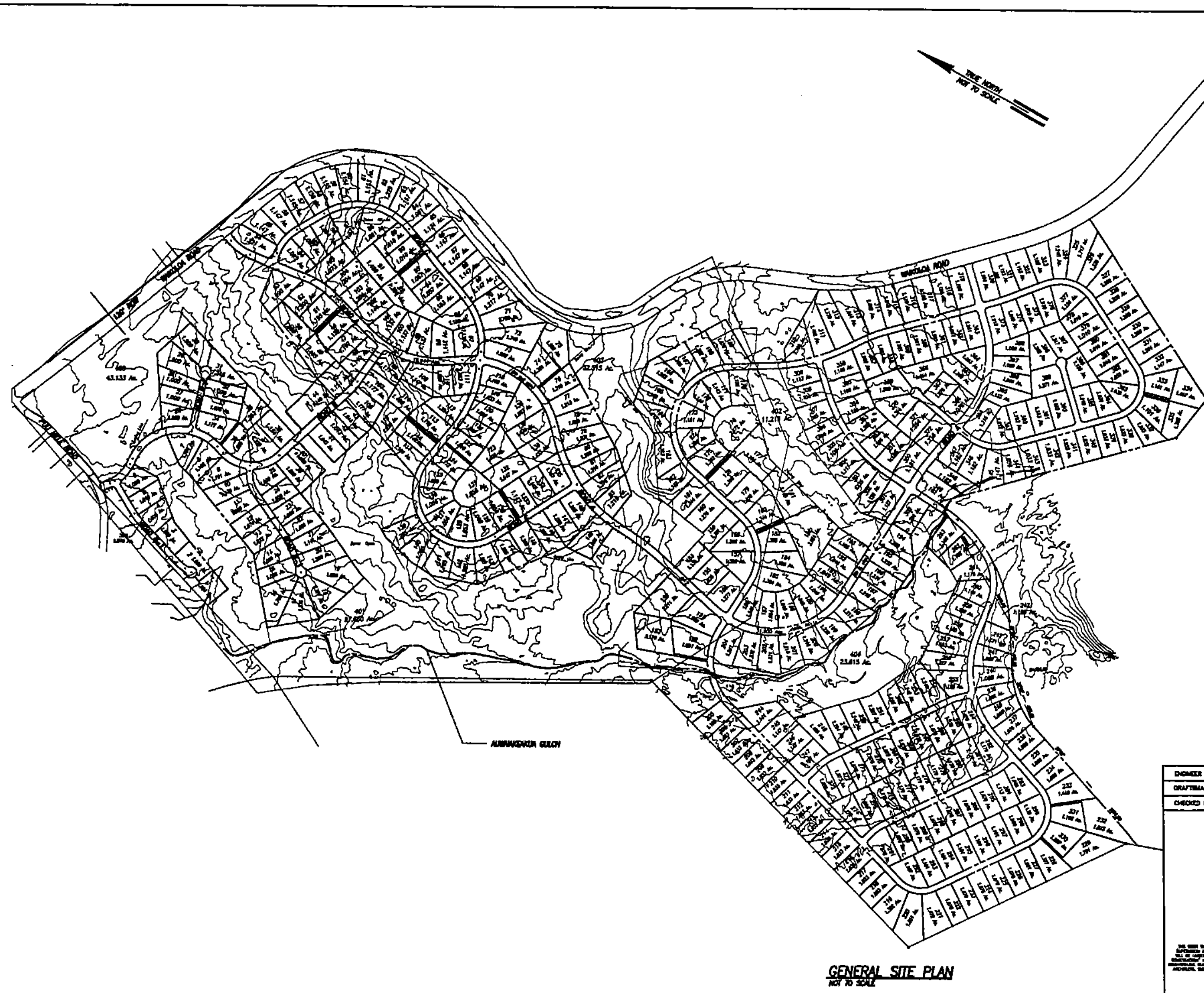


FIGURE 1
VICINITY MAP



GENERAL SITE PLAN
NOT TO SCALE

ENGINEER	MHS					
DRAFTSMAN	MHS					
CHECKED BY	HIT	REV	DATE	BRIEF	BY	APPROVED

R. M. TOWILL CORPORATION

WAIKOLOA HIGHLANDS SUBDIVISION
WAIKOLOA, SOUTH KOHALA, ISLAND OF HAWAII, HAWAII

