2. RECONNAISSANCE AND FIXES

2.1 GENERAL

JTWC depends primarily on two reconnaissance platforms, satellite and radar, to provide accurate and timely meteorological information in support of advisories, alerts and warnings. When available, synoptic and aircraft reconnaissance data are also used to supplement the above. As in past years, optimal use of all available reconnaissance resources to support JTWC's products remains a primary concern. Weighing the specific capabilities and limitations of each reconnaissance platform and the tropical cyclone's threat to life and property both afloat and ashore continues to be an important factor in careful product preparation.

2.2 RECONNAISSANCE AVAILABILITY

2.2.1 SATELLITE Interpretation of satellite imagery by analysts at Air Force/Navy tactical sites and on Navy ships yields tropical cyclone positions, estimates of the current intensity and 24-hour forecast intensity. Additional positioning and surface wind field estimation information are available for analysis from DMSP SSM/I data and the ERS-2 scatterometer.

2.2.2 RADAR Interpretation of land-based radar, which remotely senses and maps precipitation within tropical cyclones, provides positions in the proximity (usually within 175 nm (325 km)) of radar sites in Kwajalein, Guam, Japan, South Korea, China, Taiwan, Philippine Islands, Hong Kong, Thailand and Australia. Where Doppler radars are located, such as the Weather Surveillance Radar-1988 Doppler (WSR-88D) on Guam, Okinawa, and Korea, measurements of radial velocity are also available, and observations of the tropical cyclone's horizontal velocity field and vertical wind structure are possible.

2.2.3 AIRCRAFT No weather reconnaissance aircraft fixes were received at JTWC in 1997.

2.2.4 SYNOPTIC JTWC also determines tropical cyclone positions based on analysis of conventional surface/gradient-level synoptic data. These positions are an important supplement to fixes derived from remote sensing platforms, and become most valuable in situations where satellite, radar, and aircraft fixes are unavailable or are considered unrepresentative.

2.3 SATELLITE RECONNAISSANCE SUMMARY

Per USCINCPAC INSTRUCTION 3140.1W , the Pacific Air Force (PACAF) has primary responsibility for providing tropical cyclone reconnaissance for the U.S. Pacific Command (USPACOM). The JTWC tasks all reconnaissance requirements. Operational control of radar and satellite readout sites engaged in tropical cyclone reconnaissance remains in normal command channels. However, the Guam DMSP site is delegated the authority to manage the Pacific DMSP Tropical Cyclone Reconnaissance Network (hereafter referred to as Network) in support of JTWC. The Network control and the personnel of Satellite Operations

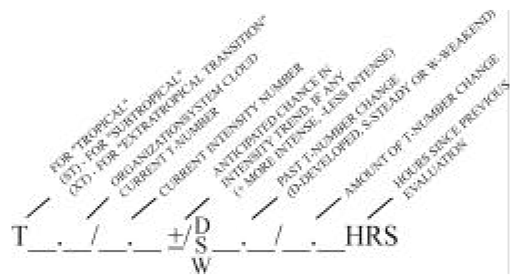
(SATOPS) are members of the 36 OSS/OSJ, and are collocated with JTWC at Nimitz Hill, Guam. The network sites are listed in Table 2-1.

TABLE 2-1 USPACOM SATELLITE RECONNAISSANCE NETWORK SITES

UNIT	ICAO
15 OSS/OSW, Hickam AFB, Hawaii	PHIK
18 OSS/OSW, Kadena AB, Japan	RODN
36 OSS/OSJ, Nimitz Hill, Guam	PGTW
607 COS/DOW, Yongsan Garrison Republic of Korea	RKSY
Air Force Weather Agency, KGWC Offutt AFB, Nebraska	
NPMOD DGAR, Diego Garcia	FJDG

