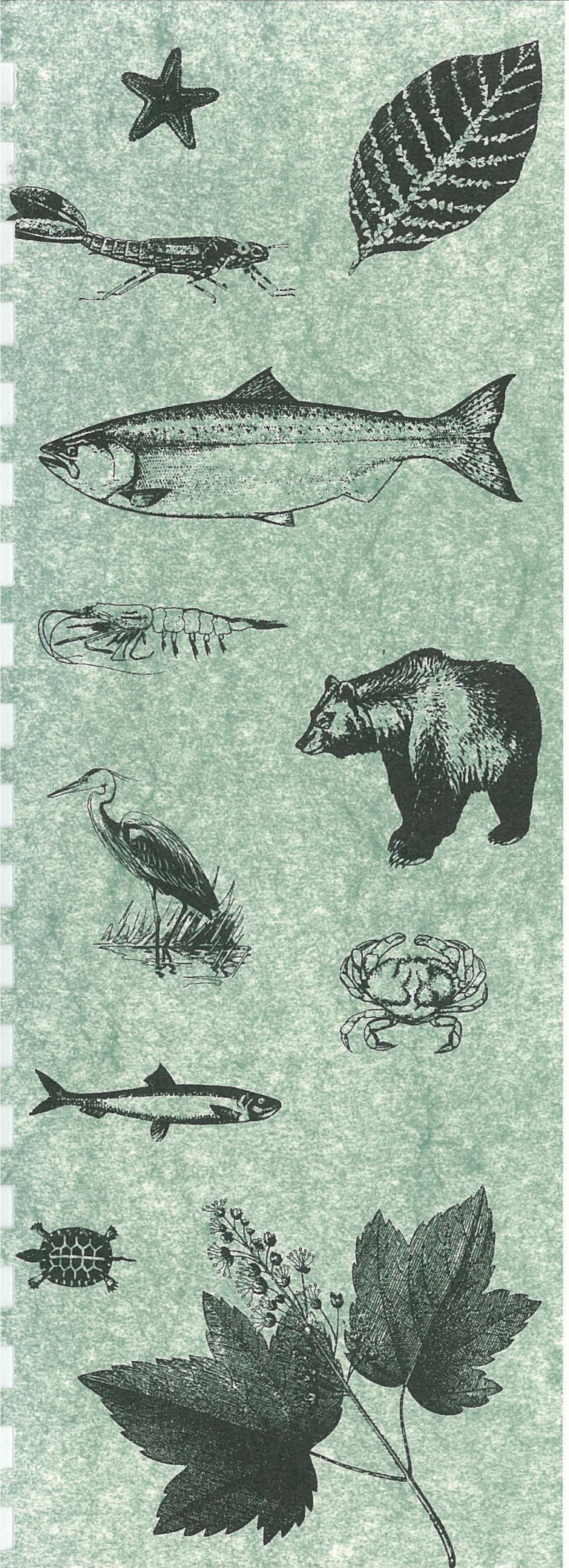

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USING RADARSAT IMAGERY TO ASSESS RESIDUAL ENVIRONMENTAL EFFECTS OF THE VIET NAM WAR (1961 - 1975)

PWGSC FILE NO. 9F005-5-0930/01-SW

PHASE IIa REPORT

Prepared for:

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JUNE 1997

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1.0 INTRODUCTION

Numerous areas within Indochina require rehabilitation from environmental damage caused by the Viet Nam war (second Indochina war). Environmental damage includes forest and other vegetation removal as a direct consequence of herbicide applications, soil erosion caused by bombing and shelling, vegetation burning and clearing by bulldozer, and the draining of wetlands.

This project uses RADARSAT imagery to assess land use, forest cover, and coastal features of various areas of Viet Nam and Laos affected by war damage; results will aid Hatfield Consultants Ltd. (HCL) and others to assess current levels of war-related environmental damage in these countries, to propose plans for mitigation, rehabilitation, or future environmental study in these areas, and to better develop and design future environmental monitoring projects, while at the same time field-testing the capabilities of RADARSAT imagery for terrestrial and coastal environmental monitoring and management.

The project involves several phases. Phase I was carried out from summer 1996 to March 1997, and included project scoping, acquisition and preliminary analysis of RADARSAT imagery from areas of southern Viet Nam known to be affected by war damage, and an initial evaluation of the ability of RADARSAT imagery to detect ground features of interest. The following is a report on Phase IIa of the project, which was undertaken from approximately March to May 1997. Activities in Phase IIa included ground-truthing of selected imagery of southern Viet Nam collected in Phase I, acquisition of supporting environmental and geographic information for future image analyses, further evaluation of existing Phase I imagery, meetings with remote sensing and environmental agencies in Viet Nam and Laos, and selection of areas for detailed study in Phase IIb of the project.

2.0 ACTIVITIES CARRIED OUT IN PHASE IIA

2.1 GROUND-TRUTHING OF SELECTED PHASE I IMAGERY

2.1.1 Study Areas Chosen to Evaluate Imagery

Based on available data sources, the following three areas in southern/central Viet Nam were selected for testing the RADARSAT imagery (Figure 1).

The following areas were ground-truthed:

- Ma Da forest region, Song Bé River drainage, Song Bé province (Phase I report: Figure 10);
- Ma Da forest region, Dong Nai River drainage, Dong Nai province (Phase I report: Figure 11); and
- Rung Sat mangrove forest, Ho Chi Minh City province (Phase I report, Figures 12 and 13).

These areas were chosen for ground-truthing due to the diversity of ground features apparent in each image, their proximity within a one-day drive from Ho Chi Minh City, and the history of intense warfare and herbicide spraying undertaken in these areas in the late 1960s and early 1970s.

2.1.2 Description of Ground Features and Their Visibility in RADARSAT Imagery

2.1.2.1 Methods

Paper copies of sections of RADARSAT images contained in the Phase I report were ground-truthed from April 15 to 17, 1997. Logistical support was provided by local representatives of the National 10-80 Committee (under the Ministry of Science, Technology and Environment), and local representatives of the provincial governments of Song Bé, Dong Nai, and Ho Chi Minh City provinces. Scientific and historical information was provided by Dr. Boi of the Forest Inventory and Planning Institute (FIPI), who accompanied HCL field personnel on each ground-truthing trip.

Hand-held Garmin 45XL global positioning systems (GPS) were used to locate the study team in each image area. Despite the inherent spatial error of hand-held GPS, and image scenes not having been rectified to a digital elevation model, spatial fidelity of map-derived coordinates and those derived using GPS was generally high. This is likely partly due to the relative flatness of the areas examined. To facilitate maximum spatial coverage by the field team, ground-truthed areas were generally restricted to those nearby roadways; as many areas as possible were examined given daily time constraints. GPS waypoints were recorded regularly throughout each

study area; at each waypoint, visible ground features were described and compared with the RADARSAT imagery. These waypoints appear on the images, which are reproduced in this report (Figures 1 to 3). Photodocumentation of ground-truthed areas also was undertaken.

2.1.2.2 Ma Da Forest Region, Dong Nai River Drainage (Figure 1)

Image Description

- Standard 6 (Descending), collected August 31, 1996.
- Ground-truthed April 15, 1997.
- GPS waypoints and feature descriptions are presented in Table A1.1.

Interpretation

This area is located to the northeast of the Tri An Reservoir. National Highway #20 runs across the upper left quadrant of the image. Scattered homes and buildings line the highway near the western edge of the image for approximately 2 km (i.e., one gridline). Northeast of this point, the road enters a forest plantation area (Plate 1), which extends to either side of the road for approximately 400 m; this forest plantation consists of tall, broad-leaved trees (*Techona grandis* [teak] and *Hopea* sp.), and is clearly visible on the RADARSAT image (Figure 1). Along the road beyond the plantation to the northern edge of the image, human settlement becomes more dense, and is visible in the image as white patches along the road.

To the north and south of this plantation area, large areas of mixed agricultural plots were present, containing papaya, banana, cassava, and other small tree, root and leguminous crops (Plate 2); numerous large, volcanic rocks were spread throughout this area. The indistinct, salt-and-pepper nature of the radar backscatter from these areas likely resulted from the broken, patchy nature of land cover in this area and the presence of numerous large rocks - in other words, the variable and often rough surface texture of the area. To the north of the plantation area, a few steep, bare, flat-topped hills were observed (Plate 3), which also are visible in the image as back circles with white eastern edges in this descending image (approximate UTM coordinates 1246000N, 762000E). A similar large hill was observed to the southeast of the plantation, and is also visible in the image.