INCREMENT 1

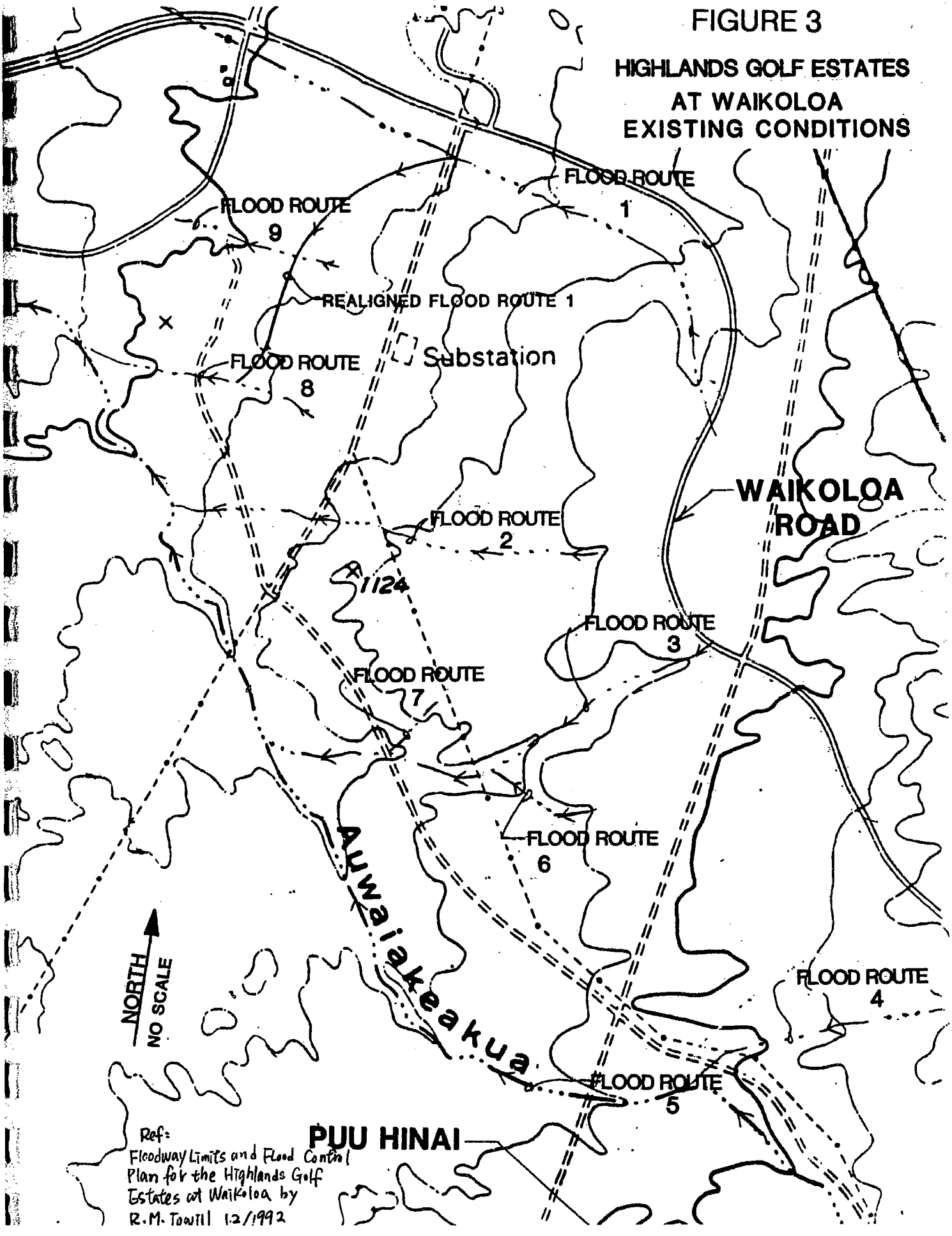
FIGURE 2 GENERAL SITE PLAN

APPROVED :

R. M. TOWILL CORPORATION

FIGURE 3

HIGHLANDS GOLF ESTATES AT WAIKOLOA EXISTING CONDITIONS



Ref:
Floodway Limits and Flood Control Plan for the Highlands Golf Estates at Waikoloa by R.M. Towill 12/1992

