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**Marshall Islands Program
Field Operations Report**

**Bikini Island Geographical
Information System (GIS) Sample Site
Mapping**

J.L. Brunk

S.R. Kehl

T.F. Hamilton

January 2007

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Mapping**

J.L. Brunk, S.R. Kehl, and T.F. Hamilton

**Lawrence Livermore National Laboratory
Livermore, CA 94551**

U.S.A.

(hamilton18@llnl.gov)

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Bikini Island Geographical Positioning System (GPS) Sample Site Mapping

J.L. Brunk, S.R. Kehl, and T.F. Hamilton
Lawrence Livermore National Laboratory
Livermore, CA, 94551
U.S.A.

Overview

Bikini Atoll is located at 11.6°N, 165.5°E in the north equatorial Pacific Ocean and is one of two former atmospheric nuclear test sites within the Republic of the Marshall Islands. There are no permanent residents living on the atoll although the Bikini council provides infrastructure support for a commercial dive program as well as ongoing scientific studies conducted under working agreements between the local government, the United States (U.S.) Department of Energy (DOE) and the Lawrence Livermore National Laboratory (LLNL). The scientific program on Bikini has largely focused on the development of remediation techniques and obtaining relevant data to provide accurate assessments of radiological conditions on the islands. The general aim of the environmental program on Bikini is to improve on our knowledge of the unique behaviors and transport pathways of residual fallout radionuclides in coral atoll ecosystems. Such information is essential in making accurate predictions of future change and in developing sound strategies for rehabilitation of the islands.

In recent years, satellite imaging technology has become much more affordable. Consequently, we are now using satellite images coupled with geographical positioning system (GPS) sample site mapping to provide accurate location information on experimental plots and sample survey sites. This report gives an account of our GPS mapping capability and lists the coordinates of major experiments and sample tree sites on Bikini Island for use in associated Geographical Information Systems (GIS) software.

Mapping was done with the Trimble Pro XR system. The Trimble Pro XR system provides sub meter accuracy while minimizing site occupation time. One instrument is placed over a control location while other instruments are used as rover units in the field. The control location system is connected to a VHF radio and broadcasts corrective signals. The rover unit receives these signals and uses the correction in real time to improve on the accuracy of site positioning. The Trimble Pro XR system offers sufficient accuracy to record the location of specific sites so they can be reoccupied or

sampled in the future. On a practical level this means that we are able to locate specific sampling trees rather than rely on markings. By providing more accurate site control we will be able to accurately track future change in radiological conditions on the atoll and verify the effects of any remedial work. Moreover, GPS site mapping allows our experimental plots and sample survey sites to be more accurately depicted on accompanying satellite images and for use in GIS applications.

Background

Geographic control is problematic on Bikini Island. The first effort to use GPS technology to map the sample site locations on Bikini Atoll occurred in May 1999. This was during the time when civilian use of the system was intentionally degraded with a random error of about ± 90 meters. Our base station control benchmark site during the May 1999 survey was assigned a value of $11^{\circ} 37' 46.127774''$ N, $165^{\circ} 32' 47.620825''$ E in the WGS84 datum. On a subsequent field mission about two months later, a value of $11^{\circ} 37' 47.787844''$ N, $165^{\circ} 32' 46.29915''$ E was established for the same benchmark. Both sets of measurements were performed with selective availability error and resulted in a 55 meter 142° true offset between the datasets. However, since 2000, the selective availability error has been turned off allowing for more accurate site positioning using civilian GPS.

In order to reconcile the differences between GPS data collected on early field missions, a study of post selective availability accuracy was made during the March 2006 mission. Four long observations of the control location were made. Additionally, the nearby roads were mapped providing a basis for using GIS software to correct sample site information transposed onto satellite images. Figure 1 shows the variation in the geographical location of the different surveys. One arc second is about equivalent to 30 meters distance. The GPS data contained in this report has all been collected relative to the base station coordinates established during the July 1999 mission.