The ground-truthing team followed a narrow, gravel road down the approximate centre of the image; this road is indistinct in the image, although habitation along the road is somewhat apparent along some stretches. Areas along the road were relatively flat or gently-rolling, and contained small, thatch-roofed homes with small, mixed agricultural plots. Small areas of rice fields and fish ponds are visible in the image just east of the road (approximately 1241000N). A visible line running NNE between areas of different contrast corresponds to a drop in ground elevation from higher, mixed crop areas to the NW and lower, wetter areas of forest and paddy cultivation to the SE.

At approximately 1240000N, the road curved to the east, and through a small village, visible on the image as an area of high backscatter (white). The road continues through the village to a dam on a small river; the dam and river are both visible in the image. From this dam, the landscape was clear to the north and south (Plates 4 and 5). Large wetland areas occurred to the north and south, both visible in the image. Numerous large areas of wet paddy cultivation were apparent to the south, which appear in the image as large, dark areas with regular sides. Surrounding these wet areas were marshy areas vegetated with grasses and sparse trees. Farther south, the grassy wetland area met a regular border with a treed area (Plate 5). This border between forest and grassland is very clear in the lower portion of the RADARSAT image. It was not clear if this forested area was plantation or native forest.

A Standard 7 (ascending) image of this area collected August 15, 1997, was reexamined during Phase IIb. Several of the land features discussed above were more distinct in the S7 image, particularly edges between different vegetation types, and patterns of cultivation and settlement to the west of the forest plantation. However, the edge between forest and wet grassland in the lower portion of the figure was less clear in the S7 image, perhaps due to a greater effect of soil moisture on radar backscatter in the S6 image.

Environmental Significance

This area was heavily sprayed by herbicides during the Viet Nam war; almost all of the native forest and crop vegetation was destroyed. Ground-truthing of this area indicated that significant changes have been made to the landscape in the years following the war. Since the war, local people have harvested the dead, standing trees for firewood and replanted areas with fruit trees and other plantation crops in dry areas, and undertaken or resumed rice patty cultivation in wetter areas.

When compared with historical forest cover information and herbicide spray data (now in progress), it may become apparent that land-use changes from natural forest to the barren, rocky agricultural plots seen during ground-truthing, resulted directly from conversion of forest land to low-yield agriculture following destruction of standing forests by herbicide application. Such a conclusion would lead to questions about potential contaminant uptake by agricultural crops in the area, and the possible bioaccumulation of these contaminants in humans and livestock.

The ground-truthing team did not observe areas of visible, lasting herbicide damage; bomb craters were observed in some plantation areas, although their presence would have been obscured from above by the dense cover of plantation trees. There are other areas in this region which the team has visited on previous trips where lasting herbicide damage is still visible on the ground; these areas will be ground-truthed during Phase IIb.

Large wetlands and paddy cultivation areas in lowlands of the southeast quadrant of the image were visible in both S6 and S7 imagery; these areas may serve as "sinks" for water or sediment-borne contaminants. Regardless, the ability of RADARSAT to show small ponds and areas of high soil moisture may allow for inferences concerning suitability of certain agricultural crops for these areas, or construction of roadways and other linear infrastructure.

2.1.2.3 Ma Da Forest Region, Song Bé River Drainage (Figure 2)

Image Description

- Standard 6 (Descending), collected August 31, 1996.
- Ground-truthed April 14, 1997.
- GPS waypoints and feature descriptions are presented in Table A1.2.

Interpretation

This figure shows an area surrounding the Song Bé River, between National Highway 13 to the west and Tri An Reservoir to the southeast. The Song Bé River is very clear in the image, running north to south along the centre of the image. Two secondary gravel roads were present in the imaged area, to the west and to the east; these roads were followed by the field team during ground-truthing. These roads generally are not visible in this standard-mode image, even despite the fact that a powerline right-of-way follows this road for much of its length. A variety of contrasting shades appear throughout the image. Generally, it was difficult to identify ground features which clearly corresponded to areas of different backscatter intensities.

Along the western road (waypoints were taken south to north along this road), a small stream was crossed (Plate 6); this drainage may be visible in the image as a narrow region of darker shade running NNW from the most southerly waypoint along this road. Generally, small drainages and wet areas were relatively clear on the image as darker areas.

Land cover was relatively similar along the entire western area of the image: rubber and cashew plantations of varying age, height, and density, with small rural villages mixed throughout (Plate 7). Some faint, regular lines, possibly corresponding to plantation edges, may be visible in this area of the image, but these are not obvious. It is worth noting that to the east and west of this road, the height of land declined, particularly to the east toward the river; these lower areas appear somewhat darker in the image, perhaps due to greater moisture content and possible paddy cultivation. The general lack of distinct land features visible in this area of the RADARSAT image may be due to the small scale and diverse and variable nature of land use. A Standard 7 (ascending) image of this area, collected August 15, 1996 and reexamined following the ground-truthing trip, showed edges between agricultural plots more clearly than the S6 image, although small tributaries of the Song Bé watershed visible in the S6 image were sometimes less evident.

To the east of the river, areas along the road were more densely populated; this road is barely visible in some areas of the image. Particularly in the north and central sections of the image, numerous small, bright returns are visible which likely correspond to built-up areas with larger concrete or metal-roofed homes.

A large, irregularly shaped dark area east of the centre of the image corresponds to low-lying areas of paddy cultivation, aquaculture ponds, and possibly other moisture-tolerant crops. Where the ground-truthing team crossed this darker area (at approximately 1254000N, 690000E), the

road dropped from a dry, upland area of mixed plantation to a lower-lying area of paddy cultivation and small aquaculture (Plate 8); these ponds and wet areas are plainly visible in the image as a dark return. Beyond this point, the road ascended back into upland plantation and mixed, low- to moderate-density rural villages.

Environmental Significance

The ability of RADARSAT to discern watershed drainage patterns clearly, particularly small tributaries, is a major advantage over optical satellites such as SPOT or LANDSAT, which tend to only show larger tributaries which are not hidden by dense forest cover. An understanding of drainage patterns is extremely important when evaluating potential environmental effects of developments such as land clearing, forestry, road building, and hydroelectric developments. This applies similarly to RADARSAT's ability to visualize small-scale wet paddy agriculture. Both of these capabilities were well-illustrated in this area.

The Song Bé River drainage, particularly the area shown in the northern half of the figure, were heavily sprayed by herbicides during the war (Song Bé Peace Hospital, *unpubl. data*, 1997), and was also subjected to heavy bombing and shelling. Former forest land in this area has now been converted to sparse plantations of rubber or cashew; young mixed forest has redeveloped in some areas. As discussed for the previous image, the RADARSAT images clearly show paddy fields, small lakes, and wetlands in this area which could serve as contaminant sinks. As with imagery of the Dong Nai drainage, the lack of evidence of large-scale residual war damage in the RADARSAT imagery corresponds with the lack of visible damage on the ground.

2.1.2.4 Rung Sat Mangrove Forest/Ho Chi Minh City (Figure 3)

Image Description

- ScanSAR Narrow (Descending), collected August 24, 1996; and
- Fine 4 (Descending), collected August 24, 1996.
- Ground-truthed April 16, 1997.
- GPS waypoints and feature descriptions are presented in Table A1.3.

Interpretation

Figure 3 is a ScanSAR scene of the Rung Sat mangrove forest, south of Ho Chi Minh City (HCMC). Ho Chi Minh City is visible as the large, bright return in the northwest corner of the image; Tan Sun Nhat Airport runways are visible as dark lines northwest of the city. Heavily developed areas along National Highway 1 are apparent to the northeast of HCMC, including the industrial city of Bien Hoa. The Sai Gon River bisects the image from the north to the south (Plate 9); this river marks the border between Ho Chi Minh City province to the east and Dong Nai province to the west. This area is almost perfectly flat, and therefore contains very little distortion resulting from relief.