Direct readout Network sites provide coverage of the tropical western North Pacific, South China Sea, and south central Indian Ocean using DMSP and NOAA TIROS polar orbiting satellites. PACAF Instruction 15-102 requires each network site to perform a minimum of two fixes per tropical cyclone per day if a tropical cyclone is within a site's coverage. Network direct readout site coverage is augmented by other sources of satellite-based reconnaissance. Air Force Weather Agency (AFWA) provides AOR-wide coverage to JTWC using recorded smooth DMSP and NOAA TIROS imagery. This imagery is recorded and stored on the satellites for later relay to a command readout site, which in turn passes the data via a communications satellite to AFWA. Civilian contract weather support for the Army at Kwajalein Atoll provides additional polar orbiting satellite-based tropical cyclone reconnaissance in the Marshall Islands and east of 180W as needed. The NOAA/NESDIS Satellite Applications Branch at Suitland, Maryland (ICAO identifier KWBC) also performs tropical cyclone fix and intensity analysis over the JTWC AOR using METEOSAT and GMS geostationary platforms.

The Network provides tropical cyclone positions and intensity estimates once JTWC issues either a TCFA or a warning. An example of the Dvorak code is shown in Figure 2-1. Each satellite-derived tropical cyclone position is assigned a Position Code Number (PCN) (Arnold and Olsen, 1974), which is a statistical estimate of fix position accuracy. The PCN is determined by: 1) the availablility of visible landmarks in the image that can be used as references for precise gridding, and 2) the degree of organization of the tropical cyclone's cloud system (Table 2-2)



Example: T 3.5/4.5+/W1.5/24 HRS

Figure 2-1 Dvorak code for communicating estimates of current and forecast intensity derived from satellite data. In the example, the current "T-number" is 3.5, but the current intensity is 4.5. The cloud system has weakened by 1.5 "T-numbers" since the evaluation conducted 24 hours earlier. The plus (+) symbol indicates an expected reversal of the weakening of the tropical cyclone during the next 24-hour period.

TABLE 2-2 POSITION CODE NUMBER (PCN)

PCN	CENTER DETERMINATION/GRIDDING METHOD
1	EYE/GEOGRAPHY
2	EYE/EPHEMERIS
3	WELL DEFINED CIRCULATION CENTER/GEOGRAPHY
4	WELL DEFINED CIRCULATION CENTER/EPHEMERIS
5	POORLY DEFINED CIRCULATION CENTER/GEOGRAPHY
6	POORLY DEFINED CIRCULATION CENTER/EPHEMERIS

Once a tropical cyclone reaches an intensity of 50 kt (26 m/sec), AFWA and SATOPS analyze the 35-kt (18-m/sec) wind distribution surrounding the tropical cyclone based on microwave satellite imagery.

SATOPS provides three-hourly positions and six-hourly intensity estimates for all tropical cyclones in TCFA or warning status. Current intensity estimates are made using the Dvorak technique for both visible and enhanced infrared imagery. The standard relationship between tropical cyclone "T-number", maximum sustained surface wind speed, and minimum sea-level pressure (Atkinson and Holliday, 1977) for the Pacific is shown in Table 2-3. Subtropical cyclone intensity estimates are made using the Hebert and Poteat (1975) technique. Intensity estimates of tropical cyclones undergoing extratropical transition are made using the Miller and Lander (1997) technique.

Table 2-3 ESTIMATED MAXIMUM SUSTAINED WIND SPEED (KT) AS A FUNCTION OF DVORAK CURRENT AND FORECAST INTENSITY NUMBER AND MINIMUM SEA-LEVEL PRESSURE (MSLP)

T-NUMBER	ESTIMATED WIND SPEED-KT	(M/SEC)	MSLP(MB) (PACIFIC)
0.0	<25	<(13)	---
0.5	25	(13)	---
1.0	25	(13)	---
1.5	25	(13)	---
2.0	30	(13)	1000
2.5	35	(13)	997
3.0	45	(13)	991
3.5	55	(13)	984
4.0	65	(13)	976
4.5	77	(13)	966
5.0	90	(13)	954
5.5	102	(13)	941
6.0	115	(13)	927
6.5	127	(13)	914
7.0	140	(13)	898