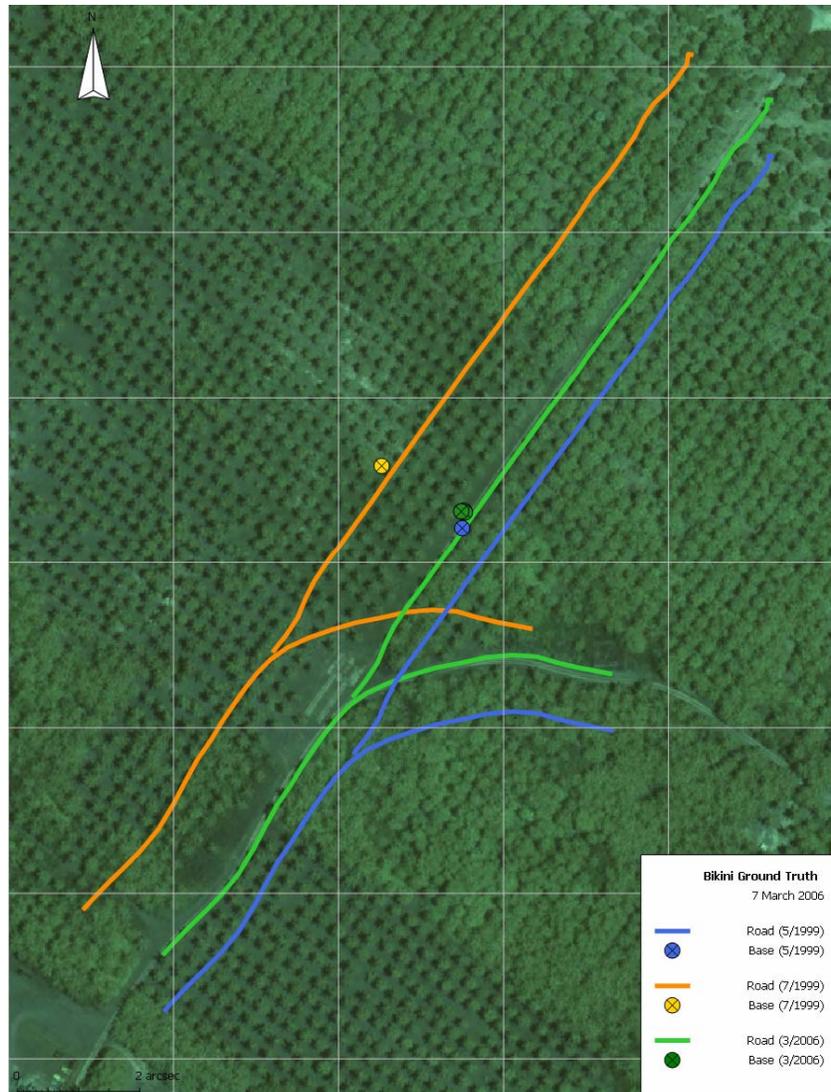


Figure 1. Map of ground truth GPS measurements taken on different field missions to Bikini Island.

Site Mapping Studies

Gamma Benchmark Locations

Prior to 1999, several locations were identified for external gamma exposure rate measurements. These sites were intended to be revisited as benchmark sites to track changes in external gamma dose rates over time. The gamma benchmark sites (N=18) are identified by a small numbered steel plate buried in the soil and were first mapped during the May 1999 survey. However, we were unable to reproduce the positions on subsequent missions. The benchmarks were identified on this current mission and

mapped relative to the base station coordinates established during July 1999 (refer to Table 1 and Figure 2).

Table 1. Location of external gamma benchmark sites on Bikini Island.

Site	Experimental Plot	Tree Row	Latitude (°N)	Longitude (°E)
A	KNPK	F1-2	11.626031426	165.549823101
B	KNPK	F9-10	11.625669205	165.550333490
C	KNPK	L6-7	Could not locate – heavy scrub vegetation	
D	KNPK	L21-22	11.624777822	165.550828812
E	KNPK	S21-22	11.624329923	165.550512722
F	KNPK	C16-17	11.625553269	165.550913491
G	KNPK	M6-7	11.625368209	165.549834342
H	CLC	K27-28	11.624570181	165.551257638
I	CLC	H29-30	11.624675078	165.551514208
J	WLR	E10-11	11.624508851	165.549312810
K	WLR	C8-9	11.624729713	165.549274437
L	EX Control	K3-J3	11.627839980	165.548568122
M	EX Control	I3-J5	Site reportedly destroyed	
O	B1	F4-5	11.628949556	165.544702289
P	HEJ	H40-41	11.626450187	165.547728598
Q	HEJ	I14-15	11.627664085	165.546114111
R	B1	H2-3	11.628728990	165.544741900
S	ACS	VV11-12	11.625553435	165.548338860



Figure 2. Map showing location of external gamma benchmark sites on Bikini Island.