The Rung Sat area was extremely heavily sprayed by herbicides in the late 1960s; most of the existing forest was completely destroyed. In the intervening time since, the Vietnamese government has undertaken a massive replanting effort, and most of the Rung Sat area is now covered by mangroves of varying ages and heights (both *Rhizophora* sp. and *Avicennia* sp.) (Plate 10). Other land features in the southern Rung Sat area include large salt ponds (where salt water is impounded after a high tide, evaporated in the sun, and the remaining salt subsequently harvested), and several areas of shrimp aquaculture (Plate 11), which are all now abandoned and are being steadily replanted with mangroves. The large salt ponds were very visible in the ScanSAR Narrow image, as well as small areas of human settlement along the southern coast of the Rung Sat area. The narrow, paved road through the mangrove forests of southern Rung Sat is visible in the ScanSAR image, primarily due to the existence of numerous bright human structures along it. The road and individual abandoned shrimp farm ponds in southern Rung Sat are plainly visible in the fine mode imagery of this area, all of which was not included in the Phase I report, but which was subsequently re-examined after the field trip.

Of particular interest, the ScanSAR image clearly discriminates between undeveloped mangrove areas of southern Rung Sat, and semi-developed rural, agricultural areas immediately to the north of it (Plate 12); the boundary between these different types of land use is quite visible. The semi-developed rural area to the northwest of the mangroves contains mixed agricultural plantations of *Nipa* palm, small paddy cultivation, and rural villages. In the fine mode imagery of this area (Figure 13 in the Phase I report), individual agriculture and aquaculture plots, roads, and small mangrove swamp channels are readily identified. The ground-truthing team and Vietnamese experts who accompanied us during ground-truthing were very impressed with the quality of the fine mode RADARSAT imagery for Rung Sat.

Due to the complete replanting and recolonization of the Rung Sat area, and the existence of a large protected forest area along the western edge of southern Rung Sat, extremely good land use data on this area exists in Ho Chi Minh City and the protected area office in Rung Sat district, which will be used to help interpret and analyze RADARSAT imagery in Phase IIb of the project.

Environmental Significance

Almost all of the natural forest in the Rung Sat area was destroyed by heavy herbicide application during the war. While evidence of herbicide damage was not visible in the imagery or on the ground in the form of barren areas or scrubland, there was strong visible evidence of war damage in all mangrove areas in the sense that many stages of young mangrove forest were seen in all rehabilitated areas (almost the entire delta). This new range of forest growth is a direct result of defoliation by herbicides.

Over the intervening years since the war, the Vietnamese government has replanted almost all of the southern Rung Sat area with mangroves (*Rhizophora* sp. and *Avicennia* sp.). Different areas were rehabilitated in different years, resulting in a patchwork of mangrove forests of different ages and sizes. Potentially, through use of different incidence angles and multi-temporal

imagery, RADARSAT could aid in monitoring the rehabilitation and recovery of these reforested areas.

Additionally, areas of northern Rung Sat contain mixed wet and dryland agricultural crops, which were clearly differentiated by RADARSAT from the mangroves protected area to the south. Incursion of local people into protected forests to undertake illegal forestry and swidden agriculture, is currently a very important issue in biodiversity-rich tropical countries such as Viet Nam and Laos. Typically, countries such as these do not have the ability or resources to police or monitor the integrity of protected areas, particularly with respect to illegal resource extraction in border areas. As such, the ability of RADARSAT to monitor such effects on a regular, as-needed basis is potentially a valuable tool for tropical protected areas and natural landscape managers.

2.2 ACQUISITION OF SUPPORTING GEOGRAPHIC AND ENVIRONMENTAL DATA

2.2.1 Viet Nam

- Numerous topographic maps of various scales and publication dates were acquired in Hanoi for study areas in Viet Nam.
- Land use and forest cover maps of southern Viet Nam, particularly Rung Sat mangrove forest, were obtained from the Ministry of Science, Technology and Environment (MOSTE) in Ho Chi Minh City.
- Land-use and forest cover data for Rung Sat and Ho Chi Minh City were examined in the offices of various government agencies in Ho Chi Minh City.

2.2.2 Laos

- Both 1:1,000,000 and 1:100,000 scale topographic maps of potential study areas of Laos were acquired from the National Geographic Department of the Government of Laos.
- Forest cover data for various areas of Laos, collected by the German aid group GTZ and the Mekong Commission, was examined.
- Information on war-damaged areas of Laos, collected by Handicap International and the United Nations UXO program, was examined and procured.

Following undertaking of MOUs with various Vietnamese and Lao agencies, several possible avenues for collection of digital and other secondary data will be available.

2.4 FURTHER EVALUATION OF EXISTING PHASE I IMAGERY

Subsequent to field studies in Viet Nam and Laos, preliminary imagery collected in Phase I was re-examined, to evaluate its utility and usability in subsequent phases of the project. Raw

imagery was examined, without elaborate filtering or despeckling. From this evaluation, it was concluded that much of the imagery collected in Phase I could be used effectively in Phase IIb, in the compilation of multi-temporal scenes and scenes with multiple incidence angles. From a re-examination of the Phase I imagery, it was determined that fine mode imagery was most effective at highlighting ground features of interest, and that multiple-pass scenes of study areas were most likely to highlight visible differences between adjacent ground features of interest (e.g., forest versus grassland, or wetland versus paddy cultivation).

2.5 MEETINGS WITH REMOTE SENSING AND ENVIRONMENTAL AGENCIES IN VIETNAM AND LAOS

2.5.1 Hanoi, Viet Nam

Table 2.1 Summary of Agencies and Personal Contacted in Hanoi

Contact Name	Agency	Fax	Phone
Pham Van Cu, Deputy Director	Center for Remote Sensing and Geomatics	844-835-1493	844-835-1493
Nguyen Cong Tuyet, Deputy Director	Center for Remote Sensing and Geomatics	844-835-1493	844-835-1493
To Quang Thinh Director	Remote Sensing Center, General Department of Land Administration	844-835-0728	844-835-0728
Dr. Nguyen Manh Cuong	Head of Remote Sensing Section Forestry Inventory and Planning Institute	844-861-2881	844-861-5513
Dr. Tran Cong Yen Director, Database	Ministry of Science, Technology and Environment (MOSTE) - GIS Division		844-824-8346
Prof. Hoang Trong Quynh, President of the Scientific Society	Center for Research Against Cancer	844-825 0000	844-826-1576
Prof. Cau Chairman	10-80 Committee	844-852-3514	

2.5.2 Ho Chi Minh City, Viet Nam

Summary of Agencies and Personnel Contacted in Ho Chi Minh City and Environs

Contact Name	Agency	Fax	Phone
Nguyen Thi Ha Sinh, Director	Health Service of Binh Duong province (formerly southern Song Bé province)	-	844-822-639
Vien Ngoc Nam, Deputy Chief of Forestry	Ho Chi Minh City Agriculture & Rural Development Service	848-829-4764	848-829-2354
Pham Thuyet, Vice Director	Ho Chi Minh City Agriculture & Rural Development Service	848-829-4764	848-829-7653

Contact Name	Agency	Fax	Phone
Tran Ngoc Lang, Head, Business Development	Ho Chi Minh City Agriculture & Rural Development Service	848-829-4764	848-829-1381
Nguyen Viet Chien, Head, Information and Remote Sensing Div.	National Center for Natural Sciences and Technology of Vietnam	848-222-248	848-244-188
Lam Dao Nguyen, Remote Sensing and GIS Division	National Center for Natural Sciences and Technology of Vietnam	848-829-6101	848-824-4188
To Thi Thuy Hang, Researcher	Institute for Economic Research of Ho Chi Minh City	848-824-3896	848-824-4371
Dr. Nguyen Van Nhan, Deputy Director	Integrated Resources Mapping Centre	848-822-3233	848-824-3163
Dr. Tran Vinh Phuoc, Director	Centre for IT and GIS, Vietnam National University at Ho Chi Minh City	848-863-5719	848-864-2768

2.5.3 Vientiane, Laos

Summary of Agencies and Personnel Contacted in Vientiane

Contact Name	Agency	Fax	Phone
Pho Muangnalad, Director	Science, Technology and Environment Organization (STENO)	856-21-21-3472	856-21-21-3470
Sitha Phouyavong, Deputy Director	Science, Technology and Environment Organization (STENO)	856-21-3472	856-21-3470
Ian Mansfield, Program Management Advisor	National UXO Programme (United National Development Program)	856-21-214-819	856-21-222-779
Hans-Jurgen Stibeg, Director, Forest Cover Monitoring Project	Department of Forestry/Mekong River Commission/GTZ	856-21-215-628	856-21-413-283
Bouthsy Boukhamvilay, Chief, Aerial Photommetry	Prime Minister's Office, National Geographic Department	-	856-21-218-470
Sangkhane Thiangthammavong, Deputy Chief of Cartography	Prime Minister's Office, National Geographic Department	856-21-214-915	856-21-213-662

2.6 SELECTION OF STUDY AREAS FOR DETAILED STUDY IN PHASE IIB

The following study areas have been chosen for further examination during Phase IIb:

Vietnam

- Rung Sat Mangrove Forest (HCMC Province);
- Ma Da Upland Forest (Song Bé/Dong Nai Provinces);
- A Luoi Valley (Hué Province);
- DMZ area (Hué and Quang Tri Provinces);
- Plain of Reeds/Mekong River delta area (south of HCMC);
- Dac Lac province near the Cambodian border (Dac Lac Province); and
- Iron Triangle area (north of Ho Chi Minh City).