SATOPS at Nimitz Hill uses hourly full disk GMS imagery to observe 70% of the JTWC Area Of Responsibility (AOR) from 80E to 180W (Figure 2-2). Images are remapped to a Mercator projection to enhance imagery limb coverage at 80E - 100E. Animated geostationary imagery is a valuable tool for determining the location and motion of tropical cyclones. Animated water vapor channel imagery is useful for observing environmental synoptic features that affect tropical cyclone development and movement.

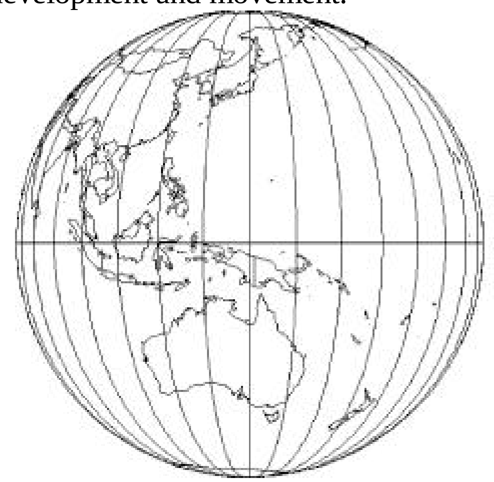


Figure 2-2 GMS full disk coverage

SATOPS has access to polar and geostationary data on both the Air Force Mark IVB workstation and the Meteorological Imagery, Data Display, and Analysis System (MIDDAS). The MIDDAS consists of a network of three DEC Vax 3400s running advanced graphics software, with two large screen workstations. The Mark IVB is the SATOPS backup satellite data analysis system with the ability to ingest and process both polar and geostationary satellite data, and display imagery on one large screen workstation. The Mark IVB also acts as a front end for the MIDDAS which has no independent receiver/antenna. Both the MIDDAS and the Mark IVB can display NOAA Advanced Very High Resolution Radiometer (AVHRR), DMSP Operational Linescan System (OLS) and Special Sensor Microwave/Imager

(SSM/I), and also geostationary visible, infrared and water vapor channel imagery. The MIDDAS can display NOAA TIROS Operational Vertical Sounder (TOVS) data, and the Mark IVB can display DMSP SSM/T1 and SSM/T2 sounder data.

NOAA TIROS AVHRR imagery provides five channels of imagery — visible, near and middle IR, and two in the far IR channels. DMSP OLS provides imagery in two channels — visible/near IR (commonly referred as broadband visible), and far IR. TOVS includes the High Resolution Infrared Radiation Sounder/2 (HIRS/2), the Microwave Sounding Unit (MSU), and the Stratospheric Sounding Unit (SSU).

2.3.1 SATELLITE PLATFORM SUMMARY Figure 2-3 shows the operational status of polar orbiting spacecraft. Imagery was received from five DMSP and two NOAA satellites during 1997. Both Operational Line Scan (OLS) and Special Sensor Microwave Imagery (SSM/I) was received from F13 and F14 (F14 began transmitting data in early summer). F12 produced only OLS imagery and F10 and F11 only SSM/I imagery. After transmitting four years beyond its normal life expectancy, F10 went into an uncontrollable spin in November and was unrecoverable. NOAA-12 and NOAA-14

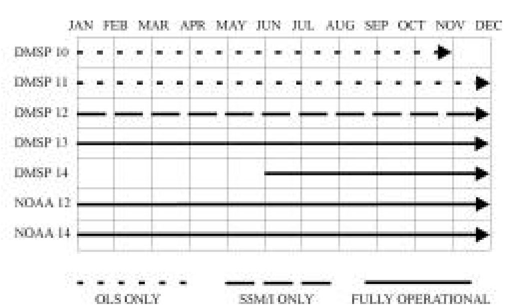


Figure 2-3 Polar orbiting spacecraft status for 1997.

were operational throughout the year, with fully functional AVHRR imagers.