Ground water sampling wells and lysimeter experiment locations on Bikini Island

Bikini Island has several experiments designed to study the cycling of cesium-137 (^{137}Cs) as well as other fallout radionuclides in soils and water. Several ground water sampling wells have been established and are periodically analyzed for a range of fallout radionuclides. We have also installed a number of large plate lysimeters to determine the rate of removal of ^{137}Cs from the upper soil column through the action of rainfall. Recent studies demonstrate that these environmental processes are more important than radiological decay in controlling the fate of ^{137}Cs in the environment. A number of new GIS locations were established during the March 2006 mission in support of these on-going studies (refer to Table 2 and Figure 3). All data are reported relative to the base station coordinates established in July 1999.

Table 2. Ground water sampling wells and lysimeter experiment locations on Bikini Island.

Location	Latitude (°N)	Longitude (°E)
Community Well	11.627359182	165.549966596
Lysimeter 1 plate	11.626278433	165.549672555
Lysimeter 2,3,4 (center plate)	11.628413159	165.547614114
Lysimeter 2,3,4 well	11.628426819	165.547651520
Lysimeter 2,3,4 well	11.628427091	165.547651746
Lysimeter 12 plate	11.626231590	165.548965830
Lysimeter 12 well	11.626172054	165.549030631
Slotted Well B1	11.628784539	165.544742066
Slotted Well B4	11.625733244	165.548937800
Slotted Well CLC	11.624352541	165.550825362
Slotted Well H5	11.629765250	165.541902493



Figure 3. Map showing ground water well sampling and lysimeter experiment sites.

External gamma survey sites for the proposed village area on Bikini Island

During the late 1990s a strip of land extending from the existing service area along the lagoon road towards the northern end of Bikini Island was cleared of scrub vegetation and declared as a potential village and housing area. An external gamma survey grid that covered a portion of the village area was established in May 1999. The survey grid was extended in March 2006 to include 96 new locations over a distance of 2.5 km along the lagoon road. An initial point at the northeastern end of the lagoon road was marked. Two points were placed thereafter at every 50 m distance. The 50 m increments were numbered with respect to distance from the initial point and assigned as either point A sites located at 10 m distance or point B sites located at 25 m distance on the island interior side of the lagoon road. Please note that row 350 was omitted due to it falling on the fuel farm and row 1050 was similarly omitted since it fell on a large stand of vegetation. The GIS coordinates from these sites are shown in Table 3 and Figure 4 relative to base station coordinates established in July 1999.

Radiological survey tree sampling locations on Bikini Island

The Marshall Island Program has also been using an empirical approach in estimating the effective half-life of ^{137}Cs in coconuts and other food crops. This work is dependent on sampling the same sample monitoring trees over many years. Several of these sampling trees were located during the March 2006 and GIS locations established for the sites. The nature of some tree locations presented challenges to getting precise data. Many trees were located in dense areas of the jungle while others were located in the less maintained southwestern portion of the island. Attempts were made to take measurements as close to the trunks as possible. Where this was not feasible, a measurement was attempted under the tree's canopy. In several cases, the satellite coverage was so poor in the immediate vicinity of the tree, that an offset measurement was required. The offset and direction was noted in each of these cases.