Laos

- Xieng Khuong (Plain of Jars area, north-central Laos); and
- Bolavens Plateau/Saravan/Highway 9 area (southeastern Laos).

These areas have been chosen based on the nature of forest cover and land use in each area (particularly as these conditions have resulted from war damage and recovery), potential availability of secondary data, accessibility of these sites for ground-truthing, and potential for collaboration with Vietnamese and Lao organizations and experts in image interpretation and analysis.

2.6.1 Rung Sat Mangrove Forest (Ho Chi Minh City Province, southern Viet Nam)

Rationale:

- heavily sprayed during the war, then replanted at various times and stages with mangroves (both *Rhizophora* sp. and *Avicennia* sp.);
- wide variety of land uses and forest cover in the area, including mangrove forests, *Nipa* palm plantations, rice, salt flats, shrimp farms, semi-urban development, etc., many of which were clearly visible on Fine-mode and even ScanSAR imagery collected in Phase I;
- good area to test RADARSAT abilities to visualize small stream networks and differences in land use and forest cover;
- excellent availability and quality of secondary data in HCMC regarding forest cover and land use spanning several decades;
- local HCMC agencies have good knowledge of remote sensing, including some experience and understanding of RADARSAT; and
- close to HCMC, facilitating logistics and enhancing marketing potential at end of project.

Challenges:

- the sheer volume of supporting data for the area (held in HCMC) will require some time in HCMC to sort through and acquire; and
- some supporting data (e.g., replanting times for mangrove areas) is semi-confidential in HCMC (i.e., we were allowed to see it in April, but couldn't copy or photograph).

2.6.2 Ma Da Upland Forest (Song Bé/Dong Nai Provinces, southern Viet Nam)

Rationale:

- heavily sprayed during the war, with lasting visible effects to today; Dr. Boi (FIPI-Hanoi) believes this is where residual herbicide effects are most apparent in southern Vietnam;
- good supporting maps and data on forest cover and land use in the area, including other international projects working in the area;
- area is not highly urbanized or developed, which should enhance abilities to detect differences in forest cover; and
- sprayed area is close to HCMC.

Challenges:

- sprayed area is somewhat hilly, potentially reducing the ability of RADARSAT imagery to detect differences in cover;
- revegetation work has been undertaken over several years, which may complicate image interpretation; and
- study area straddles two provinces, perhaps making it difficult to collect/coordinate secondary data and field studies.

2.6.3 A Luoi Valley (Hué Province, central Viet Nam)

Rationale:

- heavily sprayed during the war, with residual effects still apparent;
- HCL has good experience in the area from previous dioxin work and already have much supporting data from dioxin work, including digital basemaps, land use maps, topography, digital elevation model (DEM), spray data, video and still photography, socio-cultural data);
- SPOT data were acquired during Phase I which could be used with SAR data to allow better visualization of the area, enhance graphical output, and allow better evaluation of SAR data as a stand-alone and complementary RS product; and

- work here would complement well the dioxin work HCL has already conducted here.

Challenges:

- mountainous terrain likely limits usefulness of SAR data beyond A Luoi valley proper; and
- logistics difficult (but known).

2.6.4 Former Demilitarized Zone (DMZ) Area (central Viet Nam)

Rationale:

- heavily sprayed, bombed, ploughed, etc. during the war;
- HCL staff are somewhat familiar with the area, having previously undertaken exploratory sampling trips for other projects;
- some supporting data of Hue province already from dioxin work;
- close to Hue (approximately two hours over good road), reducing overall logistical costs;
- relatively flat terrain near coast; and
- not heavily populated.

Challenges:

- relatively mountainous in some parts away from coast;
- logistics likely difficult (but known);
- lingering problems with unexploded ordinance in area; and
- currently, HCL has have little supporting information about Quang Tri Province.

2.6.5 Plain of Reeds/Mekong River Delta Area (southern Viet Nam)

Rationale:

- heavily sprayed during the war;
- relatively close to HCMC;
- this area has very obvious and understood applications for RADARSAT imagery, for flood monitoring and rice crop monitoring; several parties in HCMC expressed interest in RADARSAT imagery of this area;
- collecting imagery of adjacent areas of Cambodia during flood conditions would be valuable from a marketing perspective in both Viet Nam and Cambodia; and

- some existing imagery from Phase I.

Challenges:

- may be very difficult to work in this area near the end of the rainy season (difficult logistics).

2.6.6 Dac Lac Province (near Cambodian border)

Rationale:

- heavily bombed and sprayed during the war;
- good potential for collaboration with Mekong Secretariat/German GTZ-funded forest cover study of the entire Mekong drainage, in interpretation of RADARSAT imagery and provision of digital forest cover to this project; and
- area is within one-day trip of HCMC.

Challenges:

- logistics may be difficult from HCMC; liaison with Dac Lac provincial government would be required.

2.6.7 Iron Triangle and other areas near Ho Chi Minh City (southern Viet Nam)

Rationale:

- other areas of the south were heavily affected by spraying, bombing and land clearing during the war, particularly areas of Song Bé (Iron Triangle), Tay Ninh, and Minh Hai (U Minh and Ca Mau);
- relatively close to HCMC (particuiarly the Iron Triangle); and
- many of these areas will be covered by Phase I ScanSAR imagery of the south, and therefore should not be discounted until Phase I imagery has been fully re-evaluated.

Challenges:

- examination of too many areas in the study could result in more limited effort spent on each individual area (these areas should be considered low priority for new imagery/interpretation until after existing Phase I imagery has been re-evaluated); and
- logistics of some areas (e.g., Ben Tre, Minh Hai) would be difficult from HCMC; liaison with several provincial governments would be required.

2.6.8 Xieng Khuong (Plain of Jars area, Laos)

Rationale:

- extremely heavily bombed by the US in the late 1960s and early 1970s;
- bomb craters very visible from the air (as are cleared areas on hill slopes used to capture songbirds, which could approximate bomb craters in imagery);
- severe residual problems exist with unexploded ordinance in the area, a potential natural tie-in for RADARSAT imagery;
- flat topography of the valley results in good potential to image land cover information with RADARSAT;
- good topographic and general land use information already acquired (1:100,000 scale) for this and other areas of Laos;
- moderate degree of support from local UNDP/NGO organizations working on unexploded ordinance in this area; and
- relatively easily accessible from Vientiane (Mr. Martin Davies visited this area in October 1996).

Challenges:

- existence/quality of other supporting data uncertain; and
- much of the damage we are looking for (i.e., craters) is relatively small scale and might not show up clearly; however, we do know that these features are there, so the area provides a good test for the satellite.

2.6.9 Bolavens Plateau, Saravan and other areas of Southern Laos

Rationale:

- relatively heavily bombed and affected during the war (particularly Ho Chi Minh Trail area);
- relatively severe deforestation (some illegal) and wide-spread swidden agriculture in areas of southern Laos may be good future monitoring applications for RADARSAT imagery;
- several very large hydroelectric and roadway developments proposed for this area, for which RADARSAT might be extremely useful in the near future; and
- high level of interest from Lao government officials in examining the usefulness of RADARSAT in this region for the applications mentioned above, due to numerous large-scale development projects proposed for this area.

Challenges:

- some areas very mountainous, potentially limiting the ability of RADARSAT to be used for forest cover and land use monitoring; and
- logistics from Vientiane moderately difficult (however, government support for a trip to this area is high).