2.3.2 STATISTICAL SUMMARY During 1997, over 91% of all fixes for input into JTWC's warnings were satellite based tropical cyclone positions and intensities. The PACOM satellite reconnaissance network and other agencies provided JTWC with 10,726 fixes: 6,114 western North Pacific, 313 northern Indian Ocean, 3,419 Southern Hemisphere, and 880 for circulations which did not develop into significant tropical cyclones. SATOPS provided 7,601, accounting for nearly 71% of all fixes. A comparison of total fixes from the network and western North Pacific over the past seven years is shown in Figure 2-4.

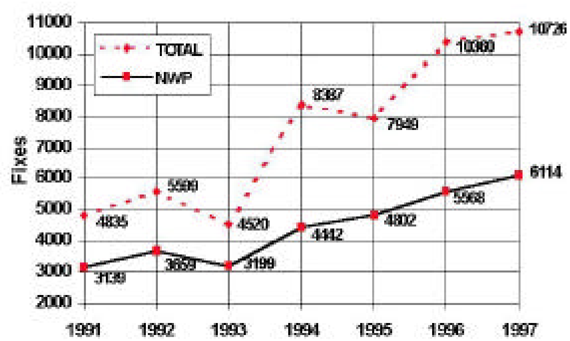


Figure 2-4 Comparison of fixes for the AOR (Total) and western North Pacific for the period 1991 - 1997.

2.3.3 APPLICATION OF NEW TECHNIQUES AND TECHNOLOGY
SATOPS continues to push advances in satellite meteorology to improve the support provided to JTWC. A new geostationary satellite, Feng Yun 2, owned by China/PRC, became operational for a short period during the year. Unfortunately, this satellite failed and became unusable within a few

Table 2-4 POSITION CODE NUMBER (PCN) CRITERIA AND FIX CODES FOR TC LOW-LEVEL CCs FROM SATELLITE

PCN	PCN	Definitions	Sensor /technique type and fix code					
Grid By Geog (note 2)	Grid by Ephem (note2)		IR	Vis	Both	SSM/I only (note 3)	Vis/IR & SSM/I (note 3)	Anmtn (note 4)
1	2	Eye						
(EYE)	(EYE)	CDO type eye, geometric center (regular/round, any diameter) (note 6)	1	2	3	4	S	A
(EYE)	(EYE)	Small eye (irregular/ragged, diameter > 30 nm on long axis) (note 6)	5	6	7	8	S	A
3	4	Well defined CC						
(EYE)	(EYE)	Eye(ragged/irregular, diameter > 30 nm center > 1/2 enclosed by wall cloud) (note 6)	9	10	11	12	S	A
(EYE)	(EYE)	Tightly curved band/banding type eye (band curves at least 1/2 distance around center, diameter < 90 nm)	13	14	15	16	S	A
(LLCC)	(LLCC)	Exposed low-level CC	17	18	19	20	S	A
(CDO)	(CDO)	Small CDO (round with well Defined edges, positioned near Geometric center, diameter < 80 nm)		21	22	23	S	A
(EMB)	(EMB)	Small embedded center (diameter < 80 nm)	24		25	26	S	A
(CDO)	(CDO)	Large CDO (with clear Indications of shearing, low-level cloud lines, or overshooting tops that bias low-level center Position away from the geometric center, diameter > 80 nm)		27	28	29	S	A
(CDO)	(CDO)	Any CDO or Embedded Center with low-level CC clearly visible on co-registered SSM/I (note 7)	30	31	32	33	S	
5	6	Poorly Defined						
		Large eye (ragged/irregular, 30 nm diameter on long axis, 1/2 Enclosed by wall cloud)	34	35	36	37	S	A
		Spiral banding systems (convective curvature) not Classifiable as banding eye or Tightly curved band	38	39	40	41	S	A
		Large CDO		43	44	45	S	A
		Embedded center positioned with IR	46					A
		Partially exposed low-level Centers with the CC less than half Exposed	47	48	49	50	S	A
		Cloud minimum wedge/cold Comma	51	52	53	54	S	A
		Central cold cover	55	56	57	58	S	A
		Cirrus outflow - upper level Outflow provides the only Circulation parameters	59	60	61	62	S	A
		Poorly organized low-level center Evident only in high resolution Animation (Vis/IR or both)						
		All others						
		Monsoon depressions or multiple cloud clusters, positioned using any of the following methods:	Any combination of Vis , IR/EIR, and SSM/I					