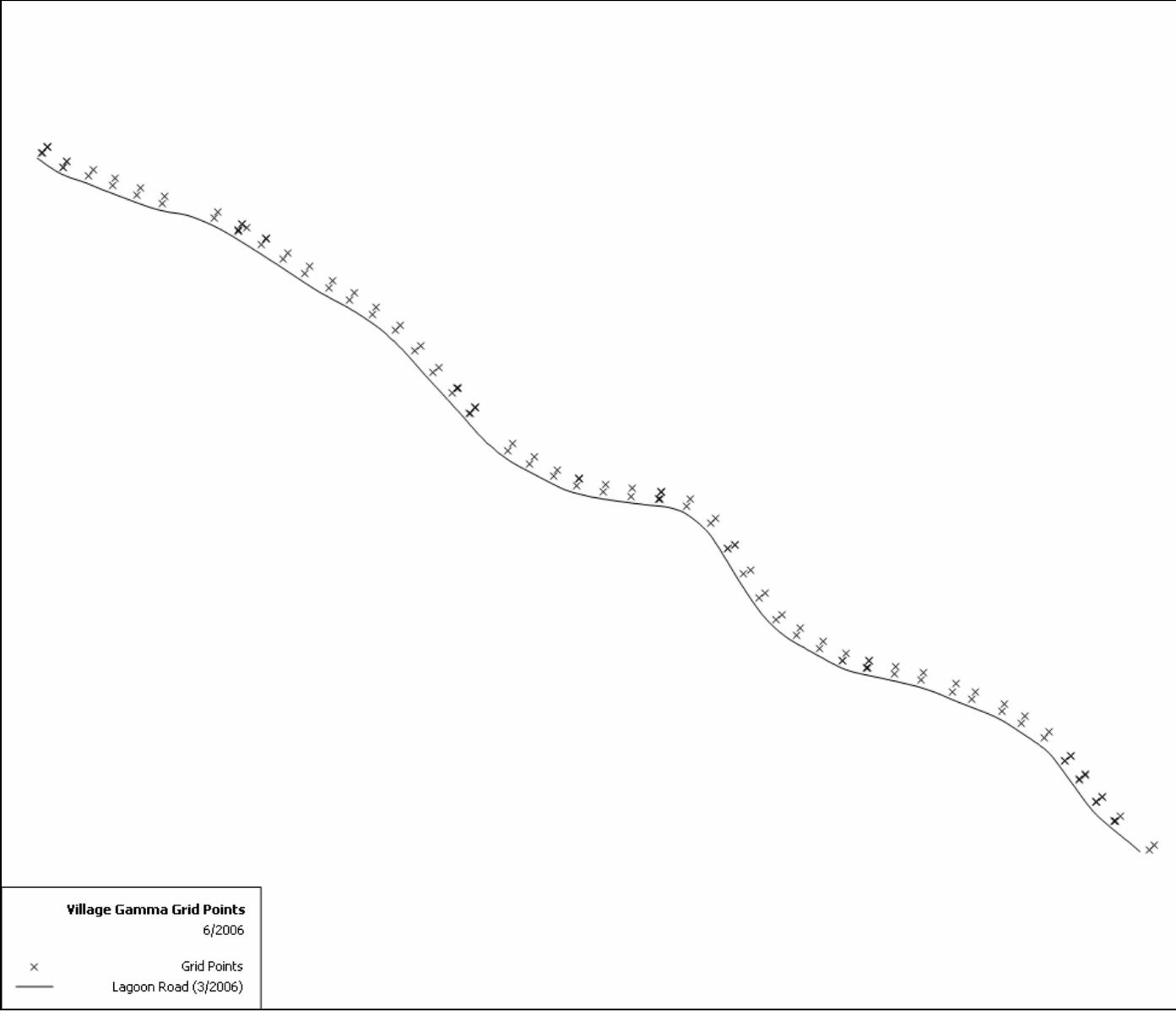


Figure 4. Map of survey sites for proposed the village area on Bikini Island.

Table 3. Survey sites for proposed the village area on Bikini Island.