3.0 PHASE IIB WORKPLAN

3.1 OBJECTIVES AND TASKS FOR PHASE IIB

Phase IIb will encompass the largest share of work undertaken for the project. Objectives and tasks of this phase are as follows:

- finalize RADARSAT image acquisition plans for Phase IIb (including spatial coverage and mode and beam type), focusing on study areas described in Section 2.6 and based on the results of Phase IIa;
- retain a geomatics subconsultant to work with HCL to aid with image interpretation, classification and production;
- order and receive RADARSAT imagery of study areas;
- collect secondary data from all possible sources (in Southeast Asia and Canada) to use in interpreting RADARSAT images (e.g., forest and land cover maps, digital basemaps, etc.);
- with the geomatics subconsultant, explore the use of digital classification for interpretation and analysis of RADARSAT images;
- work with Vietnamese and Lao partner agencies to interpret and ground-truth RADARSAT imagery of study areas in each respective country;
- based on digital and visual image interpretation and classification and groundtruthing, determine the ability of RADARSAT imagery to discern forest cover, land use, and coastal features of interest;
- based on information derived from RADARSAT imagery, develop environmental site assessments of each study area;
- based on site assessments of each study area, develop potential environmental mitigation and monitoring proposals for each area;
- gauge the level of interest in RADARSAT imagery in Vietnam and Laos through discussions with partner agencies and other interested parties and documentation of potential applications of RADARSAT data in each country; and
- produce a report detailing the findings of Phase IIb, including RADARSAT imagery, image analyses, and supporting secondary data.

3.2 TIMETABLE FOR PHASE IIB

The approximate schedule for completion of Phase IIb tasks described above is as follows:

Task	Completion Date
Re-examination of Phase I imagery and finalization of Phase II image acquisition plans	June 30, 1997
Order and acquisition of RADARSAT imagery	June to September, 1997
Acquisition and analysis of secondary geographic data (Vancouver and Bangkok)	June to October, 1997
Trip to Hanoi, Ho Chi Minh City and Bangkok to collect secondary data and liaise with cooperating government agencies	July 15 to 31, 1997
Classification and analysis of Phase II imagery	August to December, 1997
Ground-truthing trip to selected study areas in Viet Nam and Laos to evaluate RADARSAT ability to image and discern forest and land cover features	October 1997
Cooperative interpretation of RADARSAT imagery with local Vietnamese and Lao experts in each country	October 1997
Development of rehabilitation/monitoring plans for selected study areas based on RADARSAT imagery and supporting information	November and December, 1997
Final analysis of RADARSAT imagery, production of Phase IIb report	November and December, 1997
Completion and submission of Phase IIb report	December 31, 1997

4.0 MARKET STUDY UPDATE

In the HCL August 1995 proposal to the RUDP Coordination Office titled "Using RADARSAT Imagery to Assess Residual Environmental Effects of the Viet Nam War (1961 - 1975) on the Mekong River Drainage", Section 9.8 (page 9/15) contained a "RADARSAT Demonstration and Marketing Action Plan". This action plan as stated in the original proposal was set out as follows:

"9.8 RADARSAT DEMONSTRATION AND MARKETING ACTION PLAN

Opportunities have been identified in Indonesia, Thailand, and other countries in the region such as Viet Nam, Cambodia, and Laos. A basic objective of the Hatfield Group will be to develop a core group of technical specialists in Vancouver, Bangkok, and Jakarta that will work initially on projects in Viet Nam, Thailand, and Indonesia, but will offer services to other South East Asia areas. An action plan for the Hatfield Group for the next three years, commencing in 1997, is outlined in the following sections:

9.8.1 1997

Private-Sector Industrial Clients

- *To concentrate on providing additional RADARSAT related services to private sector industrial clients for pre-development environmental impact assessment and for post-development monitoring (e.g., development of forestry cutting plans, plantations, etc.);*
- *To begin with projects requiring assistance in the area of land management and aquaculture development. Other disciplinary areas such as wildlife and vegetation biodiversity will be developed as opportunities are defined; and*
- *To focus on projects in Viet Nam, Thailand, and Indonesia in the first year, but examine opportunities elsewhere in adjacent countries on an ongoing basis.*

Government Resource Planning Agencies

- *To provide assistance to Vietnamese, Thai, and Indonesia government resource planning agencies for projects involving biological resource development and regional environmental management. This will include projects funded by external banks and aid agencies (ADB, World Bank, CIDA, Japanese OECF, Mekong Secretariat, etc.). These projects often have a lengthy application stage so efforts in 1996 will concentrate on project definition and prioritization.*

Training

- *To develop expertise amongst Vietnamese, Thai, and Indonesian technical personnel by providing ongoing training; and*
- *To provide specific environmental analytical services, including the design of RADARSAT programs and field surveys to collect biological data, the analysis of data, and the interpretation of results. A three and a half year CIDA-supported project to provide further EIA training in Thailand is presently being carried out by HCL and Pro-En Envirosciences Ltd. This program would be expanded to include RADARSAT technology training if desirable.*

9.8.2 1998

- *To undertake long-term projects developed in 1997 related to regional resource planning and environmental monitoring;*
- *To continue working with private sector clients on short-term projects as they present themselves;*
- *To continue training programs as needed for Vietnamese, Thai, and Indonesian technical personnel;*
- *To develop projects in the countries adjacent to Thailand; and*
- *To identify and pursue projects with private sector clients interested in pursuing aquaculture projects. Site evaluation and selection steps could use RADARSAT technology as a tool in these processes.*

9.8.3 1999

- *Initial RADARSAT project development activities undertaken in 1997 and 1998 will be expanded upon. A mixture is expected of short-term projects with private sector clients (e.g., industrial developers, pulpmill proponents, etc.) and long-term projects with some private sector clients and government planning agencies; and*
- *Similarly, these activities are expected to be comprised partly of projects within Viet Nam, Thailand, and Indonesia and partly of projects in adjacent country areas."*

At the time this action plan was prepared it was only possible to have overall objectives and implementation steps. None of these objectives or steps have changed in light of the experience in using the RADARSAT technology gained by members of the Hatfield project who are involved in carrying out the RUDP to date. However, because of RADARSAT experience gained by the project team and further contacts made both in Canada and Southeast Asia, it has been possible to refine the action plan implementation steps into a number of specific projects which are all designed to result in expanded work for Hatfield Group companies.

A. On-going projects:

1. **Project No. 1** - To order test imagery of the Freeport McMoran Inc. copper/gold open pit mining property and tailings disposal area in Irian Jaya, Indonesia to test the imagery for use as a monitoring tool for evaluating the biodiversity environmental impacts of mine site expansion and tailings disposal practices. Freeport is an existing client of the Hatfield Group's Indonesian company, PT Hatfindo Prima (PTHP). PTHP is carrying out a major multi-year ecosystem biodiversity baseline study in the area of the mine. The test imagery project is being carried out with RADARSAT International. If successful, Hatfield Consultants Ltd. (HCL) would market the results of the test to another major client in Indonesia with operations in Kalimantan, BHP Minerals. Beyond these existing clients, HCL would then market the use of RADARSAT for environmental monitoring to other mining companies operating in Indonesia, such as Inco, Newmont, Aurora Gold, etc.

2. **Project No. 2** - To order test imagery of a part of the coast of southern Thailand north of Songkhla which is undergoing major development for shrimp farming. The test imagery would be obtained to demonstrate the use of RADARSAT to private shrimp farm companies, local communities, and government agencies in the area for future shrimp farm planning, new pond construction monitoring, and operations monitoring. Results would be marketed to the above parties and outside agencies having strong interests in aquaculture and coastal zone planning, such as the Asia Development Bank (ADB), CIDA, World Bank, etc.

3. **Project No. 3** - Participation in a USD $500,000 ADB funded program in Indonesia to use RADARSAT imagery for coastal planning. The project would be carried out jointly with RSI and other Canadian consultants. Results of the project will be marketed to other Indonesian planning agencies.

4. **Project No. 4** - Participation in a CIDA funded environmental institutional strengthening and training project in the coastal area of Danang, Viet Nam, using RADARSAT for coastal planning. Hatfield has been subcontracted by SNC-Lavalin for this work. Results of this RADARSAT demonstration will be marketed to environmental and planning government and international financing agencies (e.g., ADB, UNDP, World Bank, etc.) in Viet Nam.