Table 2-4 (Continued)

		Cirle method	68		
		Conservative feature	69		A
		Animation	70		
		Extrapolation	71		

Note 1: Use the following steps to determine the PCN and Fix Code:

a. Based on the analysis of the circulation parameters, determine a TC low-level CC position.

b. Go to Table 2-2, then to the definitions column. Choose a PCN based on the cloud pattern, discrete measurements, as necessary, and/or technique used to determine the position.

c. Move across to the Fix Code columns, and based on the sensor(s) used, select a fix code.

Note 2: Odd PCNs (1, 3, 5) are gridded with geography, the low-level CC being within 10 degrees (600 nm) of the geographic feature used for gridding. Even PCNs (2, 4, 6) are gridded with ephemeris, or the low-level CC is not within 10 degrees (600 nm) of the geographic feature used for gridding.

Note 3: SSM/I only fixes - Use PCN of 5 or 6, and fix code based on Note 1, para a & c.

Note 4: Append "S" to the numerical fix code entry to indicate Special Sensor Microwave Imager (SSM/I) and visible and/or infrared data was used in determining the low-level CC (i.e. 18S). Defense Meteorological Satellite Program (DMSP) fixes only. For the purposes of this fix code, SSM/I (S) and Animation (A) are mutually exclusive.

Note 5: Append "A" to the numerical fix code entry to indicate animation was used in determining the low-level CC (i.e. 11A). Geostationary fixes only. For the purposes of this fix code, SSM/I (S) and Animation (A) are mutually exclusive.

Note 6: For fix code entries 1-9, encode 01-09.

Note 7: In order to use SSM/I data to position low-level CCs, you must be able to correct the navigation/gridding and interrogate the SSM/I imagery directly for latitude/longitude (DMSP fixes only).

months. However, there were indications late in 1998 that some operational capability was being regained. When operational, this satellite has the potential of filling in the gap between METEOSAT and GMS-5 (Figure 2-5).

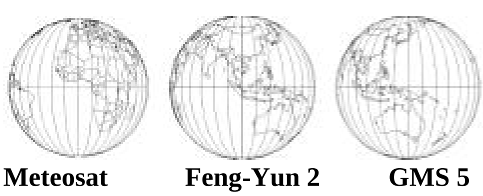


Figure 2-5 Geostationary spacecraft coverage of AOR. The PRC satellite Feng-Yun 2 was briefly available in late 1997 and early 1998 before being rendered useless by the failure of onboard instrumentation. There has been some success late in 1998 in restoring it to service.

SATOPS continued to make use of real-time SSM/I data on the Mark IVB to

determine storm structure and better identify 35-kt (18 m/s) winds surrounding tropical cyclones. Several upgrades on the Mission Sensor Tactical Imaging Computer (MISTIC) helped us better interrogate time-late SSM/I data stored on DMSP spacecrafts and forwarded from FNMOC to provide full coverage of JTWC's AOR. The acquisition of DMSP F14 data in the early summer helped increase the area covered by microwave imagery.

Additionally, to give the TDO a better statistical value for each satellite derived fix, SATOPS used animated geostationary imagery and multispectral display capability to apply Position Code Numbers (PCN) (Table 2-4) and fix codes to a particular tropical cyclone pattern based on sensor type (See Statistical Summary and Figure 2-6).