Grid point	Latitude	Longitude	Grid point	Latitude	Longitude
50a	11.636784364	165.527976695	1350a	11.630820562	165.538186152
50b	11.636880358	165.528064489	1350b	11.630955216	165.538206916
100a	11.636523769	165.528332049	1400a	11.630770911	165.538667658
100b	11.636636756	165.528411586	1400b	11.630902027	165.538698521
150a	11.636378450	165.528784675	1450a	11.630640963	165.539149574
150b	11.636491543	165.528855891	1450b	11.630767975	165.539213582
200a	11.636207093	165.529188765	1500a	11.630344582	165.539551489
200b	11.636331670	165.529239904	1500b	11.630440150	165.539642215
250a	11.636043787	165.529618237	1550a	11.629915782	165.539858188
250b	11.636161089	165.529677169	1550b	11.629970708	165.539984553
300a	11.635905214	165.530051187	1600a	11.629467092	165.540130099
300b	11.636030381	165.530090239	1600b	11.629537523	165.540250994
400a	11.635643591	165.530950193	1650a	11.629056003	165.540402443
400b	11.635756100	165.531021455	1650b	11.629138128	165.540511741
450a	11.635423634	165.531372436	1700a	11.628679082	165.540699192
450b	11.635542176	165.531445206	1700b	11.628767574	165.540805444
500a	11.635183225	165.531770529	1750a	11.628405799	165.541045991
500b	11.635288302	165.531852715	1750b	11.628520794	165.541119522
500b	11.635287772	165.531852416	1800a	11.628178003	165.541445367
550a	11.634927609	165.532155022	1800b	11.628295402	165.541512897
600a	11.634686378	165.532530195	1850a	11.627970612	165.541841699
600b	11.634801246	165.532601761	1850b	11.628090241	165.541904703
650a	11.634437970	165.532936130	1900a	11.627827908	165.542265418
650b	11.634551538	165.533014825	1900b	11.627955712	165.542311428
700a	11.634230639	165.533311962	1950a	11.627726816	165.542743676
700b	11.634349545	165.533376305	1950b	11.627866559	165.542769042
750a	11.633979943	165.533708616	2000a	11.627625040	165.543211560
750b	11.634102056	165.533772696	2000b	11.627752138	165.543247325
800a	11.633689958	165.534096122	2050a	11.627428025	165.543756891
800b	11.633788707	165.534181807	2050b	11.627556152	165.543809490
850a	11.633336010	165.534432295	2100a	11.627286051	165.544086484
850b	11.633432195	165.534529471	2100b	11.627413354	165.544137896
900a	11.632961325	165.534740673	2150a	11.627092200	165.544598297
900b	11.633056666	165.534842017	2150b	11.627211561	165.544655316
950a	11.632609429	165.535075699	2200a	11.626879148	165.544951243
950b	11.632704715	165.535160401	2200b	11.626991854	165.545015094
1000a	11.632258614	165.535378236	2250a	11.626628962	165.545343287
1000b	11.632354116	165.535473395	2250b	11.626731251	165.545428634
1100a	11.631616360	165.536047849	2300a	11.626225616	165.545690431
1100b	11.631726672	165.536125316	2300b	11.626306908	165.545806113
1150a	11.631384852	165.536427902	2350a	11.625900265	165.545942892
1150b	11.631492646	165.536511128	2350b	11.625982824	165.546047202
1200a	11.631163659	165.536831446	2400a	11.625513739	165.546243292
1200b	11.631280636	165.536906849	2400b	11.625592353	165.546346173
1250a	11.630994328	165.537241448	2450a	11.625171405	165.546563074
1250b	11.631128302	165.537277385	2450b	11.625267847	165.546661817
1300a	11.630899322	165.537708253	2500a	11.624668131	165.547155277
1300b	11.631029298	165.537736437	2500b	11.624764819	165.547243236

Table 4. Radiological survey sampling tree locations on Bikini Island.

Tree Number	Latitude	Longitude	Tree Number	Latitude	Longitude
tree b1	11.626626661	165.546717959	tree 54	11.635030726	165.537798070
tree t01	11.622829364	165.553967788	tree 56	11.628393556	165.543763167
tree wb1a	11.628672579	165.545112628	tree 57	11.628436877	165.543698732
tree wb1b	11.628634877	165.545169508	tree 77	11.632557518	165.543542503
tree wb1c	11.628576687	165.545125945	tree b150	11.626774037	165.547864558
tree wb1d	11.628622481	165.545073333	tree b151	11.626686841	165.551128602
tree t02	11.628695144	165.544000618	tree 154	11.615817508	165.552880753
tree b3	11.631775091	165.542665146	tree 158	11.629110146	165.540888622
tree b6	11.622062578	165.553193241	tree 170	11.626177513	165.546139711
tree b7	11.627206591	165.550345935	tree 200	11.626407256	165.546414399
tree b8	11.617446574	165.553774425	tree 201	11.626556078	165.546256854
tree b9	11.632848459	165.544588390	tree 202	11.626297346	165.546536054
tree b10	11.624892887	165.549099813	tree 220	11.626224750	165.549878018
tree b10ab	11.633560522	165.544096375	tree 221	11.626286184	165.549803211
tree b11	11.633253170	165.544010004	tree 230	11.626686163	165.550397256
tree b12	11.627575037	165.543076982	tree 231	11.636215024	165.528766919
tree b13	11.629703359	165.546023763	tree 233	11.631568397	165.535809781
tree b14	11.626661419	165.546544043	tree 235	11.626375848	165.545895670
tree b15	11.615550824	165.552126587	tree 300	11.627241119	165.549228748
tree 16	11.630499677	165.541482138	tree 401	11.634204020	165.536373924
tree b19	11.631826546	165.543063854	tree 402	11.634625348	165.535599371
tree b19a	11.631834436	165.543035064	tree 403	11.635199068	165.534774666
tree b20d	11.634628271	165.534388129	tree 407	11.631189087	165.543450060
tree 22	11.630705329	165.544129734	tree 408	11.630206780	165.544739174
tree 23	11.627879583	165.548568907	tree 409	11.629911528	165.545280506
tree b24	11.624190966	165.550107190	tree 409ab	11.629860858	165.545343839
tree b25	11.619811379	165.552746130	tree 455	11.628205725	165.543350700
tree 30	11.626669435	165.546088150	tree 462	11.624156656	165.549984629
tree 31	11.626298293	165.546455532	tree 507 508	11.626976406	165.550323355
tree 32r	11.619185128	165.551080995	tree 513	11.628316807	165.548596670
tree 33r	11.621461307	165.550458539	tree 514	11.628294281	165.548551794
tree 35	11.626257605	165.546578545	tree 523 524	11.628439582	165.544392405
tree b42	11.615908798	165.552758102	tree 525 526	11.628518402	165.544351275
tree b43	11.615951899	165.552819214	tree 527 528	11.629007074	165.545180766
tree 46	11.629117564	165.540849666	tree 529	11.628828011	165.544894489
tree 50r	11.619377386	165.551100340	tree 552	11.620996213	165.552816465
tree 51	11.617085690	165.551487448	tree 557	11.630516706	165.546501922
			tree b561	11.630810554	165.541040653