5. **Project No. 5** - Tracking of lead passed on to RSI regarding flood monitoring in rice growing areas in the Mekong drainage of Cambodia. The monitoring is being carried out by an office of the World Food Program (WFP) of the United Nations based in Phnom Penh. If rice crops are excessively flooded (over the tops of the plants) for more than two weeks, the rice crop is lost. The WFP is interested in using RADARSAT imagery to assist in calculating rice crop losses in order that rice shortfalls can be predicted with sufficient lead time to permit an efficient WFP response

to import rice from abroad to prevent local population starvation. The results obtained in Cambodia will be marketed by RSI to other similar areas in Asia.

6. **Project No. 6** - Testing of RADARSAT imagery in Laos to detail areas of significant residual soil disturbance, vegetation changes, etc. caused by past war activity damage. These areas often contain unexploded mines, bombs, and artillery ordnance. UXO-Lao field operations presently have significant programs in Laos and elsewhere to map and mark these areas on the ground and eventually clear them to make the areas safer for local people. At present, an average of ten fatalities per year month occur from unexploded ordnance areas from conflicts between farming, forest gathering, and other local activities. If the RADARSAT technology is successful in assisting in the ordnance removal process, the lead would be given to RSI to follow up.

7. **Project No. 7** - Using RADARSAT imagery to delineate particular forest stands in the Mekong drainage which only lose their leaves during the monsoon season. The German international aid agency GZT is mapping forest resources in the Mekong drainage (particularly Laos and Viet Nam) using primarily Landsat and Spot imagery. However, there are areas in the drainage where cloud cover, particularly during the monsoon season, precludes coverage. RADARSAT can hopefully overcome this problem in these special areas. Some imagery obtained for the Hatfield RUDP project will be in areas of special interest for the GZT project as well. If RADARSAT is successful in delineating these special forest areas, this ability will be marketed to other forestry agencies, forest companies, IFIs, etc. having interests in the area.

8. **Project No. 8** - Using RADARSAT imagery to monitor flooding in major delta areas of Viet Nam (likely the Red River delta in the north and Mekong River delta in the south). Flooding is a frequent occurance in Viet Nam which causes widespread rice crop failures, infrastructure damage, and loss of human life. Since flooding occurs during and after the monsoon season, monitoring using optical satellites is unreliable because of cloud cover. This project is proposed as a joint endeavour between Hatfield and RSI using CIDA Inc. seed funding to carry out a feasibility study.

9. **Project No. 9** - Using RADARSAT imagery for locating solid waste disposal sites in the provinces of Indonesia. The Indonesian technology development agency (BPPT) would be the funding source for this work and RSI a partner.

10. **Project No. 10** - Our RADARSAT RUDP project funding has been leveraged to gain approval for a further $80,000 funding from the CIDA short-term training fund to assist Hatfield to carry out training of Vietnamese staff of two dioxin analytical laboratories in Viet Nam. The RUDP program imagery will be used during this dioxin sampling and analysis training program to select sampling points in the Agent Orange sprayed areas, etc.

11. **Project No. 11** - Our RADARSAT RUDP project funding has also been leveraged to gain approval for a further $30,000 funding from Environment Canada for Hatfield to carry out a workshop in Viet Nam related to dioxin sampling and analyses.

B. Pending Project Proposals Related to RADARSAT RUDP Project in Viet Nam and the Mekong River Drainage

1. **Proposal No. 1** - To US Institute of Medicine of the American Association for the Advancement of Science (AAAS) to participate in a major dioxin exposure modeling study related to estimating the likely effects of Agent Orange on US Viet Nam war veterans. Hatfield's role in this work would be to design and implement field studies related to assessing the present level of dioxin contamination of the environment of Viet Nam. RADARSAT imagery would be used in the sampling program design phase of the project.

2. **Proposal No. 2** - To the Bangkok-based Mekong Commission, to carry out an assessment of Agent Orange-related dioxin contamination of the Viet Nam, Laos and Cambodia portions of the Mekong River drainage basin. RADARSAT imagery would be used in the sampling program design phase of the project.

3. **Proposal No. 3** - To UNDP/World Bank-funded Global Environment Facility (GEF), to carry out an assessment of Agent Orange-related dioxin contamination of the environment of nature reserve areas of Viet Nam. RADARSAT imagery would be used in the sampling design phase of this project.

Figures

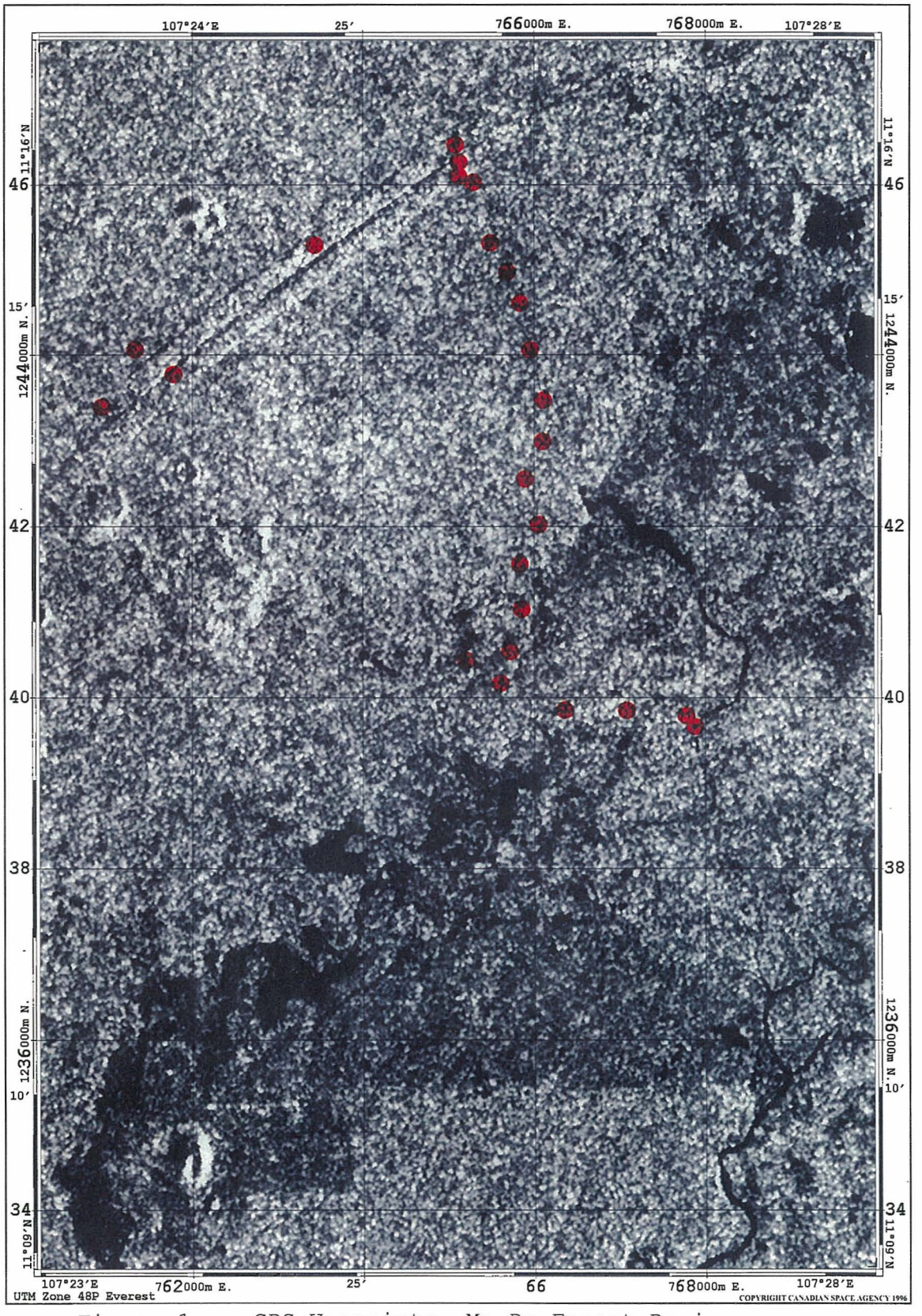

Figure 1 GPS Waypoints, Ma Da Forest Region.