The XT technique (Miller and Lander, 1997) was developed and used operationally to better estimate tropical cyclones undergoing extratropical transition.

Several Mark IVB Network sites received the new Build 8 software in late 1997. This upgrade made the system

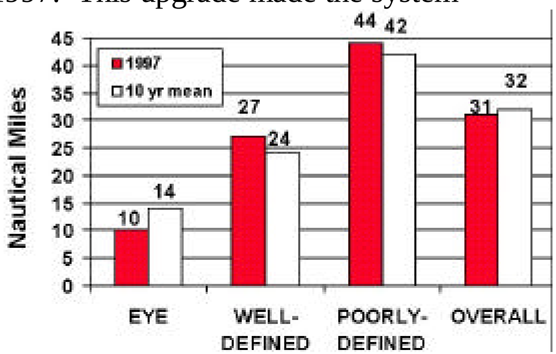


Figure 2-6 Western North Pacific Ocean satellite position errors (nm).

more user-friendly and much easier to interrogate several tropical cyclones at once--something previous software builds lacked.

2.3.4 FUTURE OF SATELLITE RECONNAISSANCE SATOPS will continue to strive to improve satellite reconnaissance to support JTWC in 1998. The 1995 Base Realignment and Closure (BRAC) directed JTWC to move from Guam to Hawaii by 1999. Preparing for this move, while continuing to provide uninterrupted support, will be a major challenge. Initiatives are currently being taken to move the Mark IVB to Andersen AFB,Guam by 1 April 1999.

2.4 RADAR RECONNAISSANCE SUMMARY

Of the 33 significant tropical cyclones in the western North Pacific during 1997, 13 passed within range of land-based radar with sufficient precipitation and organization to be fixed. A total of 466 land-based radar fixes were logged at JTWC. As defined by the World Meteorological Organization (WMO), the accuracy of these fixes falls within three categories: good [within 10 km (5 nm)], fair [within 10 - 30 km (5 - 16 nm)], and poor [within 30 - 50 km (16 - 27 nm)]. Of the 466 radar fixes encoded in this manner, 198 were good, 201 fair, and 182 poor. The radar network provided timely and accurate fixes which allowed JTWC to better track and forecast tropical cyclone movement. In addition to fixes, the Guam and Okinawa WSR-88D radars supplied meteorologists with a look into the vertical and horizontal structure of precipitation and winds in tropical cyclones passing nearby.

In the Southern Hemisphere, 40 radar reports were logged for tropical cyclones. No radar fixes were received for the North Indian Ocean.

2.5 TROPICAL CYCLONE FIX DATA

Table 2-5a delineates the number of fixes per platform for each individual tropical cyclone for the western North Pacific. Totals and percentages are also indicated. Similar information is provided for the North Indian Ocean in Table 2-5b, and for the South Pacific and South Indian Ocean in Table 2-5c.