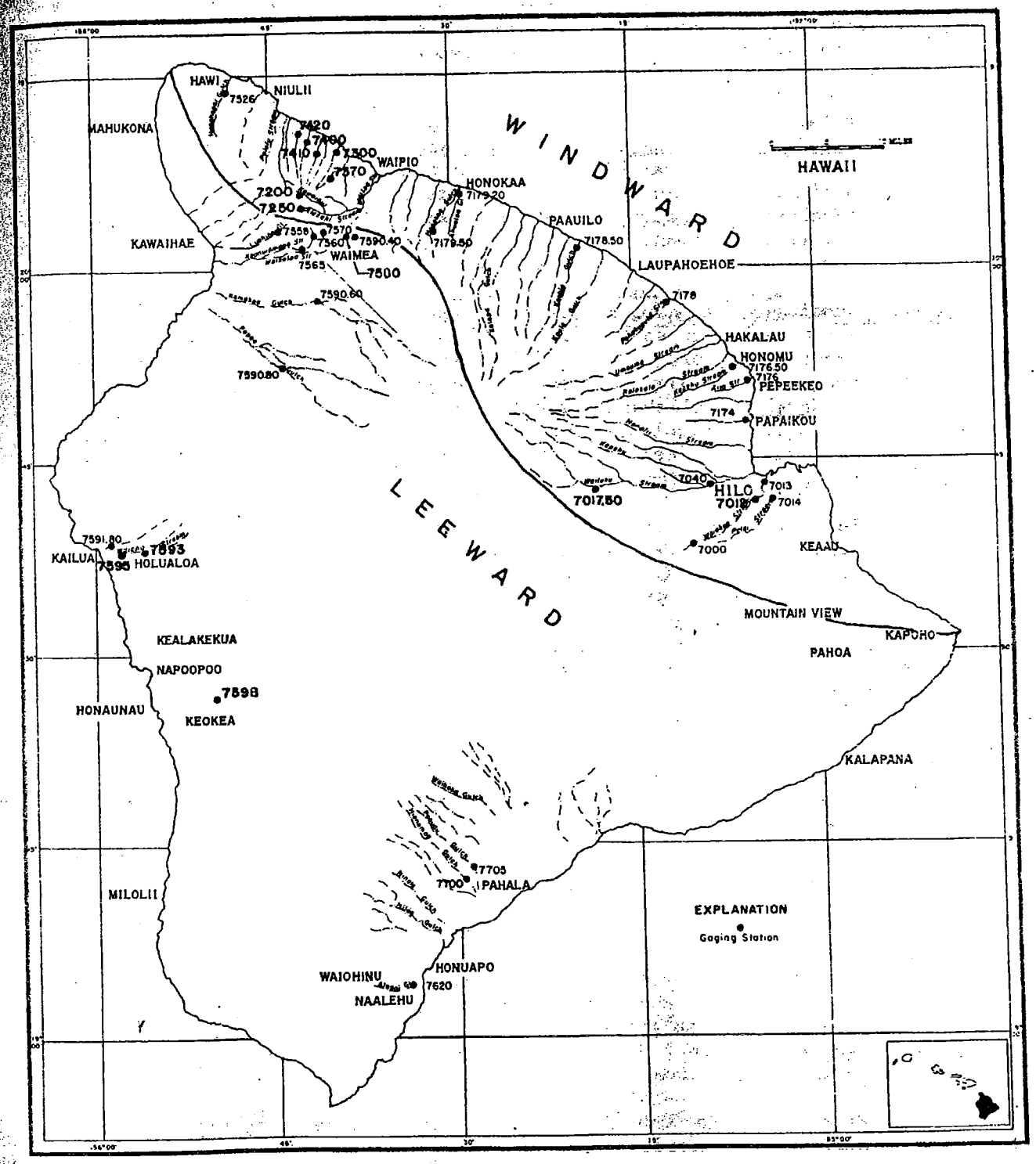


FIGURE 4 REGRESSION