Acknowledgment

We are indebted to the Marshall Islands logistics support group at Bechtel Nevada for their valuable support. Gerald Chin was especially helpful with the experimental tree portion of the mapping project. Douglas Miller and Lance Yamaguchi braved the rain and bad satellite coverage in order to help establish the external gamma survey grid in the proposed village area.

Appendix I

GPS File Archive

Table 1A. GPS File Archive Listing.

Date	Time	Size	Name
3/6/2006	11:10p	194148	A6030710.ssf
3/6/2006	11:10p	474718	A6030713.ssf
3/6/2006	11:10p	661200	B6030708.ssf
3/6/2006	11:40p	76017	B6030718.ssf
3/7/2006	07:51p	508375	B6030813.ssf
3/7/2006	11:43p	124621	B6030818.ssf
3/8/2006	08:29p	790821	B6030912.ssf
3/9/2006	03:01p	921879	B6031007.ssf
3/9/2006	07:10p	521355	B6031012.ssf
3/9/2006	09:01p	353503	B6031015.ssf
3/9/2006	10:18p	104875	B6031017.ssf
3/10/2006	04:27p	867571	B6031107.ssf
3/10/2006	09:57p	230397	B6031113.ssf
3/6/2006	07:30p	30,500	J030709A.ssf
3/6/2006	11:19p	2,680	J030718A.ssf
3/6/2006	11:38p	16,805	J030718B Amber.cor
3/6/2006	11:40p	16,805	J030718B Jim.cor
3/6/2006	11:36p	16,805	J030718B Steve.cor
3/6/2006	11:40p	4,947	J030718B.LOG
3/6/2006	11:19p	49,882	J030718B.ssf
3/7/2006	07:51p	103,573	J030813A.cor
3/7/2006	07:51p	13,405	J030813A.LOG
3/10/2006	10:05p	320,827	J030813A.ssf
3/7/2006	11:43p	48,033	J030818A.cor
3/7/2006	11:43p	4,308	J030818A.LOG
3/7/2006	11:39p	186,511	J030818A.ssf
3/8/2006	08:29p	151,975	J030913A.cor
3/8/2006	08:29p	27,782	J030913A.LOG
3/8/2006	08:15p	517,341	J030913A.ssf
3/10/2006	10:57a	177,509	J031007A.cor
3/10/2006	10:57a	39,577	J031007A.LOG
3/9/2006	02:59p	625,455	J031007A.ssf
3/9/2006	07:10p	122,829	J031013A.cor
3/9/2006	07:10p	10,725	J031013A.LOG
3/9/2006	07:02p	424,545	J031013A.ssf
3/9/2006	09:01p	27,036	J031015A.cor
3/9/2006	09:01p	4,921	J031015A.LOG
3/9/2006	08:59p	80,587	J031015A.ssf
3/9/2006	09:01p	44,695	J031016A.cor