Standard 6 (Descending) - August 31, 1996

1:70 000 Scale

Kilometres 1 0 1 2 3 4 5 6

Miles 1 0 1 2 3

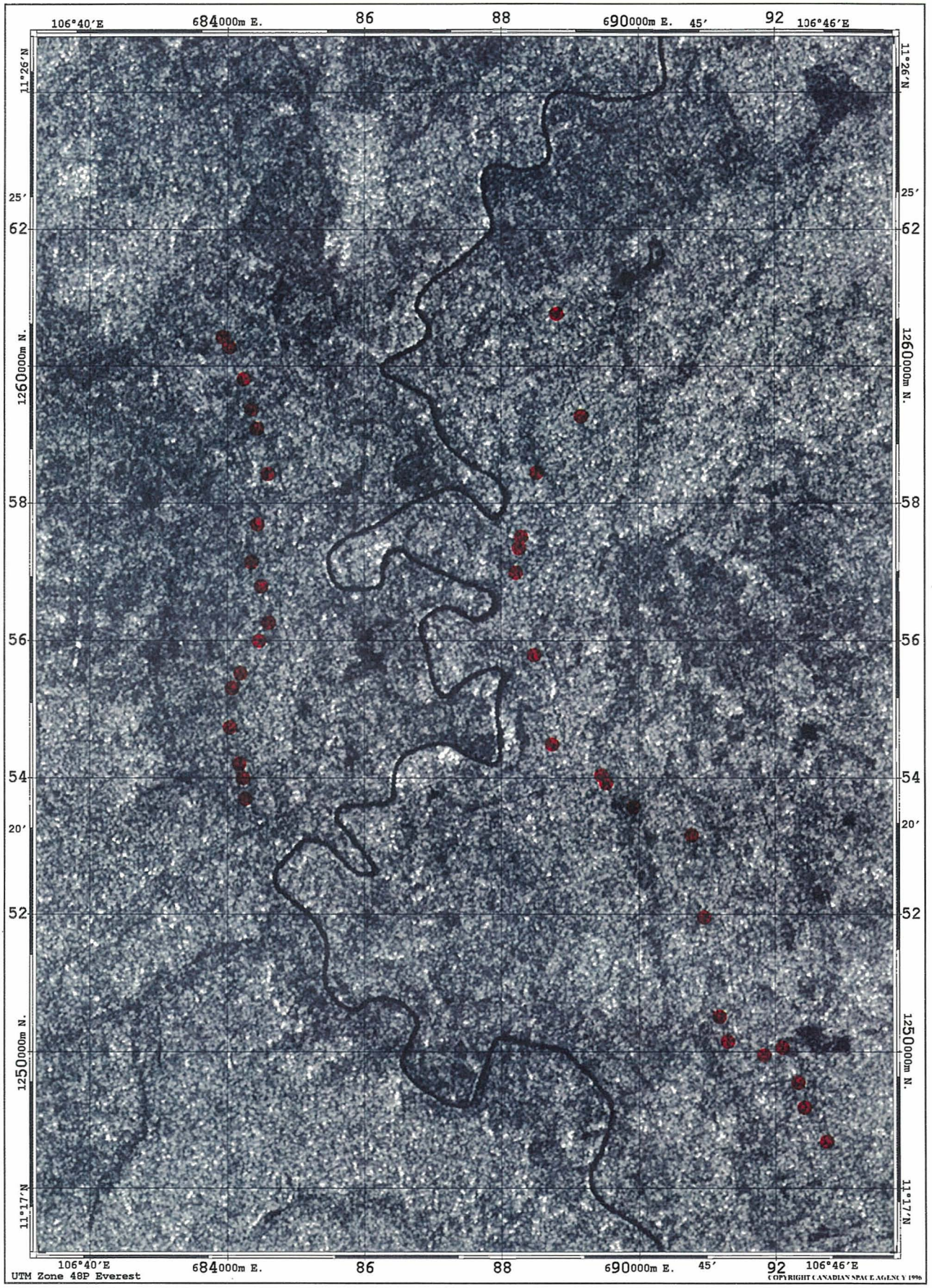

Figure 2 GPS Waypoints, Ma Da Forest Region.

Standard 6 (Descending) - August 31, 1996

1:80 000 Scale

Kilometres 1 0 1 2 3 4 5 6 7

Miles 1 0 1 2 3 4

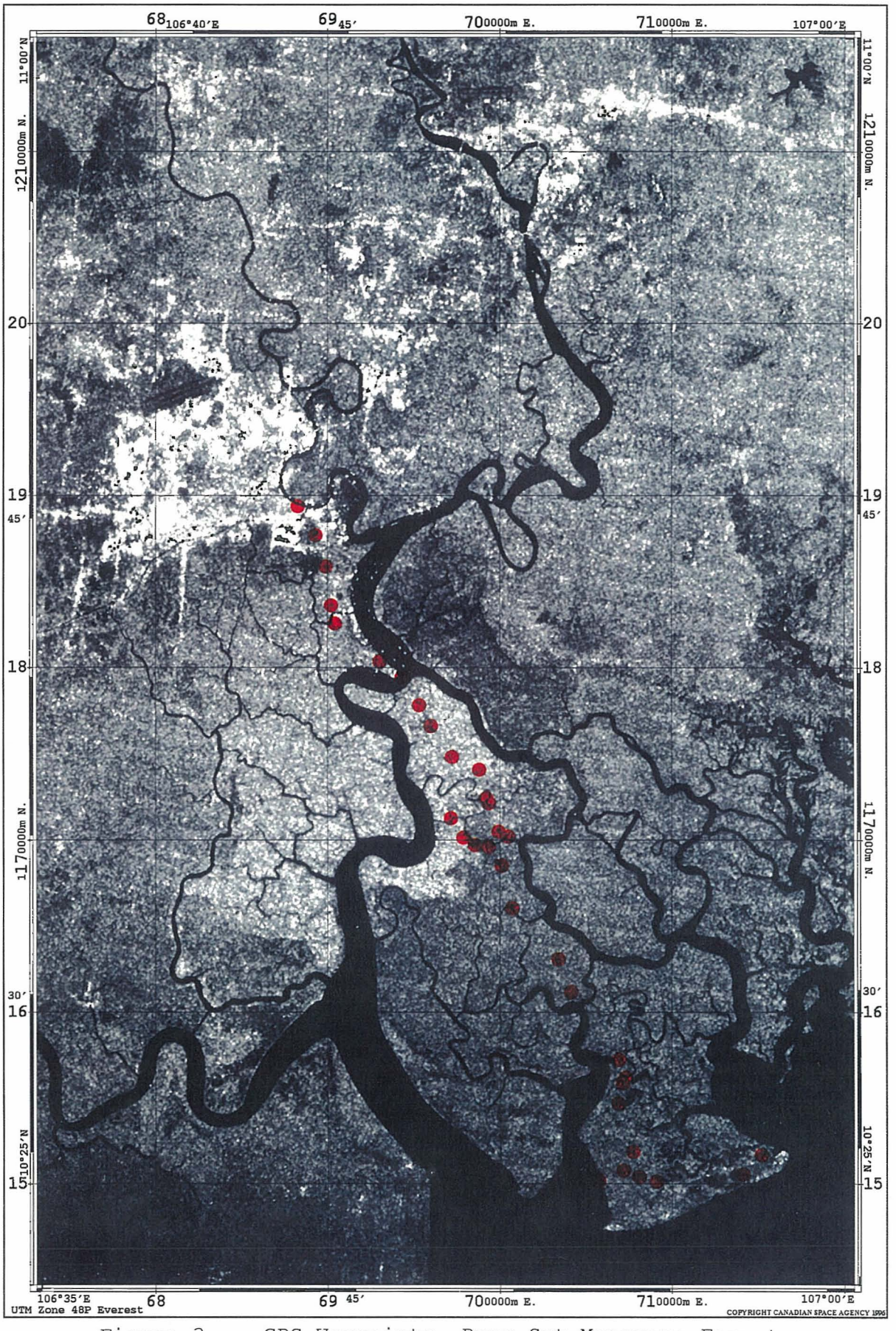

Figure 3 GPS Waypoints, Rung Sat Mangrove Forest.