EQUATION GROUP

Source:
Hawaii County FIS 1995, FEMA

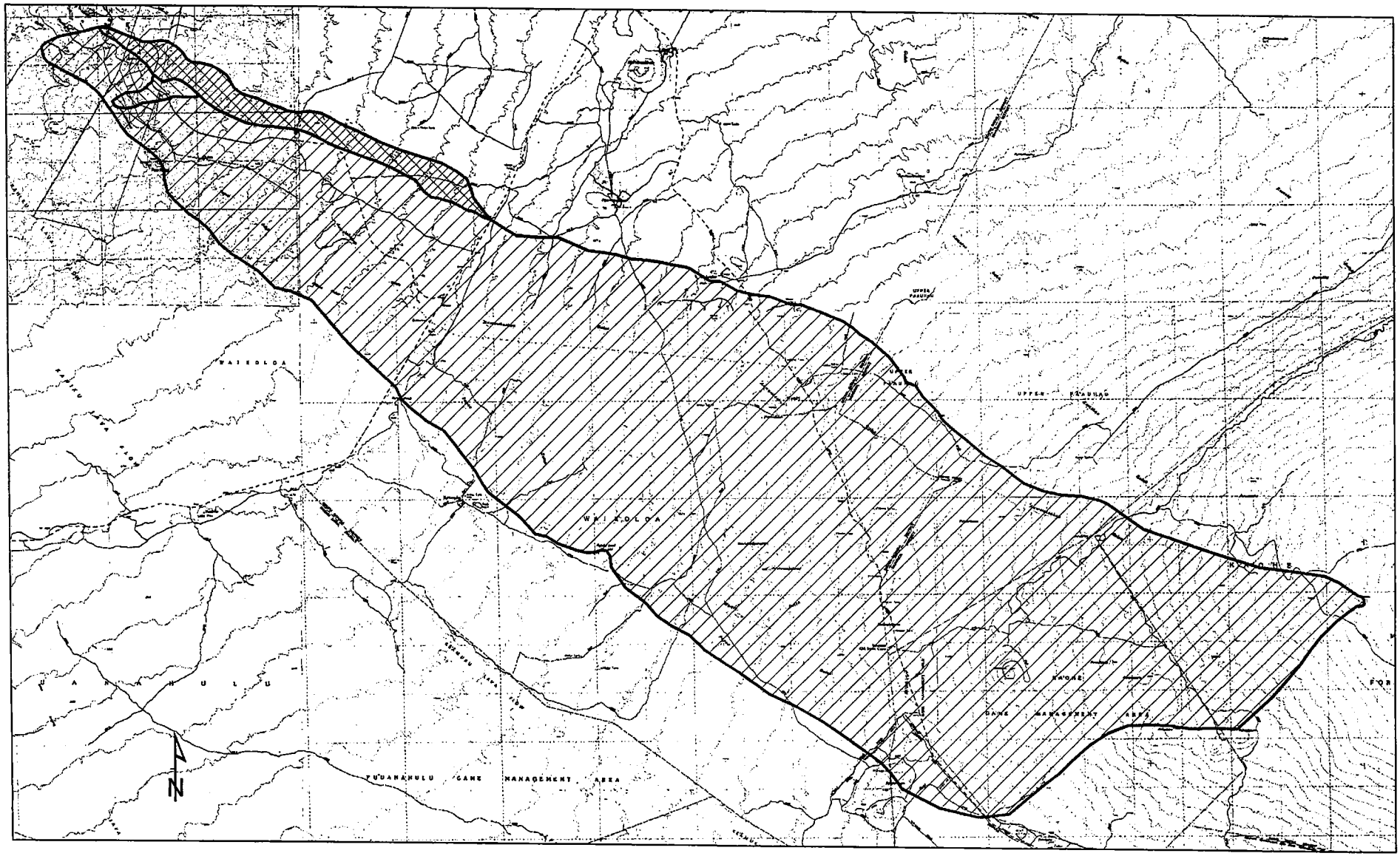
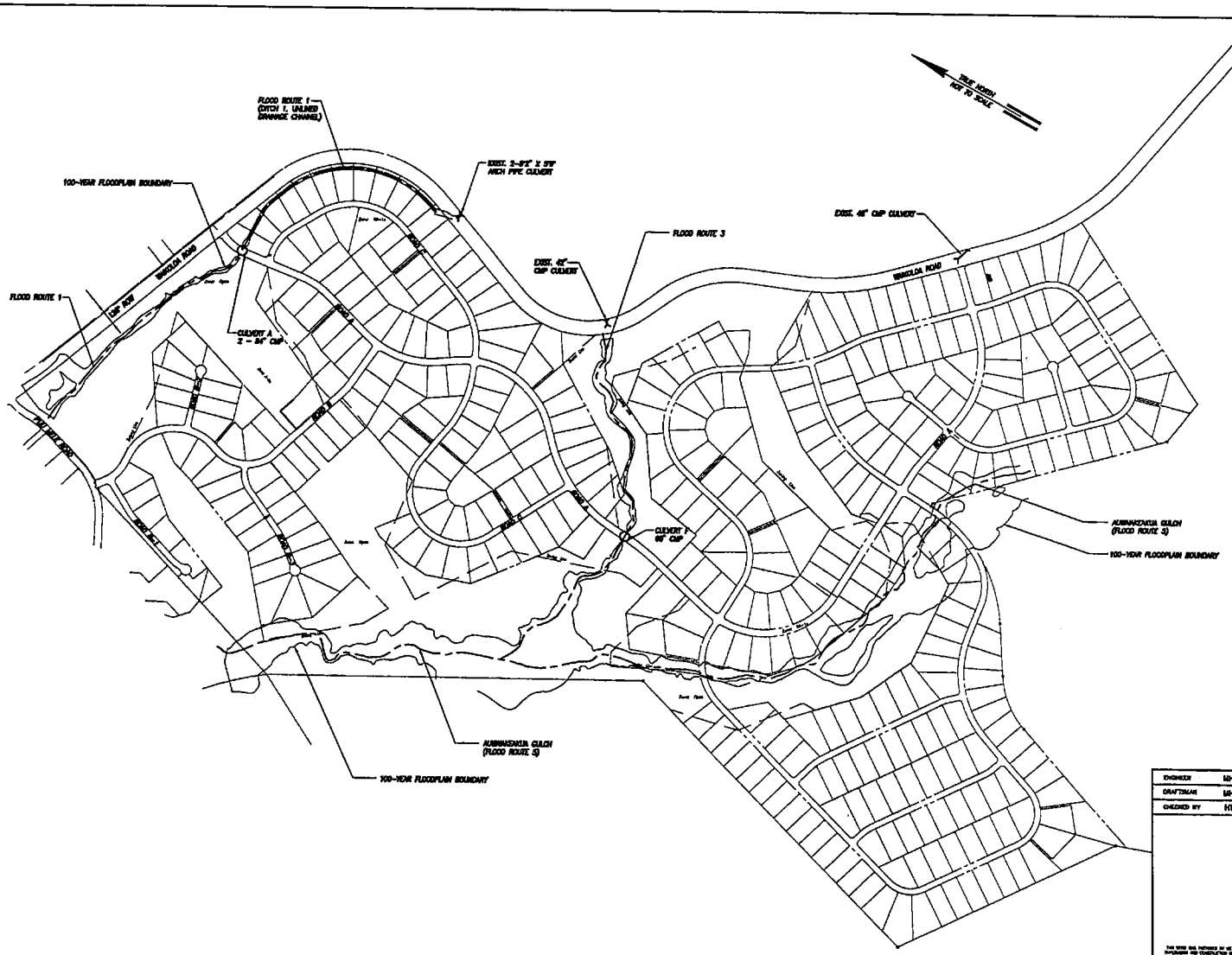