Table 1A, cont'd

Date	Time	Size	Name
3/9/2006	09:01p	8,400	J031016A.LOG
3/9/2006	08:59p	118,624	J031016A.ssf
3/9/2006	10:18p	21,914	J031017A.cor
3/9/2006	10:18p	4,323	J031017A.LOG
3/9/2006	10:17p	73,441	J031017A.ssf
3/10/2006	04:27p	166,390	J031108A.cor
3/10/2006	04:27p	70,778	J031108A.LOG
3/10/2006	04:25p	554,007	J031108A.ssf
3/10/2006	09:57p	246,684	J031113A.cor
3/10/2006	09:53p	696,693	J031113A.ssf
3/8/2006	08:29p	175,450	V030913A.cor
3/8/2006	08:29p	29,411	V030913A.LOG
3/8/2006	08:23p	559,024	V030913A.ssf
3/9/2006	07:10p	110,754	V031013A.cor
3/9/2006	07:10p	12,556	V031013A.LOG
3/9/2006	07:07p	416,488	V031013A.ssf
3/6/2006	11:17p	292,215	Z030711A.ssf
3/6/2006	11:17p	985,364	Z030715A.ssf
3/7/2006	03:47p	145,722	Z030806A.ssf
3/7/2006	03:47p	363,307	Z030809A.ssf

Appendix II

GIS Metadata Summary Information

GIS Metadata Information

Identification_Information

Citation

Citation_Information

Originator: James L. Brunk

Publication_Date: January 2007

Title: Bikini Island Geographical Information System (GIS) Sample Site Mapping

Geospatial_Data_Presentation_Form: Tables and diagrams

Publication_Information

Publication_Place: Livermore, California

Publisher: Lawrence Livermore Laboratory

Other_Citation_Details: UCRL-MI-231650

Online_Linkage:

Description

Abstract: During March 2006, new radiological survey sites were established on Bikini Island (Bikini Atoll) in the northern Marshall Islands. New points were placed on the ocean side of the lagoon road. Existing gamma benchmark points were resurveyed to identify locations. Existing experimental trees were surveyed. A study of relative ground truth between three surveys was investigated.

Purpose: These data provide positional information for radiological survey data

Time_Period_of_Content

Time_Period_Information

Range_of_Dates/Times

Beginning_Date: 7 March 2006

Ending_Date: 11 March 2006

Currentness_Reference:

Status

Progress: Completed

Maintenance_and_Update_Frequency: none

Spatial_Domain

Bounding_Coordinates

West_Bounding_Coordinate: 165.5278 °E

East_Bounding_Coordinate: 165.5540 °E

North_Bounding_Coordinate: 11.6369 °N

South_Bounding_Coordinate: 11.6156 °N

Keywords

Theme

Theme_Keyword: GPS

Theme_Keyword: Radiological

Place

Place_Keyword: Bikini Atoll

Access_Constraints:

Use_Constraints: Information is provided as is.

Point_of_Contact

Contact_Information

Contact_Person_Primary

Contact_Person: James L. Brunk

Contact_Organization: Lawrence Livermore National Laboratory

Contact_Address

Address_Type:

Address: P.O. Box 808, L-231

City: Livermore

State_or_Province: CA

Postal_Code: 94550

Country: USA

Contact_Voice_Telephone: 925-422-6631

Contact_Facsimile_Telephone: 925-422-3160

Contact_Electronic_Mail_Address: brunk1@llnl.gov

Hours_of_Service: 8 am – 4 pm

Spatial_Reference_Information

Horizontal_Coordinate_System_Definition

Planar

Grid_Coordinate_System

Grid_Coordinate_System_Name: Latitude / Longitude

Geodetic_Model

Horizontal_Datum_Name: WGS84

Ellipsoid_Name: WGS84

Semi-major_Axis: 6378137 m

Denominator_of_Flattening_Ratio: 298.257223563 (derived from the value of the normalized second degree zonal harmonic coefficient of the gravitational field: -484.16685 x 10⁻⁶)

Metadata_Reference_Information

Metadata_Date: April 2006

Metadata_Contact

Contact_Information

Contact_Organization_Primary

Contact_Organization: Lawrence Livermore National Laboratory

Contact_Position:

Contact_Address

Address_Type:

Address: P.O. Box 808

City: Livermore

State_or_Province: California

Postal_Code: 94550

Country: USA

University of California
Lawrence Livermore National Laboratory
Technical Information Department
Livermore, CA 94551