ScanSAR Narrow 2 (Descending) - August 24, 1996

1:325 000 Scale

Kilometres 10 0 10 20

Miles 10 0 10

Plates

Plate 1 **Forest plantation (teak [*Tectona grandis*] and *Hopea* sp.) along Highway 20, Dong Nai Province.**

Plate 2 **Mixed agricultural plots and sparse fruit trees near Highway 20, Dong Nai Province.**

Plate 3 **Modified, flat-topped hills with mixed agricultural, near Highway 20, Dong Nai Province.**

Plate 4 **Wetland area north of a dam on the La Nga River, Dong Nai Province.**

Plate 5 **Wetland and paddy cultivation with forest in the distance, looking south from a dam on the La Nga River, Don Nai Province.**

Plate 6 Bridge over a small tributary of the Song Bé River, with rubber and cashew plantation in background, Song Bé Province.

Plate 7 Barren fields and sparse rubber trees of mixed age and density, near Song Bé River, Song Bé Province.

Plate 8 Low-lying area of paddy cultivation and finfish aquaculture near the Song Bé River, Song Bé Province.

Plate 9 The Sai Gon River, south of Ho Chi Minh City.

Plate 10 **Newly-planted and young (approximately ten years old) mangrove, Rung Sat mangrove forest, south of Ho Chi Minh City.**

Plate 11 **Non-operational shrimp aquaculture ponds, Rung Sat mangrove forest, south of Ho Chi Minh City.**

Plate 12 **Northern boundary of protected Rung Sat mangrove forest, showing *Nipa* palm plantation to the north (right side) of the channel and mangrove forest of mixed species and age to the south (left side).**

Appendix A1

Table A1.1 GPS Waypoints, Ma Da Forest Region (Song Be), April 15, 1997.

Waypt.	Easting	Northing	Comments
1	0684231	1253705	W side of river; bridge over small creek; young rubber & bamboo
2	0684200	1254009	Along road
3	0684145	1254218	Along road (powerline follows road)
4	0684010	1254748	Along road
5	0684041	1255322	Along road
6	0684162	1255536	Village
7	0684435	1256008	Along road (cashews)
8	0684572	1256275	Bend in road
9	0684465	1256800	Along road (cashew trees, some homes)
10	0684322	1257148	Rubber trees, then cashews again
11	0684411	1257700	Young rubber trees, cleared ground
12	0684561	1258435	Mixed plantation, bend in road
13	0684400	1259100	Rubber to left of road
14	0684323	1259387	Powerline ends
15	0684213	1259835	Area opens up a bit
16	0684000	1260300	Lots of rubber plantations
17	0683908	1260445	Stop#2; mixed plantation and barren areas; near Bung Say
18	0692717	1248695	Now on E side of river; cashew and grazing fields, small huts
19	0692396	1249194	Along road
20	0692305	1249557	Powerlines cross road; sparse cashews after poweline right-of-way
21	0692075	1250069	Bend in road
22	0691807	1249959	More bends; cashew plantations
23	0691275	1250162	Large open space left of road ~500 m
24	0691156	1250526	Village spread out along road (Tan Hiap)
25	0690930	1251969	End of village (more or less); cashews and mixed trees
26	0690747	1253166	Another village (Han Dien?); lots of cleared land
27	0689887	1253580	Large cleared area w/small ruuber and cashew
28	0689497	1253934	Cleared land near edge of river valley ("SB3")
29	0689426	1254046	Fish ponds, rice paddies, small aquaculture facility ("SB4")
30	0688707	1254499	Village; sparse buildings; cashews
31	0688444	1255800	Phuoc Sang village (Anh Linh); fairly densely built
32	0688180	1256998	Sparse homes and cashew trees
33	0688225	1257352	Anh Linh school with large, open grounds
34	0688484	1258452	Wide, flat road, fairly straight; cashews and sparse homes
35	0689135	125927	Village centre (dense)
36	0688780	1260784	End of road (does not continue as map suggests); some homes
37	0688259	1257520	Large church in Anh Linh (on way back)

Table A1.2 GPS Waypoints, Ma Da Forest Region (Dong Nai), April 14, 1997.

Waypt.#	Easting	Northing	Comments
1	0760100	1242400	Best guess where road enters the figure on the W side ("DN1")
2	0760945	1243400	Plantation of *Tectona grandis* and *Hopea* sp begins ("DN2")
3	0761779	1243782	Cleared fields at the southern edge of plantation (mixed crops and homes) ("DN3")
4	0761332	1244070	Looking from NE edge or forested strip (N of road): cleared land, mixed crops, some huts ("DN4")
5	0763438	1245294	Village ("DN5")
6	0765077	1246468	Intersection in village where we turned right ("DN6")
7	0765117	1246265	Along road (in village)
8	0765114	1246100	Village thinning out
9	0765285	1246028	Large concrete/metal building on left
10	0765483	1245316	Thin plantation (mixed crops: vegetables, banana, papaya) on both sides
11	0765681	1244975	As above
12	0765832	1244611	As above (somewhat more treed)
13	0765950	1244063	Plantations of small trees, sparse homes
14	0766106	1243473	As above; small school on left
15	0766098	1242991	Cleared crop fields, lychee & papaya trees; Tra Co "km 4" marker
16	0765890	1242555	As 14.
17	0766052	1242020	Tra Co "km5" marker; land use as above; flat, swampy area ~1 km to left
18	0765830	1241556	Start of wide, flat rice-growing area; line visible in south of image is paddy/forest boundary ("DN7")
19	0765851	1241033	Mixed rice and palm plantations, some small fish ponds
20	0765714	1240537	Intersection of road (Dr. Boi says it's a new road)
21	0765602	1240169	Middle of Phu Dien village (fairly large)
22	0766358	1239856	Large compound on right
23	0767079	1239850	Large open areas of rice paddy on both sides of road for a couple of km at least in each direction
24	0767775	1239788	Large brick factory
25	0767876	1239659	Dam across stream; large wetlands visible to north and south ("DN9")
26	0765200	1240435	On way back; rice fields and orchards

Table A1.3 GPS Waypoints, Rung Sat Mangrove Forest, April 16, 1997.

Waypt.#	Easting	Northing	Comments
1	0699028	1172548	~50 m long bridge spanning ~15 m wide stream
2	0699734	1170619	~60 m bridge over ~50 m river flowing E to W; mangroves (replanted) to S; *Nipa* palm to N ("RS1").
3	0700296	1170325	Main buildings at shrimp farm office (ponds v. visible on Figure 13) ("RS2")
4	0699909	1168645	Another bridge, south of Figure 13; surrounding mangrove 20-30m high (all replanted since war)
5	0700512	1166165	Bridge, sign on S side indicates entry into protected forest (~40,000 ha large, according to Dr. Boi).
6	0703190	1163186	Along road
7	0703911	1161276	Ferry across river
8	0706680	1157287	Along road just before clearing
9	0707067	1156239	Large clearing (aquaculture/salt ponds) east of road; W remains mangrove (*Rhizophora*)
10	0706904	1155936	Large shrimp ponds on east side, followed by salt ponds
11	0706653	1154738	End of pond area
12	0707477	1151938	Large field of young mangrove on east side; old shrimp farms on west
13	0706911	1150843	Nature reserve buildings & museum; mangroves in this area are *Avicennia*.
14	0705458	1150276	Solar power station on coast (path leads to it)
15	0707820	1250460	Main forest park office
16	0713816	1150573	Large war memorial just before Van Thanh village
17	0714880	1151702	Restaurant in village; large ponds and channels all around
18	0708827	1150202	Edge of reserce; bridge over river; sparse mangrove & shrimp farms (replanted or abandoned)
19	0699150	1169720	Left turn at intersection
20	0698353	1169834	Small village left of road; mixed forest to right; *Nipa* south of village
21	0697687	1170271	Ponds to left; dry paddy field on both sides of road, some *Nipa*
22	0696973	1171394	Road bends left; rice paddies and *Nipa* palm ("RS3")
23	0699181	1172275	Bend in road near bridge
24	0698632	1174211	Bend in road (villages, homes along road)
25	0697057	1174946	Bend in road (villages, homes along road)
26	0695831	1176747	Bend in road (villages, homes along road)
27	0695164	1177953	Large factory visible west of road (1-2 km?) w/ very large smokestack
28	0694163	1179559	Ferry terminal #1 (south end)
29	0692883	118496	Ferry terminal #1 (north end)
30	0690293	1182707	Along road (very densely built up)
31	0690075	1183761	Major bridge across river
32	0689762	1186022	Along road (very densely built up)
33	0689190	1187842	Graveyard along road
34	0688153	1189533	Bridge over Saigon R. leading into HCMC proper.