FIGURE 5 WATERSHED MAP



FLOODPLAIN BOUNDARY
NOT TO SCALE

ENGINEER	MHS
DRAFTSMAN	MHS
CHECKED BY	MTT

NO	DATE	BY	APPROVED

R. M. TOWILL CORPORATION

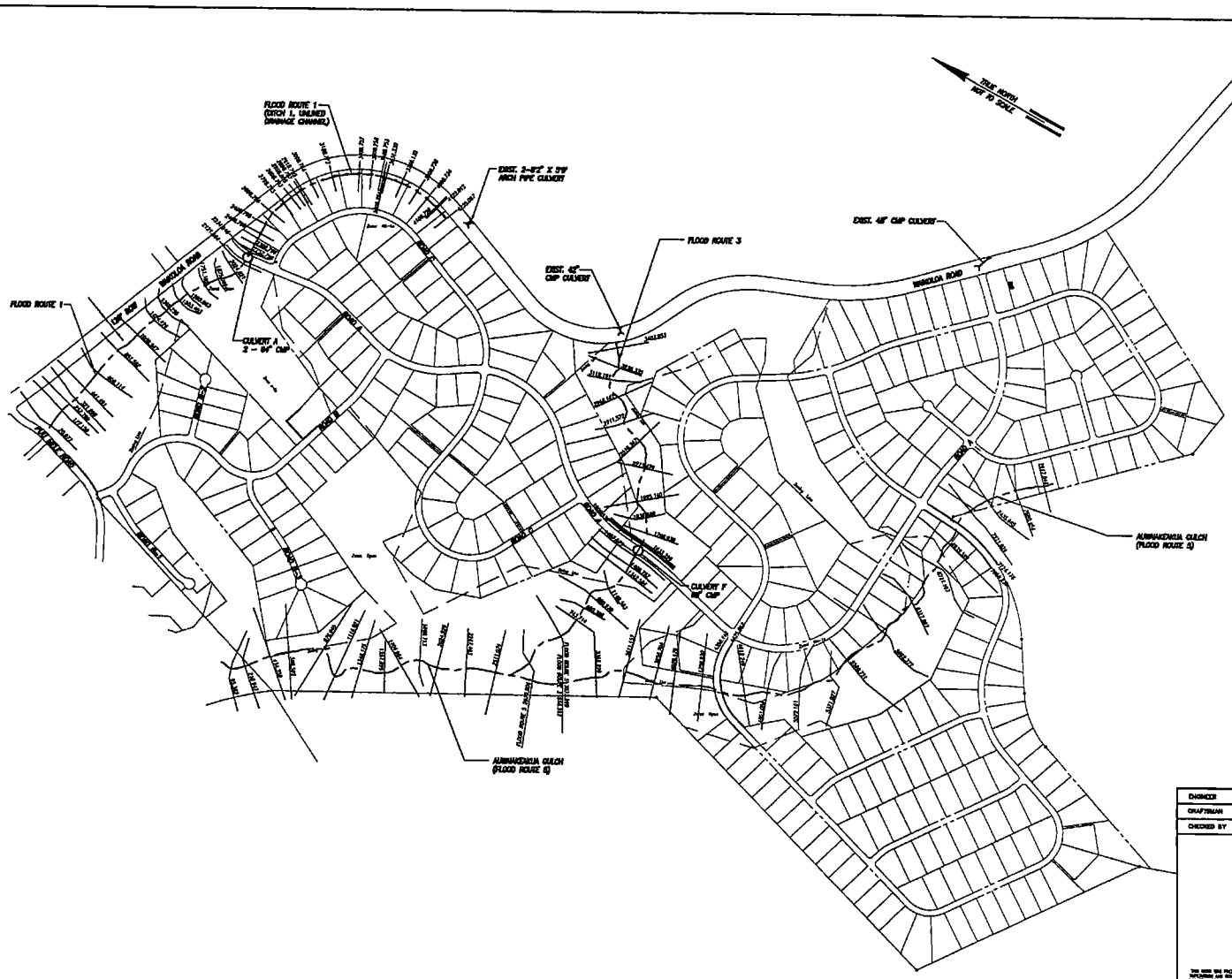
WAIKOLOA HIGHLANDS SUBDIVISION
WAIKOLOA, SOUTH KOHALA, ISLAND OF HAWAII, HAWAII
OWNER/DEVELOPER – WAIKOLOA MAINS, LLC

INCREMENT 1

FIGURE 6 FLOODPLAIN BOUNDARY

APPROVED :

C-8 SHEET 5 OF XX SHEETS



HEC-RAS XS LABELING
NOT TO SCALE

ENGINEER	MHS
DRAFTSMAN	MHS
CHECKED BY	HTT

REV	DATE	BRIEF	BY	APPROVED

R. M. TOWILL CORPORATION

WAIKOLOA HIGHLANDS SUBDIVISION
WAIKOLOA, SOUTH KOHALA, ISLAND OF HAWAII, HAWAII
OWNER/DEVELOPER - WAIKOLOA MAUKA, LLC

INCREMENT 1

FIGURE 7 HEC-RAS XS LABELING

APPROVED 1

C-8 SHEET 5 OF XX SHEETS