Table 2-5a WESTERN NORTH PACIFIC OCEAN FIX PLATFORM SUMMARY FOR 1997

TROPICAL CYCLONE	SATELLITE	SCATTEROMETER	RADAR	SYNOPTIC	AIRCRAFT	TOTAL
01W HANNAH	117	1	0	0	0	118
02W ISA	362	7	32	0	0	401
03W JIMMY	114	5	0	0	0	119
04W KELLY	120	10	3	3	0	136
05W LEVI	116	3	9	0	0	128
06W MARIE	155	6	0	0	0	161
07W NESTOR	276	13	0	2	0	291
08W OPAL	173	7	34	11	0	225
09W PETER	156	14	37	23	0	230
10W ROSIE	221	1	45	8	0	275
11W SCOTT	173	3	0	0	0	176
12W TINA	300	4	96	4	0	404
13W VICTOR	75	0	17	0	0	92
14W WINNIE	385	2	71	7	0	465
15W YULE	157	3	0	1	0	161
16W -	49	2	0	0	0	51
17W ZITA	68	1	14	8	0	91
18W AMBER	238	4	18	9	0	269
19W BING	218	4	0	3	0	225
20W CASS	69	0	0	2	0	71
02C OLIWA	369	4	49	8	0	430
21W DAVID	197	5	0	3	0	205
22W FRITZ	95	1	0	3	0	99
23W ELLA	8	1	0	0	0	9
24W GINGER	156	4	0	0	0	160
25W HANK	50	2	0	0	0	52
26W -	82	0	0	0	0	82
27W IVAN	279	3	18	6	0	306
28W JOAN	269	3	23	2	0	297
29W KEITH	336	6	58	15	0	415
30W LINDA	196	3	0	5	0	204
31W MORT	162	3	0	8	0	173
05C PAKA	480	8	57	4	0	549
TOTALS	6221	133	581	135	0	7070
PERCENTAGE OF TOTAL	88%	2%	8%	2%	0%	100%

Table 2-5b NORTH INDIAN OCEAN FIX PLATFORM SUMMARY FOR 1997

TROPICAL CYCLONE	SATELLITE	SCATTEROMETER	RADAR	SYNOPTIC	AIRCRAFT	TOTAL
01B	137	5	0	0	0	142
02B	76	0	0	4	0	80
03A	23	2	0	1	0	26
04A	110	1	0	2	0	113
TOTALS	346	8	0	7	0	361
PERCENTAGE OF TOTAL	96%	2%	0%	2%	0%	100%

Table 2-5c SOUTH PACIFIC AND SOUTH INDIAN OCEAN FIX PLATFORM SUMMARY FOR 1997

TROPICAL CYCLONE	SATELLITE	SCATTEROMETER	RADAR	SYNOPTIC	AIRCRAFT	TOTAL
01S LINDSAY	41	1	0	0	0	42
02S -	91	2	0	0	0	93
03S -	78	1	0	0	0	79
04S ANTOINETTE	80	2	0	0	0	82
05S MELANIE/BELLAMI	242	4	0	0	0	246
06P CYRIL	106	2	0	1	0	109
07S CHANTELLE	121	2	0	0	0	123
08S DANIELLA	67	4	0	5	0	76
09S ELVINA	130	0	0	8	0	138
10P NICHOLAS	60	3	0	5	0	68
11S OPHELIA	147	0	0	0	0	147
12P PHIL	247	1	1	1	0	250
13P FERGUS	123	1	0	4	0	128
14S FABRIOLA	42	1	0	7	0	50
15S RACHEL	128	3	16	14	0	161
16P DRENA	130	2	0	7	0	139
17P EVAN	49	2	0	1	0	52
18S -	80	1	0	0	0	81
19S PANCHO-HELINDA	378	4	0	0	0	382
20S GRETELLE	76	3	0	4	0	83
21S ILETTA	76	2	0	0	0	78
22P FREDA	133	1	0	1	0	135
23S JOSIE	93	2	0	1	0	96
24P GILLIAN	47	1	0	1	0	49
25S KARLETTE	135	2	0	0	0	137
26P HAROLD	102	1	0	1	0	104
27S -	107	2	0	0	0	109
28P ITA	13	0	0	0	0	13
29P -	12	0	0	3	0	15
30S LIZETTE	19	2	0	0	0	21
31P GAVIN	151	4	4	1	0	160
32P JUSTIN	343	8	18	3	0	372
33P HINA	72	1	0	0	0	73
34P IAN	53	7	0	3	0	63
35P JUNE	135	10	0	2	0	147
36S RHONDA	178	9	0	0	0	187
37P -	54	0	0	0	0	54
38P KELI	113	4	0	0	0	117
TOTALS	4252	95	39	73	0	4459
PERCENTAGE OF TOTAL	95%	2%	1%	2%	0%	100%